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10 CFR 50
10 CFR 51
10 CFR 54

November 1, 2019

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555-0001

Peach Bottom Atomic Power Station, Units 2 and 3
Renewed Facility Operating License Nos. DPR-44 and DPR-56
NRC Docket Nos. 50-277 and 50-278

Subject: Response to Request dated October 31, 2019 for Docketing of Additional Documents to Support NRC's Environmental Review of the Peach Bottom Atomic Power Station, Units 2 and 3, Subsequent License Renewal Application

References:

1. Letter from Michael P. Gallagher, Exelon Generation Company, LLC (Exelon), to U.S. Nuclear Regulatory Commission (NRC) Document Control Desk, "Application for Subsequent Renewed Operating Licenses," dated July 10, 2018
2. Email from Lois James, NRC, to Michael P. Gallagher, Exelon regarding "Request for Additional Information for the Environmental Review of the Peach Bottom Subsequent License Renewal Application – Set 2 (EPID No. L-2018-RNW-0013)," dated October 31, 2019

In the Reference 1 letter, Exelon Generation Company, LLC (Exelon) submitted the Subsequent (i.e., Second) License Renewal Application (SLRA) for the Peach Bottom Atomic Power Station, Units 2 and 3 (PBAPS). In the Reference 2 email, the NRC requested that additional documents, which were listed in an attachment, be docketed to support the Staff's review of the PBAPS SLRA Environmental Report (Appendix E to the SLRA). The table below lists the documents requested by the Reference 2 email attachment.

Each requested document is being provided for docketing as a separate enclosure to this letter.

Enclosure #	Requested Document
01	Exelon Generation Company LLC. Letter from M. Herr, Plant Manager, Exelon, to J. Kim, Environmental Engineering Specialist, Pennsylvania Department of Environmental Protection. Subject: Exelon Generation Co., LLC – Peach Bottom Atomic Power Station NPDES Permit No. PA0009733 Renewal, Peach Bottom Township, York County. March 29, 2019.

Enclosure #	Requested Document
02	AECOM. 2019. 316(b) Summary Document, Peach Bottom Atomic Power Station, Delta, PA. March 2019. 30 p
03	AECOM. 2019. 40 CFR 122.21(r)(2-8) NPDES Application Requirements for Facilities with Cooling Water Intake Structures, Exelon Generation Company LLC, Peach Bottom Atomic Power Station, Delta PA. March 2019. 109 p.
04	Normandeau Associates, Inc. 2019. Entrainment Characterization Study at Peach Bottom Atomic Power Station. Clean Water Act 316(b) Compliance Report for 40 CFR 122.21(r)(9), NPDES Permit No. PA 0009733. January 19, 2019. 384 p.
05	AECOM. 2019. 40 CFR 122.21(r)(10) NPDES Application Requirements for Facilities with Cooling Water Intake Structures, Exelon Generation Company LLC, Peach Bottom Atomic Power Station, Delta PA. January 2019. 155 p.
06	Exelon Generation Company LLC. 2019. PA0009733 NPDES Permit Renewal Application, Appendix F, CWA 316(a) Thermal Variance. March 2019. 236 p.

This letter and its enclosures contain no regulatory commitments.

If you have any questions, please contact Ms. Nancy Ranek, Environmental Lead, Exelon Generation License Renewal, at 267-533-1506.

I declare under penalty of perjury that the foregoing is true and correct. Executed on the 1st day of November 2019.

Respectfully,

Michael P. Gallagher
Vice President - License Renewal and Decommissioning
Exelon Generation Company, LLC

Enclosures: 01 through 06

cc: Regional Administrator - NRC Region I (w/o Enclosures)
NRC Project Manager (Environmental Review), NRR-DMLR (w/o Enclosures)
NRC Project Manager (Safety Review), NRR-DMLR (w/o Enclosures)
NRC Project Manager, NRR-DORL Peach Bottom Atomic Power Station (w/o Enclosures)
NRC Senior Resident Inspector, Peach Bottom Atomic Power Station (w/o Enclosures)
Rich Janati, PADEP-BNR (w/o Enclosures)
D.A. Tancabel, State of Maryland (w/o Enclosures)

ENCLOSURE 01

Exelon Generation Company LLC. Letter from M. Herr, Plant Manager, Exelon, to J. Kim, Environmental Engineering Specialist, Pennsylvania Department of Environmental Protection. Subject: Exelon Generation Co., LLC – Peach Bottom Atomic Power Station NPDES Permit No. PA0009733 Renewal, Peach Bottom Township, York County. March 29, 2019.

Exelon Generation

March 29, 2019

Mr. Jinsu Kim
Environmental Engineering Specialist
Pennsylvania Department of Environmental Protection
Southcentral Regional Office
909 Elmerton Avenue
Harrisburg, PA 197110

Subject: Exelon Generation Co., LLC – Peach Bottom Atomic Power Station
NPDES Permit No. PA0009733 Renewal
Peach Bottom Township, York County

Dear Mr. Kim:

Enclosed are an original and three (3) additional copies of Exelon Generation Co., LLC's (Exelon) application package for renewal of their National Pollutant Discharge Elimination System (NPDES) Permit No. PA009733, issued September 22, 2014, for the Peach Bottom Atomic Power Station (Peach Bottom or PBAPS) located in Peach Bottom Township, York County, Pennsylvania.

The Application package includes sections containing the required forms and attachments; an appendix containing evidence of required Act 14, 67, 68 and 127 Notifications; an appendix containing the Clean Water Act (CWA) 40 CFR §316(b) Reports, including the §122.21(r)(2-13) reports for the Facility; and an appendix containing documentation to support the request for alternative thermal effluent limitations according to the Federal Water Pollution Control Act, as amended by the CWA of 1977, Section 316(a) [33 U.S.C 1326] for thermal discharges. A check in the amount of $25,000 payable to the "Commonwealth of Pennsylvania" is also included for the application fee.

Exelon respectfully requests the Pennsylvania Department of Environmental Protection's (PADEP's) consideration of the following items during the review and renewal of the NPDES Permit Number PA009733:

- Revisions to Outfall 003 - Water Treatment Settling Basin: Peach Bottom would like to request a modification to the discharge of Outfall 003 to allow the infrequent discharge of domestic drinking water containing a disinfectant (Chlorine note sodium hypochlorite is identified as an additive for this outfall) during maintenance activities. Up to five thousand gallons (e.g. when the accumulator tank is drained) would be emptied and discharged through floor drains to Outfall 003. Additional information including sampling results of the proposed water to be discharged has been included with NPDES permit renewal application.
- Authorization to Use Wood Flour / Sawdust for Condenser Treatment: Peach Bottom would like to request authorization to allow for the use of Wood Flour (Sawdust) to temporarily plug small holes in the condenser when needed. Peach Bottom anticipates use of Wood Flour at an application rate of up to 3,000 pounds per day, for a duration as needed for condenser

operation. A copy of the Safety Data Sheet for Wood Flour has been included in Appendix D of the attached application package.

- Authorization to Use Sodium Pentaborate: Peach Bottom would like to request authorization to release dilute Sodium Pentaborate when needed. Sodium Pentaborate is housed in the Standby Liquid Control (SLC) System. Use of Sodium Pentaborate is safety-related, to provide backup capability for reactivity control in the event that a normal operating system fails. When initiated, the SLC system injects neutron absorbing Sodium Pentaborate solution into the reactor vessel to shut down the reactor, even if control rods fail. It has been difficult to call this a chemical additive as it does not provide a treatment to a system, however it is an infrequent waste water stream for Peach Bottom. Exelon usually has "waste" SLC after testing of the system which occurs during the outage. There is also a collection drum for any cleanups, leaks, or flushes. Exelon would like to discharge this waste Sodium Pentaborate with the laundry drain tank releases which contain mostly mop water. Typically, the station generates approximately 500 gallons of water containing trace amounts of Sodium Pentaborate solution over a 2-year period, which would be released in a batch. Additional information can be provided upon PADEP's request.
- NPDES Permit Application form 3800-PM-BCW0008b: As discussed during the March 14, 2019 Pre-Application meeting between PADEP, Exelon, and AECOM, the Peach Bottom permit renewal application was substantially completed before the revised permit application form 3800-PM-BCW0008b was re-issued with a revision date of January 2019. Since there have been only two technical changes to the form to update the Cooling Water Intake Structures section and remove the option for Stormwater only permits from fee category section on page 1, those two pages of the attached application form have been replaced with the revised form dated January 2019.
- Clean Water Act (CWA) §316(b) Reports: In accordance with 40 CFR Part 122.21(r)(1)(ii)(A) and (B) and the PADEP June 3, 2016 letter regarding the Existing NPDES Facilities Final Rule requirements, Exelon is submitting the information required under paragraphs 122.21(r)(2) through (13) for Peach Bottom to inform your Best Technology Available (BTA) determination for minimizing adverse environmental impacts from entrainment and impingement. The reports and additional information are provided in Appendix C of the attached NPDES permit renewal application package.
- Clean Water Act (CWA) Alternative Thermal Effluent Limitations: Peach Bottom is requesting a continuation of the current thermal variance with some modifications. This request is supported with copies of recent reports and documentation providing results of comprehensive physical and biological field data collection in Conowingo Reservoir. The reports and additional information are provided in Appendix F of the attached NPDES permit renewal application package.

If you have any questions, please do not hesitate to contact Samantha Rice at 717-456-4526, or by e-mail at Samantha.Rice@exeloncorp.com. Thank you.

Sincerely,

Matthew J. Herr
Plant Manager, Peach Bottom Atomic Power Station

Enclosures:
1. $25,000 Check for Application Fee
2. NPDES Permit Application (Original plus three additional copies)

Applicant Name:

CERTIFICATION AND SIGNATURE OF APPLICANT

I certify under penalty of law that this document and all attachments and modules were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gathered and evaluated the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations. See 18 Pa. C.S. § 4904 (relating to unsworn falsification).

Matthew J. Herr	Plant Manager
Name (Type or Print Legibly)	**Official Title**
Matt Herr	3/27/2019
Signature	**Date**

(Use corporate or professional seal as appropriate.)

November 1, 2019
U.S. Nuclear Regulatory Commission

ENCLOSURE 02

AECOM. 2019. 316(b) Summary Document, Peach Bottom Atomic Power Station, Delta, PA. March 2019. 30 p.

APPENDIX C

316 (b) COOLING WATER INTAKE STRUCTURE REPORT

316(b) SUMMARY DOCUMENT

Peach Bottom Atomic Power Station

Delta, PA

Prepared By:

AECOM Conshohocken
625 West Ridge Pike, Suite E-100
Conshohocken, PA 19428

March 2019

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Attachment A: List of the Historical Studies Conducted at the Peach Bottom Atomic Power Station

1.0 INTRODUCTION

This Summary Document presents a synopsis of the detailed information provided in each of the 316(b) reports required under 40 CFR § 122.21(r)(2-13). Also provided is a holistic review of the results of the entrainment reduction technology evaluation and Peach Bottom Atomic Power Station's (PBAPS') recommended compliance approach. Detailed, independently reviewed, technical data and documentation referenced in this summary document is provided as an attachment to the NPDES renewal application.

PBAPS, located in Delta, York County, Pennsylvania, is a two unit (Units 2 & 3) nuclear-fueled boiling water reactor electric power generating facility. The facility is located on the western shore of the Conowingo Reservoir roughly five miles upstream from the Pennsylvania-Maryland border.

The Conowingo Reservoir is among the most widely studied bodies of water in Pennsylvania. Experts have conducted numerous biological monitoring studies over the past 50+years, both prior to operation of PBAPS in 1974 and in the subsequent operational periods. Sampling has been performed upstream, downstream and in the immediate vicinity of the station. These studies suggest a balanced indigenous aquatic community has existed and continues to exist in the Conowingo Reservoir. The studies also indicate that PBAPS' intake and discharge canals provide beneficial habitat for many species as indicated by the increase in ichthyoplankton density between the intake structure and the final discharge. Raw data indicate a net increase of more than 50% in organisms returned to the Conowingo Reservoir.

A partial list of the technical studies conducted on the Conowingo Reservoir can be found in Attachment A of this report. Further, as described below and detailed in this comprehensive 316(b) study, is an in-depth evaluation of the source waterbody as well as biological, technical, and economic studies required to help inform PADEP's site-specific Best Technology Available (BTA) decision for entrainment. Finally, PBAPS proposes a BTA to further improve the protective nature of the stations intake systems for impingement.

2.0 § 122.21(r)(2) THROUGH (8)

The § 122.21(r)(2) through (8) reports provide narratives, drawings, and supporting calculations to describe the PBAPS cooling water system, cooling water intake structure, and operations, along with the physical and biological nature of the cooling water source water body. Historical studies to evaluate the performance of entrainment reduction technologies, through-facility entrainment survival, or other entrainment studies are summarized. Additionally, the proposed method for compliance with the impingement mortality standard is outlined.

2.1 § 122.21(r)(2) Source Water Physical Data

PBAPS withdraws cooling water from the Conowingo Reservoir, a reservoir formed in the lower Susquehanna River by the Conowingo Dam in Maryland. The Susquehanna River from its origin to the MD-PA state line is designated under Title 25, Chapter 93 of the Pennsylvania Code as a warm-water fishery (WWF) and migratory fishery (MF) (PFBC 2011). Water temperatures are typical for those in the mid-Atlantic United States, with peaks during the summer and lows during the winter. Dissolved oxygen concentrations are inversely related to water temperature, decreasing as water temperature increases; however, water temperatures measured at the outer intake structure did not reach hypoxic or anoxic levels (NAI 2018).

Base flow conditions of Conowingo Reservoir are the result of power production activities at the Holtwood and Conowingo dams, and to a lesser extent, the Muddy Run Pumped Storage Facility (PFBC 2011). Releases from these projects are episodic and tied to peak power generation. The 25-year daily average discharge measured at the Conowingo Dam ranges from 13,100 cubic feet per second (cfs) to 97,800 cfs (USGS 2018).

Conowingo Reservoir has a required pool elevation of 101.2 feet to support various usages. Its normal fluctuation ranges from 101.2 and 110.2 feet National Geodetic Vertical Datum (NGVD) 1929 (PFBC 2011). The average water depth of the Reservoir is 20 feet, and the Reservoir has a maximum depth of approximately 90 feet in the vicinity of Conowingo Dam (NAI and GSE 2012a). Like lake environments, the Conowingo Reservoir has a design storage capacity of 310,000 acre-feet (NAI and GSE 2012a).

Habitat within the lower Conowingo Reservoir is mostly characteristic of a relatively still-water (lentic) system (NAI and GSE 2012b). Limited flowing-water (lotic) habitat occurs in the upper end of Conowingo Reservoir, below the Holtwood Dam. The reach of Conowingo Reservoir near PBAPS shows it generally has greater depths and slower water velocities compared to the upstream reach. Lentic conditions result in more fine-grained, silty substrates, so the lack of riverine habitat limits available spawning habitat for fish species requiring sandy or cobble sediments and higher water velocities (NAI and GSE 2012b).

2.2 § 122.21(r)(3) Cooling Water Intake Structure Data

The PBAPS cooling water intake structure provides a continuous supply of water from the Conowingo Reservoir to Units 2 and 3 and includes the following major components:

- Outer Intake Structure
  - Twenty-nine (29) active trash racks
  - Twenty-four (24) through-flow traveling water screens
- Two (2) Intake Basins
- Inner Screenhouse Structure
  - Six (6) dual-flow circulating water traveling screens
  - Four (4) through-flow service water traveling water screens
- Six (6) Circulating Water Pumps
- 6 Service Water Pumps
- 8 High Pressure Service Water Pumps
- 2 Emergency Service Water Pumps
- 3 Outer Screen Wash Water Pumps
- 2 Inner Screen Wash Water Pumps
- 2 Fire Protection Pumps

Water flows from the outer intake structure into two intake basins (1 per unit) before reaching the inner screenhouse structure. Water from the basins enters the inner screenhouse structure through eight bays (4 per unit). Six of the bays, each with their own traveling screen, direct the water to six circulating water pumps (3 per unit). These screens are dual-entry, single-exit (dual-flow) traveling screens, originally manufactured by FMC, with ¼-inch by ½-inch opening mesh. The remaining two bays (1 bay per unit) have four traveling screens installed (2 per bay), which are a single-entry, single-exit (through-flow) design. The water pumped from these two bays provides service water to the units. Historically, a limited amount of debris, including a *de minimis* number of non-fragile fish, was removed from the screens by a high-pressure spray-wash system on the ascending side of the screens to sluiceways (1 per unit). The debris is collected in dumpsters and disposed of off-site.

Approximately 47 feet downstream of the inner dual-flow and through-flow screens are six circulating water pumps (three per unit) and six service water pumps (three per unit), respectively. Units 2/3 cooling water intake structure DIF, conservatively based on design pump capacities (excluding installed spare pumps, pumps that operate under shutdown, emergency, or testing conditions only, and pumps that do not increase intake flow requirements) and maximum operating demands, is 2,240.6 million gallons per day (MGD). The average actual intake flow (AIF), calculated as the average of all flow data from January 2015 to December 2017 is approximately 2,157.5 MGD.

The outer intake structure was designed and installed to reduce impingement by lowering the approach and through-screen velocities, having flush alignment of the screens with the shoreline with lateral fish escape passages, and eliminating the need for intake canals. PBAPS conducted an analysis to compare the existing system, which was specifically designed to limit impingement and entrainment, to the newly adopted standards under 316(b).

The analysis evaluated the approximate area of influence within the 0.5 feet per second (fps) velocity contour. The United States Environmental Protection Agency (USEPA) considers this velocity to be a *de minimis* value relative to significant impingement concerns because fish have the swimming ability to overcome this velocity and avoid impingement. The USEPA value is conservative and meant to apply to most fish nationally, while PBAPS intake design used a site-specific approach velocity of 0.75 fps to protect Conowingo-specific species from impingement. In fact, the approach velocity immediately in front of the traveling screens is 0.65 fps at a Conowingo Reservoir elevation of 104.0 feet, which is a highly conservative (i.e., an unlikely worst-case scenario) estimate. Based on the USEPA value of 0.5 fps and using a worst-case scenario for Reservoir elevation, the hydraulic zone of influence at PBAPS exists between the outer intake trash racks and traveling water screens and does not extend beyond the cooling water intake structure into the Conowingo Reservoir. The calculated approach velocity at both the trash racks and immediately in front of the screens is less than the PBAPS site-specific approach velocity of 0.75 fps.

The inner intake structure was the original design and represents baseline practices, procedures, and structural configuration of the facility. The efficacy of the outer intake structure in reducing impingement was assessed by estimating the annual impingement at the inner intake structure based on TSV to that at the outer intake structure. Based on 2005-2006 impingement data and assumptions that were made to calculate impingement mortality reduction at the lower end of the range, the outer intake structure reduces impingement mortality by approximately 85% (URS Corporation 2008).

2.3 § 122.21(r)(4) Source Water Baseline Biological Characterization Data

The aquatic community of Conowingo Reservoir has been researched since the pre-operational studies performed for PBAPS in the mid-1960s. Results of the pre- and post-operational studies, as well as Section 316(a) assessments in the 1980s, 1990s, 2010-2013, and 2016, suggest a balanced indigenous aquatic community has existed and continues to exist in the Conowingo Reservoir.

The lentic habitat of Conowingo Reservoir supports a fish community composed primarily of common warm-water species that are found in lakes, ponds, and reservoirs from the southeastern U.S. to Canada (NAI and ERM 2017). The fisheries community is generally dominated by representatives of the families Clupeidae, Cyprinidae, Centrarchidae, and Ictaluridae, constituting 95% of the fish community in Conowingo Reservoir (NAI and ERM 2017). Forage species are primarily clupeid and cyprinid species. The dominant clupeid taxon in Conowingo Reservoir, gizzard shad (*Dorosoma cepedianum*), is also the most dominant species overall. Additionally, hundreds of thousands of gizzard shad enter Conowingo Reservoir annually via the Conowingo Dam East Fish Lift (EFL). Approximately 96% of cyprinids collected in Conowingo Reservoir between 2010 and 2013 were from four species: spotfin shiner (*Cyprinella spiloptera*), spottail shiner (*Notropis hudsonius*), comely shiner (*N. amoenus*), and bluntnose minnow (*Pimephales notatus*).

The most recent impingement characterization study collected samples from the Unit 2 outer intake structure from October 18, 2017 through October 4, 2018 (NAI 2018). Twenty-nine species from nine families were collected, dominated by bluegill (43%), gizzard shad (33%), comely shiner (11%), and channel catfish (7.5%). These species were also commonly collected during impingement sampling in 2005-2006 and prior studies (NAI 2018).

The most recent entrainment characterization study was conducted from March 21 through October 2, 2016 (NAI 2017a). Samples were collected from three locations: the outer intake structure, the circulating water discharge outfall for Units 2 and 3, and the discharge canal outfall. The most frequently collected entrainable organism were lifestages belonging to members of the Clupeidae family, which dominated collections with 96.0% of collected organisms. This primarily comprised of the alewife/gizzard shad taxon. The remaining 4.0% of organisms entrained were unidentified organisms (1.1%), tessellated darter (0.9%), common carp (0.7%), carp and minnow family (0.4%), and *Lepomis* species (0.4%) (NAI 2017a).

Based on the existing fisheries, impingement, and entrainment data, the following species were identified as the most likely to be impinged and entrained:

- American shad
- Banded darter
- Bluegill
- Channel catfish
- Comely shiner
- Common carp
- Gizzard shad
- Tessellated darter
- Walleye
- White crappie
- White perch

Federally and state-listed aquatic species, if any, that may be present near the PBAPS intake were evaluated through on-line reviews of the USFWS' Information for Planning and Consultation (IPaC) database and the Pennsylvania Natural Heritage Program's (PNHP) Pennsylvania Natural Diversity Inventory (PNDI) database. USFWS (2018) reported no federally protected aquatic species or critical habitat occurring within the vicinity of the PBAPS cooling water intake structure. The results of the PNDI search indicated that disturbance in and around the PBAPS site potentially could affect a state-protected aquatic species, the Chesapeake logperch, which in Pennsylvania and Maryland is listed as threatened. This species has been impinged and entrained at PBAPS (NAI 2007, 2017a).

Although it was not identified by the PNDI report, the state-endangered hickory shad (*Alosa mediocris*) has been recorded entering Conowingo Reservoir via the East Fish Lift (NAI 2010-2013a, 2014a, 2015a, 2016, 2017b). This species has not been impinged or entrained at PBAPS (NAI 2007, 2017a, 2018). The state-endangered cisco (*Coregonus artedi*) was introduced to the upper Susquehanna River and Conowingo Reservoir (Fuller and Neilson 2016). However, the cisco failed to establish a population within the Susquehanna River basin and is unlikely to be collected near PBAPS (USGS 2016). This species has not been impinged or entrained at PBAPS (NAI 2007, 2017a, 2018).

The predominant fragile species impinged at PBAPS is gizzard shad, the most impinged taxon. Other fragile impinged species include American shad, alewife, and blueback herring (NAI 2007, NAI 2014b, NAI 2015b, NAI 2016b, NAI 2017c). Thirty-three percent of the impinged fish collected between October 18, 2017 and October 4, 2018 were fragile species, including alewife, American shad, blueback herring, and gizzard shad (NAI 2018).

2.4 § 122.21(r)(5) Cooling Water System Data

The once-through cooling water system at PBAPS consists of the cooling water intake structure, a supply conveyance network to the main condensers and other equipment requiring raw water for non-contact cooling or other processes, and a discharge conveyance network to dissipate waste heat and discharge wastewater into the Conowingo Reservoir through a discharge structure or other outfalls. During normal operation, approximately 96% of the design intake flow is used for condenser cooling with the remainder used for plant services (URS 2008).

As previously noted, non-contact cooling water is withdrawn through the outer intake structure and pumped from the cooling water intake structure through the main condensers, where it becomes heated, and then flows to a discharge basin and canal that flows back to the Conowingo Reservoir downstream of the intake. The discharge basin and discharge canal also provide a place of discharge for heated water

from the Service Water System, the High-Pressure Service Water System, the Emergency Service Water System, and other process wastewaters.

Following the combined discharge of once-through cooling water from Units 2 and 3, heated water enters a common discharge basin prior to being discharged back to the Conowingo Reservoir through a discharge canal. Three 'helper' cooling tower blocks exist at the facility to provide cooling to the once-through cooling water that enters the discharge basin. These cooling towers are used during warm weather months to reduce its thermal discharge. The facility's NPDES permit establishes cooling tower operating conditions based on specific time periods and ambient water conditions.

PBAPS is a base-load plant that is available to operate year- round. Either unit could be in shutdown mode or operating at less than 100% capacity for maintenance, due to reduced electric demand, or other factors. Based on annual operations from 2013 through 2017, the PBAPS station's average net facility capacity utilization rate was 93.5%. Typically, cooling water demand is less during the winter months (late November/early December through March) due to colder intake water temperatures. The shutdowns result in approximately 3.7% flow reduction annually (based on water withdrawal data for the period of January 2015 through December 31, 2017) (Exelon 2018a, b, and c).

2.5 § 122.21(r)(6) Chosen Method of Compliance with Impingement Mortality Standard

The Peach Bottom cooling water intake structure's original design was comprised of six (6) traveling water screens for the circulating water pumps, along with four (4) additional traveling water screens for the service water system. This original design was replaced with an expanded structure specifically designed and installed to reduce impingement by lowering the approach and through-screen velocities. The expanded outer intake structure includes 24 traveling water screens to provide a reduced approach and through-screen velocity. The shoreline configuration of the outer intake structure prevents attracting fish into an embayment. Additionally, current operational measures reduce flow, approach velocities, and through-screen velocities. Studies determined that the implementation of the outer intake structure and the circulating pump shutdowns that occurred at the time during the winter months resulted in an estimated impingement mortality reduction of 85% (URS 2008).

Pursuant to the 316(b) requirements, PBAPS' team of experts considered each of USEPA's pre-approved impingement mortality reduction alternatives. As part of the evaluation process, a comprehensive list of potential options available at PBAPS was assembled using a list of technology or operational measures developed from input from USEPA Technical Development Documents and electric utility experience. The initial screening was then performed for each technology option to identify potential restrictions to feasibility, or impediments to implementation that cannot be resolved through mitigation methods. The initial screening was based on several criteria that generally included: whether the technology is commercially available and/or proven in the nuclear industry; whether the technology would be generally consistent with the Nuclear Regulatory Commission (NRC) General Design Criteria (GDC) and other safety, licensing, or design requirements; whether PBAPS would be able to obtain approval from permitting agencies; whether there is available real estate in which to implement or install the technology; whether the technology may provide impingement and entrainment benefits beyond that available from equivalent/existing technologies and/or measures. Due to higher criteria of acceptance, entrainment technology evaluations typically govern and determine compliance paths related to impingement. Based on the thorough evaluation of impingement control technologies, PBAPS is recommending modified traveling screens and a fish return system, as defined in § 125.92(s), be approved as BTA to improve impingement survival. This proposed technology is predicated on PADEP's concurrence that the existing system, that has a demonstrated net benefit based on ichthyoplankton densities, is BTA for entrainment.

2.6 § 122.21(r)(7) Entrainment Performance Studies

Entrainment characterization studies at PBAPS have been conducted since the pre- and post-operational reports on the ecology of the Conowingo Reservoir from 1966 and 1974 through 1979 (Robbins and Mathur 1974a, 1974b, 1975a, 1975b, 1975c, 1976, 1977; Ichthyological Associates, Inc. 1977a, 1977b; RMC Ecological Division 1979). The passage of zooplankton through PBAPS was studied by Boyer (1970, 1971) and Anjard (1978). The most recent entrainment studies were conducted between March 8, 2012 and September 27, 2012 and between March 21, 2016 and October 2, 2016 (NAI 2013b, 2017a). Results of those studies indicated that entrainment was mostly of the forage species gizzard shad and tessellated darter, and impacts to the Susquehanna River from entrainment at PBAPS are likely low. In fact, comparison of ichthyoplankton densities among three sampling locations showed higher total annual ichthyoplankton estimates at the discharge canal outfall compared to the outer intake structure. These results suggest:

- that spawning is occurring within the intake canals and the discharge canal;
- ichthyoplankton may be surviving passage through the condenser; and
- the PBAPS cooling water system, including the intake canals and discharge canal, produces more ichthyoplankton than the quantity removed at the outer intake structure.

2.7 § 122.21(r)(8) Operational Status

PBAPS is a two-unit (Units 2 & 3) nuclear-fueled boiling water reactor electric power generating facility with a generating capacity of 2,770 megawatts-electric. Unit 2 began commercial operation in June 1974 and Unit 3 entered commercial service in December 1974. PBAPS is a base-load plant that is available to operate year-round. Either unit could be in shutdown mode or operating at less than 100% capacity because of maintenance outages, reduced electric demand, or other factors. Typically, one outage occurs per year and begins in mid-October and lasts roughly 21 days. Based on annual operations from 2013 through 2017, PBAPS' average capacity utilization rate was 93.5%.

PBAPS' Units 2 & 3 had an Original Licensed Thermal Power of 3,293 megawatts-thermal (MWth) for each unit. Since initial service, the following updates have occurred (Exelon 2018d; USNRC 2018):

- 1994/1995: 5% (165 MWth) Stretch Power Uprate for Units 2 and 3, respectively
- 2002: 1.62% (57 MWth) Measurement Uncertainty Recapture Power Uprate for each Unit
- 2014: 12.4% (437 MWth) Extended Power Uprate (EPU) for each Unit
- 2017: 1.66% (65 MWth) Measurement Uncertainty Recapture Power Uprate for each unit

PBAPS Units 2 and 3 are currently licensed to operate until 2033 and 2034, respectively; however, Exelon submitted a license renewal application to the USNRC in July 2018 for a 20-year operating license extension for each of Units 2 and 3, anticipating that the process will take several years (Exelon 2018e).

3.0 § 122.21(r)(9) THROUGH (13)

The § 122.21(r)(9) through (13) reports have been prepared and are being submitted to help inform the director in establishing a site-specific Best Technology Available (BTA) selection for entrainment based on best professional judgment.

3.1 § 122.21(r)(9) Entrainment Characterization Study

Entrainment characterization studies were conducted at PBAPS from March through September 2012 and 2016. Samples were collected from three locations in 2016: the outer intake structure, the circulating water discharge outfall, and the discharge canal outfall. The circulating water discharge outfall was sampled in 2012. Alewife/gizzard shad and gizzard shad were the dominant taxa during both years (71% in 2012 and 96% in 2016). Both alewife and gizzard shad are fragile species, as identified in § 125.92(m).

Over 90% of the entrained organisms were larval life stages and entrainment density peaked June during both years. Comparison of ichthyoplankton densities among three sampling locations showed statistically higher annual ichthyoplankton densities at the discharge canal outfall compared to the outer intake structure.

Annual Entrainment Abundance based on Mar-Sep 2016
AIF at PBAPS

		Entrainment Abundance (millions)			
Location	Taxon	Unit 2	Unit3	Total	%
Outer Intake Structure (Location 1)	Gizzard Shad/Alewife	2079	2189	4268	88.7%
	Gizzard Shad	143	150	293	6.1%
	Combined Gizzard/Ale	2222	2339	4561	94.7%
	Other	124	130	253	5.3%
	Total	2346	2469	4814	100.0%
Circulating Water Discharge Outfall (Location 2)	Gizzard Shad/Alewife	3152	3318	6470	91.5%
	Gizzard Shad	170	179	349	4.9%
	Combined Gizzard/Ale	3322	3497	6819	96.4%
	Other	124	130	255	3.6%
	Total	3446	3627	7074	100.0%
Discharge Canal Outfall (Location 3)	Gizzard Shad/Alewife	3482	3318	6800	89.0%
	Gizzard Shad	100	105	205	2.7%
	Combined Gizzard/Ale	3582	3423	7005	91.7%
	Other	139	493	632	8.3%
	Total	3721	3916	7637	100.0%

3.2 § 122.21(r)(10) Comprehensive Technical Feasibility and Cost Evaluation Study

The Rule at § 122.21(r)(10) requires that Exelon provide the results of engineering study of the technical feasibility and incremental costs of candidate entrainment control technologies for PBAPS. In alignment with the requirements, three multi-disciplined studies were performed to evaluate the technological feasibility, economic costs and benefits, and environmental impacts of potential technologies to reduce entrainment at PBAPS. Several potential entrainment mortality reduction alternatives were screened, including various closed-cycle recirculating system retrofit options, narrow-slot wedgewire screens, aquatic filter barriers, modular inclined screens, and timing of the outage period, among others. Following the initial screening, Exelon then performed a comprehensive, peer-reviewed evaluation of potential entrainment reduction options. The study evaluated a closed-cycle recirculating system (CCRS) and installation of fine-mesh screens with a mesh size of 2 millimeters (mm) or smaller to reduce entrainment. A mesh size of 2 mm was chosen for evaluation because EPRI studies found that survival of collected organisms (i.e., previously entrained) decreases significantly with screen mesh size ≤ 2 mm, potentially negating the benefit of reducing entrainment for the very early life stages. The numerically dominant taxa in entrainment samples at PBAPS were the fragile species alewife and gizzard shad, which have high natural mortality and low benefit value as forage. Therefore, using finer mesh to retain the numerically

dominant species would result in an insignificant increase in benefit, but would increase the through-screen velocity and susceptibility to fouling. The report also discussed available sources of process water, grey water, wastewater, reclaimed water, or other waters for cooling at PBAPS. Because the alternatives evaluated could also result in an overall reduction in impingement mortality, effects on impingement were included in the evaluation. An engineering Class 4 evaluation and cost estimate was provided for the applicable technologies.

Candidate entrainment control technologies were selected based on station-specific information, operating data, and previous studies and reports. This and other information were used as the basis to develop conceptual design for the construction and operation of selected technologies at PBAPS, and the conceptual design, in turn, was used to establish costs to implement the technologies. Technologies to reduce impingement mortality and entrainment at PBAPS were previously evaluated by Alden Research Laboratory, Inc. (Alden) and the Electric Power Research Institute (EPRI) in 2003, and by URS Corporation in 2008 (URS 2008). The results of those evaluations were incorporated into this assessment and updated based on the 2014 Existing Facility Rule requirements and updated facility conditions. This § 122.21(r)(10) study included an evaluation of site constraints, operability, and interferences, along with potential permitting issues and requirements. The study provided a range of cost estimates to retrofit PBAPS with each respective candidate technology, including an evaluation of the effects on plant efficiency and capacity, if closed-cycle cooling were implemented.

3.2.1 CCRS

Based on a consideration of the alternatives, the all-wet CCRS with a mechanical-draft cooling tower is the most feasible cooling tower retrofit option at PBAPS. A review of the likely installation considerations and additional costs to be encountered at PBAPS put the retrofit at this site in the "more difficult" category. A CCRS would require demolition of the existing helper towers, and modification and extension of the existing condenser discharge structure which would require substantial construction and new infrastructure, as well as construction sequencing required to allow for use of the existing helper towers as much as possible to meet NPDES permit requirements and minimize facility downtime, an acceptable location for the towers appears to be available. Additional factors such as drift, plume, noise, aesthetics, air permitting, environmental permitting, siting, safety, security, and NRC review and approval would have to be considered further, but do not appear to be prohibitive for the retrofit. However, the high costs associated with the retrofit appear to be prohibitive.

Using the methodology and results from the EPRI (2011) document on national retrofit costs, which was used by USEPA in developing the cost/performance basis for the CWA Section 316(b) Rule in the associated Technical Development Document (USEPA 2014), the project capital costs were estimated to be approximately $1,146 million. The project operation, maintenance, and heat rate penalty costs per year were estimated to be in the range of $11.3 million, $3.9 million, and $18.5 million, respectively. Replacement power during installation could cost an additional $370 million.

Total annualized costs (EAC) (including amortized capital costs), not including replacement costs during installation are estimated at $126 million per year and total present-value life costs (NPV) for the cooling tower retrofit (including annual operation, maintenance, and heat rate penalty costs) are estimated at $1,565 million, assuming the USEPA's useful life of cooling towers of 30 years and a discount rate of 7%.

EAC costs (including amortized capital costs), not including replacement costs during installation are estimated at $92 million per year and NPV costs for the cooling tower retrofit (including annual operation, maintenance, and heat rate penalty costs) are estimated at $1,807 million, a assuming the USEPA's useful life of cooling towers of 30 years and a discount rate of 3%.

Note that Unit 2 and Unit 3 are currently licensed to operate until 2033 and 2034, respectively (Exelon 2018e), so the assumed 30 years of useful life is overestimated, unless the NRC license is extended. It is

anticipated that Exelon will apply for a 20-year extension of their operating licenses for each unit, with a decision expected from NRC in 2020 or 2021. Thus, the total annualized costs may be underestimated in this analysis, depending on the long-term life of the operating license for each unit.

The social cost of the CCRS option PBAPS has been calculated in pre-tax U.S. Dollars as described above. At a discount rate of 3%, the present value social cost is $1.3 billion which is equivalent to an annualized value of $44.2 million. At a discount rate of 7%, the present value social cost is $667.6 million which is equivalent to an annualized value of $22.3 million.

3.2.2 Wedgewire Screens

Based on a consideration of alternative designs, Option A was selected as the wedgewire screen retrofit option for comprehensive evaluation at PBAPS. This option includes the use of the most commercially-available (least customized) materials or equipment, which lowers construction time and costs, and provides more predictability for cost estimating. Selection of this alternative also satisfies the recommended installation requirements for both types of cleaning systems (mechanical-brush and air-burst cleaning systems), which allows flexibility for the detailed design selection. Additionally, Option A has the smallest footprint of the three alternatives assessed, which limits the obstruction in Conowingo Reservoir. If this alternative were to be selected for implementation, a detailed engineering design and assessment may identify a configuration with better hydraulic, cost, and/or operational benefits.

Using the methodology and results described in this report, the project capital costs were estimated to be approximately $61.3 million. The project incremental operation costs and project incremental maintenance costs per year were estimated to be approximately $47,000 and $454,000, respectively. Total annualized costs (EAC) (including amortized capital costs), not including replacement energy costs during installation, are estimated at $5.45 million per year and total present-value life costs (NPV) for the wedgewire retrofit (including annual O&M costs) are estimated at $67.5 million, assuming the USEPA's useful life of wedgewire screens of 30 years and a discount rate of 7%. EAC costs (including amortized capital costs), not including replacement energy costs during installation, are estimated at $3.63 million per year and NPV costs for the wedgewire screen retrofit (including annual O&M costs) are estimated at $71.1 million, assuming the USEPA's useful life of wedgewire screens of 30 years and a discount rate of 3%.

Note that Unit 2 and Unit 3 are currently licensed to operate until 2033 and 2034, respectively (Exelon 2018e), so the assumed 30 years of useful life is overestimated, unless the NRC license is extended. In July 2018, Exelon applied to NRC for a 20-year extension of their operating licenses for each unit, anticipating the process to take several years. Thus, the total annualized costs may be underestimated in this analysis, depending on the long-term life of the operating license for each unit. In addition, PBAPS may first pilot test a wedgewire screen to confirm the performance and reliability of the cooling water supply prior to full scale implementation. This could involve a prototype screen and monitoring over a year period. This would extend the over installation schedule.

The social cost of the wedgewire screen retrofit at PBAPS has been calculated in pre-tax U.S. Dollars. At a discount rate of 3%, the present value social cost is $117.1 million which is equivalent to an annualized value of $3.9 million. At a discount rate of 7%, the present value social cost is $59.0 million which is equivalent to an annualized value of $2.0 million.

3.2.3 Modified-Ristroph Traveling Screens with Seasonal Fine-Mesh Baskets / Panels

This option includes upgrading the existing traveling screens with modified-Ristroph screens with seasonal fine mesh baskets / panels, and construction of a fish handling and return system. Based on a consideration of the alternatives, Option A was the fine-mesh traveling screen retrofit option chosen for comprehensive evaluation at PBAPS since it is considered to have higher biological benefits due to

reduced re-impingement and entrainment of organisms. However, other fish return configurations may be considered during the detailed design, if this alternative is selected for implementation.

Using the methodology and results described in this report, the project capital costs were estimated to be approximately $36.3 million. The project incremental operation costs and project incremental maintenance costs per year were estimated to be approximately $0.42 million and $1.07 million, respectively. Total annualized costs (EAC), not including replacement costs during installation, are estimated at $4.92 million per year and total present-value life costs (NPV) for the fine-mesh traveling screen retrofit (including annual O&M costs) are estimated at $52.1 million, assuming the USEPA's useful life of traveling screens of 20 years and a discount rate of 7%. EAC costs (including amortized capital costs), not including replacement costs during installation, are estimated at $3.93 million per year and NPV costs for the fine-mesh traveling screen retrofit (including annual O&M costs) are estimated at $58.5 million, assuming the USEPA's useful life of traveling screens of 20 years and a discount rate of 3%.

Note that Unit 2 and Unit 3 are currently licensed to operate until 2033 and 2034, respectively (Exelon 2018e), so the assumed 30 years of useful life is overestimated, unless the NRC license is extended. In July 2018, Exelon applied to NRC for a 20-year extension of their operating licenses for each unit, anticipating the process to take several years. Thus, the total annualized costs may be underestimated in this analysis, depending on the long-term life of the operating license for each unit.

The social cost of the fine-mesh traveling screen retrofit option at PBAPS has been calculated in pre-tax U.S. Dollars. At a discount rate of 3%, the present value social cost is $37.1 million which is equivalent to an annualized value of $1.9 million. At a discount rate of 7%, the present value social cost is $21.0 million which is equivalent to an annualized value of $1.1 million.

NOTE: The social cost estimates provided above did not consider recent EPRI studies that revealed higher than expected ichthyoplankton mortality rates from the use of seasonal fine-mesh baskets and panels.

3.2.4 Water Reuse and Potential Alternative Water Source

None of the available alternative water sources could provide a reliable source of water at the volume (flow) and water quality required for operation of the cooling water system at PBAPS. The increase in both cost and difficulty with using one of the potential alternative cooling water sources identified, while at the same time potentially only reducing the required intake water flow marginally, makes these alternative sources not practical.

3.3 § 122.21(r)(11) Benefits Valuation Study

The Rule at § 122.21(r)(11) requires that Exelon provides the results of a benefit valuation study for PBAPS. Benefits were valued for the technologies selected for a comprehensive technical feasibility and cost evaluation in the § 122.21(r)(10) Comprehensive Technical Feasibility and Cost Evaluation Study, including:

- CCRS, specifically mechanical-draft cooling towers
- Fine-mesh screens with a mesh size of 2 millimeters (mm) or smaller:
    - Modified Ristroph traveling screens with seasonal fine-mesh overlays and fish return
    - Narrow-slot cylindrical wedgewire screens

Commercial and recreational benefits were estimated using entrainment data collected in 2012 and 2016, and impingement data from 2005 through 2006. Not unexpectedly for a natural system, the species composition and lifestages varied between entrainment sampling years and the number of ichthyoplankton collected in 2016 was more than six times that collected in 2012. Therefore, annualized benefits were provided as a range to account for natural variability in fish populations.

Commercial fishing is not allowed in the Pennsylvania portion of the Susquehanna River. However, south of the Conowingo Dam, "a handful of commercial fishing operations" are based in Cecil County, Maryland (Cecil County Planning Commission 2010). Those commercial fishers may be affected by changes to fish populations upstream because juvenile and small adult fish pass through the Conowingo Dam turbines to the downstream waters of the Susquehanna River, Susquehanna Flats, and the Chesapeake Bay. Impacts to the downriver commercial fishery from impingement and entrainment at PBAPS are limited, and therefore inclusion of the commercial fishery estimates in the evaluation overestimates the benefits of the entrainment reduction technologies.

3.3.1 CCRS

Retrofit to a closed-cycle recirculating system would reduce entrainment by approximately 96.9% thereby reducing losses of Equivalent Adults, Forgone Yield, and Production Forgone biomass by the same percentage. It is assumed that installation of a closed-cycle recirculating system would result in minimized impingement because the intake velocities would be less than 0.5 fps. However, it is possible that some impingement would occur after installation of a closed-cycle recirculating system; therefore, this assumption overestimates the benefits of this entrainment reduction alternative.

The total annualized social benefits of installing a closed-cycle recirculating system discounted at 3% range from $3,400 to $9,100 and range from $1,600 to $4,300 when discounted by 7%.

3.3.2 Wedgewire Screens

Installation of this technology would result in little to no reduction in entrainment of eggs and many larval species. However, it was assumed that impingement would be reduced by 100% because the through-slot velocity would be less than 0.5 fps. Additionally, all organisms excluded by 2.0 mm slot openings were assumed to have 100% survival because they would not be retained on and washed from the screen.

Installation of narrow-slot cylindrical wedgewire screens may result in total annualized social benefits ranging from $3,400 to $7,800, using a 3% discount rate. If a 7% discount rate is assumed, the annualized social benefits range from approximately $1,600 to $3,700.

3.3.3 Modified-Ristroph Traveling Screens with Seasonal Fine-Mesh Baskets / Panels

Like narrow-slot wedgewire screens, this alternative would not provide much entrainment reduction for eggs and many larval species. The benefits may be overestimated because one older American eel (127 mm long) was collected during the 2012 entrainment study and EPRI (2013) found 100% survival for American eel on Ristroph-type traveling screens with fine-mesh. Additionally, recent EPRI studies suggest that fine-mesh screens may cause higher mortality for eggs and smaller larvae compared to entrainment through the facility given the high through-facility entrainment survival found at other power stations.

The total annualized social benefits of seasonal fine-mesh baskets / panels and fish return range from $2,900 to $6,200 (using a 3% discount rate) or from $1,500 to $3,300 (with a 7% discount rate).

3.4 § 122.21(r)(12) Non-water Quality Environmental and Other Impacts Study

The Rule at § 122.21(r)(12) requires that Exelon provides the results of a non-water quality and other impacts study conducted for PBAPS that evaluates the environmental and other impacts of the technologies evaluated in the § 122.21(r)(10) Comprehensive Technical Feasibility and Cost Evaluation Study [§ 122.21(r)(10)]. The major non-water quality environmental and other impacts focused on the retrofit of a CCRS, since they are most significant. A discussion of the impacts of fine-mesh screens was

also provided. The option of water reuse or alternative sources of cooling water was not considered practical, as discussed in the § 122.21(r)(10) report, and was therefore not discussed in the § 122.21(r)(12) report.

The following impacts were assessed:

- Changes to energy consumption;
- Air pollutant emissions, including salt and mineral drift;
- Changes in noise;
- Safety, including visible plumes, icing/fogging, and availability of emergency cooling water;
- Facility reliability; and
- Changes in water consumption.

A discussion of mitigation for each of the impacts was also included.

3.4.1 CCRS

The location of the cooling tower on the existing site, currently occupied by three helper cooling towers, would utilize as much of the existing infrastructure as possible. The tower would be aligned with the prevailing winds to minimize potential recirculation of the plumes. Although drift deposition has the potential to impact nearby facilities and solids deposition may occur on the switchyard, transmission lines and local roadways, drift eliminators are included in the design of the closed-cycle cooling retro fit to mitigate Particulate Matter (PM) drift. There would be a visible plume that extends to the southeast of the towers. This would not present a safety issue since the plume is approximately 25 miles from the nearest public airport. No mitigation was incorporated in the design for fogging, plumes, and icing because:

- modeling predicted that the plume would not reach the nearest airport;
- the duration of offsite fogging at any one point is modeled to be less than 0.5 hours; and
- the models suggested no offsite roadways would be impacted.

In addition, due to the lack of evidence for regulations on plumes set forth by the Peach Bottom Zoning Ordinance, there does not appear to be a regulatory requirement for plume abatement measures. The plume would have negative effects on quality of life by causing viewshed deterioration and shadowing. However, plume abatement technology would add significant cost and increase power consumption and associated air emissions impacts. Noise modeling suggested that there would be no noise impacts requiring mitigation. Water withdrawals for cooling towers would represent a very small percentage of the Susquehanna River flow and therefore, no impacts to facility reliability were anticipated.

3.4.2 Wedgewire Screens

To account for frazil ice, biofouling, debris plugging, and other possible intake issues, the narrow-slot cylindrical wedgewire screen configuration included a 10% ‘safety factor’ or increase in required screen area. Additionally, safety-related bypasses were included in the design to mitigate for potential impacts to safety and facility reliability. The air burst cleaning system would also result in a large bubble of air rapidly rising to the water surface that could capsize a small water craft. An exclusion area above the screens would be needed to warn small water craft of the hazard.

Construction-related outage would be significant, and would increase air pollutant emissions and would impact grid reliability during that time. Overall construction of the wedgewire screens is expected to take approximately 20 months and is expected to be completed in phases. However, construction would be sequenced to limit outage time as much as possible. If construction sequencing proceeds as estimated, the PBAPS outage or downtime would be minimized to four months per unit. During this period, the generation losses would be replaced on the PJM East power grid by existing power generating facilities with excess capacity (typically fossil plants).

The installation of narrow-slot cylindrical wedgewire screens would require additional studies and permitting to address dredging and habitat loss. This option could need PADEP Chapter 105 and US Army Corps Section 10/404 permits and a Submerged Lands License. However, this option is not expected to have any other significant non-water quality environmental impacts other than outage during construction, and therefore no further mitigation measures would be needed.

3.4.3 Modified-Ristroph Traveling Screens with Seasonal Fine-Mesh Baskets / Panels

Construction-related outage would be significant, and would increase air pollutant emissions and impact grid reliability during that time. Therefore, construction would be sequenced to limit outage time as much as possible.

Replacing the existing screens with modified-Ristroph-type traveling screens with fine-mesh overlays is not expected to have any significant non-water quality or other environmental impacts and therefore no mitigation measures would be needed.

3.5 § 122.21(r)(13) Peer Review

Exelon has undertaken a peer review of reports prepared pursuant to 40 CFR § 122.21(r)(10-13) for PBAPS, recognizing the obligation of PADEP to consider factors identified in § 125.98(f)(2 and 3) while making a BTA determination. As required by § 122.21(r)(13), the review process included:

- selection of expert peer reviewers independent of those preparing the § 122.21(r)(10-12) reports and having the appropriate credentials and expertise;
- pre-approval of the expert reviewers by the PADEP;
- instructions and charge questions provided to the experts; expert review of the § 122.21(r)(10-12) reports;
- independent review of the of the peer review comments; and
- production of a comprehensive peer review report that compiles the expert's comments and discusses comments not accepted, and demonstrates, based on peer review that the § 122.21(r)(10-12) report conclusions are supported by the technical information and analyses provided.

The peer review was conducted by a team of experts in the biological and engineering disciplines from Kleinschmidt Associates (Kleinschmidt) and resource economics experts from Industrial Economics, Inc. (IEc).

The § 122.21(r)(13) peer review report attached summarizes and documents the peer review process performed for PBAPS.

4.0 OTHER CONSIDERATIONS

In addition to the factors that the Director must consider in determining the BTA for reducing entrainment mortality, the Director may consider entrainment impacts on the waterbody. Only a small percentage of the source water body is withdrawn by the PBAPS cooling water intake structure. During peak entrainment months, between 5 and 18% of the average streamflow of the Susquehanna River is withdrawn by PBAPS, thus between 82 and 95% of the entrainable organisms bypass the station. Of the ichthyoplankton that are entrained, many may survive as is suggested by PBAPS' entrainment studies that found the ichthyoplankton density at the discharge canal outfall (1.6 billion ichthyoplankton) was greater than the densities at the circulating water outfall (1.4 billion ichthyoplankton) and the outer intake

structure (963 million ichthyoplankton). These results suggest potential entrainment survival and spawning is occurring within the intake canals and the discharge canal, and that the PBAPS cooling water system, including the intake canals and discharge canal, returns more ichthyoplankton than the quantity removed at the outer intake structure. Additionally, as reported by EPRI, high through the plant entrainment survival has been confirmed at other power stations.

Results of the extensive studies of the Conowingo Reservoir have found that decades of PBAPS operations has not negatively impacted the balanced indigenous fish community (BIC) of the Reservoir. Water quality, hydrology, and biological monitoring beginning with pre-operational monitoring in the mid-1960s support this conclusion. In addition to the original CWA Section 316(a) and (b) demonstrations in the 1970s, impingement monitoring has been performed throughout the 1970s, 1980s, and 1990s. The most recent impingement studies were completed in 2005-2006 and 2017-2018. There is a similar long history of ichthyoplankton and entrainment studies. All these studies (see Attachment A for a complete bibliography) and the subsequent permits granted based on their conclusions show that there is a diverse fish community within Conowingo Reservoir, and the historical and current operating conditions of PBAPS are protective of the BIC of aquatic biota. Therefore, the environmental impact of entrainment at PBAPS is minimal.

The site-specific studies performed for PBAPS support USEPA's position that entrainment was not a concern for facilities withdrawing from lakes or reservoirs. The suspended 2004 Phase II Existing Facilities Rule required those facilities to only comply with the impingement mortality performance standard, explaining "Performance standards for entrainment do not apply to facilities … that withdraw cooling water from a lake (other than one of the Great Lakes) or reservoir because such facilities have a low propensity for causing significant entrainment impacts due to … general waterbody characteristics." (69 FR 41598). USEPA[1] noted that the principal spawning and nursery area in lakes and reservoirs is the littoral zone, and fish in that zone typically deposit eggs in prepared nests, on the bottom, or attached to submerged substrates. Once hatched, many of the larvae complete their life cycle within the littoral zone. However, many facilities, including PBAPS, withdraw water from the cooler, deeper profundal zone, which typically lowers the potential impingement and entrainment impacts.

5.0 COST-BENEFIT COMPARISON

The Rule states at § 125.98(f)(4) that "The Director may reject an otherwise available technology as a BTA standard for entrainment if the social costs are not justified by the social benefits". Each of the entrainment reduction alternatives evaluated are feasible. However, social costs of all of the technologies far outweigh the social benefits.

[1] USEPA. 2004. Technical Development Document for the Final Section 316(b) Phase II Existing Facilities Rule. EPA 821-R-04-007, DCN 6-0004.

Cost-Benefit Ratios of Entrainment Reduction Technologies Based on Annualized Social Costs and Benefits

Discount Rate	Technology	2012 Entrainment Data			2016 Entrainment Data		
		Costs	Benefits	Cost-Benefit Ratio	Costs	Benefits	Cost-Benefit Ratio
3%	Closed-cycle Recirculating System Retrofit	$44.2M	$3.4k	13,000	$44.2M	$9.1k	4,857
	2-mm Wedgewire Screens	$3.9M	$3.4k	1,147	$3.9M	$7.8k	500
	2-mm Fine-Mesh Screens*	$1.9M	$2.9k	655	$1.9M	$6.2k	306
7%	Closed-cycle Recirculating System Retrofit	$22.3M	$1.6k	13,938	$22.3M	$4.3k	5,186
	2-mm Wedgewire Screens	$2.0M	$1.6k	1,250	$2.0M	$3.7k	541
	2-mm Fine-Mesh Screens*	$1.1M	$1.5k	733	$1.1M	$3.3k	333

* Modified Ristroph screens with seasonal 2-mm overlays and fish return

These benefits are likely overestimated because the Rule indicates that the § 122.21(r)(9) Entrainment Characterization Study should be performed at a location in the vicinity of the cooling water intake structure; therefore, benefits estimated in the § 122.21(r)(11) Benefits Valuation Study used data collected at the circulating water outfall. However, annual entrainment estimated on that data is nearly half a billion ichthyoplankton greater than the estimate using intake structure data. The benefits are further overestimated because there is nearly double the quantity of darter ichthyoplankton, particularly tessellated darter, at the circulating water outfall than at the intake structure. Due to the life history of these species, the majority of the ecological benefits estimated for the entrainment reduction technologies when expressed as equivalent adults are from reducing entrainment of tessellated darter, an abundant forage species. The costs are entirely disproportionate to the benefits for even the alternative with the lowest cost to benefit ratios (300 to 700) – seasonal fine-mesh baskets / panels and fish return.

Additionally, a closed-cycle recirculating system at PBAPS would be very difficult to construct. Issues include routing the condenser discharge piping under the new 'cool water' basin to the hot basin and the substantial construction required to reconfigure the discharge channel and demolish the existing helper towers. The cooling tower would also have an adverse environmental impact by increasing direct (PM_{10}) from the tower and indirect (replacement power from the region grid) emissions of 570 tons per year (tpy) nitrogen oxides, 1,488 tpy sulfur dioxide, 15.7 tpy of volatile organic compounds, 630,724 tpy carbon dioxide equivalents (a factor for combined Greenhouse Gases, an equivalent to carbon dioxide warming potential), 335.9 tpy PM_{10} (cooling tower drift and power increase combustion), and 12.8 pounds per year of mercury emissions. Nearby residences would experience viewshed alteration from the visible vapor plume. These social costs were not monetized. Narrow-slot wedgewire screens would also be difficult to install, requiring extensive dredging and possibly creating preferential flow pathways that may necessitate flow regulating / flow balancing measures.

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Entrainment

The PBAPS cooling water system is BTA for entrainment because:

- The ichthyoplankton density data indicates a net increase in organisms returned to the Conowingo Reservoir across the existing system. Ichthyoplankton density at the discharge canal outfall (1.6 billion ichthyoplankton) that are higher than at the intake structure (963 million ichthyoplankton)

indicating potential entrainment survival and spawning is occurring within the intake canals and the discharge canal;

- The disproportionately high social costs compared to the social benefits of entrainment reduction technologies;
- Issues with construction feasibility and adverse environmental impacts of cooling towers;
- Large in-river footprint and associated impacts of narrow-slot wedgewire screens;
- Cooling water intake structures on a lake or reservoir have a low propensity for causing significant entrainment impacts; and
- Decades of studies demonstrate minimal adverse impact to the Conowingo Reservoir fish population.

The results of the engineering, biological, and economic evaluations of entrainment reduction technologies indicate that the current cooling water system at PBAPS is BTA for minimizing impacts from entrainment and no further entrainment reduction technologies are warranted.

6.2 Impingement

As previously mentioned, PBAPS redesigned its intake structure and configuration with the express intent of reducing impingement. Conowingo Reservoir biological studies were completed, aquatic species were identified and researched, and a representative species (white crappie) was selected to establish intake/approach velocity design criteria. More specifically, the structure was designed based on the results of numerous fish swim speed studies that found that juvenile white crappie was particularly fragile and susceptible to impingement mortality. By protecting white crappie, the rest of the aquatic community was also protected. Additionally, the outer intake structure was designed flush to the shoreline to avoid eddies and velocity traps, allowing lateral fish escape routes. This configuration of the cooling water intake structure results in a hydraulic zone of influence (as defined by the 0.5 fps contour) located between the trash racks and the outer intake structure traveling water screens. It does not extend beyond the cooling water intake structure into the Conowingo Reservoir. In addition, an air bubbler system is used on the outer intake structure for breaking up surface ice formation at the inlet side of the structure, which may encourage fish avoidance behavior.

To further enhance impingement survival, PBAPS proposes to operate modified traveling screens as defined at § 125.92(s) with a fish handling return system. This proposed approach is predicated on PADEP concurring with the station's independent experts' opinion that the existing system is BTA for entrainment. PBAPS may consider a pilot study of various modified Ristroph-type traveling screens or existing screen upgrades to determine the most appropriate type of screens for PBAPS. Once upgraded, a traveling screen performance optimization study will be completed.

ATTACHMENT A
LIST OF THE HISTORICAL STUDIES CONDUCTED AT THE PEACH BOTTOM ATOMIC POWER STATION

March 2019

1. 316(b) Demonstrations

Philadelphia Electric Company. 1977. 316(b) Demonstration for PBAPS Units No. 2 & 3 on Conowingo Pond. Materials prepared for the Environmental Protection Agency, June 1977.

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Normandeau Associates. 2016. Revised Scope of Work for Peach Bottom Atomic Power Station's Entrainment Abundance and Latent Impingement Mortality Characterization. Revision 2. Prepared for Exelon's Peach Bottom Atomic Power Station.

2. Pre-and Post-Operational Reports that Include Impingement and Entrainment Results

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Ichthyological Associates, Inc. 1977. Peach Bottom Atomic Power Station Post-operational Report No. 7 on the ecology of Conowingo Pond for the period July 1976-December 1976. Ichthyological Associates, Inc., Drumore, Pa., prepared for Philadelphia Electric Company, xxi + 313 pp.

Ichthyological Associates, Inc. 1977. Peach Bottom Atomic Power Station Post-operational Report No. 8 on the ecology of Conowingo Pond for the period January 1977-June 1977. Ichthyological Associates, Inc., Drumore, Pa., prepared for Philadelphia Electric Company, xi + 186 pp.

RMC Ecological Division. 1979. Peach Bottom Atomic Power Station, Post-operational Report No. 9 on the ecology of Conowingo Pond for the period of July 1977-December 1977. Prepared for Philadelphia Electric Company. Muddy Run Ecological Laboratory, Drumore, Pa. xiv + 245 pp.

3. Other Reports/Presentations/Papers

3.1. Impingement

Robbins, Timothy W., Pauline L. Heisey, and Paul G. Heisey. 1975. Environmental deviation report for impingement of fishes at the Peach Bottom Atomic Power Station Units No. 2 and 3 on 25-27 February 1975. Ichthyological Associates, Inc., Drumore, Pa., March 1975, prepared for Philadelphia Electric Company, 10 pp.

Mathur, Dilip, Paul C. Heisey, and Nancy C. Magnusson. 1976. Impingement of fishes at a nuclear power station on the lower Susquehanna River. A paper presented at the 106th Ann. Meeting Amer. Fish Soc., Dearborn, Michigan.

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Normandeau Associates, Inc. 1996. Environmental review of proposed upgrade to intake water system at Peach Bottom Atomic Power Station, York County, Pennsylvania. Prepared for PECO Energy Company. 3 pp.

Matty, R.M. Jr., D. Mathur, P. L. Harmon. 1999. PECO Energy's 316(b) experience with specific reference to Peach Bottom Atomic Power Station, Pennsylvania. In Proceeding: 1998 EPRI Clean Water Act Section 316(b) Technical Workshop, Coolfont Conference Center. EPRI 1999 TR-112613.

Normandeau Associates, Inc. 2000. Data report on intake screen sampling at the Peach Bottom Atomic Power Station in 1999. Prepared for Peach Bottom Atomic Power Station. 3 pp.

Normandeau Associates, Inc. 2007. Summary of Fish Impingement Sampling at Peach Bottom Atomic Power Station, Conowingo Pond, Pennsylvania, 2005-2006. Prepared for Exelon Nuclear. September 2007.

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Normandeau Associates, Inc. 2014. Data Report on Intake Screen Sampling at Peach Bottom Atomic Power Station in 2014. December.

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3.2. Entrainment

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Normandeau Associates. 2013. Peach Bottom Atomic Power Station Entrainment Characterization Study 2012. Prepared for Exelon Generation.

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3.3. Swim Speed

Schuler, Victor J. 1968. Progress report of swim speed study conducted on fishes of Conowingo Reservoir. Ichthyological Associates, Holtwood, Pa., Progress Report 1B, prepared for Philadelphia Electric Company, 61 pp.

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4. Pre- and Post-Operational Reports (including limnology, fish distribution, abundance, and movement, thermal testing, and creel surveys)

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RMC Ecological Division. 1979. Peach Bottom Atomic Power Station, Post-operational Report No. 11 on the ecology of Conowingo Pond for the period of July 1978-December 1978. Prepared for Philadelphia Electric Company. Muddy Run Ecological Laboratory, Drumore, Pa. xiv + 245 pp.

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5. NPDES/Cooling Tower Reduction Studies

RMC Environmental Services, Inc. 1994 (*January*). A report on the fish populations in Conowingo Pond relative to the NPDES permit application for the Peach Bottom Atomic Power Station, Pennsylvania. Prepared for Philadelphia Electric Company. 8 pp.

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Normandeau Associates, Inc. 1996 (*May*). Study plan to assess fish populations in Conowingo Pond relative to the reduction in cooling tower operation at the Peach Bottom Atomic Power Station, Pennsylvania. Prepared for PECO Energy Company. 19 pp.

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Normandeau Associates, Inc. 1998 (*February*). A report on the thermal conditions and fish populations in Conowingo Pond relative to zero cooling tower operation at Peach Bottom Atomic Power Station (June-October 1997). Prepared for PECO Energy Company. 67 pp. + Appendices.

Normandeau Associates, Inc. 1999 (*February*). A report on the thermal conditions and fish populations in Conowingo Pond relative to zero cooling tower operation at Peach Bottom Atomic Power Station (June-October 1998). Prepared for PECO Energy Company. 67 pp. + Appendices.

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6. 316(a) Demonstration Studies

Hocutt, Charles H. 1970. The effects of temperature on the swimming performance of the largemouth bass, spotfin shiner, and channel catfish. Ichthyological Associates, Holtwood, Pa., Progress Report 5, February 1970, prepared for Philadelphia Electric Company, 65 pp.

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40 CFR §122.21(r)(2-8) NPDES APPLICATION REQUIREMENTS FOR FACILITIES WITH COOLING WATER INTAKE STRUCTURES

Exelon Generation Company, LLC

Peach Bottom Atomic Power Station

Delta, Pennsylvania

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1.0 INTRODUCTION

1.1 REGULATORY REQUIREMENT

40 CFR §122.21(r) contains National Pollutant Discharge Elimination System (NPDES) application requirements for facilities with cooling water intake structures. Pursuant to the 2014 Existing Facilities Rule (Rule), all existing facilities must submit, to the Director for review, the information required under paragraphs (r)(2) and (3), and applicable provisions of (r)(4), (5), (6), (7), and (8) of §122.21. This information consists of physical, biological, and operational data for each cooling water source, cooling water intake structure (CWIS), and cooling water system utilized at the facility.

The Rule also establishes a site-specific entrainment standard based on Best Professional Judgment. Furthermore, for facilities with actual cooling water intake flows greater than 125 MGD, there are additional study requirements. Peach Bottom Atomic Power Station's (PBAPS')' actual cooling water intake flow is greater than 125 MGD, thus these additional studies are required by the Rule.

Therefore, in accordance with 40 CFR Part 122.21(r)(1)(ii)(A) and (B), PBAPS is submitting the information required under paragraphs § 122.21(r)(2) through (13). In addition to providing the required station background data and source waterbody information, these documents provide the biological, technical, and economic studies to inform the Pennsylvania Department of Environmental Protection's (PADEP's) site-specific decision with regard to Best Technology Available (BTA) for reducing fish mortality from entrainment through PBAPS CWIS and cooling water system.

This document is intended to:

- Fulfill the regulatory requirement for submittal of §122.21(r)(2-13) information for PBAPS, an existing facility subject to the Rule; and
- Fulfill the requirements set forth in Part C, Section II "Cooling Water Intake Structure" of PBAPS' NPDES permit.

1.2 FACILITY DESCRIPTION AND REGULATORY STATUS

PBAPS, located in Delta, York County, Pennsylvania, is owned and operated by Exelon Generation Company, LLC (Exelon). PBAPS is a two unit (Units 2 & 3) nuclear-fueled boiling water reactor electric power generating facility with a generating capacity of 2,770 megawatts-electric (URS 2008; Exelon 2018h). Unit 2 began commercial operation in June 1974 and Unit 3 entered commercial service in December 1974. The facility also has one closed power generating unit (Unit 1). The facility is located on the western shore of the Conowingo Reservoir at River Mile (RM) 18 of the Susquehanna River, approximately five miles upstream from the Pennsylvania-Maryland border.

PBAPS withdraws water for cooling and service/process water needs from the Conowingo Reservoir of the Susquehanna River through an outer intake structure located on the shoreline. Water flows through the screens of the outer intake structure, through two 3-acre intake ponds, and then through an inner intake structure/pumphouse. These components supply water for once-through cooling of the main condensers and for plant services (process/equipment needs)

PBAPS is subject to the requirements of the Existing Facilities Rule at §122.21(r) since it meets the following three criteria stated in §125.91(a):

- The facility is a point source;
- The facility uses or proposes to use one or more cooling water intake structures with a cumulative design intake flow (DIF) of greater than 2 million gallons per day (MGD) to withdraw water from waters of the United States; and

- Twenty-five percent or more of the water the facility withdraws on an actual intake flow (AIF) basis is used exclusively for cooling purposes.

2.0 §122.21(r)(2) - SOURCE WATER PHYSICAL DATA

2.1 SOURCE WATERBODY NARRATIVE DESCRIPTION

Regulatory requirement at §122.21(r)(2)(i): "A narrative description and scaled drawings showing the physical configuration of all source water bodies used by your facility, including areal dimensions, depths, salinity and temperature regimes, and other documentation that supports your determination of the waterbody type where each cooling water intake structure is located."

PBAPS withdraws cooling water from the Conowingo Reservoir, a reservoir formed in the lower Susquehanna River by the Conowingo Dam in Maryland at RM 10 (**Appendix A**). The Reservoir extends about 14 miles upstream into Pennsylvania; PBAPS is located on the west side of the Reservoir at RM 18. The limit of tidal influence in the Susquehanna River is downstream of Conowingo Dam in Maryland, near the mouth of Deer Creek at RM 6 (Webb & Heidel 1970). Thus, the PBAPS intake is located in a freshwater waterbody.

The Susquehanna River originates near Cooperstown, New York at Otsego Lake and flows for about 444 miles to the Chesapeake Bay at Havre de Grace, Maryland (PFBC 2011). The lower Susquehanna River begins at the York Haven Dam at RM 56. Upstream of the York Haven Dam, the Susquehanna River is characterized as a large, free flowing river with several run of the river dams throughout its length. Downstream of the York Haven Dam, the river is significantly affected by the three hydroelectric dams forming a reservoir system stretching 32 river miles (Hainly et al. 1995). These include the Conowingo Dam at RM 10, Holtwood Dam at RM 25, and the Safe Harbor Dam at RM 32.

Extensive environmental monitoring in the Conowingo Reservoir has been performed, including water quality, hydrology, and biological studies both pre- and post-operation of PBAPS. Monitoring data since 1966 do not show substantial thermal stratification in Conowingo Reservoir (NAI and ERM 2017). However, if water temperatures in the Reservoir exceed 75˚F during the summer and water flow is simultaneously less than 12,000 cubic feet per second (cfs), then dissolved oxygen stratification can occur, particularly in deeper areas of lower Conowingo Reservoir (near the Dam). Thermal stratification quickly breaks down during periods of heavy rain and high winds (NAI and ERM 2017). Dissolved oxygen typically remains relatively well mixed throughout most of the year, but variations with depth do occur in summer, especially in the deeper waters of the lower Reservoir, and surface-to-bottom dissolved oxygen differences of 5 milligrams per liter (mg/L) or more may occur. Significant dissolved oxygen stratification rarely occurs during other months or in shallower areas of the Reservoir (NAI 2000).

The Susquehanna River from its origin to the MD-PA state line is designated under Title 25, Chapter 93 of the Pennsylvania Code as a warm-water fishery (WWF) and migratory fishery (MF) (PFBC 2011). As a result of these designations, water quality parameters (including alkalinity, ammonia nitrogen, dissolved oxygen, total recoverable iron, osmotic pressure, pH, temperature, and total residual chlorine) are regulated and monitored. Additionally, the Susquehanna River Basin Commission (SRBC) employs water quality standards for physicochemical and biological parameters in order to ensure water quality in the Susquehanna River through their Large Rivers Monitoring Program (PFBC 2011).

Approximately 5.5 miles upstream of PBAPS, the United States Geological Survey (USGS) maintains a water quality station USGS 01576980 at the Holtwood Dam in Holtwood, PA (USGS 2018a). This station has monitored water temperature, specific conductance, and turbidity since October 2014. Water temperature trends are typical for those in the mid-Atlantic United States, with peaks during the summer and lows during the winter. Daily average temperatures peak during late July and early August. Specific conductance peaks during the late summer when flows are the lowest, and is lowest during the late-winter and early spring, when flows are highest (USGS 2018a; 2018b). Daily average turbidity peaks in

February and April. The average during October is relatively high, but this spike in turbidity is attributed to a single event in late October 2016. Turbidity is often increased during storm events. Data indicate this occurred during a high discharge event (USGS 2018b). Data are provided in **Table 2-1** through **Table 2-3** and **Figure 2-1** through **Figure 2-3**.

Table 2-1: Daily Average Susquehanna River Water Temperatures (˚F) at Holtwood Dam (2015-2017)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	40.28	34.88	43.2	48.7	61.2	75.2	75.0	84.0	80.2	70.7	55.0	44.1
2	39.56	34.88	44.1	49.3	60.6	75.7	75.2	83.8	80.2	69.3	54.9	44.8
3	39.38	34.88	43.2	49.8	60.6	74.8	74.7	83.5	80.2	68.0	54.7	45.0
4	39.02	34.88	41.5	50.4	60.6	74.1	74.1	83.3	80.6	66.7	54.1	44.8
5	37.58	34.16	40.5	50.5	60.4	73.2	74.1	82.8	80.4	64.2	54.0	44.2
6	36.32	35.06	40.1	50.2	60.6	72.3	75.4	82.6	80.4	63.0	54.3	43.7
7	34.7	36.32	40.8	48.9	60.1	71.6	75.9	82.2	80.4	63.1	54.7	43.5
8	33.62	37.4	42.4	48.0	60.1	71.1	76.8	82.2	80.6	63.3	54.3	43.0
9	33.62	38.3	44.2	48.2	60.6	70.9	77.7	82.2	80.6	63.7	54.3	42.3
10	34.16	38.3	46.0	48.0	61.5	71.6	78.3	81.5	80.4	63.3	54.3	41.4
11	34.7	36.86	46.8	48.2	62.1	72.5	78.8	81.1	79.7	63.3	54.3	40.5
12	35.06	35.6	46.0	49.5	62.2	73.6	79.3	81.1	79.5	63.5	53.8	40.1
13	33.98	35.42	45.7	51.1	62.4	74.7	79.3	81.3	78.3	63.5	53.1	39.9
14	33.26	34.52	45.0	52.5	62.8	76.3	80.1	82.4	77.4	63.5	51.6	40.1
15	33.44	34.16	43.2	54.0	63.5	77.4	80.4	82.6	76.8	63.5	50.7	40.5
16	33.62	34.16	42.3	53.8	63.9	77.7	80.4	82.6	76.8	63.1	49.6	40.3
17	34.16	34.34	42.4	55.8	63.9	78.1	80.2	82.6	76.3	62.8	49.3	40.3
18	34.52	34.52	42.8	57.4	65.1	78.1	80.2	82.8	75.7	62.4	49.3	40.8
19	34.16	35.24	43.3	58.6	66.7	78.1	80.1	83.1	75.4	61.9	49.6	40.8
20	34.52	36.68	44.1	59.2	68.2	78.1	81.0	83.3	75.2	61.7	49.5	39.6
21	34.88	37.76	44.6	59.7	68.4	78.4	82.0	83.1	74.8	61.0	48.7	39.0
22	35.06	39.2	44.6	59.9	67.3	78.6	82.6	82.6	74.5	60.6	48.0	37.9
23	35.24	40.46	44.8	59.0	66.4	78.6	82.6	82.2	74.1	59.9	46.8	37.4
24	35.6	41.9	45.3	57.0	65.8	78.8	81.7	81.5	74.3	59.2	45.7	37.8
25	36.14	44.24	46.8	56.3	66.0	78.8	81.7	81.1	73.6	57.0	44.8	38.7
26	36.68	44.6	48.0	56.7	66.9	78.6	82.2	80.4	73.2	55.9	44.2	40.5
27	37.04	43.34	48.9	57.6	68.5	77.9	82.6	80.1	72.7	55.6	44.2	41.0
28	36.32	41.9	49.3	58.6	70.2	76.8	82.8	79.9	72.5	55.0	44.1	40.6
29	35.6	39.38	49.5	59.9	72.0	75.6	82.9	79.9	72.1	54.7	44.1	40.3
30	35.6	-	49.5	61.2	73.2	75.0	83.3	80.2	71.6	55.2	43.9	40.1
31	35.06	-	48.7	-	74.3	-	83.5	80.6	-	55.0	-	40.6
Average	**35.6**	**37.4**	**44.8**	**53.9**	**64.7**	**75.7**	**79.5**	**82.0**	**77.0**	**61.7**	**50.3**	**41.1**
Min	**33.3**	**34.2**	**40.1**	**48.0**	**60.1**	**70.9**	**74.1**	**79.9**	**71.6**	**54.7**	**43.9**	**37.4**
Max	**40.3**	**44.6**	**49.5**	**61.2**	**74.3**	**78.8**	**83.5**	**84.0**	**80.6**	**70.7**	**55.0**	**45.0**

Source: USGS (2018a)

Figure 2-1: Daily Average Susquehanna River Water Temperature Trends (˚F) at Holtwood Dam (2015-2017)

Source: USGS (2018a)

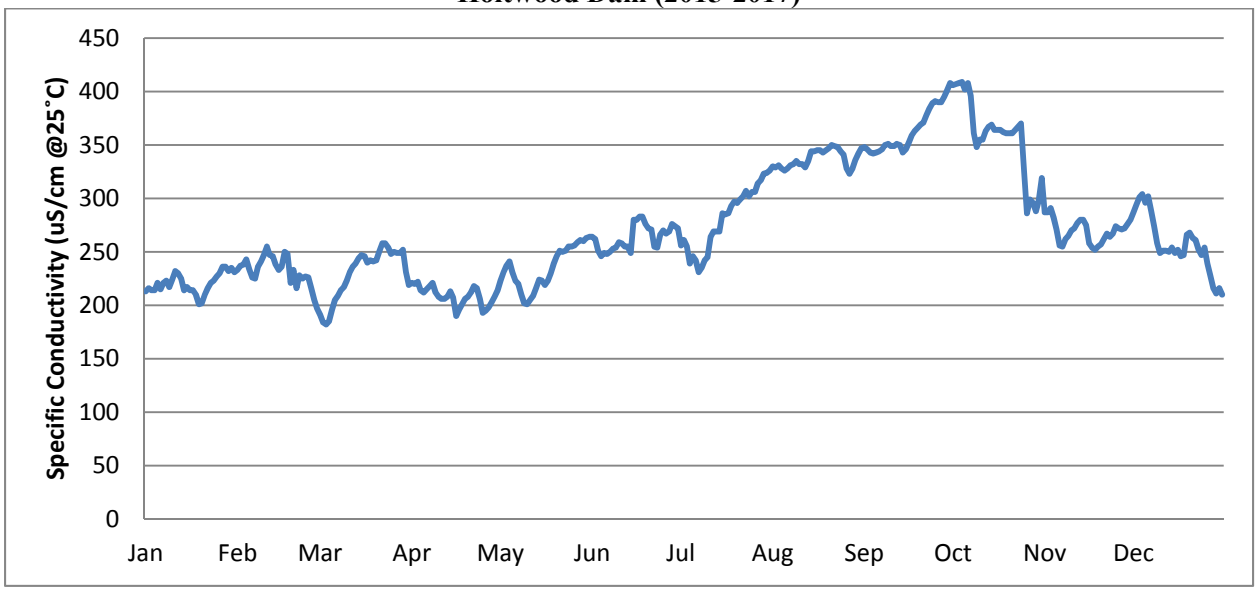
Table 2-2: Daily Average Susquehanna River Specific Conductance (µS/cm @ 25˚C) at Holtwood Dam (2015-2017)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	213	233	191	221	223	264	256	330	348	406	287	287
2	216	237	184	220	231	262	261	329	346	407	287	294
3	214	238	182	222	237	251	255	331	343	408	291	301
4	214	243	185	214	241	246	239	328	342	409	282	304
5	221	234	196	212	231	249	246	326	343	402	271	296
6	215	226	205	215	223	248	242	328	344	408	256	302
7	221	225	209	218	220	250	231	331	346	396	255	288
8	223	236	214	221	210	253	235	332	350	361	262	274
9	217	241	217	212	202	254	242	335	351	348	265	258
10	224	247	223	208	201	259	245	332	349	355	270	249
11	232	255	231	206	205	258	264	332	349	355	272	251
12	230	247	236	206	209	255	269	329	351	363	277	251
13	225	246	239	208	216	255	269	335	350	367	280	250
14	214	238	244	213	224	249	269	344	343	369	280	254
15	217	233	247	207	223	280	286	344	346	364	275	249
16	214	236	246	190	219	280	285	345	352	364	258	252
17	214	250	240	196	223	283	286	345	359	364	254	246
18	210	248	242	201	230	283	293	343	363	362	252	247
19	201	221	241	206	239	276	297	345	366	361	255	266
20	202	233	242	208	246	272	296	347	369	361	257	268
21	210	216	250	212	251	271	299	350	371	361	262	263
22	216	228	258	218	250	255	302	349	378	364	267	261
23	221	225	258	216	251	254	307	348	384	367	264	252
24	223	227	254	206	255	266	302	344	389	370	267	247
25	227	226	248	193	255	270	306	341	391	326	274	254
26	230	216	250	195	256	267	306	328	390	286	272	239
27	236	205	249	198	259	269	314	323	390	299	271	228
28	236	197	249	203	261	276	317	328	395	296	272	216
29	232	178	252	208	260	274	323	336	401	288	276	211
30	235	-	231	214	263	272	324	342	408	298	280	216
31	231	-	219	-	264	-	326	347	-	319	-	210
Average	**220**	**231**	**230**	**209**	**235**	**263**	**280**	**337**	**364**	**358**	**270**	**258**
Min	**201**	**178**	**182**	**190**	**201**	**246**	**231**	**323**	**342**	**286**	**252**	**210**
Max	**236**	**255**	**258**	**222**	**264**	**283**	**326**	**350**	**408**	**409**	**291**	**304**

Source: USGS (2018a)

µS/cm @ 25˚C = microSiemens per centimeter at 25 degrees Celcius

Figure 2-2: Daily Average Susquehanna River Specific Conductance Trends (µS/cm @ 25°C) at Holtwood Dam (2015-2017)



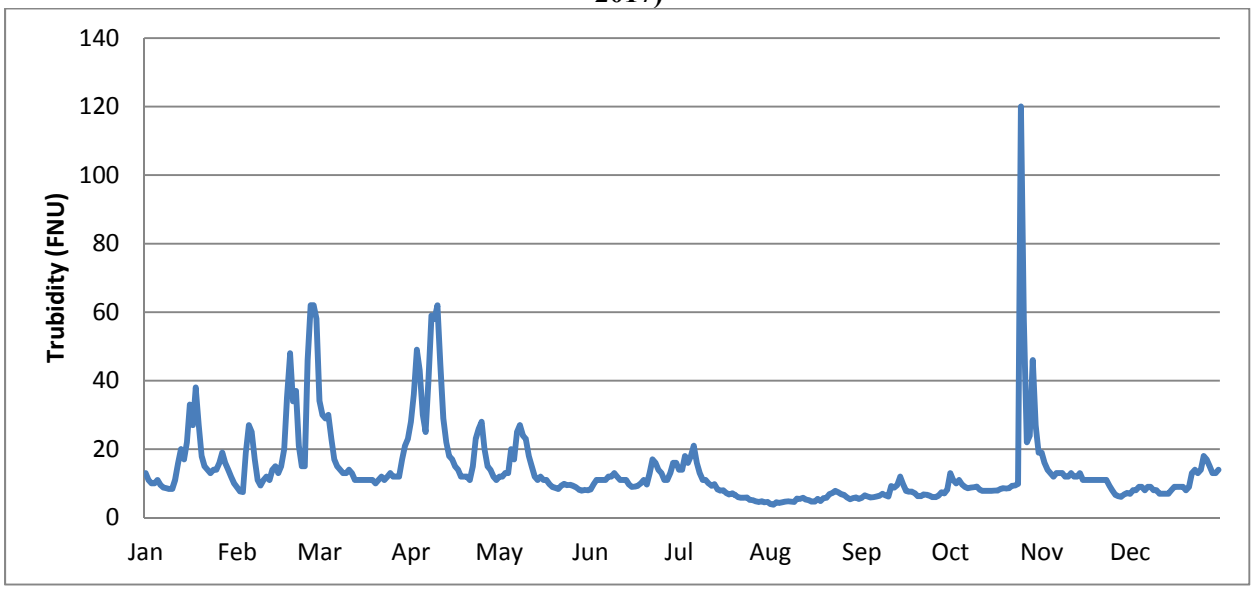
Source: USGS (2018a)
µS/cm @ 25˚C = microSiemens per centimeter at 25 degrees Celcius

Table 2-3: Daily Average Susquehanna River Turbidity (FNU) at Holtwood Dam (2015-2017)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	13	8.9	34.0	28.0	12.0	8.3	14.0	4.0	5.8	13.0	19.0	7.0
2	11	7.7	30.0	36.0	12.0	9.8	14.0	3.8	6.5	11.0	16.0	8.0
3	10	7.5	29.0	49.0	13.0	11.0	18.0	4.5	6.2	10.0	14.0	8.0
4	10	19	30.0	43.0	13.0	11.0	16.0	4.3	5.9	11.0	13.0	9.0
5	11	27	23.0	30.0	20.0	11.0	18.0	4.5	6.0	9.7	12.0	9.0
6	9.6	25	17.0	25.0	17.0	11.0	21.0	4.7	6.2	9.0	13.0	8.0
7	8.8	17	15.0	40.0	25.0	12.0	16.0	4.8	6.4	8.6	13.0	9.0
8	8.6	11	14.0	59.0	27.0	12.0	13.0	4.7	7.0	8.8	13.0	9.0
9	8.4	9.4	13.0	58.0	24.0	13.0	11.0	4.6	6.5	8.9	12.0	8.0
10	8.4	11	13.0	62.0	23.0	12.0	11.0	5.6	6.2	9.1	12.0	8.0
11	11	12	14.0	45.0	18.0	11.0	10.0	5.5	9.2	8.2	13.0	7.0
12	16	11	13.0	29.0	15.0	11.0	9.3	5.8	8.8	7.8	12.0	7.0
13	20	14	11.0	22.0	12.0	11.0	9.8	5.3	9.5	7.8	12.0	7.0
14	17	15	11.0	18.0	11.0	9.7	8.3	5.1	12.0	7.8	13.0	7.0
15	22	13	11.0	17.0	12.0	9.0	7.9	4.7	9.8	7.8	11.0	8.0
16	33	15	11.0	15.0	11.0	9.1	8.0	4.7	7.8	7.9	11.0	9.0
17	27	20	11.0	14.0	11.0	9.3	7.2	5.5	7.6	7.9	11.0	9.0
18	38	35	11.0	12.0	9.8	10.0	6.8	4.9	7.6	8.4	11.0	9.0
19	27	48	11.0	12.0	9.0	11.0	7.1	5.7	7.1	8.6	11.0	9.0
20	18	34	10.0	12.0	8.7	9.7	6.6	5.8	6.3	8.5	11.0	8.0
21	15	37	11.0	11.0	8.4	13.0	6.0	6.9	6.3	8.6	11.0	9.0
22	14	21	12.0	15.0	9.3	17.0	5.8	7.2	6.8	9.3	11.0	13.0
23	13	15	11.0	23.0	9.9	16.0	5.8	7.8	6.7	9.4	11.0	14.0
24	14	15	12.0	26.0	9.5	14.0	5.9	7.4	6.4	9.9	9.3	13.0
25	14	46	13.0	28.0	9.6	13.0	5.2	6.9	6.0	120.0	7.9	14.0
26	16	62	12.0	20.0	9.3	11.0	5.1	6.6	6.0	58.0	6.7	18.0
27	19	62	12.0	15.0	8.9	11.0	4.8	5.9	6.4	22.0	6.3	17.0
28	16	58	12.0	14.0	8.2	13.0	4.6	5.4	7.4	24.0	6.1	15.0
29	14	80	17.0	12.0	7.9	16.0	4.8	5.7	7.1	46.0	6.8	13.0
30	12	-	21.0	11.0	8.1	16.0	4.5	5.9	8.2	27.0	7.2	13.0
31	10	-	23.0	-	8.0	-	4.6	5.5	-	19.0	-	14.0
Average	15.6	26.1	15.7	26.7	12.9	11.7	9.4	5.5	7.2	17.2	11.2	10.2
Min	8.4	7.5	10.0	11.0	7.9	8.3	4.5	3.8	5.8	7.8	6.1	7.0
Max	38.0	80.0	34.0	62.0	27.0	17.0	21.0	7.8	12.0	120.0	19.0	18.0

Source: USGS (2018a)
FNU = Formazin Nephelometric Unit

Figure 2-3: Daily Average Susquehanna River Turbidity Trends (FNU) at Holtwood Dam (2015-2017)



Source: USGS (2018a)
FNU = Formazin Nephelometric Unit

Water quality was measured at the PBAPS Unit 2 outer intake structure during 18 impingement sampling events between October 18, 2017 and October 4, 2018 except during January 2018 (NAI 2018a). Water quality measurements included water temperature, dissolved oxygen concentration (in milligrams per liter [mg/L]), pH, and specific conductivity. Water temperature peaked during mid-July, and was lowest during late December. Dissolved oxygen concentrations peaked during late December, and were lowest in early September. pH levels peaked during early August, and were lowest during mid-February. Specific conductivity peaked during mid-December, and was lowest during mid-June (NAI 2018a). Water quality data are provided in **Table 2-4** and **Figure 2-4** through **Figure 2-7**.

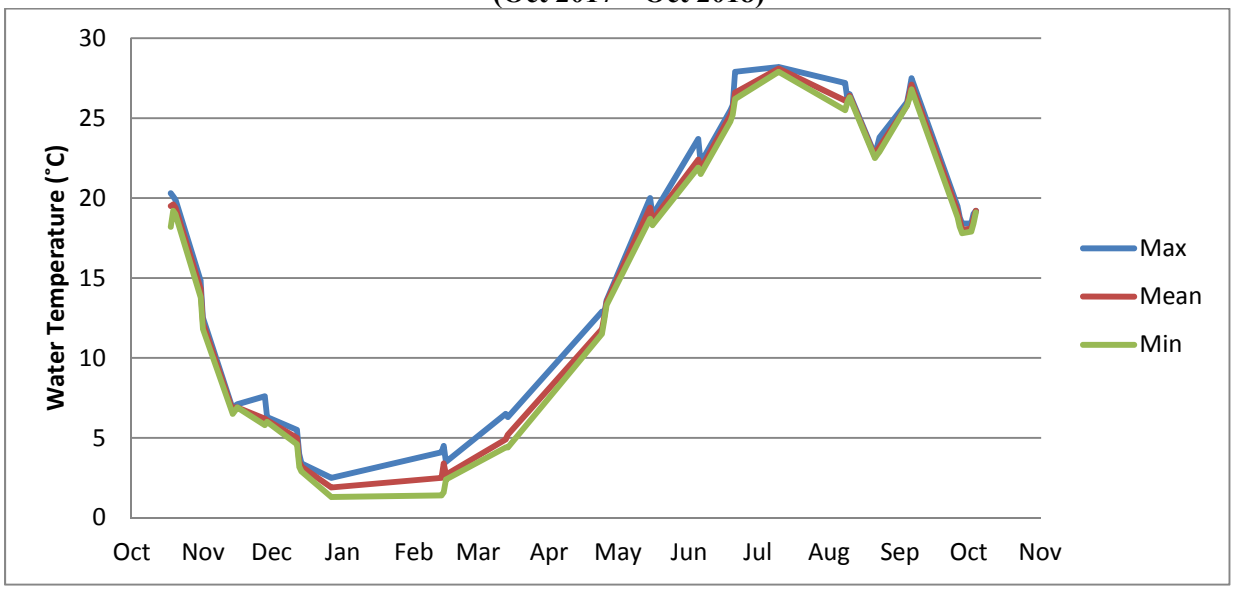
Table 2-4: Water Quality Data Collected at the PBAPS Unit 2 Outer Intake Structure during Impingement Sampling (October 18, 2017 – October 4, 2018)

Sampling Date	Water Temperature (˚F)			Dissolved Oxygen (mg/L)			pH			Specific Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
10/18/2017	67.1	64.8	68.5	7.2	7.0	7.4	7.5	7	7.6	401	352	420
10/19/2017	67.3	66.6	68.2	7.2	7.0	7.5	7.6	7.5	7.7	395	391	400
10/20/2017	66.9	66.2	67.8	7.4	7.1	7.7	7.6	7.6	7.7	390	384	393
10/31/2017	57.7	56.8	58.6	9.1	8.8	9.5	8.2	8.1	8.4	332	325	339
11/1/2017	54.0	53.2	54.5	10.5	10.1	10.6	8.2	8.1	8.2	231	224	250
11/14/2017	44.1	43.7	44.2	11.5	11.2	11.7	8.1	7.9	8.3	195	194	197
11/15/2017	44.4	44.1	44.6	11.2	10.6	12	8.1	7.9	8.3	194	192	196
11/16/2017	44.4	44.4	44.8	10.8	10.2	11.4	8.2	8.1	8.4	196	187	201
11/28/2017	43.2	42.4	45.7	12.3	11.5	12.9	-	-	-	246	241	248
11/29/2017	43.0	42.8	43.3	12.1	12.0	12.2	7.7	7.7	7.7	249	240	255
12/12/2017	41.0	40.3	41.9	11.8	10.5	12.7	8.3	8.3	8.5	270	263	278
12/13/2017	38.3	37.8	39.2	13.2	12.5	13.5	8.3	8.3	8.4	270	266	274
12/14/2017	37.8	37.2	38.1	10.3	9.6	10.5	8.0	7.8	8.1	430	423	434
12/27/2017	35.4	34.3	36.5	13.9	13.1	14.8	8.2	8.1	8.4	288	230	300

Sampling Date	Water Temperature (˚F)			Dissolved Oxygen (mg/L)			pH			Specific Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2/13/2018	36.5	34.5	39.4	10.2	9.2	11.1	7.4	6.3	7.6	272	251	281
2/14/2018	38.1	34.9	40.1	9.8	9.5	10.3	7.5	7.4	7.6	262	250	275
2/15/2018	36.9	36.3	38.3	10.2	10.0	10.5	7.4	7.4	7.5	269	266	272
3/13/2018	40.8	39.9	43.7	12.4	11.6	12.5	7.8	7.3	8.0	211	195	221
3/14/2018	41.4	39.9	43.3	12.1	11.6	12.5	7.9	7.7	7.9	212	205	216
4/24/2018	53.2	52.7	55.2	11.1	11.0	11.2	7.9	7.8	8.0	174	167	185
4/25/2018	54.7	54.3	55.0	10.7	10.6	10.9	7.9	7.8	8.0	177	171	183
4/26/2018	56.3	55.9	56.5	11.0	10.8	11.2	7.9	7.9	7.9	188	187	189
5/15/2018	66.9	65.7	68.0	9.6	9.4	9.9	7.8	7.7	7.9	238	226	244
5/16/2018	65.5	64.9	66.0	9.7	9.6	9.7	7.7	7.7	7.8	185	180	189
6/5/2018	72.3	71.4	74.7	8.0	7.6	8.3	7.8	7.7	7.8	221	211	229
6/6/2018	71.2	70.7	72.0	8.7	8.1	9.0	7.9	7.8	8.0	240	236	245
6/19/2018	77.4	76.6	77.9	8.9	7.9	9.4	8.3	8.0	8.5	221	113	266
6/20/2018	78.1	77.4	78.4	8.2	7.3	9.0	8.1	7.8	8.3	272	225	282
6/21/2018	79.9	79.2	82.2	8.0	7.6	8.8	8.0	7.9	8.3	290	289	291
7/10/2018	82.6	82.2	82.8	8.1	7.6	8.5	8.1	7.9	8.3	240	234	245
8/8/2018	79.0	77.9	81.0	8.1	7.9	8.3	7.5	7.3	7.6	163	131	174
8/9/2018	79.0	78.8	79.2	8.0	7.9	8.1	7.7	7.6	7.8	185	180	188
8/10/2018	79.5	79.3	79.7	7.3	7.0	8.1	8.6	8.4	8.8	158	152	160
8/21/2018	72.7	72.5	72.9	7.4	7.0	7.8	7.5	7.3	7.6	178	174	182
8/22/2018	73.4	72.9	73.8	7.7	7.3	8.2	7.7	7.6	7.9	195	188	205
8/23/2018	73.8	73.2	74.8	7.9	7.1	8.8	7.9	7.7	8.3	202	191	207
9/4/2018	78.4	78.4	78.8	7.1	6.1	8.1	7.6	7.5	7.8	250	222	256
9/5/2018	79.7	79.2	80.1	7.7	7.4	7.9	7.8	7.6	8.0	254	249	258
9/6/2018	80.8	80.2	81.5	7.4	7.0	7.7	7.8	7.7	7.9	258	243	266
9/26/2018	66.6	65.8	67.1	9.4	9.0	9.6	7.9	7.8	8.0	175	174	176
9/27/2018	65.5	64.8	65.8	9.5	9.2	9.7	8.0	7.8	8.1	188	187	190
9/28/2018	64.4	64.0	65.1	9.9	9.7	10.0	7.9	7.8	7.9	176	174	180
10/2/2018	64.6	64.2	65.1	9.7	9.6	9.8	7.9	7.7	8.0	169	167	171
10/3/2018	65.7	65.1	66.2	9.7	9.5	9.7	7.9	7.9	7.9	177	174	181
10/4/2018	66.6	66.4	66.6	9.5	9.4	9.6	8.0	8.0	8.0	185	183	187
All	59.7	34.3	82.8	**9.7**	**6.1**	**14.8**	**7.9**	**6.3**	**8.8**	**243**	**113**	**434**

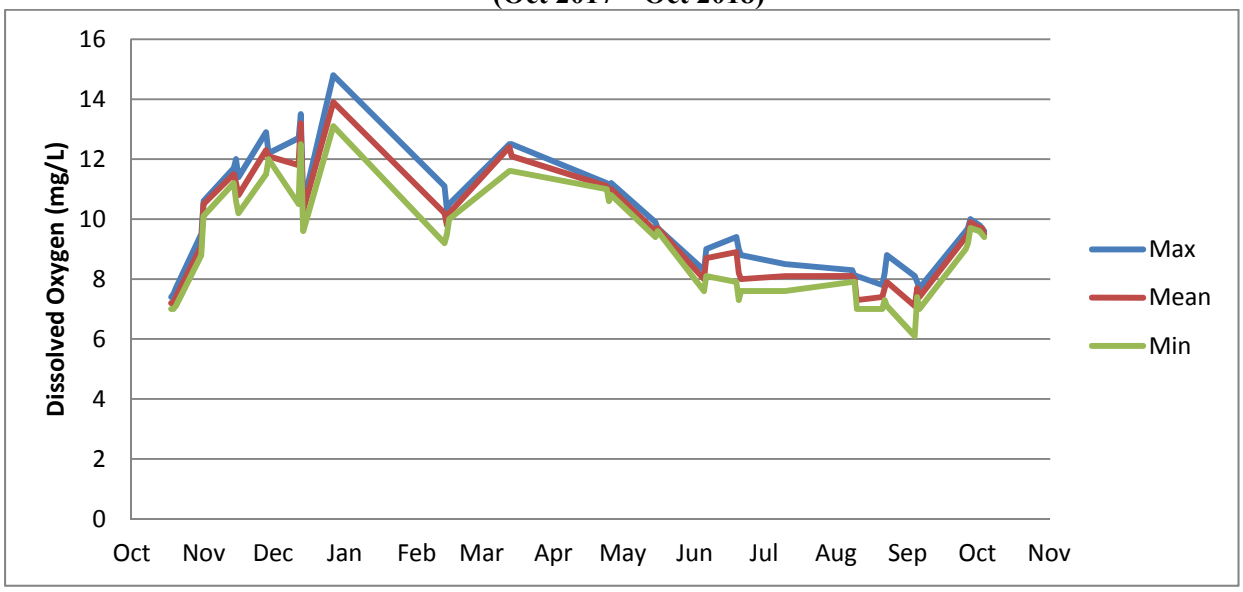
Table directly reproduced from NAI (2018a).

Figure 2-4: Water Temperature (˚C) Trends at the PBAPS Unit 2 Outer Intake Structure (Oct 2017 – Oct 2018)



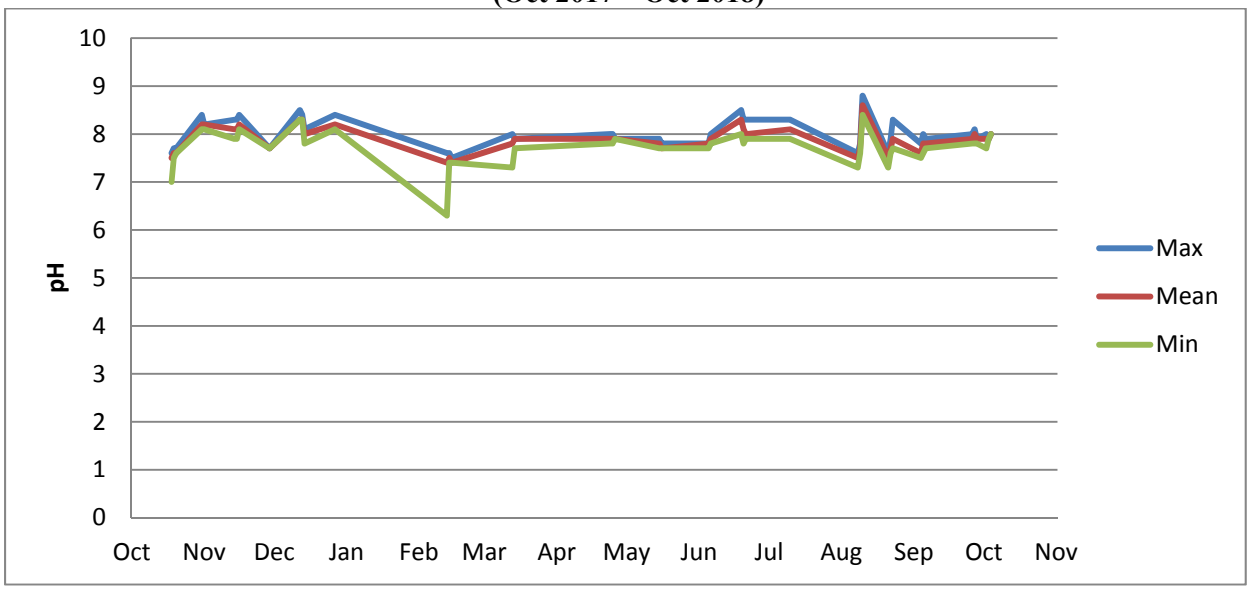
Data source: NAI (2018a)

Figure 2-5: Dissolved Oxygen (mg/L) Trends at the PBAPS Unit 2 Outer Intake Structure (Oct 2017 – Oct 2018)



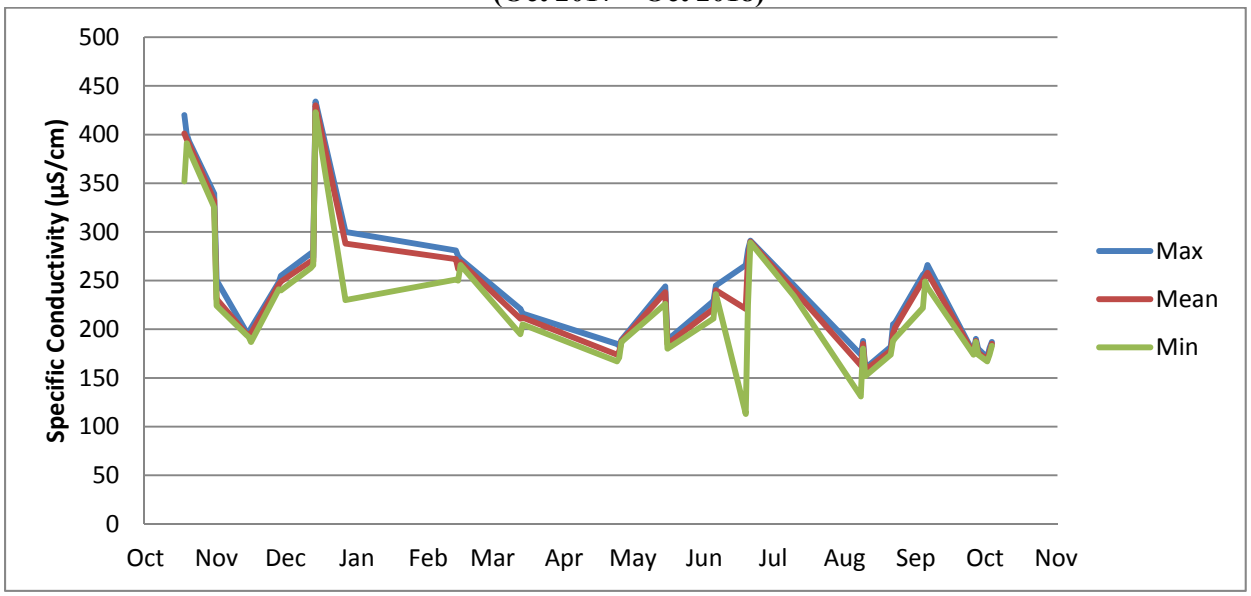
Data source: NAI (2018a)

Figure 2-6: pH Trends at the PBAPS Unit 2 Outer Intake Structure (Oct 2017 – Oct 2018)



Data source: NAI (2018a)

Figure 2-7: Specific Conductivity (µS/cm) Trends at the PBAPS Unit 2 Outer Intake Structure (Oct 2017 – Oct 2018)



Data source: NAI (2018a)

2.2 Hydrological and Geomorphological Features

Regulatory requirement at §122.21(r)(2)(ii): "Identification and characterization of the source waterbody's hydrological and geomorphological features, as well as the methods you used to conduct any physical studies to determine your intake's area of influence within the waterbody and the results of such studies."

2.2.1 HYDROLOGY AND GEOMORPHOLOGY

The drainage area of the Susquehanna River encompasses parts of New York, Pennsylvania and Maryland and covers 27,510 square miles (mi^2) (PFBC 2011). Approximately 77% of the basin is contained within the borders of Pennsylvania, and provides approximately 43% of the total drainage area of the Chesapeake Bay. Conowingo Reservoir occurs within the Lower Susquehanna River Subbasin (SRBC 2018). The Lower Susquehanna River Subbasin comprises 5,809 square miles of central Pennsylvania and northern Maryland. This Subbasin includes the urban areas of Harrisburg, York, and Lancaster, Pennsylvania (SRBC 2018), and more than a million acres of agricultural land (PFBC 2011).

The basin is comprised of portions of five physiographic provinces: Piedmont, Blue Ridge, Valley and Ridge, New England, and Appalachian Plateaus (PFBC 2011). PBAPS is located within the Piedmont Province. From the Holtwood Dam downstream to the Maryland border, the average width of the Susquehanna River/Conowingo Reservoir is 2,963 feet. When the Susquehanna River enters Pennsylvania from New York, it is considered a sixth order stream. Upon its exit into Maryland, the river has increased to an eight order stream. The river gradient from below Lake Clarke (Safe Harbor Dam) to the mouth is 0.9 m/km (PFBC 2011).

Base flow conditions of Conowingo Reservoir are the result of power production activities at the Holtwood and Conowingo dams, and to a lesser extent, the Muddy Run Pumped Storage Facility (PFBC 2011). Releases from these projects are episodic and tied to peak power generation. Conowingo Reservoir has a required pool elevation of 101.2 feet to support various usages. Its normal fluctuation varies between 101.2 and 110.2 feet National Geodetic Vertical Datum (NGVD) 1929 (PFBC 2011). Conowingo Reservoir/Susquehanna River discharge data are available from USGS 01578310 at the Conowingo Dam, approximately 8 miles downstream of PBAPS. Daily average discharge data over 25 years (1993-2017) are provided in **Table 2-5** and **Figure 2-8**.

Table 2-5: 25-Year Daily Average Discharge (cfs) from USGS 01578310 Conowingo, MD

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	41,100	42,500	52,600	93,000	58,300	31,300	32,600	18,000	15,200	29,500	38,900	57,600
2	47,200	45,800	53,500	92,300	55,400	33,300	29,800	19,400	15,100	25,700	36,500	63,100
3	49,100	44,200	58,400	96,000	55,000	33,500	27,800	20,000	15,500	26,500	32,500	67,800
4	47,300	43,300	57,400	97,800	49,700	32,300	24,400	19,000	16,000	25,400	28,300	63,100
5	44,900	44,000	56,300	93,700	53,400	31,700	25,000	17,000	17,800	22,200	27,000	57,300
6	44,600	42,400	67,100	88,800	51,800	33,800	23,700	15,300	18,900	20,600	26,200	52,400
7	49,300	41,300	66,800	88,000	53,300	30,900	23,300	16,500	23,100	19,500	24,300	48,400
8	50,600	43,000	68,100	87,200	50,000	30,100	22,400	15,000	40,300	20,600	25,200	49,300
9	53,300	41,900	67,100	79,800	47,800	32,500	20,600	13,800	43,300	18,500	28,400	46,100
10	56,700	39,500	67,100	76,700	45,000	28,600	18,500	13,500	36,800	16,700	34,000	43,000
11	51,300	36,600	73,500	80,300	44,200	28,600	16,300	13,700	32,800	19,800	35,800	40,600
12	48,000	37,500	78,400	84,500	48,200	27,500	17,100	14,400	25,400	19,100	32,600	46,300
13	47,400	36,800	72,600	79,500	50,600	27,200	17,500	17,100	22,200	17,600	31,900	53,200
14	49,700	38,500	72,200	77,300	51,200	27,400	17,400	18,100	20,300	18,200	30,300	55,600
15	54,100	38,700	76,800	74,700	51,300	27,200	18,900	15,800	18,700	17,100	31,600	54,400
16	56,800	39,900	75,100	78,700	51,300	27,200	16,800	15,800	19,200	16,600	29,500	51,800
17	53,700	37,600	78,300	82,500	51,600	28,800	16,400	15,400	16,500	19,100	32,600	46,800
18	51,100	36,800	73,200	84,500	50,000	28,100	16,900	16,100	21,000	20,100	34,500	45,800
19	50,200	39,600	69,300	78,700	50,000	29,000	16,100	16,000	36,500	22,000	36,400	46,500
20	64,300	40,200	67,100	69,600	47,700	25,600	15,500	19,900	36,700	24,200	36,700	46,300
21	72,900	43,600	73,400	67,200	45,300	26,700	16,300	18,100	27,100	27,200	39,100	45,200
22	61,100	43,100	80,800	67,300	43,400	29,000	14,700	16,800	22,100	29,900	38,100	45,200
23	50,500	48,500	80,300	66,500	42,000	27,100	15,300	16,400	19,500	33,900	36,900	43,700

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
24	46,200	52,500	82,000	63,800	39,600	27,700	16,500	16,600	22,200	31,200	35,600	45,800
25	51,400	54,600	85,100	61,000	38,000	25,000	17,200	17,100	19,400	30,300	33,600	44,200
26	52,800	54,000	81,400	59,500	37,000	25,800	19,200	15,000	18,700	27,900	33,300	53,800
27	55,200	54,600	79,200	57,600	35,200	26,700	17,900	13,400	17,600	28,500	33,300	55,500
28	58,900	52,700	79,600	64,500	35,600	30,000	18,600	13,100	20,000	30,400	36,300	51,000
29	51,900	88,500	83,900	64,900	36,100	38,000	20,200	13,300	27,500	31,000	46,300	49,000
30	46,400	-	94,000	61,400	35,500	35,800	20,200	14,700	30,700	35,700	52,700	48,100
31	43,500	-	93,500	-	32,500	-	18,900	14,700	-	37,500	-	45,800
Mean	51,661	44,903	73,035	77,243	46,323	29,547	19,742	16,097	23,870	24,597	33,947	50,410
Min	41,100	36,600	52,600	57,600	32,500	25,000	14,700	13,100	15,100	16,600	24,300	40,600
Max	72,900	88,500	94,000	97,800	58,300	38,000	32,600	20,000	43,300	37,500	52,700	67,800

Source: USGS (2018b)

Figure 2-8: 25-Year Daily Average Discharge from Conowingo Dam

Source: USGS (2018b)

Bathymetric contours of the Reservoir (surveyed 1993) in the vicinity of PBABS are provided in Reed and Hoffman (1997). The bottom across the Reservoir at PBAPS is uneven. Measured from the edge of the intake bay structure in the Reservoir, the river width is about a mile and a quarter. Depths to bottom sediments rapidly approach 15 feet (from the normal water surface elevation of 108.5 feet) within 250 feet of the PBAPS intake structure, after which the bottom flattens out for about 1,500 feet (Reed and Hoffman 1997).

Similar to lake environments, the Conowingo Reservoir has a design storage capacity of 310,000 acre-feet (NAI and GSE 2012a). The average depth of the Reservoir is 20 feet, and the Reservoir has a maximum depth of approximately 90 feet in the vicinity of Conowingo Dam (NAI and GSE 2012a). The minimum water depth in front of the existing CWIS is approximately 20 feet. This 20-foot water depth only extends approximately 250-300 feet in front of the intake. Shallows less than 10 feet deep are located about 1,700 to 2,700 feet from the intake bay structure. Another deeper pool of approximately 20 feet deep occurs approximately 4,200 feet in front of the CWIS (§ 122.21(r)(10)).

Sediments in the Reservoir consist of sand, river coal, silt and clay (Hainly et al. 1995). The USGS divides the Reservoir into three subareas (Mt. Johnson Island, Middle Reservoir, Lower Reservoir) each with different overall sediment characteristics. The PBAPS CWIS is located at the lowermost end of the Mt. Johnson Island Subarea. Sand and coal content decrease from 45 and 30%, respectively, in Mt.

Johnson Island Subarea to 5 and 2%, respectively, just above the dam in the Lower Reservoir Subarea. In contrast, silt and clay content increases from 18 and 7%, respectively, in the Mt. Johnson Island Subarea to 58 and 35%, respectively, above the dam. Sediment thickness also increases from the upper to lower reaches of the Reservoir. Sediment thicknesses range zero to ten feet in the Mt. Johnson Island Subarea, ten to 20 feet in the Middle Reservoir Subarea, and greater than 20 feet in the Lower Reservoir Subarea (Hainly et al. 1995).

Habitat within the lower Conowingo Reservoir is mostly characteristic of a relatively still-water (lentic) system (NAI and GSE 2012b). Limited flowing-water (lotic) habitat occurs in the upper end of Conowingo Reservoir, below the Holtwood Dam. The reach of Conowingo Reservoir near PBAPS has generally greater depths and slower water velocities compared to the upstream reach. Lentic conditions result in more fine-grained, silty substrates, so the lack of riverine habitat limits available spawning habitat for fish species requiring sandy or cobble sediments and higher water velocities (NAI and GSE 2012b). Conowingo Reservoir is characterized by steep banks and few in-river features (SRBC 2015). As a result, the available shallow, shoreline habitat considered important for many species of fish and macroinvertebrates is limited (NAI and ERM 2017). Shallow shoreline habitats compose only approximately 6% of the total area of Conowingo Reservoir. The majority, roughly 63%, of these shallow shoreline habitats occur upstream of PBAPS, likely due to the more lotic conditions occurring below the Holtwood Dam (NAI and ERM 2017).

2.2.2 AREA OF INFLUENCE

It is important to note that the outer intake structure at PBAPS was specifically designed and installed to reduce impingement by lowering the approach and through-screen velocities. The approach velocity of the outer intake was designed for 0.75 fps[1], as a conservative criterion based on the highly sensitive white crappie, which "could not withstand velocity in excess of 0.8" fps (Harmon et al. 1999). The highly fragile gizzard shad is now one of the most commonly impinged species, but was not included in the evaluation because it was not anticipated to establish a population in the Reservoir. However, the 0.75 fps criterion is protective of this species because juvenile gizzard shad attain swimming speeds of 23 centimeters per second (0.75 fps) (Williamson and Nelson 1985).

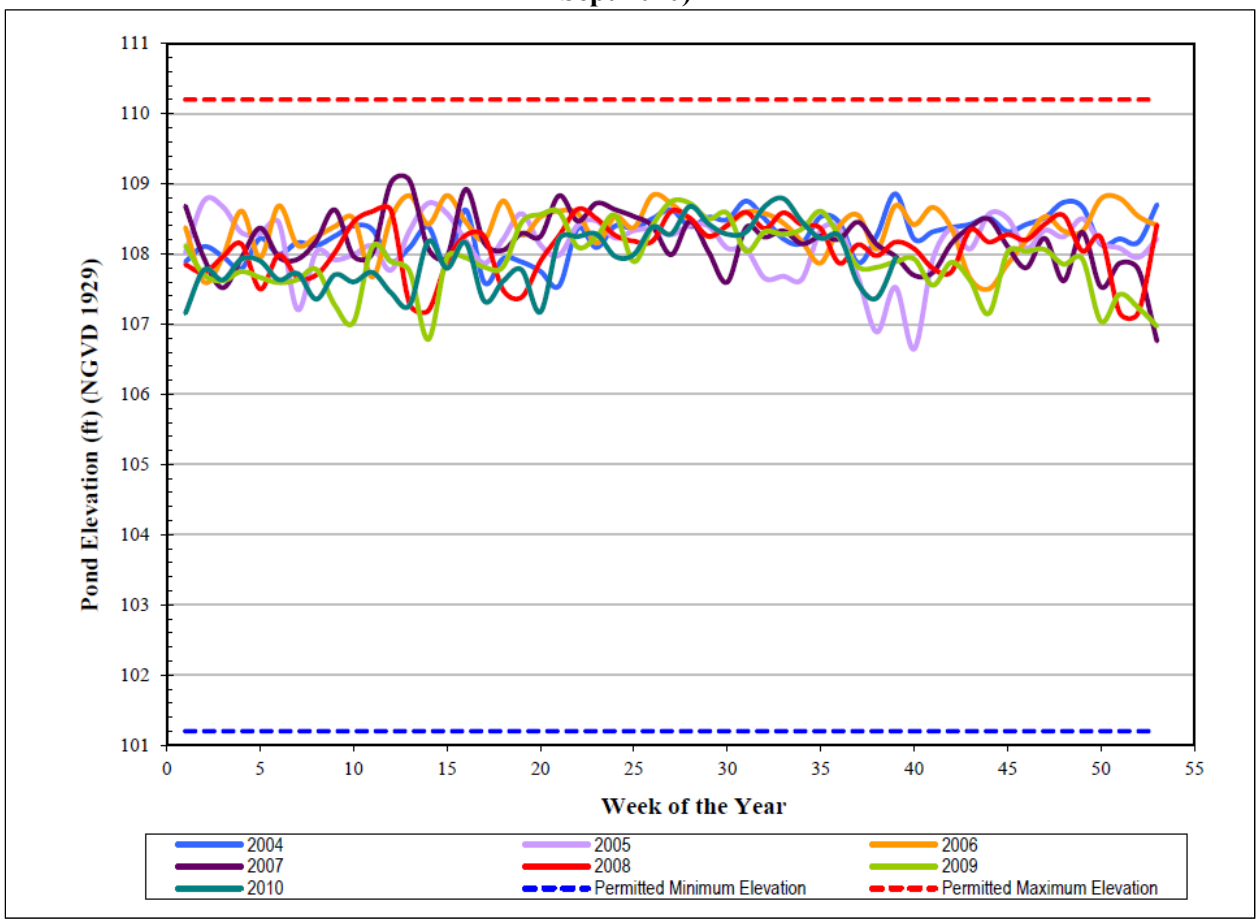
A desktop analysis was performed to calculate the approximate area of influence within the 0.5 fps velocity contour. The USEPA considers this velocity to be a *de minimis* value relative to significant impingement concerns because fish have the swimming ability to overcome this velocity and avoid impingement. The USEPA value is conservative and meant to apply to most fish nationally. PBAPS intake design used a site-specific approach velocity of 0.75 fps to protect Conowingo -specific species from impingement. Although the normal water level of the Conowingo Reservoir at PBAPS is between 104.5 feet and 108.5 feet (Conowingo Datum[2]), the lowest the Reservoir can be without causing the shutdown of the Muddy Run facility is 104.0 feet (Conowingo Pond Management Plan, SRBC 2006).

An analysis of water elevation data of Conowingo Reservoir collected at half-hourly intervals at Conowingo Dam from January 2004 through September 2010 shows that fluctuations in water levels were generally limited to between 107 feet and 109 feet (NGVD 1929) based on weekly averages (Figure 2-5) (URS and GSE 2012). These data indicate that Reservoir elevation rarely drops below 106.3 feet (Conowingo Datum).

[1] As discussed below the calculated as built approach velocity at both the trash racks (0.48 fps) and immediately in front of the screens (0.65 fps) is less than the PBAPS site- specific approach velocity of 0.75 fps.

[2] The Conowingo Datum, used exclusively at PBAPS, is 0.7 feet below the NGVD 1929 datum.

Figure 2-9: Weekly Average Water Level Fluctuation Data from Conowingo Reservoir (Jan 2004 – Sept 2010)



Source: URS and GSE (2012)

Given that the Reservoir elevation is above 104.0 feet most of the time, using this elevation in the calculations provides a highly conservative (i.e., an unlikely, worst case scenario) estimate of the intake's area of influence. Based on the physical dimensions of the outer intake structure, the design intake flow, the Reservoir low water elevation of 104.0 feet and the bathymetry of the Conowingo Reservoir in the vicinity of the outer intake structure, the approach velocity[3] at the outer intake structure trash racks is computed to be 0.39 fps. The design through-bar velocity of the trash racks is 0.48 fps and the velocity of the water in the pool between the trash racks and the screens ranges from 0.44 fps (immediately behind the trash racks) to 0.65 fps (immediately in front of the screens) (**Appendix B**). At a lower pool elevation, the velocities would be higher but would only extend a few feet beyond the trash racks into the waterbody.

Therefore, the hydraulic zone of influence at PBAPS based on the USEPA national value exists between the outer intake trash racks and traveling water screens and does not extend beyond the CWIS into the Conowingo Reservoir. The as built calculated approach velocity at both the trash racks (0.48 fps) and immediately in front of the screens (0.65 fps) is less than the PBAPS site-specific approach velocity of 0.75 fps.

[3] Using Velocity = Flow / Area

2.3 LOCATIONAL MAPS

Regulatory requirement at §122.21(r)(2)(iii): "Locational maps."

Location maps are provided in **Section 10** – see **Appendix A**.

3.0 §122.21(r)(3) - COOLING WATER INTAKE STRUCTURE DATA

3.1 NARRATIVE DESCRIPTION OF COOLING WATER INTAKE STRUCTURE

Regulatory requirement at §122.21(r)(3)(i): "A narrative description of the configuration of each of your cooling water intake structures and where it is located in the water body and in the water column"

The PBAPS CWIS provides a continuous supply of water from the Conowingo Reservoir to Units 2 and 3 and includes the following major components:

- Outer Intake Structure
  - Twenty-nine (29) active trash racks
  - Twenty-four (24) through-flow traveling water screens
- Two (2) Intake Basins
- Inner Screenhouse Structure
  - Six (6) dual-flow circulating water traveling screens
  - Four (4) through-flow service water traveling water screens
- Six (6) Circulating Water Pumps
- 6 Service Water Pumps
- 8 High Pressure Service Water Pumps
- 2 Emergency Service Water Pumps
- 3 Outer Screen Wash Water Pumps
- 2 Inner Screen Wash Water Pumps
- 2 Fire Protection Pumps

The installation of the outer intake structure was designed and installed to reduce impingement by lowering the approach and through-screen velocities, having flush alignment of the screens with the shoreline with lateral fish escape passages, and eliminating the need for intake canals. The PBAPS intake design used a site-specific approach velocity of 0.75 fps to protect Conowingo Reservoir-specific species from impingement. The outer intake structure is approximately 480 feet long and 32 feet high. The structure occupies the water column from the surface down to the level of the bottom of the trash racks, at an elevation of 84'-0" (Conowingo Datum[4]). The operating floor level of the screenhouse is at elevation 116'-0" (Conowingo Datum) and is enclosed with walls and a roof. To prevent large debris and ice chunks from entering the intake, there are 29 active trash racks with ¼-inch wide by 3-inch deep steel bars spaced 3 ½ inches on center on the face of the outer intake structure. Divers manually clean the trash racks periodically when needed and collected debris is disposed of offsite. Structures for a previous automatic raking system with a manual collection system are still in place. 24 traveling water screens (12 per unit) are located approximately 44 feet inboard of the trash racks. Each screen, most recently rebuilt by Hawco Screens, Inc., is 10 feet wide with a ⅜-inch square opening mesh. Debris, including fish, is removed from the screens by a high-pressure spray-wash system on the ascending side of the screens to sluiceways (one per unit). The debris from the screens is collected in dumpsters and disposed of off-site.

Water flows from the outer intake structure into two intake basins (1 per unit) before reaching the inner screenhouse structure. Water from the basins enters the inner screenhouse structure through eight bays (4 per unit). Six of the bays, each with their own traveling screen, direct the water to six circulating water pumps (3 per unit). These screens are dual-entry, single-exit (dual-flow) traveling screens, originally

[4] The Conowingo Datum, used exclusively at PBAPS, is 0.7 feet below the NGVD 1929 datum.

manufactured by FMC, with ¼-inch by ½-inch opening mesh. The remaining two bays (1 bay per unit) have four traveling screens installed (2 per bay), which are a single-entry, single-exit (through-flow) design. The water pumped from these two bays provides service water to the units. Historically, a limited amount of debris and some non-fragile fish were removed from the screens by a high-pressure spray-wash system on the ascending side of the screens to sluiceways (1 per unit). The debris is collected in dumpsters and disposed of off-site.

Approximately 47 feet downstream of the inner dual-flow and through-flow screens are six circulating water pumps (three per unit) and six service water pumps (three per unit), respectively.

The pumps that withdraw water from the intake structure and their design flow rates are shown in **Table 3-1**.

Table 3-1: PBAPS Intake Pump Design Capacities

Operation	Number of Installed Pumps	Design Flow (gpm)[1]	Total Design Flow (MGD)
Condenser Cooling	6 (3 per unit)	250,000 each	2,160.0
Service Water	6 (2 plus 1 spare per unit)	14,000 each	80.6
High Pressure Service Water	8 (4 per unit)	4,700 each	0[3]
Emergency Service Water	2 (common to both units)	8,000 each	0[3]
Outer Screen Wash	3 (1 per unit and 1 common to both units)	4,400 each[2]	0[3]
Inner Service Water Screen Wash	2 (1 per unit)	475 each	0[3]
Fire Protection	2 (1 electric and 1 diesel driven)	2,500 each	0[3]
Total DIF (Circulating and House Service Waters)		1,556,000[4]	2,240.6[3]

[1] These flow capacities are based on the pump manufacturer's ratings and do not account for dual operation head loss, pipe capacity, and other "as-built" conditions.
[2] These pumps withdraw water from the condenser discharge (not the intake).
[3] Excludes shutdown, emergency, and testing period.
[4] Total gpm for condenser typically operating cooling and service water pumps.

3.2 Latitude and Longitude of Cooling Water Structure

Regulatory requirement at §122.21(r)(3)(ii): "Latitude and longitude in degrees, minutes and seconds for each of your cooling water structure"

The outer intake structure is located at 39° 45' 36" North and 76° 15' 55" West (URS 2008).

3.3 Cooling Water Intake Structure Operation

Regulatory requirement at §122.21(r)(3)(iii): "A narrative description of the operation of each of your cooling water intake structures, including design intake flows, daily hours of operation number of days of the year in operation and seasonal changes, if applicable"

The Units 2/3 CWIS operates to provide a continuous supply of water from the Conowingo Reservoir to PBAPS for once-through cooling of the main condensers, when condenser cooling is required, and for other plant service water needs.

The six circulating water pumps are started up as required for condenser cooling during plant startup to generate electricity and shut off when no longer required. Certain operational measures at PBAPS result in flow variations. Through most of the year (April through October), all six circulating water pumps are in operation. However, in the winter months (late November/early December through March) lower water temperatures in the Reservoir may allow for one or two pumps to be shut down. Once a year, for approximately 21-days, one unit is shut down for refueling and maintenance, leaving only three pumps in operation for the other operating unit.

The various service water pumps are started when necessary to meet the normal and emergency plant demands during plant operation or shutdown, and shut off when no longer required. Normally, two service water pumps per unit run to supply water for equipment and building cooling, to water treatment facilities for production of domestic and demineralized water, and for washing of the traveling screens in the inner screen structure associated with the circulating water pumps. One service water pump per unit is an installed spare. Normally, the other service water pumps (i.e., the high pressure and emergency service water pumps) and Fire Protection Pumps are maintained in standby for operation as necessary only during plant shutdown, in the event of an emergency, or required testing. Each pump bay is provided with a sluice gate, which may be closed in the event of high or low water levels in the Reservoir.

The outer and inner traveling water screens are normally operated automatically, but can be operated manually from local control panels. In normal (automatic) operation, rotation of the screens is activated by preset timers for a predetermined time as set by duration timers, and, additionally, by a set pressure differential across the screens.

During automatic operation, required pumps and valves are started / opened to provide wash water to the screens. For the outer intake structure, the wash water is supplied from screen wash pumps that take suction from the cooling water discharge pond. After the debris is separated from the wash water, the wash water flows to a sump located in the trash pit and is pumped to the Reservoir. For the inner screen structure, wash water for the circulating water screens is supplied from the service water pump discharge headers, and wash water for the service water screens are supplied from screen wash pumps that take suction from the screen structure. For the inner screen structures, the debris is separated from the wash water and the wash water is returned to the intake water flow using sump pumps located in the trash pits.

Intake flows are calculated based on pump run time and design pump capacity.

Heated water is provided from the circulating water system discharge canal through a recirculation gate for freeze protection of the CWIS in the winter. Also, an air bubbler system is provided for the outer intake structure for breaking up surface ice formation at the inlet side of the structure (URS 2008).

Units 2/3 CWIS design intake flow, conservatively based on design pump capacities (excluding installed spare pumps, pumps that operate under shutdown, emergency, or testing conditions only, and pumps that do not increase intake flow requirements) and maximum operating demands, is 2,240.6 MGD (**Table 3-1**). The average AIF, calculated as the average of all flow data from January 2015 to December 2017 is approximately 2,157.5 MGD (**Table 3-2**).

Table 3-2: Annual Average Withdrawals

Year	Average Actual Intake Flow (MGD)[1]
2015	2,138.0
2016	2,156.1
2017	2,178.2
Actual Intake Flow	2,157.5

Source: Exelon (2018a, b, and c)
[1]Maximum AIF at PBAPS is equal to the DIF.

The PBAPS Units 2/3 CWIS operates to supply water to support facility demand in line with its power generation and process needs.

3.4 WATER BALANCE

Regulatory requirement at §122.21(r)(3)(iv): "A flow distribution and water balance diagram that includes all sources of water to the facility, recirculating flows, and discharges"

A schematic diagram showing the flow distribution and water balance is provided in **Section 10** as **Appendix C** – Drawings and Schematics.

3.5 ENGINEERING DRAWINGS

Regulatory requirement at §122.21(r)(3)(v): "Engineering drawings of the cooling water intake structure"

Engineering drawings of the cooling water intake structure are provided in **Section 10** as **Appendix C** – Drawings and Schematics.

4.0 §122.21(r)(4) - SOURCE WATER BASELINE BIOLOGICAL CHARACTERIZATION DATA

4.1 UNAVAILABLE DATA

Regulatory requirement at §122.21(r)(4)(i): "A list of the data in paragraphs (r)(4)(ii) through (vi) of this section that are not available and efforts made to identify sources of the data."

The Conowingo Reservoir has been extensively studied, including water quality, hydrology, and biological monitoring, both pre- and post-operation of PBAPS. Therefore, ample data regarding impingement, entrainment, and the fisheries community near PBAPS were available for the purposes of this 122.21(r)(4) report.

4.2 TAXA IN THE VICINITY OF THE CWIS

Regulatory requirement at §122.21(r)(4)(ii): "A list of species (or relevant taxa) for all life stages and their relative abundance in the vicinity of the cooling water intake structure."

The aquatic community of Conowingo Reservoir has been researched since the pre-operational studies performed for PBAPS in the early 1970s. Results of the pre- and post-operational studies, as well as Section 316(a) assessments in the 1980s, 1990s, 2010-2013, and 2016 suggest a balanced indigenous aquatic community has existed and continues to exist in the Conowingo Reservoir.

The lentic habitat of Conowingo Reservoir supports a fish community composed primarily of common warm-water species that are found in lakes, ponds, and reservoirs from the southeastern U.S. to Canada (NAI and ERM 2017). The fisheries community is generally dominated by representatives of the families Clupeidae, Cyprinidae, Centrarchidae, and Ictaluridae, constituting 95% of the fish community in Conowingo Reservoir (NAI and ERM 2017). Forage species are primarily clupeid and cyprinid species. The dominant clupeid taxon in Conowingo Reservoir, gizzard shad (*Dorosoma cepedianum*), is also the most dominant species overall. Additionally, hundreds of thousands of gizzard shad enter Conowingo Reservoir annually via the Conowingo Dam East Fish Lift (EFL). Approximately 96% of cyprinids collected in Conowingo Reservoir between 2010 and 2013 were from four species: spotfin shiner (*Cyprinella spiloptera*), spottail shiner (*Notropis hudsonius*), comely shiner (*N. amoenus*), and bluntnose minnow (*Pimephales notatus*).

Centrarchids, the third most abundant family in Conowingo Reservoir sampling, are primarily represented by bluegill (*Lepomis macrochirus*), green sunfish (*L. cyanellus*), rock bass (*Ambloplites rupestris*), and smallmouth bass (*Micropterus dolomieu*). Channel catfish (*Ictalurus punctatus*) is one of the most abundant large-bodied species in Conowingo Reservoir and accounted for 12% of fish collected between 2010 and 2013 (NAI and ERM 2017).

Other families with significant representation in Conowingo Reservoir include Percidae (2.1%), represented primarily by the tessellated darter (*Etheostoma olmstedi*), Chesapeake logperch (*Percina bimaculata*), and walleye (*Sander vitreus*); Catostomidae (1.2%), represented primarily by the shorthead redhorse (*Moxostoma macrolepidotum*); and Fundulidae (1.1%), represented only by the banded killifish (*Fundulus diaphanus*) (NAI and ERM 2017).

A total of 53 species representing 13 families were collected between 2010 and 2013 in Conowingo Reservoir (**Table 4-1**). Thirty-one species were represented by less than 100 collected individuals, and 18 species were represented by less than 10 individuals (NAI and ERM 2017). Fisheries community diversity and relative abundance were similar throughout the Conowingo Reservoir year round. However, avoidance occurred below the PBAPS discharge during the months of July and August, and attraction to the PBAPS discharge occurred during the winter. Fish assemblages throughout the year were consistent in thermal and non-thermal areas of Conowingo Reservoir and demonstrated no loss of trophic structure over the course of the study period. Additionally, habitat avoidance as a result of PBAPS operations did not occur during May and June, the peak spawning period for most Conowingo Reservoir fish species (NAI and ERM 2017). Electrofishing conducted by the SRBC in August 2014 also demonstrated species diversity is highest in the upper portion of Conowingo Reservoir below the Holtwood Dam (River Mile [RM] 22), where more riverine conditions exist. Diversity and catch per unit effort (CPUE) during August were similar in the lentic area of Conowingo Reservoir both above (RM 18) and below (RM 14) the PBAPS discharge (SRBC 2015).

The Conowingo Dam contains a fish lift on the eastern side of the dam to allow fish passage upstream into Conowingo Reservoir (NAI 2017a). The East Fish Lift (EFL) Passage Facility started operation in 1991 and is monitored every spring by identifying and enumerating the fish passing into Conowingo Reservoir during upstream migration. Data provided in **Table 4-2** summarize fish passage through the EFL since 2010 (NAI 2010, 2011, 2012, 2013a, 2014a, 2015a, 2016a, 2017a; Exelon 2018d). Over 8 million fish representing 47 species and 15 families were passed between 2010 and 2018. Gizzard shad accounted for 97% of fish passing into Conowingo Reservoir via the EFL. The second most observed species was American shad (1.2%). The remaining 1.9% of fish passing through the EFL includes channel catfish, white perch, quillback, shorthead redhorse, walleye, common carp, and smallmouth bass (NAI 2010, 2011, 2012, 2013a, 2014a, 2015a, 2016a, 2017a, Exelon 2018d).

Table 4-1: Conowingo Reservoir Fish Community Sampling (2010-2013, 2016)

Family	Common Name	Scientific Name	2010		2011		2012		2013		2016		Total	
			N	%	N	%	N	%	N	%	N	%	N	%
Anguillidae	American eel	*Anguilla rostrata*	0	0	0	0	0	0	0	0	1	0.01	1	<0.01
Clupeidae	Alewife	*Alosa pseudoharengus*	0	0	1	<0.01	0	0	0	0	0	0	1	<0.01
	American shad	*Alosa sapidissima*	0	0	1	<0.01	0	0	0	0	0	0	1	<0.01
	Gizzard shad	*Dorosoma cepedianum*	5,905	47.4	10,265	40.0	8,388	24.4	3,046	16.6	4,301	29.52	31,905	30.26
Salmonidae	Brown trout	*Salmo trutta*	0	0	0	0	0	0	2	0.01	0	0	2	<0.01
Osmeridae	Rainbow smelt	*Osmerus mordax*	0	0	1	<0.01	0	0	0	0	0	0	1	<0.01
Esocidae	Muskellunge	*Esox masquinongy*	0	0	0	0	0	0	1	0.01	0	0	1	<0.01
	Tiger muskellunge	*Esox masquinongy X E. lucius*	0	0	0	0	1	<0.01	0	0	0	0	1	<0.01
Cyprinidae	Central stoneroller	*Campostoma anomalum*	0	0	0	0	0	0	6	0.03	1	0.01	7	0.01
	Rosyside dace	*Clinostomus funduloides*	0	0	0	0	8	0.02	0	0	0	0	8	0.01
	Grass carp	*Ctenopharyngodon idella*	0	0	0	0	0	0	1	0.01	0	0	1	<0.01
	Spotfin shiner	*Cyprinella spiloptera*	1,061	8.52	1,942	7.56	1,120	3.26	1,390	7.56	724	4.97	6237	5.91
	Common carp	*Cyprinus carpio*	81	0.65	239	0.93	217	0.63	107	0.58	69	0.47	713	0.68
	Cutlips minnow	*Exoglossum maxillingua*	0	0	0	0	1	<0.01	0	0	0	0	1	<0.01
	Common shiner	*Luxilus cornutus*	0	0	7	0.03	1	<0.01	1	0.01	0	0	9	0.01
	River chub	*Nocomis micropogon*	0	0	1	<0.01	2	0.01	0	0	0	0	3	<0.01
	Golden shiner	*Notemigonus crysoleucas*	17	0.14	15	0.06	46	0.13	20	0.11	398	2.73	496	0.47
	Comely shiner	*Notropis amoenus*	155	1.24	2,456	9.56	9,373	27.3	1,953	10.6	459	3.15	14396	13.65
	Spottail shiner	*Notropis hudsonius*	100	0.80	1,031	4.01	710	2.07	746	4.06	65	0.45	2652	2.51
	Swallowtail shiner	*Notropis procne*	6	0.05	3	0.01	4	0.01	4	0.02	0	0	17	0.02
	Rosyface shiner	*Notropis rubellus*	0	0	0	0	1	<0.01	0	0	0	0	1	<0.01
	Mimic shiner	*Notropis volucellus*	0	0	25	0.10	3	0.01	2	0.01	2	0.01	32	0.03
	Bluntnose minnow	*Pimephales notatus*	131	1.05	545	2.12	442	1.29	1,488	8.10	108	0.74%	2714	2.57
	Blacknose dace	*Rhinichthys atratulus*	0	0	0	0	0	0	1	0.01	1	0.01	2	<0.01
	Creek chub	*Semotilus atromaculatus*	1	0.01	3	0.01	20	0.06	12	0.07	0	0.	36	0.03
	Fallfish	*Semotilus corporalis*	1	0.01	35	0.14	14	0.04	4	0.02	4	0.03	58	0.06
Catostomidae	Quillback	*Carpiodes cyprinus*	16	0.13	86	0.33	18	0.05	26	0.14	3	0.02	149	0.14
	White sucker	*Catostomus commersonii*	6	0.05	7	0.03	31	0.09	102	0.55	1	0.01	147	0.14
	Northern hogsucker	*Hypentelium nigricans*	14	0.11	27	0.11	32	0.09	10	0.05	2	0.01	85	0.08
	Shorthead redhorse	*Moxostoma macrolepidotum*	41	0.33	104	0.40	247	0.72	300	1.63	18	0.12	710	0.67
Ictaluridae	Channel catfish	*Ictalurus punctatus*	2,217	17.8	5,215	20.3	2,749	8.00	931	5.07	406	2.79	11518	10.92
	Flathead catfish	*Pylodictis olivaris*	21	0.17	39	0.15	44	0.13	40	0.22	38	0.26	182	0.17
Belonidae	Atlantic needlefish	*Strongylura marina*	0	0	0	0	5	0.01	0	0	0	0	5	<0.01
Fundulidae	Banded killifish	*Fundulus diaphanus*	185	1.49	88	0.34	65	0.19	700	3.81	283	1.94	1321	1.25
Poeciliidae	Eastern mosquitofish	*Gambusia holbrooki*	0	0	1	<0.01	0	0	0	0	0	0	1	<0.01
Moronidae	White perch	*Morone americana*	5	0.04	35	0.14	62	0.18	49	0.27	27	0.19	178	0.17
	Striped bass	*Morone saxatilis*	0	0	1	<0.01	1	<0.01	0	0	0	0	2	<0.01

Family	Common Name	Scientific Name	2010		2011		2012		2013		2016		Total	
			N	%	N	%	N	%	N	%	N	%	N	%
	Hybrid striped bass	*Morone chrysops x M. saxatilis*	0	0	9	0.04	30	0.09	5	0.03	0	0	44	0.04
Centrarchidae	Rock bass	*Ambloplites rupestris*	154	1.24	353	1.37	303	0.88	417	2.27	250	1.72	1477	1.40
	Redbreast sunfish	*Lepomis auritus*	1	0.01	8	0.03	11	0.03	13	0.07	2	0.01	35	0.03
	Green sunfish	*Lepomis cyanellus*	597	4.79	910	3.54	1,286	3.74	1,678	9.13	912	6.26	5383	5.10
	Pumpkinseed	*Lepomis gibbosus*	2	0.02	11	0.04	10	0.03	19	0.10	8	0.05	50	0.05
	Bluegill	*Lepomis macrochirus*	1,120	8.99	1,395	5.43	8,140	23.7	3,246	17.7	5,422	37.22	19323	18.32
	Smallmouth bass	*Micropterus dolomieu*	172	1.38	381	1.48	387	1.13	1,124	6.12	787	5.40	2851	2.70
	Largemouth bass	*Micropterus salmoides*	61	0.49	108	0.42	148	0.43	149	0.81	107	0.73	573	0.54
	White crappie	*Pomoxis annularis*	2	0.02	18	0.07	12	0.03	22	0.12	1	0.01	55	0.05
	Black crappie	*Pomoxis nigromaculatus*	2	0.02	3	0.01	7	0.02	9	0.05	0	0	21	0.02
Percidae	Greenside darter	*Etheostoma blennioides*	13	0.10	6	0.02	3	0.01	27	0.15	1	0.01	50	0.05
	Banded darter	*Etheostoma olmsted*	5	0.04	0	0	0	0	0	0	0	0	5	<0.01
	Tessellated darter	*Etheostoma olmstedi*	197	1.58	116	0.45	190	0.55	142	0.77	28	0.19	673	0.64
	Yellow perch	*Perca flavescens*	1	0.01	14	0.05	23	0.07	103	0.56	26	0.18	167	0.16
	Chesapeake logperch	*Percina bimaculata*	77	0.62	65	0.25	80	0.23	337	1.83	74	0.51	633	0.60
	Shield darter	*Percina peltata*	9	0.07	23	0.09	0	0	39	0.21	2	0.01	73	0.07
	Walleye	*Sander vitreus*	79	0.63	97	0.38	121	0.35	109	0.59	37	0.25	443	0.42
Total Fish Collected			**6,550**		**25,690**		**34,356**		**18,381**		**14,568**		**105,450**	
Number of Species Collected			**34**		**41**		**40**		**41**		**34**		**54**	

Source: NAI and ERM (2017)

Table 4-2: Upstream Fish Passage Data through the Conowingo Dam East Fish Lift Into Conowingo Reservoir (2010-2018)

Species	Scientific Name	2010	2011	2012	2013	2014	2015	2016	2017	2018
Sea lamprey	*Petromyzon marinus*	31	20	85	51	29	46	30	30	18
American eel	*Anguilla rostrata*	4	-	4	3	15	48	17	11	-
Longnose gar	*Lepisosteus osseus*	-	-	1	-	-	-	-	1	-
Blueback herring	*Alosa aestivalis*	4	17	25	7	25	3	34	59	2
Hickory shad	*Alosa mediocris*	-	20	-	1	2	8	-	-	-
Alewife	*Alosa pseudoharengus*	1	2	27	-	111	10	-	6	58
American shad	*Alosa sapidissima*	37,757	20,571	22,143	12,733	10,425	8,341	14,276	16,265	6,992
Gizzard shad	*Dorosoma cepedianum*	813,429	257,522	1,070,672	1,076,048	1,170,200	742,661	833,681	813,687	1,022,819
Rainbow trout	*Oncorhynchus mykiss*	3	2	14	6	7	4	18	19	9
Brown trout	*Salmo trutta*	5	2	6	8	12	6	10	13	11
Brook trout	*Salvelinus fontinalis*	-	-	-	1	-	-	-	-	-
Splake trout	*Salvelinus namaycush X S. fontinalis*	-	-	6	-	-	-	-	-	-
Rainbow smelt	*Osmerus mordax*	-	-	-	-	1	-	-	-	-
Northern pike	*Esox Lucius/*	1	-	-	-	-	-	-	-	-
Muskellunge	*Esox masquinongy*	1	1	3	2	4	2	1	4	1
Tiger muskellunge	*Esox masquinongy X E. lucius*	1	-	1	-	-	-	1	3	-
Common carp	*Cyprinus carpio*	47	253	331	180	253	457	1,440	176	53
Golden shiner	*Notemigonus crysoleucas*	2	-	1	-	1	1	-	-	-
Comely shiner	*Notropis amoenus*	92	-	1,051	252	-	-	-	-	-
Spottail shiner	*Notropis hudsonius*	12	-	1	12	1	71	11	-	1
Spotfin shiner	*Cyprinella spiloptera*	98	-	-	-	2	70	-	12	-
Quillback	*Carpiodes cyprinus*	489	167	1,523	2,725	570	162	876	137	71
White sucker	*Catostomus commersonii*	9	4	1	33	11	2	9	7	5
Shorthead redhorse	*Moxostoma macrolepidotum*	43	184	334	203	1,136	210	1,019	1,386	101
Atlantic needlefish	*Strongylura marina*	4	6	13	-	-	1	49	2	-
White catfish	*Ameiurus catus*	1	-	-	-	-	-	-	-	-
Yellow bullhead	*Ameiurus natalis*	1	-	1	-	2	-	1	1	1
Brown bullhead	*Ameiurus nebulosus*	1	5	203	17	105	140	1,989	381	253
Channel catfish	*Ictalurus punctatus*	4,626	10,087	12,224	1,594	9,235	1,118	3,414	9,972	9,236
Flathead catfish	*Pylodictis olivaris*	1	-	3	-	60	-	1	1	2
White perch	*Morone americana*	21	6	39	2	97	20	6,544	120	135
Striped bass	*Morone saxatilis*	34	21	129	200	110	407	236	514	344
Hybrid striped bass	*Morone chrysops x M. saxatilis*	2	-	3	-	1	11	3	1	3
Rock bass	*Ambloplites rupestris*	8	15	5	2	4	1	7	5	-
Redbreast sunfish	*Lepomis auritus*	20	-	-	2	-	-	-	1	-
Green sunfish	*Lepomis cyanellus*	-	-	1	-	1	-	1	-	-

Species	Scientific Name	2010	2011	2012	2013	2014	2015	2016	2017	2018
Pumpkinseed	*Lepomis gibbosus*	6	-	3	-	2	1	-	1	-
Bluegill	*Lepomis macrochirus*	54	31	39	58	28	31	58	54	6
Smallmouth bass	*Micropterus dolomieu*	57	146	263	151	133	97	679	1,438	478
Largemouth bass	*Micropterus salmoides*	18	4	13	10	8	11	12	8	6
White crappie	*Pomoxis annularis*	-	-	-	-	-	-	-	2	3
Black crappie	*Pomoxis nigromaculatus*	-	-	-	-	-	-	-	2	-
Tessellated darter	*Etheostoma olmstedi*	-	-	-	-	4	-	-	-	-
Yellow perch	*Perca flavescens*	2	7	21	1	3	6	12	4	1
Chesapeake logperch	*Percina bimaculata*	-	-	-	-	2	-	-	-	-
Walleye	*Sander vitreus*	378	360	722	224	150	111	750	593	180
Northern snakehead	*Channa argus*	-	-	-	-	-	-	-	1	-
Total		**857,263**	**289,453**	**1,109,911**	**1,094,526**	**1,192,750**	**754,057**	**865,179**	**844,917**	**1,040,789**

Source: NAI (2010, 2011, 2012, 2013a, 2014a, 2015a, 2016a, 2017a); Exelon (2018d)

4.3 SPECIES AND LIFESTAGES SUSCEPTIBLE TO IMPINGEMENT & ENTRAINMENT

Regulatory requirement at §122.21(r)(4)(iii): "Identification of the species and life stages that would be most susceptible to impingement and entrainment. Species evaluated should include the forage base as well as those most important in terms of significance to commercial and recreational fisheries."

Susceptibility to impingement or entrainment is dependent on a number of biotic and abiotic factors, as shown in **Table 4-3**. Site-specific impingement and entrainment studies at PBAPS are described in **Sections 0** and **4.3.2**, below.

Table 4-3: Common Factors Effecting Susceptibility to Impingement or Entrainment

Category	Factor Type	Factors	Source
Impingement	Abiotic Factors	Water temperature, dissolved oxygen, turbidity, CWIS design, and intake velocities	Baker (2007)
	Biotic Factors	Swimming ability, body shape, size, diel and seasonal movements, and health of the organism	Baker (2007)
Entrainment	Abiotic Factors	Intake location, water volume used for cooling, velocity at intake, and screen mesh size	Ferry-Graham et al. (2008)
	Biotic Factors	Organism size, swimming ability, swimming behavior (pelagic or benthic) diurnal behavior, and spawning habitat	Ferry-Graham et al. (2008)

4.3.1 IMPINGEMENT DATA

Multiple impingement studies and programs have been conducted at PBAPS. Impingement characterization was originally conducted as part of a 316(b) demonstration between November 1973 and December 1976 (PECO 1977). The study collected a total of 58,947 fish representing 40 species and nine families. Impingement during that time period was dominated by channel catfish (59%), bluegill (14%), white crappie (5%), spottail shiner (4%), and pumpkinseed (3%). Channel catfish also account for the most biomass impinged (72%), followed by white crappie (7%), bluegill (4%), and yellow perch (4%; PECO 1977).

Since 1982, PBAPS has participated in an impingement sampling program during the fall as a part of efforts to support the Susquehanna River American shad restoration program (NAI 2007). The sampling events occur during the out-migration period of American shad in the Susquehanna River, typically between September and mid-December. The most abundant species collected during those studies is, by far, gizzard shad, a fragile species with minimal forage value (**Table 4-4**) (NAI 2007, NAI 2014b, NAI 2015b, NAI 2016b, NAI 2017b, NAI 2018b).

Table 4-4: Impingement at PBAPS during American Shad Outmigration (1997-2006, 2014-2018)

Species	97	99	00	01	02	03	04	05	06	14	15	16	17	18
American eel	-	-	-	-	-	-	-	-	-	-	4	1	1	3
American shad	64	285	100	65	18	7	-	135	59	-	62	3	15	-
Blueback herring	358	112	6	105	2	48	-	-	1	-	-	-	-	-
Alewife	1	-	2	1	5	2	6	29	6	7	5	-	2	16
Alosa sp.	-	30	-	-	-	-	-	-	-	-	1	-	-	-
Gizzard shad	**73,944**	**4,463**	**1,292**	**1,281**	**944,379**	**1,534**	**1,346**	**56,944**	**1,013**	**7,634**	**25,585**	**20,801**	**4,130**	**1,570**
Central stoneroller	-	-	-	-	-	-	-	-	1	-	-	-	-	-
Common carp	8	76	4	4	6	3	-	16	-	8	51	1	14	2
Common shiner	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Golden shiner	3	2	-	3	2	3	1	2	7	-	7	-	1	4
Comely shiner	-	4	2	5	12	16	46	29	3	16	86	1	15	55
Spottail shiner	-	4	-	7	1	1	1	7	6	4	2	-	5	-
Spotfin shiner	1	3	-	4	11	4	7	15	14	-	3	-	2	4
Swallowtail shiner	-	-	-	-	-	-	-	1	-	-	-	-	-	-
Mimic shiner	-	-	-	-	-	-	-	-	2	-	-	-	-	-
Bluntnose minnow	-	-	-	-	9	-	-	-	1	-	-	-	1	-
Fallfish	-	-	-	-	-	-	-	-	-	-	-	--	2	-
Quillback	4	1	-	-	4	1	1	2	1	-	1	-	2	1
White sucker	1	-	-	-	-	1	-	-	-	-	-	-	-	-
Shorthead redhorse	-	1	-	-	-	-	-	1	-	-	4	-	-	-
Northern hogsucker	2	-	-	-	-	-	-	10	-	-	-	-	-	-
Rainbow smelt	11	-	-	-	-	1	-	-	-	-	-	-	-	-
White catfish	1	-	-	-	1	-	-	-	-	-	-	-	-	-
Yellow bullhead	1	2	1	-	1	1	-	1	1	-	-	-	-	-
Channel catfish	113	79	100	1,326	129	80	21	346	177	395	290	59	75	188
Flathead catfish	-	-	-	-	-	-	2	19	71	12	15	2	18	19
Banded killifish	-	-	-	-	-	-	-	-	-	-	30	-	1	-
Mummichog	-	-	-	1	-	-	-	1	-	-	-	-	-	-
White perch	-	-	-	-	-	-	-	9	-	16	1,014	50	61	34
Striped bass	-	1	-	1	-	-	-	2	-	-	4	-	1	-
Rock bass	-	-	-	-	-	-	-	-	-	3	16	1	7	2
Redbreast sunfish	-	-	-	-	-	-	-	-	-	-	-	-	-	3
Green sunfish	-	-	-	-	-	-	-	-	-	3	112	4	6	7
Pumpkinseed	37	1	-	9	21	2	2	5	3	1	4	2	3	-
Bluegill	773	221	205	71	11,363	549	66	3,351	659	371	5,986	6,595	2,276	402
Smallmouth bass	15	27	4	40	45	10	5	13	-	4	19	8	3	13
Largemouth bass	10	9	-	17	9	4	8	22	9	3	34	4	2	14
White crappie	87	80	16	15	4	42	13	65	50	10	19	6	4	51

Species	97	99	00	01	02	03	04	05	06	14	15	16	17	18
Black crappie	5	1	1	4	1	1	-	-	-	-	15	4	3	1
Yellow perch	-	-	5	11	24	97	32	117	2	-	14	-	-	16
Walleye	5	1	-	6	-	3	-	198	-	-	2	2	-	1
Tessellated darter	5	-	-	-	-	5	-	15	-	6	13	4	8	2
Banded darter	-	-	-	-	-	-	-	1	-	-	-	-	-	-
Greenside darter	-	-	-	-	-	-	-	1	-	-	1	-	-	2
Chesapeake logperch	1	-	-	-	-	-	-	-	1	3	11	-	-	-
Atlantic needlefish	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Total	**75,450**	**5,403**	**1,738**	**2,976**	**956,047**	**2,415**	**1,557**	**61,357**	**2,087**	**8,496**	**33,410**	**27,549**	**6,658**	**2,411**

Source: NAI (2007, 2014b, 2015b, 2016b, 2017b, 2018b)

An additional impingement characterization study at PBAPS was conducted between August 29, 2005 and November 17, 2006 (NAI 2007). Sampling collected 61,504 impinged fish representing 40 species and eight families at both units of PBAPS. Impingement was dominated by the fragile, low-value gizzard shad (87%), followed by bluegill (7%), and channel catfish (4%) (**Table 4-5**).

Table 4-5: PBAPS Impingement Characterization Study Results (Aug 29, 2005 – Nov 17, 2006)

Family	Common Name	Scientific Name	N	%
Clupeidae	Alewife	*Alosa pseudoharengus*	38	0.1%
	American shad	*Alosa sapidissima*	183	0.3%
	Gizzard shad	*Dorosoma cepedianum*	53,432	87%
Cyprinidae	Central stoneroller	*Campostoma anomalum*	2	<0.1%
	Common carp	*Cyprinus carpio*	23	<0.1%
	Golden shiner	*Notemigonus crysoleucas*	15	<0.1%
	Comely shiner	*Notropis amoenus*	59	0.1%
	Common shiner	*Luxilus cornutus*	1	<0.1%
	Spottail shiner	*Notropis hudsonius*	21	<0.1%
	Swallowtail shiner	*Notropis procne*	1	<0.1%
	Spotfin shiner	*Cyprinella spiloptera*	45	0.1%
	Bluntnose minnow	*Pimephales notatus*	1	<0.1%
	Creek chub	*Semotilus atromaculatus*	1	<0.1%
	Mimic shiner	*Notropis volucellus*	2	<0.1%
Catostomidae	Quillback	*Carpiodes cyprinus*	11	<0.1%
	White sucker	*Catostomus commersoni*	1	<0.1%
	Northern hogsucker	*Hypentelium nigricans*	10	<0.1%
	Shorthead redhorse	*Moxostoma macrolepidotum*	5	<0.1%
Ictaluridae	White catfish	*Ameiurus catus*	1	<0.1%
	Yellow bullhead	*Ameiurus natalis*	1	<0.1%
	Channel catfish	*Ictalurus punctatus*	2,505	4.1%
	Flathead catfish	*Pylodictis olivaris*	125	0.2%
Fundulidae	Mummichog	*Fundulus heteroclitus*	2	<0.1%
Moronidae	White perch	*Morone americana*	10	<0.1%
	Striped bass	*Morone saxatilis*	2	<0.1%
Centrarchidae	Rock bass	*Ambloplites rupestris*	78	0.1%
	Redbreast sunfish	*Lepomis auritus*	3	<0.1%
	Green sunfish	*Lepomis cyanellus*	83	0.1%
	Pumpkinseed	*Lepomis gibbosus*	9	<0.1%
	Bluegill	*Lepomis macrochirus*	4,273	6.9%
	Smallmouth bass	*Micropterus dolomieu*	31	0.1%
	Largemouth bass	*Micropterus salmoides*	33	0.1%
	White crappie	*Pomoxis annularis*	120	0.2%
	Black crappie	*Pomoxis nigromaculatus*	1	<0.1%
Percidae	Tessellated darter	*Etheostoma olmstedi*	30	<0.1%
	Yellow perch	*Perca flavescens*	125	0.2%
	Logperch	*Percina caprodes*	3	<0.1%
	Walleye	*Sander vitreus*	213	0.3%
	Banded darter	*Etheostoma zonale*	1	<0.1%
	Greenside darter	*Etheostoma blennioides*	2	<0.1%
Total			**61,504**	

Source: NAI (2007)

The most recent impingement characterization study collected samples from the Unit 2 outer intake structure over 18 sampling events between October 18, 2017 and October 4, 2018 (NAI 2018a). Each event comprised of two, 12-hour impingement samples conducted over 48 hours. 6,027 fish representing 29 species from nine families were collected, dominated by bluegill (43%), gizzard shad (33%), comely shiner (11%), and channel catfish (7.5%). These species were also commonly collected during impingement sampling in 2005-2006 and prior studies (NAI 2018a) (**Table 4-6**).

Table 4-6: PBAPS Impingement Characterization Study Results (Oct 18, 2017 – Oct 4, 2018)

Species	Impingement	
	N	%
Bluegill	2,611	43.3%
Gizzard shad	1,964	32.6%
Comely shiner	657	10.9%
Channel catfish	452	7.5%
Tessellated darter	93	1.5%
Flathead catfish	76	1.3%
Green sunfish	35	0.6%
White perch	20	0.3%
Smallmouth bass	17	0.3%
White crappie	16	0.3%
Alewife	14	0.2%
American shad	10	0.2%
Rock bass	9	0.2%
Golden shiner	8	0.1%
Goldfish	8	0.1%
Bluntnose minnow	7	0.1%
Yellow perch	6	0.1%
Banded killifish	4	<0.1%
Spotfin shiner	4	<0.1%
Walleye	3	<0.1%
Blueback herring	2	<0.1%
Chesapeake logperch	2	<0.1%
Greenside darter	2	<0.1%
Spottail shiner	2	<0.1%
American eel	1	<0.1%
Black crappie	1	<0.1%
River chub	1	<0.1%
Shorthead redhorse	1	<0.1%
White sucker	1	<0.1%
Total	**6,027**	

Data source: NAI (2018a)

4.3.2 ENTRAINMENT DATA

Multiple entrainment programs have been conducted at PBAPS. Entrainment characterization was originally conducted as part of a 316(b) demonstration between May and July of 1975 and 1976 (PECO 1977). Sampling collected only 7 eggs overall, likely the result of most Conowingo Reservoir species being demersal, nest building spawners with adhesive eggs. Larvae collected represented 20 species. The most common were larvae of gizzard shad, carp, quillback, channel catfish and tessellated darter, which made up of over 80% of entrained larvae. Centrarchidae and walleye larvae comprised of 2% of entrainment. The average density of larvae was 13.2 larvae per 100m³, and the average density of gizzard shad was 5.8 larvae per 100m³. The average density of common carp larvae was 2.2 larvae per 100m³ and quillback was 2.7 larvae per 100m³. All remaining taxa accounted for less than 1 larva per 100m³ (PECO 1977).

Entrainment sampling was also conducted from March 8 through September 27, 2012 (NAI 2013b). Sampling was conducted at the PBAPS circulating water discharge outfall. A total of 1,529 ichthyoplankton were collected, representing 10 taxa. Gizzard shad (76.0%), tessellated darter (12.2%), and banded darter (1.2%), were the only identified taxa comprising of greater than 1% of composition. Collection results are provided in **Table 4-7**.

Table 4-7: Ichthyoplankton Collected from the PBAPS Circulating Water Discharge Outfall (Mar 8 – Sep 27, 2012)

Taxa	Unknown Larvae	Egg	YSL	PYSL	YOY	YROL	Total	
							N	%
American eel	-	-	-	-	-	1	1	0.1%
Banded darter	1	-	8	10	-	-	19	1.2%
Cyprinidae	-	-	-	5	-	-	5	0.3%
Channel catfish	-	-	-	3	8	-	11	0.7%
Common carp	-	1	1		-	-	2	0.1%
Etheostoma spp.	7	-	-	2	-	-	9	0.6%
Gizzard shad	600	71	285	206	-	-	1,162	76.0%
Greenside darter	-	-	-	1	-	-	1	0.1%
Lepomis spp.	-	-	-	6	-	-	6	0.4%
Spottail shiner	-	-	-	-	1	1	2	0.1%
Catostomidae	-	-	1	-	-	-	1	0.1%
Centrarchidae	-	-	-	1	-	-	1	0.1%
Tessellated darter	22	-	44	49	4	-	119	7.8%
Unidentified	134	2	-	51	-	-	187	12.2%
White sucker	1	-	-	2	-	-	3	0.2%
Total	**765**	**74**	**339**	**336**	**13**	**2**	**1,529**	

*PYSL = Post-Yolk Sac Larvae; YSL = Yolk Sac Larvae; YOY = Young of Year; YROL = Yearling or Older
Source: NAI (2013b)

The most recent entrainment characterization study was conducted for 26 consecutive weeks between March 21 and October 2, 2016 (NAI 2017c). Samples were collected from three locations: the outer intake structure, the circulating water discharge outfall for Units 2 and 3, and the discharge canal outfall. The most frequently collected entrainable organism were lifestages belonging to members of the Clupeidae family, which dominated collections with 96.0% of collected organisms. This primarily comprised of the alewife/gizzard shad taxon. The remaining 4.0% of organisms entrained were comprised primarily of unidentified organisms (1.1%), tessellated darter (0.9%), common carp (0.7%), carp and minnow family (0.4%), and *Lepomis* species (0.4%). Collection data are provided in **Table 4-8**.

Table 4-8: Entrainable Organisms Collected From Three Sampling Locations at PBAPS (Mar 21-Oct 2, 2016)

Taxa	Lifestage	Outer Intake Structure	Circulating Water Discharge	Discharge Canal Outfall	Total	
Alewife	Eggs	0	1	0	1	<0.1%
Alewife	YSL	3	2	13	18	0.1%
Alewife	PYSL	1	1	0	2	0.0%
Alewife/Gizzard shad	UNID	4,213	6,919	8,845	19,977	73.1%
Alewife/Gizzard shad	YSL	56	46	798	900	3.3%
Alewife/Gizzard shad	PYSL	1,605	1,989	557	4,151	15.2%
American shad	PYSL	0	1	0	1	<0.1%
Banded darter	PYSL	4	8	12	24	0.1%
Bluegill	YOY	5	0	0	5	<0.1%
Brown bullhead	YOY	0	3	0	3	<0.1%
Bullhead catfish family	YOY	0	1	0	1	<0.1%
Carp and minnow family	Eggs	0	1	0	1	<0.1%
Carp and minnow family	YSL	0	0	1	1	<0.1%
Carp and minnow family	PYSL	1	17	92	110	0.4%
Channel catfish	YOY	11	11	0	22	0.1%
Chesapeake logperch	PYSL	2	1	0	3	<0.1%
Chesapeake logperch	YROL	0	1	0	1	<0.1%
Common carp	Eggs	143	7	7	157	0.6%
Common carp	PYSL	8	18	10	36	0.1%
Darter sp.	YSL	3	5	9	17	0.1%
Darter sp.	PYSL	0	2	5	7	<0.1%
Darter sp.	UNID	0	17	2	19	0.1%
Flathead catfish	YOY	0	1	0	1	<0.1%
Flathead catfish	YROL	2			2	<0.1%
Gizzard shad	Eggs	64	150	164	378	1.4%
Gizzard shad	YSL	289	314	90	693	2.5%
Gizzard shad	PYSL	46	12	34	92	0.3%
Gizzard shad	YOY	6	3	0	9	<0.1%
Gizzard shad	UNID	0	4	5	9	<0.1%
Herring family	PYSL	0	1	0	1	<0.1%
Herring family	YOY	1	0	0	1	<0.1%
Ictalurus sp.	YOY	0	0	1	1	<0.1%
Lepomis sp.	YSL	0	0	1	1	<0.1%
Lepomis sp.	PYSL	38	31	11	80	0.3%
Lepomis sp.	UNID	1	3	0	4	<0.1%
Lepomis/Pomoxis sp.	PYSL	0	10	1	11	<0.1%
Quillback	PYSL	0	1	0	1	<0.1%
Quillback	YSL	2	4	8	14	0.1%
Shield darter	YOY	8	0	0	8	<0.1%
Sucker family	PYSL	0	1	1	2	<0.1%
Sunfish family	PYSL	0	1	0	1	<0.1%
Tessellated darter	YSL	9	11	9	29	0.1%
Tessellated darter	PYSL	15	36	12	63	0.2%
Tessellated darter	YOY	43	95	0	138	0.5%
Tessellated darter	YROL	7	0	0	7	<0.1%
Tessellated darter	UNID	0	1	0	1	<0.1%

Taxa	Lifestage	Outer Intake Structure	Circulating Water Discharge	Discharge Canal Outfall	Total	
Unidentified	Eggs	0	2	5	7	<0.1%
Unidentified	PYSL	3	11	1	15	0.1%
Unidentified	UNID	36	40	211	287	1.0%
White catfish	YOY	0	1	0	1	<0.1%
White perch	Eggs	4	4	12	20	0.1%
Yellow perch	PYSL	2	1	0	3	<0.1%
Total Organisms Collected		**6,631**	**9,789**	**10,917**	**27,337**	

*PYSL = Post-Yolk Sac Larvae; YSL = Yolk Sac Larvae; YOY = Young of Year; YROL = Yearling or Older; UNID = Unidentified Larvae
Source: NAI (2017c)

4.3.3 Species Most Susceptible to Impingement and Entrainment at PBAPS

Numerous field and laboratory studies were performed during the late 1960s and early 1970s to determine the critical swim speeds of more than 25 resident fish and other species likely to be introduced to the Conowingo Reservoir, such as striped bass and white perch (Harmon et al. 1999). The studies found that the most sensitive species to increased velocity was white crappie (Harmon et al. 1999) and this species was indeed collected every year during American shad outmigration impingement sampling from 1997 through 2006 and 2014 through 2018 (NAI 2007, 2014b, 2015b, 2016b, 2017b, 2018b). **Table 4-9** lists the species most susceptible to impingement and entrainment at PBAPS based on their frequency and abundance in impingement and entrainment characterization studies conducted at PBAPS since the 1990s. Life history and seasonal/daily activities of each species are provided in **Section 4.4** and **Section 4.5**, respectively.

Table 4-9: Species Most Susceptible to Impingement or Entrainment at PBAPS

Species	Justification for Inclusion
American shad	• Commonly impinged at PBAPS, particularly during the fall outmigration • Pelagic larval lifestage • The subject of restoration programs
Banded darter	• Commonly collected taxa during the two most recent entrainment studies
Bluegill	• Bluegill are the most common *Lepomis* representative during fisheries community studies • *Lepomis* spp. were a top five entrained taxa • Bluegill are among one of the top three impinged species recorded at PBAPS
Channel catfish	• One of the top three species collected during impingement studies at PBAPS • Extremely common during community studies; the most populous recreational species
Comely shiner	• Commonly impinged species at PBAPS • Most commonly encounters shiner species at in Conowingo Reservoir near PBAPS
Common carp	• Commonly collected during entrainment studies
Gizzard shad	• Extremely common during fisheries community surveys • The most impinged and entrained taxa in most studies conducted • Pelagic larval lifestage
Tessellated darter	• Often the second most entrained taxa at PBAPS • Pelagic larval lifestage
Walleye	• Top five impinged taxa in a recent impingement study (05-06)
White crappie	• Commonly impinged species at PBAPS
White perch	• Commonly impinged species at PBAPS, particularly during recent fall studies • Pelagic larval lifestage

4.4 PERIODS OF REPRODUCTION, RECRUITMENT, AND PEAK ABUNDANCE

Regulatory requirement at §122.21(r)(4)(iv): "Identification and evaluation of the primary period of reproduction, larval recruitment, and period of peak abundance for relevant taxa."

American shad

American shad are an anadromous species, living most of its life-cycle within the Atlantic Ocean, but migrate into freshwater streams to spawn (MacKenzie et al. 1985). The majority of American shad are known to return to their natal river to spawn. The freshwater spawning migration of American shad is triggered by water temperature (MacKenzie et al. 1985). Spawning occurs when water temperatures are approximately 12-20˚C, and peaks at approximately 18˚C (Wang and Kernehan 1979). Spawning has been observed to occur as early as mid-November in Florida waters and late-July in Canadian waters (MacKenzie et al. 1985). Spawning in the Mid-Atlantic typically occurs between late-April and July (Wang and Kernehan 1979). Males are known to arrive at the spawning grounds prior to females (MacKenzie et al. 1985). Spawning sites are far enough upstream that shad eggs will not drift into saltwater. Spawning in the Delaware River was observed to begins between 19:00-20:00 hours, and peaks between 21:00-23:00 hours, with most spawning subsiding by 01:00 hours. Spawning may occur earlier on overcast days, indicating that light intensity plays a role in American shad spawning. Spawning occurs at the surface, often occurring in groups. Shad are known to spawn over sand, silt, muck, gravel, and boulder substrates, often in areas where sufficient current exists to keep eggs suspended within the water column. Preferred currents are 0.5-3.0 feet per second. Preferred spawning depths are 3 to 30 feet (MacKenzie et al. 1985). Approximately 17-37% of adults spawning in Chesapeake Bay tributaries are believed to be repeat spawners (Wang and Kernehan 1979). Generally, the more southern populations of American shad tend to die after spawning, while the further northern populations tend to be more likely to survive after spawning to spawn again (MacKenzie et al. 1985).

American shad fecundity is relatively high, with 116,000-659,000 eggs per female (MacKenzie et al. 1985). Eggs survival rates are very low as a result of issues such as failure to fertilize, suffocation, and predation (MacKenzie et al. 1985). Egg diameters range from 2.9-3.4 mm and are slightly demersal and slightly adhesive (Wang and Kernehan 1979). Eggs hatch in 12-15 days at 12˚C and 6-8 days at 17˚C (Wang and Kernehan 1979). Viability of eggs is 0% when temperatures are 29˚C or higher (MacKenzie et al. 1985).

Yolk-sac larvae are 6-10 mm after hatching (MacKenzie et al. 1985). Prolarvae lengths range from 6.5-12 mm, while postlarvae lengths range from 12-30 mm (Wang and Kernehan 1979). Larvae are planktonic until reaching their juvenile stages at approximately 25-28 mm long and 4 weeks in age (MacKenzie et al. 1985). Juveniles remain in their natal streams during the summer, migrate to brackish waters, then the Atlantic Ocean during the fall outmigration. This is often triggered by cooling river water temperatures, which was recorded to begin at approximately 20˚C in the Delaware River. The peak out migration into the Chesapeake Bay often occurs between late October and late November. Shad will remain in the Atlantic Ocean until maturity. Most spawning male American shad in the Susquehanna River have been found to be four years old, while females range from 4-5 years old (MacKenzie et al. 1985).

Banded darter

Banded darters have been recorded to spawn in waters between April and May (Simon and Wallus 2006). Spawning has been recorded to become initiated at 63°F. Males tend to arrive over spawning habitats when water temperatures reach 53.6°F. Spawning habitat typically include riffle habitats over algal mats over gravel substrates with a slight to moderate current. Fecundity of banded darters in Tennessee has been recorded to average 128 mature eggs. Eggs are demersal and non-adhesive, and range in diameter from 1.2-1.6 mm. During the spawning act, eggs are deposited within algal mats. Eggs have been recorded to hatch after 168 hours at 68˚F. Larvae hatched from a Tennessee stream were 4.3 mm in

length, while those from Pennsylvania hatched at 6.2-6.5 mm. Yolk-sac absorption is complete by 7.0 mm. Immediately after hatching, larvae demonstrate pelagic behavior. Larvae do not become benthic oriented until reaching approximately 13.0 mm in length. Early juveniles are known to utilize downstream pools and backwater areas adjacent to riffles as nursery habitat, while larger juveniles occur at the margins of riffles (Simon and Wallus 2006).

Bluegill

Bluegill spawning typically occurs between May and August, peaking in June (Wang and Kernehan 1979). Spawning occurs in water temperatures ranging from 65.3°F to 77°F (Wang and Kernehan 1979). Spawning peaks in June and can continue into August, but will cease when temperatures exceed 80°F (Mecozzi 2008). Males build nests in shallow water near the shoreline over sand or gravel substrates, but may also build nests over mud substrates that are covered in debris (Wang and Kernehan 1979). Nests may occur in groups up to 40 or 50 nests (Mecozzi 2008). Eggs are demersal and adhesive (Wang and Kernehan 1979). Fecundity can reach as high as 25,000 eggs, but averages approximately 12,000 (Mecozzi 2008). Eggs hatch in 2-3 days (Wang and Kernehan 1979). The male will remain at the nest to guard the eggs and larvae several days after hatching (Mecozzi 2008). Larvae remain demersal until after the yolk-sac is absorbed. After the yolk-sac is fully absorbed, larvae begin to school above the nest. Larvae are free swimming approximately 4 days after hatching. Juveniles will disperse from the school and use shallow shoreline habitat as a nursery. Juveniles move into deeper habitats as they grow (Wang and Kernehan 1979).

Channel catfish

Channel catfish spawn between May and July (Wang and Kernehan 1979); it is triggered when water temperatures reach 69.8°F and occurs in temperatures up to 86°F (McMahon and Terrell 1982). Spawning takes place in a nest built by the male t within a cavity of a submerged object or shoreline. Immediately after mating, the male chases the female away from the nest, but she remains within the vicinity of the nest and protect it from predators from a distance (McMahon and Terrell 1982). Fecundity is as high as 20,000 eggs per female (Pool 2007). Eggs are demersal and very adhesive (Wang and Kernehan 1979). Eggs hatch in 6-7 days at 80.6°C (McMahon and Terrell 1982). Larvae remain in the nest for 7-8 days, and then disperse into shallow water areas with cover (McMahon and Terrell, 1982). Young channel catfish tend to school and frequent inshore waters (Wang and Kernehan 1979). Larvae concentrate in slow flowing (<0.5 fps) areas near rocky riffles, debris covered gravel, or sand bars in clear streams, or in shallow (< 1.6 feet) mud or sand substrate edges of flowing channels in turbid rivers and bayous (McMahon and Terrell 1982). Larvae avoid vegetation due to high predation by centrarchids. Larvae will overwinter under boulders in riffles or move into cover within deeper water. Juveniles reside in similar habitat to larvae (McMahon and Terrell 1982).

Comely shiner

Little life history data are available for comely shiner (CWFNJ 2018). They are known to spawn throughout the summer, primarily in July (CWFNJ 2018).

Common carp

Common carp spawn in northern climates typically between May and June in waters in the range of 64.4°F to 73.4°F over areas of submerged vegetation at depths of less than 1.6 feet. In warmer water, spawning may occur over a prolonged period of time, but spawning activity decreases or ceases if water temperatures are less than 64.4°F or greater than 78.8°F (Edwards and Twomey 1982).

Females lay eggs in groups of 500-600 eggs. Fecundity is variable, depending on the age and size of the female. An Age-4 female may produce an average of 56,400 eggs, while an older, large 10-15 pound female may lay more than one million eggs. Eggs are demersal and adhesive, sticking to debris, plants, or sinking to the bottom. Eggs hatch after approximately 3-16 days, dependent on temperature; at 68°F, eggs

will hatch in 3-5 days. After hatching, larvae attach to or lie near vegetation for the first two days. The yolk-sac is fully absorbed after 4-5 days. After approximately 18 days, larvae will move into deeper, but still vegetated waters, remaining there for the remainder of the summer. Young carp will leave the safety of the vegetated areas at a length of 76.2-101.6 mm (Becker 1983).

Gizzard shad: Spawning can begin in late-April or early-May, and last into early-August (Becker 1983). Gonads begin to ripen when water temperatures reach 44.6-50.0˚F (Williamson and Nelson 1985). Spawning activity begins when water temperatures reach 59.9-61.7˚F, and peaks at 66.2-69.8˚F. The maximum spawning temperature recorded for gizzard shad is 80.6˚F (Williamson and Nelson 1985). Spawning is random, occurs near the surface at night, and involves large schools (Becker 1983; Etnier and Starnes 2001).

Average fecundity is 300,000 eggs (Etnier and Starnes 2001). Eggs are demersal, adhesive, and 0.75 mm in diameter (Becker 1983). Eggs hatch into 3.5 mm long larvae in 36-95 hours, in waters 61-80˚F, respectively (Becker 1983). After one day, larvae reach 4.5-5.0 mm (Williamson and Nelson 1985). The yolk-sac is absorbed in 2-3 days. Three-four days after hatching, swimming behavior constitutes upward swimming and downward settling. Larvae are either negatively geotaxic, positively phototaxic, or both. They tend to occur closer to the surface until they reach approximately four weeks old, and then move into deeper waters. Larvae will occur closer to the surface in turbid waters (Williamson and Nelson 1985). After three-four days, fish display horizontal swimming behaviors, but are generally poor swimmers for several weeks after hatching until they reach a length approximately 25 mm (Becker 1983; Williamson and Nelson 1985).

Tessellated darter

Tessellated darter spawning occurs from late March through early May at water temperatures between 50°F and 59°F (Wang and Kernehan 1979). Eggs range in diameter from 1.2-1.6 mm, and are demersal and highly adhesive. Eggs are often attached to the underside of stones or logs. At the time of egg deposition, male darters establish a territory and guard the eggs, as well as clean them during incubation. The male will consume any dead or ruptured eggs. The female lays approximately 150-300 eggs per spawning event. Both males and females spawn multiple times during their spawning period. Males have been observed to guard territories where up to 1,500 eggs have been deposited. Larvae are not actively guarded by the male upon hatching. Larvae have pigmented eyes and well developed pectoral fins, as well as significant swimming ability. Larvae are positively thigmotaxic and negatively phototaxic (Wang and Kernehan 1979).

Walleye

Throughout their range, walleye typically spawn from March through May (Simon and Wallus 2006). Prior to the spawning season, male walleyes may reside within the spawning area for a period of 3-4 weeks, while females enter these areas only to spawn, then immediately leave (Becker 1983). In southern portions of their range, spawning runs have been observed as early as January (Simon and Wallus 2006). If there is ice formation in the waterbody, spawning tends to occur 1-20 days after ice out. The spawning season lasts 5-16 days, with a peak occurring over 1-2 days (Simon and Wallace 2006).

Walleye are broadcast spawners, with demersal and temporarily adhesive eggs (Becker 1983). Eggs become water hardened after 1-2 hours and lose their adhesive properties. This results in eggs settling within the interstitial spaces of the substrate or eggs being transported via currents or wave action (Simon and Wallus 2006). Egg diameters range from 1.8-2.1 mm. Fecundity has been recorded to range from 22,000-615,000 eggs, and is positively correlated with body weight (Simon and Wallus 2006). Eggs hatch in 26 days at water temperatures of 40˚F, 21 days at water temperatures from 50-55˚F, and as fast as 7 days at an average temperature of 57˚F (Becker 1983)

Newly hatched larvae range from 6.0-8.6 mm in length, averaging 7.6 mm (Becker 1983). Yolk-sacs are fully absorbed in 3-5 days, as larvae must leave their hatching grounds to locate a food source before that

time. Fry are often transported by currents. Yolk-sac larvae often seek out faster currents for transport. Their movement is limited to upward active swimming to the surface, then passive sinking to the mid-waters. Larvae occurring in lakes are pelagic until they reach a length of 25 mm (Becker 1983).

Immediately after hatching, yolk-sac larvae may remain near their spawning grounds for up to 12 hours before becoming pelagic (Simon and Wallus 2006). Late yolk-sac larvae tend to concentrate in the upper 3-7 feet of the water column, unless strong surface currents exist, resulting in concentrations occurring at 7-10 feet from the surface. Diel migrations involve migration to the surface at night. Post yolk-sac larvae continue their pelagic behavior in lakes, remaining near the surface in open waters, but have been reported to occur at the bottom. Larvae between 1-3 weeks old demonstrate positively phototrophic behavior, but this behavior becomes negatively phototrophic at four weeks of age (Simon and Wallus 2006).

Walleye remain pelagic until reaching lengths of 25-30 mm (Simon and Wallus 2006). Most juveniles occur in shallow habitats during the summer months, occurring in waters ≤ 4 feet deep. As the fall approaches, juveniles begin to move into deeper waters. Juveniles may exhibit schooling behavior, including mixing with juvenile yellow perch schools. Juvenile walleye schools tend to be associated with rooted aquatic vegetation. Juvenile diel behavior is negatively phototaxic, occurring in shallower waters at night (Simon and Wallus 2006).

White crappie

White crappie typically spawns between late April and early June (Wang and Kernehan 1979). Spawning activity occurs at 14-23˚C, peaking at 16-20˚C. Males build a 30 cm in diameter nest, and defend a territory of approximately $1m^2$. Nests are typically built near submerged debris or aquatic vegetation in waters 20-97 cm deep (Wang and Kernehan 1979). Nests are typically deeper than those of other sunfish (Wallus and Simon 2006). Nests are often in colonies. Fecundity has been recorded to range between 1,908 eggs to 194,100 eggs (Wallus and Simon 2006). Eggs are demersal and adhesive, ranging in diameter between 0.8 and 0.9 mm. Eggs hatch after approximately 42-43 hours in waters 18.9-22.8˚C, and 93 hours at 14.4˚C. Yolk-sac larvae range from 1.75 to 3.5 mm in length, while post-yolk sac larvae range from 3.5-15.0 mm in length. Larvae are demersal until their yolk-sac is absorbed approximately 4 days after hatching (Wang and Kernehan 1979). After yolk-sac absorption, larvae leave the nest and are free swimming (Wallus and Simon 2006). Larvae have demonstrated an even distribution through the water column near spawning sites, but slightly favor occurrence near the surface during nighttime (Wallus and Simon 2006). Juvenile white crappie is 15+ mm in length, with a body width of 24-29% of the total length (Wang and Kernehan 1979). Sexual maturity is often reached at Age-2 or Age-3 (Wallus and Simon 2006).

White perch

Spawning occurs in tidal and non-tidal freshwater and oligohaline areas of the Susquehanna River (Wang and Kernehan 1979). Spawning mostly occurs between late March and May, but occasionally extends into June. It occurs in shallow, clear waters (<1 meter) of creeks with slow current, or turbid water with swift currents. Spawning activity increases after periods of heavy runoff from spring rains. White perch are broadcast spawners (Wang and Kernehan 1979). Fecundity in white perch ranges from 20,676 eggs in Age-3 fish up to 124,289 eggs in Age-9 fish (Stanley and Danie 1983). Eggs are demersal and adhesive, attaching to substrata or submerged objects (Wang and Kernehan 1979). Some eggs may not adhere, and are semi-pelagic as they are carried downstream. Eggs hatch after 48-72 hours (Wang and Kernehan 1979). Post-hatching, larvae remain in the spawning area for 4 to 13 days (Stanley and Danie 1983). Larvae then demonstrate vertical swimming then sinking behavior, resulting in being carried downstream from spawning grounds into lower portions of the creeks or rivers. Salinities up to 5 ppt are tolerable to larvae but are lethal at 8 ppt (Stanley and Danie 1983). Larvae do not display significant vertical distribution in the water column and can be found in both surface and bottom waters (Wang and Kernehan 1979). However, as larvae grow larger, they tend to prefer increasingly demersal behavior.

Juveniles (10 mm+) often occur in tidal creeks from May through July. Some perch will overwinter in the deeper portions of these creeks, or will overwinter in the deeper waters of the lower Susquehanna River and Chesapeake Bay (Wang and Kernehan 1979).

4.5 SEASONAL AND DAILY ACTIVITIES

Regulatory requirement at §122.21(r)(4)(v): "Data representative of the seasonal and daily activities (e.g., feeding and water column migration) of biological organisms in the vicinity of the cooling water intake structure."

This section provides seasonal fisheries data from the Conowingo Reservoir. Site-specific fisheries data describe relative abundance and community composition during varying times of the year, which can represent migratory behaviors. Impingement and entrainment data are also summarized by month and diel period, providing information about potential diel water column migration.

4.5.1 SEASONAL FISHERIES DATA

Seasonal fisheries data are available from NAI and ERM (2017). Fish were collected using three types of gears: electrofishing, seine, and trawl. Sampling was conducted in 2010 through 2013 and in 2016. The most individuals were collected during August, July, and September, respectively. Species richness was highest in September (41 species), followed by August and September (38 species each). Those months are characterized by high catches up bluegill, channel catfish, and gizzard shad. CPUE and species diversity is lowest during the winter months. Data for each month sampled are provided in **Table 4-10**.

Table 4-10: Monthly CPUE of Species occurring Near PBAPS (2010-2013, 2016)

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
American eel	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0
Alewife	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0
American shad	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0
Atlantic needlefish	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3
Banded darter	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.4	0.5
Banded killifish	2.5	0.0	6.0	9.0	87.8	26.0	5.6	10.0	24.6	156.8
Black crappie	2.5	2.0	2.0	0.0	0.3	0.0	0.2	0.0	0.6	1.3
Blacknose dace	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.2	0.0	0.0
Bluegill	114.5	25.0	60.0	108.7	245.5	170.5	327.0	1,538.4	1,073.0	574.0
Bluntnose minnow	182.5	54.5	39.0	121.0	77.3	52.0	42.4	92.4	79.6	62.3
Brown trout	0.5	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Central stoneroller	0.0	0.0	0.0	0.0	0.0	0.3	1.0	0.2	0.0	0.0
Channel catfish	4.5	2.0	14.0	235.7	140.3	234.5	455.2	850.8	260.8	362.8
Chesapeake logperch	1.0	0.0	0.0	2.7	3.5	7.0	26.2	32.2	38.8	23.8
Comely shiner	1,012.5	2,015.5	693.0	333.0	112.3	20.5	74.2	105.8	577.8	582.0
Common carp	2.0	14.5	33.0	35.0	19.5	17.3	18.6	19.2	24.4	21.0
Common shiner	0.0	1.0	0.0	0.0	0.3	0.3	0.8	0.0	0.2	0.0
Creek chub	0.0	1.0	1.0	3.7	4.8	0.0	0.2	0.0	0.2	0.3
Cutlips minnow	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
Eastern mosquitofish	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
Fallfish	0.0	6.5	0.0	2.3	3.0	0.8	0.2	3.0	0.8	0.8
Flathead catfish	1.5	0.5	0.0	1.0	6.0	10.0	7.0	7.2	6.6	1.8
Gizzard shad	46.0	33.5	125.0	660.7	518.3	34.5	1,610.6	2,717.8	880.8	345.5
Golden shiner	0.5	0.5	0.0	1.0	1.8	5.3	61.8	16.6	11.2	3.8
Grass carp	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0
Green sunfish	44.0	10.5	15.0	64.0	105.5	99.8	106.2	353.6	217.8	214.5
Greenside darter	1.5	0.5	0.0	0.0	0.0	0.0	0.8	2.2	5.2	1.3
Hybrid striped bass	1.0	0.0	4.0	1.3	0.3	0.0	0.0	0.0	0.8	7.3
Largemouth bass	21.0	15.0	20.0	13.0	25.8	5.8	10.0	9.0	21.6	28.3
Mimic shiner	0.0	8.5	2.0	0.7	0.3	0.0	0.6	0.2	1.0	0.3

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Muskellunge	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Northern hogsucker	0.0	0.0	0.0	0.0	0.5	1.3	5.4	6.2	2.2	2.3
Pumpkinseed	0.0	0.0	0.0	0.3	2.8	1.8	0.4	0.8	2.6	3.0
Quillback	0.0	0.0	1.0	1.0	0.8	8.3	15.4	1.6	4.0	1.0
Rainbow smelt	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0
Redbreast sunfish	0.5	0.5	1.0	0.7	1.0	2.0	1.4	0.2	0.8	1.5
River chub	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.4	0.0	0.0
Rock bass	5.0	5.0	2.0	55.0	68.5	50.5	36.8	23.6	33.8	85.8
Rosyface shiner	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
Rosyside dace	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0
Shield darter	0.0	0.5	0.0	0.0	2.3	0.5	1.0	4.2	3.6	4.3
Shorthead redhorse	1.5	2.5	8.0	12.0	13.3	22.0	16.4	22.2	34.2	38.3
Smallmouth bass	14.0	10.0	5.0	37.3	113.3	93.0	104.8	61.4	102.2	129.8
Spotfin shiner	9.0	3.0	1.0	92.7	178.0	230.0	367.8	185.8	162.4	180.5
Spottail shiner	98.5	22.5	58.0	78.7	22.5	21.8	78.2	97.4	126.6	107.0
Striped bass	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.2	0.0
Swallowtail shiner	0.0	0.0	0.0	1.7	0.3	0.0	0.2	0.6	1.2	0.3
Tessellated darter	12.0	0.5	0.0	39.0	13.3	9.5	10.2	24.0	14.8	48.8
Tiger muskellunge	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Walleye	8.5	2.5	13.0	17.7	7.3	2.8	4.6	6.2	8.2	55.0
White crappie	3.0	0.5	0.0	1.3	0.8	0.0	0.6	0.8	3.6	4.0
White perch	0.0	0.5	0.0	1.3	11.0	0.3	6.6	2.6	3.8	15.8
White sucker	0.0	0.0	0.0	2.0	3.3	20.0	2.0	6.4	0.2	1.3
Yellow perch	0.0	0.0	0.0	6.0	18.0	2.0	3.0	1.6	4.4	12.5
Total	**1,590.5**	**2,239.0**	**1,105.0**	**1,939.7**	**1,674.0**	**1,280.7**	**3,540.5**	**6,258.3**	**3,980.0**	**3,080.0**
Number of Species	**26**	**27**	**23**	**32**	**37**	**31**	**36**	**38**	**41**	**38**

Source: NAI & ERM (2017)

4.5.2 IMPINGEMENT DATA

Impingement data are collected from the outer intake structure, which was designed and installed to reduce impingement by lowering the approach and through-screen velocities. The PBAPS intake design used a site-specific approach velocity of 0.75 fps to protect Conowingo Reservoir-specific species from impingement. The as built calculated approach velocity at both the trash racks (0.48 fps) and immediately in front of the screens (0.65 fps) is less than the PBAPS site- specific approach velocity of 0.75 fps.

Data demonstrating year-round trends in impingement at PBAPS are available for the months of August 2005 through November 2006 (NAI 2007). Species-specific data were only available for American shad, bluegill, channel catfish, gizzard shad, and walleye. Peak impingement is primarily influenced by gizzard shad, which demonstrated a peak in October and November, 2005, respectively. The large numbers of impinged gizzard shad may be attributed to water temperatures ≤ 45˚F, which are known to be correlated to large gizzard shad mortality events. American shad impingement is primarily correlated with migratory movements. Bluegill impingement tended to significantly increase during the fall and into December. Channel catfish impingement tended to occur primarily from July through September. Walleye impingement was highest during October through December 2005 (NAI 2007).

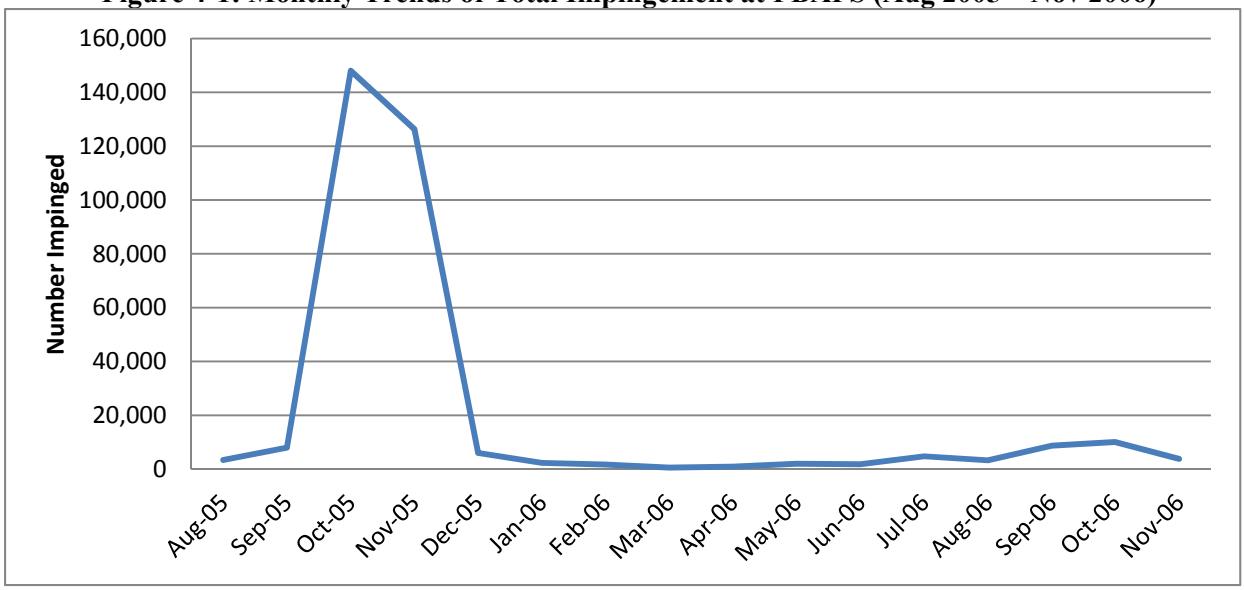
Table 4-11: Monthly Impingement at PBAPS (August 2005 – November 2006)

Month/Year	American shad	Bluegill	Channel Catfish	Gizzard shad	Walleye	Other Species
Aug-2005	0	37	1,645	1,470	74	148
Sep-2005	0	78	1,549	6,065	35	239
Oct-2005	169	4,832	479	141,496	188	899
Nov-2005	72	3,382	226	121,044	408	1,221
Dec-2005	0	3,767	290	1,424	100	426
Jan-2006	0	744	1127	73	0	396

Month/Year	American shad	Bluegill	Channel Catfish	Gizzard shad	Walleye	Other Species
Feb-2006	0	302	1122	58	0	173
Mar-2006	0	55	348	0	0	155
Apr-2006	0	12	612	12	23	221
May-2006	29	7	1601	66	29	220
Jun-2006	48	12	1203	48	24	436
Jul-2006	0	146	2491	1,334	27	726
Aug-2006	0	14	2164	869	7	210
Sep-2006	0	1,659	3808	2,608	9	604
Oct-2006	304	3,437	760	4,014	7	1,514
Nov-2006	7	2,405	239	471	0	692

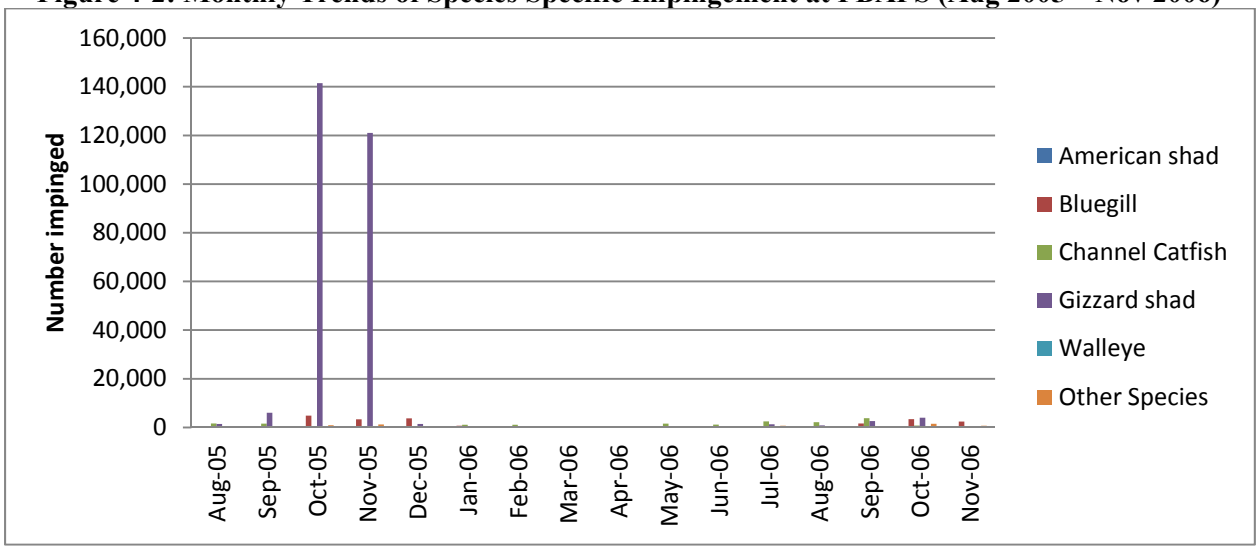
Source: NAI (2007)

Figure 4-1: Monthly Trends of Total Impingement at PBAPS (Aug 2005 – Nov 2006)



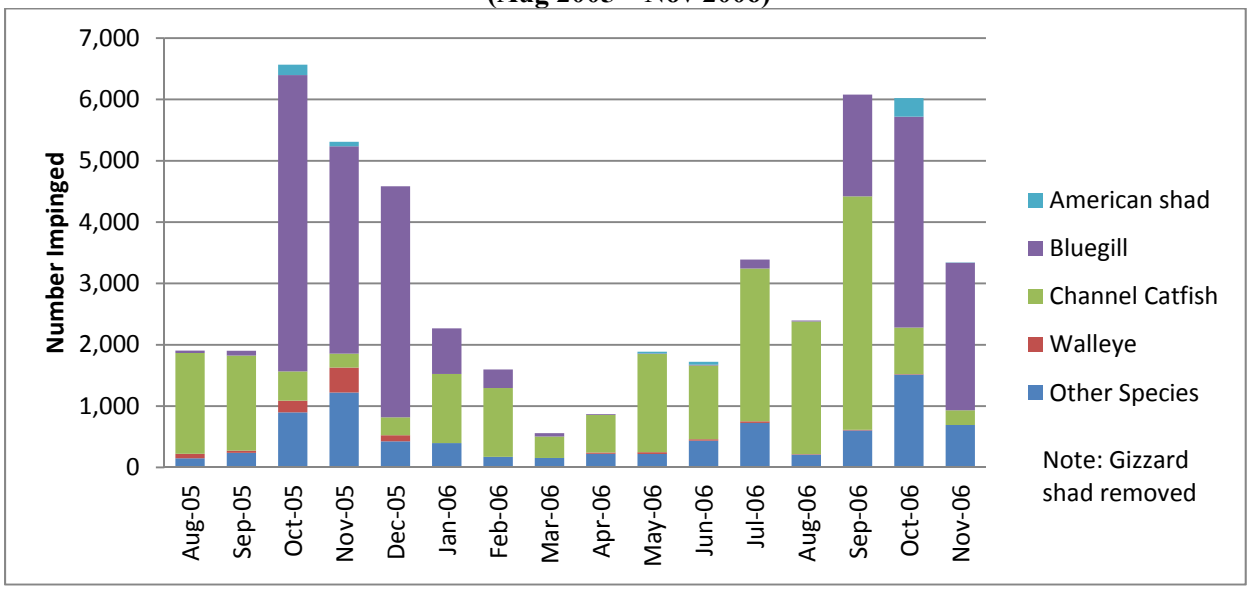
Source: NAI (2007)

Figure 4-2: Monthly Trends of Species Specific Impingement at PBAPS (Aug 2005 – Nov 2006)



Source: NAI (2007)

Figure 4-3: Monthly Trends of Impingement of Select Species at PBAPS (Aug 2005 – Nov 2006)



Source: NAI (2007)

Seasonal and diel impingement characterization data are available from the most recent study conducted between October 18, 2017 and October 4, 2018 (NAI 2018a). Impingement was slightly greater during the daytime samples (56%) compared to nighttime samples (44%). The most commonly impinged species at PBAPS, bluegill and gizzard shad, were impinged at higher rates during the day. 64% of Bluegill were collected during daytime impingement and 52% of gizzard shad were collected during daytime impingement (**Table 4-12**).

Table 4-12: Diel Composition of Impingement at PBAPS

Species	Daytime	Nighttime
Alewife	9	5
American eel	0	1
American shad	9	1
Banded killifish	3	1
Black crappie	0	1
Blueback herring	2	0
Bluegill	1,658	952
Bluntnose minnow	0	7
Channel catfish	218	234
Chesapeake logperch	1	1
Comely shiner	306	351
Flathead catfish	30	46
Gizzard shad	1,018	946
Golden shiner	6	2
Goldfish	4	4
Green sunfish	12	23
Greenside darter	2	0
River chub	1	0
Rock bass	5	4
Shorthead redhorse	1	0

Species	Daytime	Nighttime
Smallmouth bass	5	12
Spotfin shiner	0	4
Spottail shiner	2	0
Tessellated darter	69	24
Walleye	1	2
White crappie	5	11
White perch	8	12
White sucker	0	1
Yellow perch	0	6
Total	**3,375**	**2,651**
	56.0%	**44.0%**

Data source: NAI (2018a)

During this recent study, impingement CPUE at PBAPS was highest in October 2017, dominated by bluegill (NAI 2018a). The lowest rate of impingement was observed in March (**Table 4-13)**. The impingement seasonality in 2017-2018 is similar to that in 2005-2006, except for the impingement of comely shiner in February 2018.

Table 4-13: Monthly Impingement at PBAPS (October 18, 2017 – October 4, 2018)

Species	2017			2018									
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Alewife	0	0	0	-	0	0	2	4	0	0	0	3	5
American eel	0	0	1	-	0	0	0	0	0	0	0	0	0
American shad	1	5	0	-	0	0	0	0	0	0	0	4	0
Banded killifish	0	0	0	-	1	2	0	0	0	0	1	0	0
Black crappie	0	0	1	-	0	0	0	0	0	0	0	0	0
Blueback herring	0	0	0	-	0	0	1	0	0	0	0	1	0
Bluegill	2,078	413	49	-	8	2	1	0	3	0	34	21	1
Bluntnose minnow	0	0	0	-	1	0	0	1	0	0	5	0	0
Channel catfish	4	8	1	-	17	6	6	5	12	12	185	175	21
Chesapeake logperch	1	1	0	-	0	0	0	0	0	0	0	0	0
Comely shiner	3	1	2	-	615	2	0	0	13	2	12	6	1
Flathead catfish	2	14	2	-	2	2	4	1	9	0	33	6	1
Gizzard shad	7	624	20	-	0	0	0	1	1	16	1235	53	7
Golden shiner	0	0	0	-	0	0	0	0	0	0	2	6	0
Goldfish	0	7	0	-	0	0	0	0	0	0	0	1	0
Green sunfish	9	6	3	-	0	0	5	3	6	0	3	0	0
Greenside darter	0	0	0	-	0	0	0	0	2	0	0	0	0
River chub	0	0	0	-	1	0	0	0	0	0	0	0	0
Rock bass	2	1	0	-	0	0	1	3	2	0	0	0	0
Shorthead redhorse	0	0	0	-	0	0	0	0	0	0	0	1	0
Smallmouth bass	0	0	2	-	0	1	0	0	2	2	7	3	0
Spotfin shiner	0	0	0	-	0	0	0	0	0	1	2	1	0
Spottail shiner	1	0	0	-	0	0	0	0	0	1	0	0	0
Tessellated darter	19	45	0	-	0	1	5	7	10	0	3	2	1
Walleye	0	0	0	-	0	0	0	0	2	0	1	0	0

Species	2017			2018									
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
White crappie	0	4	5	-	0	0	0	0	0	0	0	3	4
White perch	0	12	1	-	0	0	0	0	0	3	4	0	0
White sucker	0	0	0	-	0	0	0	0	0	0	1	0	0
Yellow perch	0	0	0	-	2	0	0	0	0	0	2	2	0
Total	**2,127**	**1,141**	**87**	**-**	**647**	**16**	**25**	**25**	**62**	**37**	**1,530**	**288**	**41**
Number Of Sampling Events	**2**	**2**	**2**	**0***	**1**	**1**	**1**	**1**	**2**	**1**	**2**	**2**	**1**
CPUE	**1,063.5**	**570.5**	**43.5**	**-**	**647.0**	**16.0**	**25.0**	**25.0**	**31.0**	**37.0**	**765.0**	**144.0**	**41.0**

Table reproduced directly from NAI (2018a).
* No sampling in January 2018 due to icy conditions.

4.5.3 ENTRAINMENT DATA

During entrainment characterization in 2012, the majority of entrainable fish were collected between April 18 and July 27 (NAI 2013b). Peak collections occurred in late-April and late-May. Only a single entrainable organism was collected in March, while August and September only collected 3 entrainable organisms. Approximately 36% of entrainable organisms were collected during the nighttime between 18:00 – 00:00 hours. The least amount of organisms (14.7%) was collected during the morning hours, 06:00 - 12:00 hours (NAI 2013b).

During entrainment characterization in 2016, much of the peak periods of entrainment were attributed to the life-cycle of gizzard shad (NAI 2017b). As a result, most ichthyoplankton were collected during the gizzard shad spawning season, between April and June. Additionally, this resulted in most larvae being collected at nighttime (21:00-03:00 hours), due to the nocturnal behavior of gizzard shad larvae (NAI 2017b). Monthly totals of entrainable organisms collected at all sampling locations combined (outer intake structure, circulating water discharge, and discharge canal) are provided in **Table 4-14** and **Figure 4-4**.

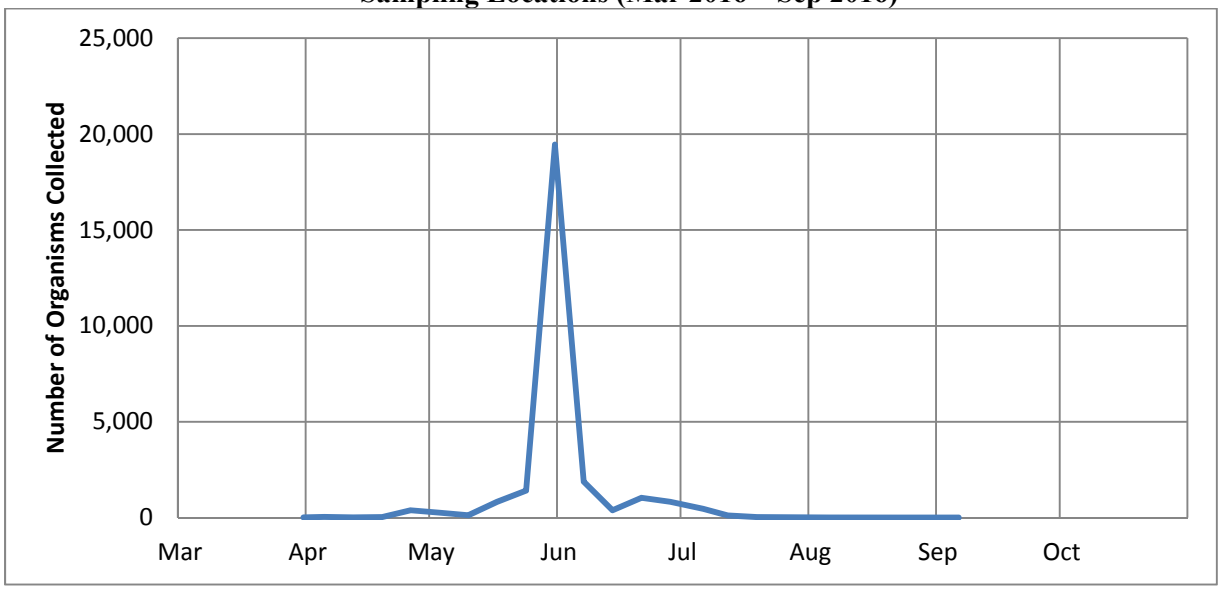
Table 4-14: Total Monthly Collections of Entrainable Organisms at All PBAPS Entrainment Sampling Locations (Mar 2016 – Sep 2016)

Taxa	Lifestage	March	April	May	June	July	August	September
Alewife	Eggs	0	0	1	0	0	0	0
Alewife	YSL	0	0	18	0	0	0	0
Alewife	PYSL	0	0	2	0	0	0	0
Alewife/Gizzard shad	UNID	0	0	18,977	1,000	0	0	0
Alewife/Gizzard shad	YSL	0	0	895	5	0	0	0
Alewife/Gizzard shad	PYSL	0	0	812	2,815	521	3	0
American shad	PYSL	0	0	0	0	1	0	0
Banded darter	PYSL	0	6	18	0	0	0	0
Bluegill	YOY	0	0	0	0	1	4	0
Brown bullhead	YOY	0	0	0	3	0	0	0
Bullhead catfish family	YOY	0	0	0	1	0	0	0
Carp and minnow family	Eggs	0	0	1	0	0	0	0
Carp and minnow family	YSL	0	1	0	0	0	0	0
Carp and minnow family	PYSL	11	63	33	2	0	1	0
Channel catfish	YOY	0	0	0	12	8	1	1
Chesapeake logperch	PYSL	0	0	2	1	0	0	0
Chesapeake logperch	Age-1+	0	0	0	0	1	0	0
Common carp	Eggs	0	0	102	52	3	0	0
Common carp	PYSL	0	0	32	4	0	0	0

Taxa	Lifestage	March	April	May	June	July	August	September
Darter sp.	UNID	0	17	2	0	0	0	0
Darter sp.	YSL	0	8	9	0	0	0	0
Darter sp.	PYSL	0	0	5	0	2	0	0
Flathead catfish	Age-1+	0	0	1	0	1	0	0
Flathead catfish	YOY	0	0	0	0	1	0	0
Gizzard shad	UNID	0	9	0	0	0	0	0
Gizzard shad	Eggs	1	70	305	2	0	0	0
Gizzard shad	YSL	0	34	653	6	0	0	0
Gizzard shad	PYSL	0	0	66	25	1	0	0
Gizzard shad	YOY	0	0	0	3	0	6	0
Ictalurus sp.	YOY	0	0	1	0	0	0	0
Herring family	PYSL	0	0	0	0	1	0	0
Herring family	YOY	0	0	0	0	0	1	0
Lepomis sp.	UNID	0	0	0	0	2	2	0
Lepomis sp.	YSL	0	0	0	1	0	0	0
Lepomis sp.	PYSL	0	0	1	28	39	12	0
Lepomis/Crappie sp.	PYSL	0	0	0	11	0	0	0
Quillback	YSL	0	0	1	0	0	0	0
Quillback	PYSL	0	0	14	0	0	0	0
Shield darter	YOY	0	0	8	0	0	0	0
Sucker family	PYSL	0	0	2	0	0	0	0
Sunfish family	PYSL	0	0	0	1	0	0	0
Tessellated darter	UNID	0	0	1	0	0	0	0
Tessellated darter	Age-1+	1	3	2	1	0	0	0
Tessellated darter	YSL	0	1	28	0	0	0	0
Tessellated darter	PYSL	1	3	21	38	0	0	0
Tessellated darter	YOY	0	0	16	109	11	2	0
Unidentified	UNID	0	245	15	14	10	3	0
Unidentified	Eggs	0	1	5	1	0	0	0
Unidentified	PYSL	0	0	2	0	12	1	0
White catfish	YOY	0	0	0	1	0	0	0
White perch	Eggs	0	0	20	0	0	0	0
Yellow perch	PYSL	0	0	3	0	0	0	0
Totals		**14**	**461**	**22,074**	**4,136**	**615**	**36**	**1**

Combined data from the outer intake structure, the circulating water discharge outfall, and the discharge canal outfall.
Source: NAI (2017b)

Figure 4-4: Total Monthly Collection Trends of Entrainable Organisms at All PBAPS Entrainment Sampling Locations (Mar 2016 – Sep 2016)



Combined data from the outer intake structure, the circulating water discharge outfall, and the discharge canal outfall.
Source: NAI (2017b)

4.6 Threatened, Endangered, and Other Protected Species

Regulatory requirement at §122.21(r)(4)(vi): "Identification of all threatened, endangered, and other protected species that might be susceptible to impingement and entrainment at your cooling water intake structures."

Federally and state-listed aquatic species that may be present near the intake were identified based on on-line reviews of the USFWS' Information for Planning and Consultation (IPaC) database and the Pennsylvania Natural Heritage Program's (PNHP) Pennsylvania Natural Diversity Inventory (PNDI) database.

USFWS (2018) reported no federally protected aquatic species or critical habitat occurring within the vicinity of the PBAPS CWIS (**Appendix D**). On September 21, 2017, a PNDI receipt was obtained from the on-line PNHP website in response to a request for a Project Environmental Review for the PBAPS SLR through the PNDI Environmental Review Tool (PA DCNR 2017). The PNDI Project Environmental Review receipt included responses from four agencies regarding their primary screening determinations of the potential for special status species to be affected by the project. The responding agencies were the USFWS, Pennsylvania Game Commission (PGC), Pennsylvania Department of Conservation and Natural Resources (PA DCNR), and the Pennsylvania Fish and Boat Commission (PFBC). The PNDI receipt also included voluntary conservation measures from USFWS that would contribute to the conservation and recovery of T&E species through improved water quality but did not identify any protected species (**Appendix D**). The results of the PNDI search indicated that disturbance in and around the PBAPS site potentially could affect a state-protected aquatic species, the Chesapeake logperch, which is Pennsylvania-listed as threatened. Chesapeake logperch is also listed as threatened by Maryland (Maryland Natural Heritage Program 2016).

Relatively little is known about the Chesapeake logperch, but its habits and biology are likely similar to logperches such the common logperch (*Percina caprodes*; NAI and ERM 2017). Fisheries sampling reports through 2014 identified only common logperch because Chesapeake logperch was not recognized as a distinct species from logperch until approximately 2008 (NAI 2007, NAI 2014a; NAI 2014b; Near 2008). Chesapeake logperch were recently found to be genetically distinct from common logperch, with

some minor morphological differences. Chesapeake logperch and Maryland darter (*Etheostoma sellare*) are the only darter species endemic to the Chesapeake Basin, and fish collected in the Susquehanna River that were identified as common logperch were confirmed to actually be Chesapeake logperch (Near 2008). This change in taxonomy is reflected in all fisheries sampling reports completed after 2014 (NAI 2015b; NAI and ERM 2017; NAI 2017c).

It is unclear whether the Chesapeake logperch spawns along the shores of Conowingo Reservoir or if spawning is restricted to the lower sections of the six tributary streams entering Conowingo Reservoir (NAI and ERM 2017). Their occurrence varies through the year, and they are most frequently collected in Conowingo Reservoir between August and October (NAI and ERM 2017). The distribution of the Chesapeake logperch in Conowingo Reservoir seems to be related to proximity to tributary streams and shallow shoreline habitat with either sand or gravel sediment present and submerged aquatic vegetation (NAI and ERM 2017). This species has been impinged and entrained at PBAPS (NAI 2007, 2017c).

The Pennsylvania Code Chapter 75 list of state threatened and endangered species was compared to fisheries data available near PBAPS to further identify aquatic species potentially vulnerable to impingement or entrainment. Although it was not identified by the PNDI report, the state-endangered hickory shad (*Alosa mediocris*) has been recorded entering Conowingo Reservoir via the EFL (NAI 2010-2013a, 2014a, 2015a, 2016, 2017a). Hickory shad documentation is limited to fish passage data from the Conowingo Dam EFL. A peak of 20 hickory shad passing into Conowingo Reservoir via the EFL was recorded in 2011 between the years of 2010 and 2017. Deer Creek, a Susquehanna River tributary approximately 3.5 miles below the Conowingo Dam, is the habitat used by what is regarded as the largest hickory shad spawning population in Maryland (NAI and GSE 2012b). The hickory shad spawning season typically occurs prior to that of the American shad, beginning in March and April (Klauda et al. 1991). Spawning habitat preferences of the hickory shad are not well defined but often overlap with those of the American shad. The majority of Conowingo Reservoir is not suitable spawning habitat for either species, and no hickory shad spawning has been documented in Conowingo Reservoir (NAI and GSE 2012b). This species has not been impinged or entrained at PBAPS (NAI 2007, 2017c, 2018a, 2018b).

The state-endangered cisco (*Coregonus artedi*) was introduced to the upper Susquehanna River (Harvey's Lake in Luzerne County, Pennsylvania) and Conowingo Reservoir (Fuller and Neilson 2016). However, the cisco failed to establish a population within the Susquehanna River basin and is unlikely to be collected near PBAPS (USGS 2016). This species has not been impinged or entrained at PBAPS (NAI 2007, 2017c, 2018a, 2018b).

4.7 PUBLIC PARTICIPATION AND AGENCY CONSULTATION

Regulatory requirement at §122.21(r)(4)(vii): "Documentation of any public participation or consultation with Federal or State agencies undertaken in development of the plan."

A PNDI database search for state protected species and an IPaC database search for federally protected species and critical habitats were completed for preparation of this §122.21(r)(4) report. As part of the Applicant's Environmental Report – Operating License Renewal Stage – Subsequent License Renewal, Exelon submitted consultation letters to USFWS, NOAA, PFBC, PGC, and PADCNR in September 2017 requesting additional information on any protected species and their habitats that may be affected by the PBAPS license renewal. Responses were received from PADCNR Bureau of Forestry in September 2017; PGC in October 2017; USFWS in November 2017; and NOAA (NMFS Greater Atlantic Regional Fisheries Office) and PFBC Division of Environmental Services in March 2018.

Additionally, in support of NPDES permitting and Section 316(b) activities, Exelon met with USFWS at PBAPS in January 2016 and with PADEP at their Harrisburg, Pennsylvania office in 2017.

4.8 SUPPLEMENTAL FIELD STUDIES

Regulatory requirement at §122.21(r)(4)(viii): "If you supplement the information requested in paragraph (r)(4)(i) of this section with data collected using field studies, supporting documentation for the Source Water Baseline Biological Characterization must include a description of all methods and quality assurance procedures for sampling, and data analysis including a description of the study area; taxonomic identification of sampled and evaluated biological assemblages (including all life stages of fish and shellfish); and sampling and data analysis methods. The sampling and/or data analysis methods you use must be appropriate for a quantitative survey and based on consideration of methods used in other biological studies performed within the same source water body. The study area should include, at a minimum, the area of influence of the cooling water intake structure."

Not Applicable – No supplemental field studies were performed as part of this §122.21(r)(4) Source Water Baseline Biological Characterization report.

4.9 REGULATORY REQUIREMENT

Regulatory requirement at §122.21(r)(4)(ix): "In the case of the owner or operator of an existing facility or new unit at an existing facility, the Source Water Baseline Biological Characterization Data is the information in paragraphs (r)(4)(i) through (xii) of this section."

Regulatory requirement cited for informational purposes only. No response necessary.

4.10 PROTECTIVE MEASURES AND STABILIZATION ACTIVITIES NEAR THE INTAKE

Regulatory requirement at §122.21(r)(4)(x): "For the owner or operator of an existing facility, identification of protective measures and stabilization activities that have been implemented, and a description of how these measures and activities affected the baseline water condition in the vicinity of the intake."

The baseline water conditions of the Susquehanna River, including the Conowingo Reservoir, are primarily influenced by operations and water releases from the Conowingo Dam. No protective measures or stabilization activities at the PBAPS screen house exist that have any known effect on the baseline water condition of the Conowingo Reservoir of the Susquehanna River.

4.11 FRAGILE SPECIES

Regulatory requirement at §122.21(r)(4)(xi): "For the owner or operator of an existing facility, a list of fragile species, as defined at 40 CFR 125.92(m), at the facility. The applicant need only identify those species not already identified as fragile at 40 CFR 125.92(m). New units at an existing facility are not required to resubmit this information if the cooling water withdrawals for the operation of the new unit are from an existing intake."

Fragile species are defined in 40 CFR §125.92(m) as…

> "*…a species of fish or shellfish that has an impingement survival rate of less than 30 percent even when the BTA technology of modified traveling screens are in operation*."

Fragile species listed in the Rule include, but are not limited to: alewife, American shad, Atlantic herring, Atlantic long-finned squid, Atlantic menhaden, bay anchovy, blueback herring, bluefish, butterfish, gizzard shad, grey snapper, hickory shad, menhaden, rainbow smelt, round herring, and silver anchovy (79 FR 48432, August 15, 2014).

The predominant fragile species impinged at PBAPS is gizzard shad, the most impinged taxon. Other fragile impinged species include American shad, alewife, and blueback herring (NAI 2007, NAI 2014b, NAI 2015b, NAI 2016b, NAI 2017b, NAI 2018a). Approximately 87% of the fish impinged at PBAPS between August 29, 2005 and November 17, 2006 were fragile species (NAI 2007). Similarly, 76% of

fish impinged between 2014 and 2018 during annual fall American shad outmigration monitoring were fragile (NAI 2014b, NAI 2015b, NAI 2016b, NAI 2017b, NAI 2018b). Rainbow smelt are fragile species historically collected during American shad outmigration studies, but have not been impinged at PBAPS since 2003 (NAI 2007). Another fragile species, hickory shad, has been collected in Conowingo Reservoir, but has not been impinged at PBAPS (NAI 2011, 2013a, 2014a, 2015a, 2018a, 2018b). Thirty-three percent of the impinged fish collected between October 18, 2017 and October 4, 2018, were fragile species, including alewife, American shad, blueback herring, and gizzard shad (NAI 2018a).

The Rule requests the identification of species not listed in 40 CFR §125.92(m) that have been impinged at the facility and may be considered a fragile species. All species impinged at PBAPS are either explicitly identified by USEPA (2014) as "non-fragile", or have a similarly related species considered be "non-fragile".

4.12 INCIDENTAL TAKE EXEMPTION OR AUTHORIZATION

Regulatory requirement at §122.21(r)(4)(xii): "For the owner or operator of an existing facility that has obtained incidental take exemption or authorization for its cooling water intake structure(s) from the U.S. Fish and Wildlife Service or the National Marine Fisheries Service, any information submitted in order to obtain that exemption or authorization may be used to satisfy the permit application information requirement of paragraph 40 CFR 125.95(f) if included in the application."

PBAPS has not obtained an incidental take exemption of authorization for its cooling water intake structures from the USFWS or NMFS. However, Exelon's consultant currently holds a PFBC Scientific Collectors' Permit Type 3 (No. 2018-03-0208). Permit condition 18 states:

> Endangered (E) and Threatened (T) species collections and reporting. Surveys for ET species require a Special Permit as per Chapter 75.4 in the Fishing and Boating Regulations (see below). Scientific Collectors' with authorization to collect ET species and collectors' observing incidental occurrences of ETC species must report ET occurrences online within 48 hours of discovery or identification of an ET species. Reporting must be conducted using the web-based interactive Scientific Collectors' Permit system.

In compliance with the Scientific Collectors' Permit requirement, collections of Chesapeake logperch have been reported to PFBC within 48 hours.

5.0 §122.21(r)(5) - COOLING WATER SYSTEM DATA

5.1 NARRATIVE DESCRIPTION OF COOLING WATER SYSTEM

Regulatory requirement at §122.21(r)(5)(i): "A narrative description of the operation of the cooling water system and its relationship to cooling water intake structures; the proportion of the design intake flow that is used in the system; the number of days of the year the cooling water system is in operation and seasonal changes in the operation of the system, if applicable; the proportion of design intake flow for contact cooling, non-contact cooling, and process uses; a distribution of water reuse to include cooling water reused as process water, process water reused for cooling, and the use of gray water for cooling; a description of reductions in total water withdrawals including cooling water intake flow reductions already achieved through minimized process water withdrawals; a description of any cooling water that is used in a manufacturing process either before or after it is used for cooling, including other recycled process water flows; the proportion of the source waterbody withdrawn (on a monthly basis)"

The once-through cooling water system at PBAPS consists of the CWIS, a supply conveyance network to the main condensers and other equipment requiring raw water for non-contact cooling or other processes, and a discharge conveyance network to dissipate waste heat and discharge wastewater into the Conowingo Reservoir through a discharge structure or other outfalls. During normal operation,

approximately 96% of the design intake flow is used for condenser cooling with the remainder used for plant services (URS 2008).

Non-contact cooling water is withdrawn through the outer intake structure, which was designed and installed to reduce impingement, and pumped from the CWIS through the main condensers, where it becomes heated, and then flows to a discharge basin and canal that flows back to the Conowingo Reservoir downstream of the intake. The discharge basin and discharge canal also provide a place of discharge for heated water from the Service Water System, the High-Pressure Service Water System, the Emergency Service Water System, and other process wastewaters.

Following the combined discharge of once-through cooling water from Units 2 and 3, heated water enters a common discharge basin prior to being discharged back to the Conowingo Reservoir through a discharge canal. Three 'helper' cooling tower blocks exist at the facility to provide cooling to the once-through cooling water that enters the discharge basin. These cooling towers are only used during warm weather months to provide a limited amount of cooling to assist the facility in reducing its thermal discharge. The facility discharge permit requires operation of the helper cooling towers during specific times and conditions.

These operating times and conditions are as follows:

- One cooling tower must be placed into operation on June 15 and must operate continuously through August 31, unless otherwise approved by the Regulatory Authority;
- A second cooling tower must be placed into operation within 48 hours of an average intake water temperature greater than 83°F. Once operation of the second tower commences, it must be maintained through August 31, unless permission to terminate the second tower operation is requested and approved by the Regulatory Authority; and
- A third cooling tower must be placed in operation within 48 hours of an average intake water temperature equal to or greater than 86°F. The third tower must remain in continuous operation for a minimum of seven days.

The discharge canal is oriented parallel to the shoreline. The discharge structure consists of one rectangular fixed opening with three regulating gates that are controlled by differential water level measurements to maintain a discharge velocity of 5 to 8 fps. This is intended to enhance mixing of the discharge with the ambient water and also to prevent immature fish from entering the canal and being exposed to potential thermal shock during plant operation. Screen wash water for the outer intake structure, derived from the discharge canal, is discharged to the Conowingo Reservoir via Outfalls 002 and 005.

Virtually all intake water is for non-consumptive use at the plant, allowing for minor evaporative losses up to approximately 2%.

PBAPS is a base-load plant that is available to operate year-round. Either unit could be in shutdown mode or operating at less than 100% capacity because of maintenance outages, reduced electric demand, or other factors. Based on annual operations from 2013 through 2017, the PBAPS station's average net facility capacity utilization rate was 93.5%. Typically, cooling water demand is less during the winter months (late November/early December through March) due to colder intake water temperatures.

Cooling water system operation generally coincides with electric power generation with additional operating time needed before plant startup and after plant shutdown.

5.2 DESIGN AND ENGINEERING CALCULATIONS

Regulatory requirement at §122.21(r)(5)(ii): "Design and engineering calculations prepared by a qualified professional and supporting data to support the description required by paragraph (r)(5)(i) of this section"

5.2.1 DESIGN INTAKE FLOW

The DIF is provided in **Section 3.3**.

5.2.2 THROUGH-SCREEN VELOCITY

The through-screen velocity was calculated for screens at the outer intake structure under normal and low water elevations for the DIF. The outer intake structure was designed to minimize fish impingement during construction of the station. Its configuration was designed to reduce velocity, create a straight shoreline to prevent attracting fish into an embayment, and was implemented for the purpose of reducing impingement. Although the normal water level of the Conowingo Reservoir at PBAPS is between 104.5 feet and 108.5 feet (Conowingo Datum), the lowest the Reservoir can be without causing the shutdown of the Muddy Run facility is 104.0 feet (SRBC 2006). Therefore, this water elevation was used as the design low water level in the through screen-velocity calculation, along with 108.5 feet (Conowingo Datum) for the normal water elevation (URS 2008). The results of these calculations show the maximum through-screen velocity at the outer intake structure screens (**Table 5-1**).

Table 5-1: Calculated Through-Screen Velocities

		Normal Water Elevation	Low Water Elevation
Water Elevation (ft.)		108.5	104.0
Screen House Floor Elevation (ft.)		84	84
Water Depth (ft.)		24.5	20
Through-Screen Velocity (fps)[1]	**DIF = Maximum AIF**	**0.984**	**1.21**

Source: URS (2008)
[1]fps = feet per second

Through-screen velocity calculations are provided in **Section 10** as **Appendix B -** Calculations.

5.2.3 PERCENT REDUCTION IN COOLING WATER

PBAPS employs once-through cooling and is a base-load plant that is available to operate year-round. Flow reductions of approximately 3.7%[5] occur annually by not operating all of the designed circulating water pumps during the late fall and winter months (late November/early December through March) and during maintenance shutdowns, and by recirculating warm discharge water to the intake basins in the winter (Exelon 2018a, b, and c).

5.2.4 PROPORTION OF THE SOURCE WATERBODY WITHDRAWN

The proportion of the source waterbody withdrawn has been calculated on a monthly basis as a percentage. The streamflow is based on flows at the USGS Gage Station 01578310, Susquehanna River near Conowingo, MD. The period of record for the average monthly streamflow in the Conowingo Reservoir is from January 1993 through December 2017. The proportion of water withdrawn as a percentage of river flow is listed in **Table 5-2**.

[5] Based on water withdrawal data for the period of January 2015 through December 31, 2017 (Exelon 2018a, b, and c).

Table 5-2: Proportion of Source Waterbody Withdrawn[1]

Month	Withdrawal as a Percent of Streamflow on a Monthly Average
January	6.3 %
February	7.2 %
March	4.6 %
April	4.5 %
May	7.4 %
June	11.8 %
July	17.8 %
August	21.8 %
September	14.0 %
October	11.6 %
November	9.5 %
December	6.7 %

Source: USGS (2018b), Exelon (2018a, b, and c)
[1]Withdrawal percentage is calculated as a proportion of the total Susquehanna River flow measured at USGS Gauge Station 01576980 at the Holtwood Dam and does not reflect the total volume of water available in the Conowingo Reservoir.

5.3 EXISTING IMPINGEMENT AND ENTRAINMENT TECHNOLOGIES

Regulatory requirement at §122.21(r)(5)(iii): "Description of existing impingement and entrainment technologies or operational measures and a summary of their performance, including but not limited to reductions in impingement mortality and entrainment due to intake location and reductions in total water withdrawals and usage"

Existing technologies and operational measures implemented at PBAPS include:

- Outer intake structure specifically designed and installed to reduce impingement by lowering the approach and through-screen velocities, having flush alignment of the screens with the shoreline with lateral fish escape passages, and eliminating the need for intake canals; and
- Flow reductions by not operating all of the designed circulating water pumps during the late fall and winter months (late November/early December through March) and during maintenance shutdowns, and by recirculating warm discharge water to the intake basins in the winter.

The outer intake structure has a physical configuration that was designed to reduce velocity, create a straight shoreline to prevent attracting fish into an embayment, and was implemented for the purpose of reducing impingement mortality. The original intake design (in 1967), consisting of only an inner set of vertical traveling screens, three per unit (a total of six), is located at the end of the intake canal. The relatively high velocity resulting from this configuration and the absence of lateral escape routes would entrap most fish in the intake canal where they would eventually become impinged. Consequently, extensive swim speed studies of resident and anadromous fishes (over 580 tests) were initiated in June 1967 to determine the most sensitive species and the critical maximum velocity that would minimize entrapment and impingement. Based on data from these studies and experience from other facilities at that time, the outer intake structure was designed with an approach velocity of 0.75 fps; the maximum velocity tolerated by most sensitive species (i.e., young white crappie). The 'as built' calculated approach velocity at both the trash racks (0.48 fps) and immediately in front of the screens (0.65 fps) is less than the PBAPS site- specific approach velocity of 0.75 fps. In addition, the PBAPS has adopted procedures that were implemented to reduce impingement mortality (e.g. the shutdown of circulation pumps in the winter). Studies determined that the implementation of the outer intake structure and the circulating pump

shutdowns that occurred at the time during the winter months resulted in an estimated impingement reduction of 85% (URS Corporation 2008).

The inner intake structure was the original design and represents baseline practices, procedures, and structural configuration of the facility. The efficacy of the outer intake structure in reducing impingement was estimated by comparing the annual impingement at the inner intake structure to that at the outer intake structure. Based on 2005-2006 impingement data and assumptions that were made to calculate impingement mortality reduction at the lower end of the range, the outer intake structure reduces impingement mortality by approximately 85% (URS Corporation 2008).

6.0 §122.21(r)(6) - CHOSEN METHOD OF COMPLIANCE WITH IMPINGEMENT MORTALITY STANDARD

Regulatory requirement at §122.21(r)(6): "The owner or operator of the facility must identify the chosen compliance method for the entire facility; alternatively, the applicant must identify the chosen compliance method for each cooling water intake structure at its facility. The applicant must identify any intake structure for which a BTA determination for Impingement Mortality under 40 CFR 125.94 (c)(11) or (12) is requested."

Under this section of the Rule, PBAPS is required to identify one of the seven compliance alternatives at § 125.94(c)(1) through (7) unless it can qualify for an exemption or less stringent standard (i.e., a *de minimis* rate of impingement [§ 125.94(c)(11)] or low capacity utilization power generating unit [§ 125.94(c)(12)]). PBAPS' existing outer intake structure cooling water intake structure was specifically designed and installed to reduce impingement by lowering the approach and through-screen velocities, having flush alignment of the screens with the shoreline with lateral fish escape passages, and eliminating the need for intake canals. Additionally, current operational measures reduce flow, approach velocities, and through-screen velocities. However, PBAPS evaluated a number of additional impingement mortality reduction alternatives and is choosing to comply with the impingement mortality standard at § 125.94(c)(5) by replacing its current traveling screens with fish-friendly modified traveling screens as defined at § 125.92(s) and installing a fish return system that will allow impinged fish to be returned to Conowingo Reservoir, provided PADEP concurs that the existing system is BTA for entrainment. The addition of these technologies will further reduce impingement mortality. PBAPS may consider a pilot study of various modified Ristroph-type traveling screens to determine the most appropriate type of screens for the upgrade at PBAPS. Per § 122.21(r)(6)(i), PBAPS will perform an impingement technology performance optimization study of the selected modified Ristroph-type traveling screens to demonstrate that the operation has been optimized to minimize impingement mortality of non-fragile species.

7.0 §122.21(r)(7) - ENTRAINMENT PERFORMANCE STUDIES

Regulatory requirement at §122.21(r)(7): "The owner or operator of an existing facility must submit any previously conducted studies or studies obtained from other facilities addressing technology efficacy, through-facility entrainment survival, and other entrainment studies. Any such submittals must include a description of each study, together with underlying data, and a summary of any conclusions or results. Any studies conducted at other locations must include an explanation as to why the data from other locations are relevant and representative of conditions at your facility. In the case of studies more than 10 years old, the applicant must explain why the data are still relevant and representative of conditions at the facility and explain how the data should be interpreted using the definition of entrainment at 40 CFR 125.92(h)."

Entrainment characterization studies at PBAPS have been conducted since the pre- and post-operational reports on the ecology of the Conowingo Reservoir from 1974 through 1979 (Robbins and Mathur 1974a, 1974b, 1975a, 1975b, 1975c, 1976, 1977; Ichthyological Associates, Inc. 1977a, 1977b; RMC Ecological

Division. 1979). The passage of zooplankton through PBAPS was studied by Boyer (1970, 1971) and Anjard (1978). The most recent entrainment studies were conducted between March 8, 2012 and September 27, 2012 and between March 21, 2016 and October 2, 2016 (NAI 2013b, 2017c). Results of those studies indicated that entrainment was mostly of the forage species gizzard shad and tessellated darter and impacts to the Susquehanna River from entrainment at PBAPS are likely low. In fact, comparison of ichthyoplankton densities among three sampling locations showed higher total annual ichthyoplankton estimates at the discharge canal outfall compared to the outer intake structure. These results suggest that spawning is occurring within the intake canals and the discharge canal and that the PBAPS cooling water system, including the intake canals and discharge canal, produces more ichthyoplankton than the quantity removed at the outer intake structure. See **Section 4.3.2** and the accompanying §122.21(r)(9) and §122.21(r)(11) reports for details and results.

8.0 §122.21(r)(8) - OPERATIONAL STATUS

8.1 NARRATIVE DESCRIPTION OF POWER PRODUCTION

Regulatory requirement at §122.21(r)(8)(i): "For power production or steam generation, descriptions of individual unit operating status including age of each unit, capacity utilization rate (or equivalent) for the previous 5 years, including any extended or unusual outages that significantly affect current data for flow, impingement, entrainment, or other factors, including identification of any operating unit with a capacity utilization rate of less than 8 percent averaged over a 24-month block contiguous period, and any major upgrades completed within the last 15 years, including but not limited to boiler replacement, condenser replacement, turbine replacement, or changes to fuel type"

PBAPS is a two-unit (Units 2 & 3) nuclear-fueled boiling water reactor electric power generating facility with a generating capacity of 2,770 megawatts-electric. Unit 2 began commercial operation in June 1974 and Unit 3 entered commercial service in December 1974. PBAPS is a base-load plant that is available to operate year-round. Either unit could be in shutdown mode or operating at less than 100% capacity because of maintenance outages, reduced electric demand, or other factors. Typically, one outage occurs per year and begins in mid-October and lasts roughly 21 days. Based on annual operations from 2013 through 2017, PBAPS' average capacity utilization rate was 93.5%. Unit capacity factors are listed in **Table 8-1** for the last five years. The factors are year-end values.

Table 8-1: Capacity Utilization Factors

Year	Capacity Utilization Factors		
	Unit 2	Unit 3	Facility Average
2013	98.5	85.3	91.9
2014	84.8	99.1	92.0
2015	95.8	89.6	92.7
2016	91.9	99.8	95.9
2017	99.2	91.4	95.3
Average	**94.0**	**93.0**	**93.5**

Source: Exelon (2018e)

8.2 DESCRIPTIONS OF UPRATES AND USNRC RELICENSING

Regulatory requirement at §122.21(r)(8)(ii): "Descriptions of completed, approved, or scheduled uprates and Nuclear Regulatory Commission relicensing status of each unit at nuclear facilities"

PBAPS' Units 2 & 3 had an Original Licensed Thermal Power of 3,293 megawatts-thermal (MWth) for each unit. Since initial service, the following updates have occurred (Exelon 2018f; USNRC 2018):

- 1994/1995 - 5% (165 MWth) Stretch Power Uprate for Units 2 and 3, respectively
- 2002 – 1.62% (57 MWth) Measurement Uncertainty Recapture (MUR) Power Uprate for each Unit

- 2014 - 12.4% (437 MWth) Extended Power Uprate (EPU) for each Unit
- 2017 - 1.66% (65 MWth) MUR Power Uprate for each unit

PBAPS Units 2 and 3 are currently licensed to operate until 2033 and 2034, respectively; however, Exelon submitted a license renewal application to the United States Nuclear Regulatory Commission (USNRC) in July 2018 for a 20-year operating license extension for each of Units 2 and 3, anticipating that the process will take several years (Exelon 2018g).

8.3 Process Units Using Cooling Water Other Than for Power Production

Regulatory requirement at §122.21(r)(8)(iii): "For process units at your facility that use cooling water other than for power production or steam generation, if you intend to use reductions in flow or changes in operations to meet the requirements of 40 CFR 125.94(c), descriptions of individual production processes and product lines, operating status including age of each line, seasonal operation, including any extended or unusual outages that significantly affect current data for flow, impingement, entrainment, or other factors, any major upgrades completed within the last 15 years, and plans or schedules for decommissioning or replacement of process units or production processes and product lines"

This section is not applicable to PBAPS.

8.4 Descriptions of Production Schedules

Regulatory requirement at §122.21(r)(8)(iv): "For all manufacturing facilities, descriptions of current and future production schedules"

This section is not applicable to PBAPS.

8.5 Plans for New Units

Regulatory requirement at §122.21(r)(8)(v): "Descriptions of plans or schedules for any new units planned within the next 5 years"

There are no plans or schedules for new units at PBAPS within the next five years.

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10.0 APPENDICES

Appendix A – Locational Maps

- Peach Bottom Atomic Power Station – Site Location Map – Aerial View; Source: ESRI. "Imagery" [basemap]. Scale Not Given. "World Imagery Map". September 14, 2018. https://www.arcgis.com/home/item.html?id=10df2279f9684e4a9f6a7f08febac2a9. (September 6, 2018).
- Peach Bottom Atomic Power Station – Site Location Map – Topographic Map; Source: ESRI. "Topographic" [basemap]. Scale Not Given. "World Topographic Map". September 14, 2018. https://www.arcgis.com/home/item.html?id=30e5fe3149c34df1ba922e6f5bbf808f. (September 6, 2018).
- Gomez and Sullivan Engineers, P.C. 2012. Figure 3: Composite elevation data set including 2011 Conowingo Pond data

Appendix B – Calculations

- Area of Influence Calculation 1: AECOM. 2018. Bar Rack Approach Velocity. Exelon Generation Company, LLC, Peach Bottom Atomic Power Station. August 2018.
- Area of Influence Calculation 2: AECOM. 2018. Bar Rack Exit Velocity. Exelon Generation Company, LLC, Peach Bottom Atomic Power Station. August 2018.
- Area of Influence Calculation 3: AECOM. 2018. Bar Rack Through-Blade Velocity. Exelon Generation Company, LLC, Peach Bottom Atomic Power Station. August 2018.
- Area of Influence Calculation 4: AECOM. 2018. Screen Approach Velocity. Exelon Generation Company, LLC, Peach Bottom Atomic Power Station. August 2018.
- AECOM. 2018. Through-Screen Velocity. Exelon Generation Company, LLC, Peach Bottom Atomic Power Station. August 2018.

Appendix C – Drawings and Schematics

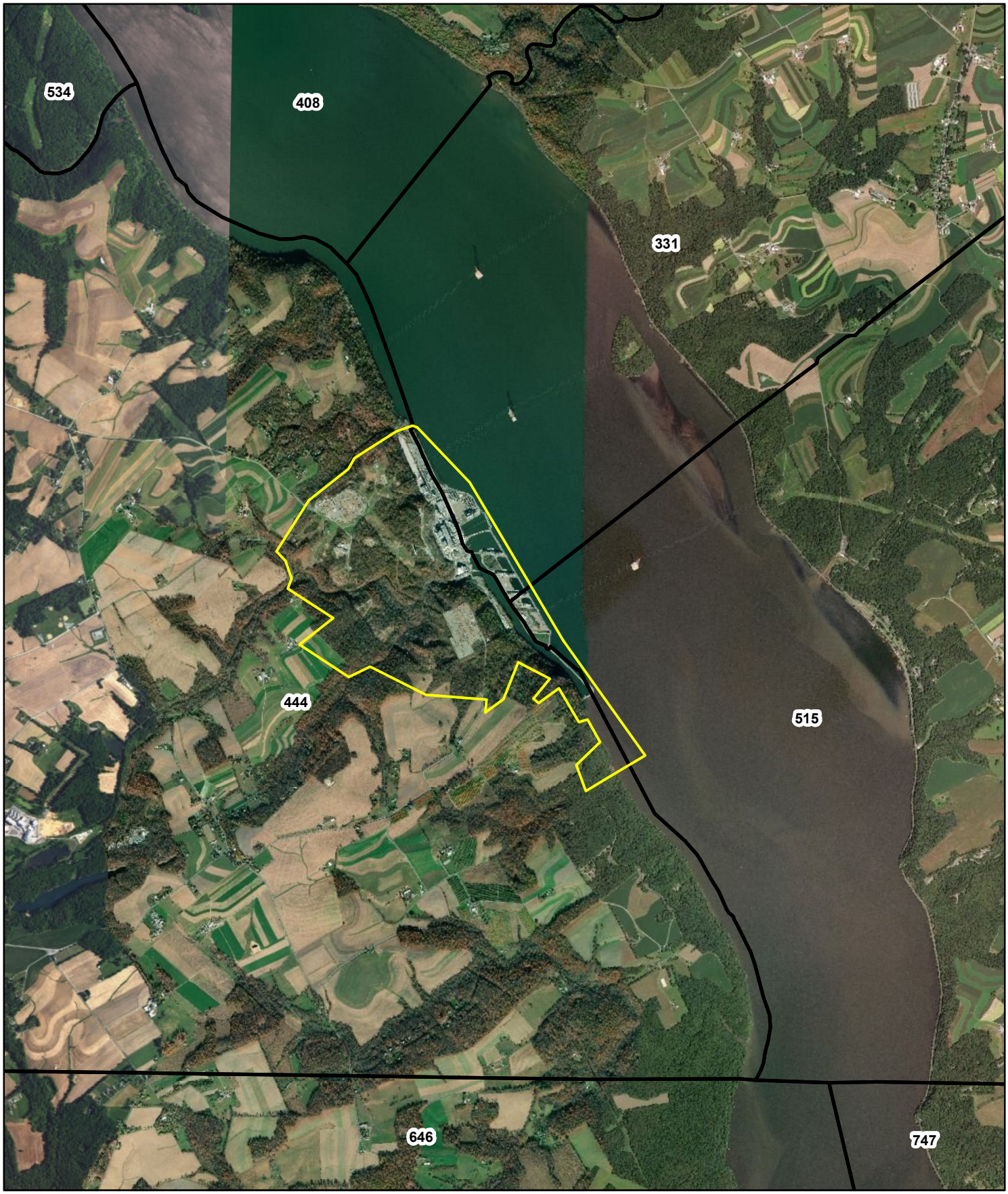
- Schematic of Water Flow, Exelon Nuclear, Figure Number NPDES-1, Rev 1, January 24, 2014
- Drawing No. M-18-62, Sheet 1, General Arrangement 10' X 33' Traveling Water
- Screens, Hawco Screens, Inc., September 25, 1992.
- Drawing No. M-18-64, Sheet 1, Traveling Water Screen Data Sheet, Hawco Screens, Inc., January 15, 1993.
- Drawing No. 6280, Sheet C-100, C.W. Screen Structure Bottom Plan, Bechtel, 1976.

- Drawing No. 6280, Sheet C-101, C.W. Screen Structure Bottom Plan, Bechtel, February 23, 1971.
- Drawing No. 6280, Sheet C-102, C.W. Screen Structure Sections, Bechtel, August 26, 1971.
- Drawing No. 6280, Sheet SKC-289, Screen Structure Trash Collection Area, Bechtel, July 1967.

Appendix D – Threatened and Endangered Species Information

- U.S. Fish & Wildlife Service IPaC Resource List
- PNDI Receipt, PNDI-617811, September 21, 2017.

APPENDIX A
LOCATION MAPS



Legend

PBAPS Site Boundary

US Census Block Groups with Total Households

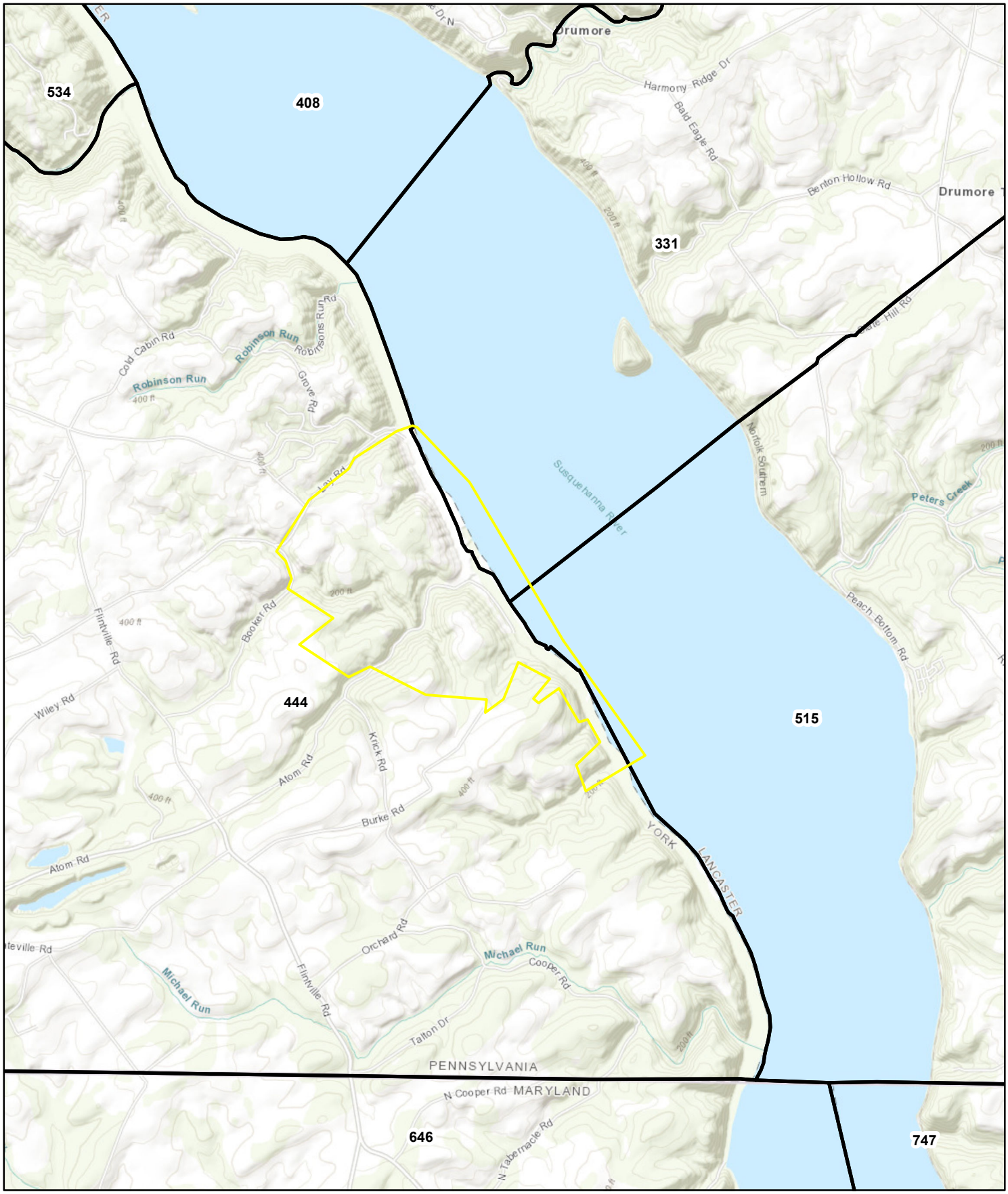
0 1,375 2,750 5,500 Feet

NAD 1983 UTM Zone 18N
Projection: Transverse Mercator
Reference: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/AirBus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
U.S. Census Bureau 2010

N

Attachment A - Figure 1
Site Location Map

AECOM



Legend

PBAPS Site Boundary

US Census Block Groups with Total Households

0 1,375 2,750 5,500 Feet

NAD 1983 UTM Zone 18N
Projection: Transverse Mercator
Reference: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/AirBus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
U.S. Census Bureau 2010

N

Attachment A - Figure 2
Site Location Map

AECOM

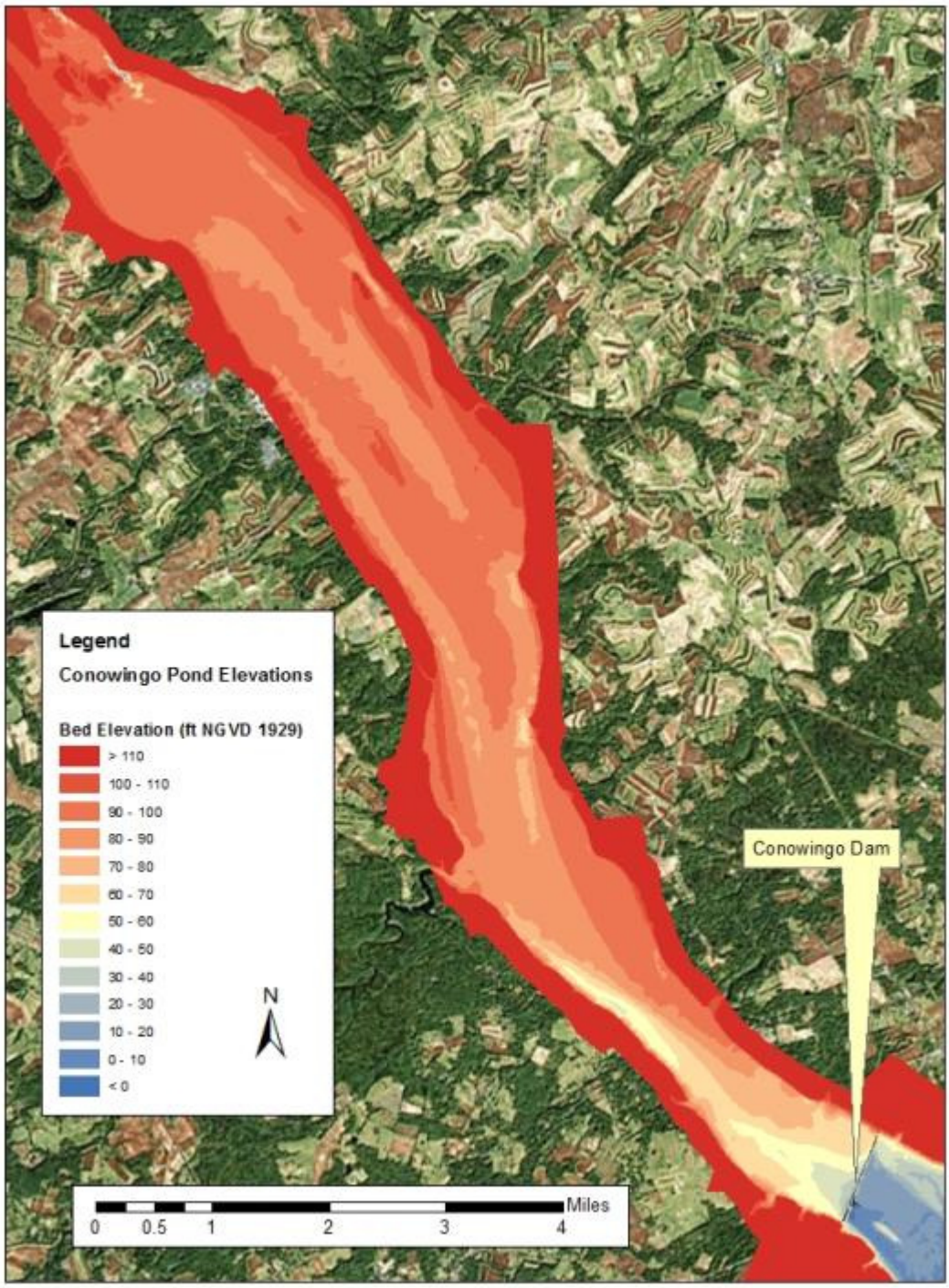


Figure 3: Composite elevation data set including 2011 Conowingo Pond data.

Source: Gomez and Sullivan Engineers, P.C. 2012. *In:* The Lower Susquehanna River Watershed Assessment (LSRWA) Final Report, Appendix G: 2011 Exelon Conowingo Pond Bathymetric Survey Analysis.

APPENDIX B
CALCULATIONS

AECOM
Conshohocken, PA

EXELON GENERATION COMPANY
Peach Bottom Atomic Power Station 316(b) Project

PEACH BOTTOM BAR RACK APPROACH VELOCITY

PREPARED FOR

Exelon

Prepared By: **Date:**
Mary Paskewicz, P.E.
Project Engineer 8/28/2018

Reviewed By: **Date:**
Susan Ambler, P.E. 8/31/2018
Senior Engineer

Approved By: **Date:**
Joella Posey, P.E. 9/4/2018
Project Manager

Rev.	Date	Prepared by	Rev'wd by	Approved by
0	9/17/07	TAJ	JLP	JMD
1	8/28/2018	MEP	SEA	JLP
2				
3				

Peach Bottom Atomic Power Station 316b Project

APPROACH VELOCITY CALCULATION

Calculation Purpose:

1. Calculate the design approach velocity for the Peach Bottom bar rack to assess area of influence.

Calculation Objectives:

1. Identify the bar rack physical parameters and design intake flow rate.
2. Calculate the wetted area immediately in front of the bar racks.
3. Calculate the design approach velocity under the listed assumptions.

System Description:
The Exelon Peach Bottom Atomic Power Station is a 2,304 MW boiling water reactor atomic generating station with two active operating units (Units 2 and 3). Cooling water for the once-through condenser cooling system is withdrawn from the Conowingo Reservoir of the Susquehanna River by six CW pumps and discharged after use to the Conowingo Reservoir downstream of the CWIS. The cooling water intake is located on the shoreline of the Conowingo Reservoir. The water flows through the outer screen structure into two 3-acre intake basins and then through the original, inner intake structure. 29 active trash racks on the outer screen structure prevent ice and large objects from entering the outer screenhouse structure. There are 24 through-flow traveling water screens in the outer screenhouse and 10 traveling water screens, 6 dual-flow screens for the cooling water and 4 through-flow screens for the service water, in the inner screenhouse.

Calculation Methodology:

The approach velocity will be calculated using the design flow through the area of the bar rack structure.

$V = Q / A = Q / (WD * BRW)$

where:

Q = flow rate in gallons per minute (gpm)
V = approach velocity in feet per second (fps)
WD = water depth in feet (ft)
BRW = nominal width of the bar rack structure through which water flows in ft

Peach Bottom Atomic Power Station 316b Project

APPROACH VELOCITY CALCULATION

Design Inputs:

Pump Design Capacities:

Unit No. 2 Circulating Pump	360.0	MGD	556.92	cfs	250,000	gpm	(Ref. 6)
Unit No. 2 Circulating Pump	360.0	MGD	556.92	cfs	250,000	gpm	(Ref. 6)
Unit No. 2 Circulating Pump	360.0	MGD	556.92	cfs	250,000	gpm	(Ref. 6)
Unit No. 3 Circulating Pump	360.0	MGD	556.92	cfs	250,000	gpm	(Ref. 6)
Unit No. 3 Circulating Pump	360.0	MGD	556.92	cfs	250,000	gpm	(Ref. 6)
Unit No. 3 Circulating Pump	360.0	MGD	556.92	cfs	250,000	gpm	(Ref. 6)
Service Water Pumps	80.6	MGD	124.75	cfs	56,000	gpm	(Ref. 7)
TOTALs	**2240.6**	**MGD**	**3466.3**	**cfs**	**1,556,000**	**gpm**	

Nominal Width of Bar Rack Structure w/ Active Racks	450.0	ft	(Ref. 3)
Number of Bar Racks	29		(Ref. 3)
Width of Each Bar Rack	13.5	ft	(Ref. 3)
Blade thickness	0.25	in	(Ref. 3)
Spacing Between Blades	3.25	in	(Ref. 3)
Screenhouse Floor Elevation	84.0	feet	(Ref. 3)
Design Water Elevation	104.0	feet	(Ref. 8)
Water Height (Depth)	20.0	feet	

Assumptions:

1. The minimum reservoir level (below which Muddy Run would shut down) of 104.0 feet is used to calculate the design approach velocity even though the minimum permitted water height for the Conowingo Reservoir is 100.5 feet.
2. No changes to as-built configuration after dates of references used.
3. There are twenty-nine active bar racks normally in service and 100% clean.
4. All pumps normally operate at their design capacity ratings.
5. Assume that the design flow is split evenly across the bar racks.
6. Check velocity for worst-case scenario, with maximum no. of pumps for each unit operating.

References Used:

1. Page 78 and 79 of Screening Equipment Handbook, 2nd Edition, 1995. Tom M. Pankratz.
2. Drawing M-18-64_sht_00001, TWS Data Sheet, 1/15/93.
3. Drawing 6280, Sheets C-100-102, C.W. Screen Structure (Bottom Plan, Top Slab Plan, & Sections), Bechtel 1971-1976.
4. Standard Handbook for Mechanical Engineers, eight edition, p. 6-45
5. 40 CFR Part 125.94(a)(1)(ii) - Ref. In Calculation Methodology Section
6. Design Basis Document: Circulating Water and Cooling Tower System, P-S-22, Revision 14, PECO Nuclear
7. Design Basis Document: Service Water System, P-S-17, Revision 9, PECO Nuclear
8. Conowingo Pond Management Plan, April 2006, pg. 22.

Summary and Conclusions:

1. The calculated design approach velocity at the bar racks for the Peach Bottom CWIS is **0.39 fps**

AECOM
Conshohocken, PA

EXELON GENERATION COMPANY
Peach Bottom Atomic Power Station 316(b) Project

PEACH BOTTOM BAR RACK EXIT VELOCITY

PREPARED FOR

Exelon

Prepared By:	**Date:**
Mary Paskewicz, P.E. Project Engineer	8/28/2018
Reviewed By:	**Date:**
Susan Ambler, P.E. Senior Engineer	8/31/2018
Approved By:	**Date:**
Joella Posey, P.E. Project Manager	9/4/2018

Rev.	Date	Prepared by	Rev'wd by	Approved by
0	9/17/07	TAJ	JLP	JMD
1	8/28/2018	MEP	SEA	JLP
2				
3				

Peach Bottom Atomic Power Station 316b Project

EXIT VELOCITY CALCULATION

Calculation Purpose:

1. Calculate the design exit velocity for the Peach Bottom bar rack to assess area of influence.

Calculation Objectives:

1. Identify the bar rack physical parameters and design intake flow rate.
2. Calculate the wetted area immediately behind the bar racks.
3. Calculate the design exit velocity under the listed assumptions.

System Description:
The Exelon Peach Bottom Atomic Power Station is a 2,304 MW boiling water reactor atomic generating station with two active operating units (Units 2 and 3). Cooling water for the once-through condenser cooling system is withdrawn from the Conowingo Reservoir of the Susquehanna River by six CW pumps and discharged after use to the Conowingo Reservoir downstream of the CWIS. The cooling water intake is located on the shoreline of the Conowingo Reservoir. The water flows through the outer screen structure into two 3-acre intake basins and then through the original, inner intake structure. 29 active trash racks on the outer screen structure prevent ice and large objects from entering the outer screenhouse structure. There are 24 through-flow traveling water screens in the outer screenhouse and 10 traveling water screens, 6 dual-flow screens for the cooling water and 4 through-flow screens for the service water, in the inner screenhouse.

Calculation Methodology:

The exit velocity will be calculated using the design flow through the area of the bar rack structure.

V = Q / A = Q / (WD * BRW)

where:

Q = flow rate in gallons per minute (gpm)
V = exit velocity in feet per second (fps)
WD = water depth in feet (ft)
BRW = nominal width of the bar rack structure through which water flows in ft

Peach Bottom Atomic Power Station 316b Project

EXIT VELOCITY CALCULATION

Design Inputs:

Pump Design Capacities:

Unit No. 2 Circulating Pump	360.0	MGD	556.92	cfs	250,000	gpm	(Ref. 6)
Unit No. 2 Circulating Pump	360.0	MGD	556.92	cfs	250,000	gpm	(Ref. 6)
Unit No. 2 Circulating Pump	360.0	MGD	556.92	cfs	250,000	gpm	(Ref. 6)
Unit No. 3 Circulating Pump	360.0	MGD	556.92	cfs	250,000	gpm	(Ref. 6)
Unit No. 3 Circulating Pump	360.0	MGD	556.92	cfs	250,000	gpm	(Ref. 6)
Unit No. 3 Circulating Pump	360.0	MGD	556.92	cfs	250,000	gpm	(Ref. 6)
Service Water Pumps	80.6	MGD	124.75	cfs	56,000	gpm	(Ref. 7)
TOTALs	**2240.6**	**MGD**	**3466.3**	**cfs**	**1,556,000**	**gpm**	

Nominal Width of Bar Rack Structure w/ Active Racks	450.0	ft	(Ref. 3)
Number of Bar Racks	29		(Ref. 3)
Width of Each Bar Rack	13.5	ft	(Ref. 3)
Blade thickness	0.25	in	(Ref. 3)
Spacing Between Blades	3.25	in	(Ref. 3)
Screenhouse Floor Elevation	84.0	feet	(Ref. 3)
Design Water Elevation	104.0	feet	(Ref. 8)
Water Height (Depth)	20.0	feet	

Assumptions:

1. The minimum reservoir level (below which Muddy Run would shut down) of 104.0 feet is used to calculate the design exit velocity even though the minimum permitted water height for the Conowingo Reservoir is 100.5 feet.
2. No changes to as-built configuration after dates of references used.
3. There are twenty-nine active bar racks normally in service and 100% clean.
4. All pumps normally operate at their design capacity ratings.
5. Assume that the design flow is split evenly across the bar racks.
6. Check velocity for worst-case scenario, with maximum no. of pumps for each unit operating.

References Used:

1. Page 78 and 79 of Screening Equipment Handbook, 2nd Edition, 1995. Tom M. Pankratz.
2. Drawing M-18-64_sht_00001, TWS Data Sheet, 1/15/93.
3. Drawing 6280, Sheets C-100-102, C.W. Screen Structure (Bottom Plan, Top Slab Plan, & Sections), Bechtel 1971-1976.
4. Standard Handbook for Mechanical Engineers, eight edition, p. 6-45
5. 40 CFR Part 125.94(a)(1)(ii) - Ref. In Calculation Methodology Section
6. Design Basis Document: Circulating Water and Cooling Tower System, P-S-22, Revision 14, PECO Nuclear
7. Design Basis Document: Service Water System, P-S-17, Revision 9, PECO Nuclear
8. Conowingo Pond Management Plan, April 2006, pg. 22.

Summary and Conclusions:

1. The calculated design approach velocity behind the racks for the Peach Bottom CWIS is **0.44 fps**

AECOM
Conshohocken, PA

EXELON GENERATION COMPANY
Peach Bottom Atomic Power Station 316(b) Project

PEACH BOTTOM BAR RACK THROUGH-BLADE VELOCITY

PREPARED FOR

Exelon

Prepared By: Mary Paskewicz, P.E.
Project Engineer — **Date:** 8/28/2018

Reviewed By: Susan Ambler, P.E.
Senior Engineer — **Date:** 8/31/2018

Approved By: Joella Posey, P.E.
Project Manager — **Date:** 9/4/2018

Rev.	Date	Prepared by	Rev'wd by	Approved by
0	9/17/07	TAJ	JLP	JMD
1	8/28/2018	MEP	SEA	JLP
2				
3				

Peach Bottom Atomic Power Station 316b Project

THROUGH-BLADE VELOCITY CALCULATION

Calculation Purpose:

1. Calculate the design through-blade velocity for the Peach Bottom bar rack to assess area of influence.

Calculation Objectives:

1. Identify the bar rack physical parameters and design intake flow rate.
2. Calculate the wetted open area of the bar racks.
3. Calculate the design through-blade velocity under the listed assumptions.

System Description:
The Exelon Peach Bottom Atomic Power Station is a 2,304 MW boiling water reactor atomic generating station with two active operating units (Units 2 and 3). Cooling water for the once-through condenser cooling system is withdrawn from the Conowingo Reservoir of the Susquehanna River by six CW pumps and discharged after use to the Conowingo Reservoir downstream of the CWIS. The cooling water intake is located on the shoreline of the Conowingo Reservoir. The water flows through the outer screen structure into two 3-acre intake basins and then through the original, inner intake structure. 29 active trash racks on the outer screen structure prevent ice and large objects from entering the outer screenhouse structure. There are 24 through-flow traveling water screens in the outer screenhouse and 10 traveling water screens, 6 dual-flow screens for the cooling water and 4 through-flow screens for the service water, in the inner screenhouse.

Calculation Methodology:

The through-blade velocity will be calculated using the design flow through the area of the bar rack structure.

V = Q / OA

where:

Q = flow rate in gallons per minute (gpm)
V = through-blade velocity in feet per second (fps)
WD = water depth in feet (ft)
W = nominal width of the between blade spacing in ft
OA = WD * W * No. spaces per bar rack * No. bar racks

Peach Bottom Atomic Power Station 316b Project

APPROACH VELOCITY CALCULATION

Design Inputs:

Pump Design Capacities:

Unit No. 2 Circulating Pump	360.0	MGD	556.92	cfs	250,000	gpm	(Ref. 6)
Unit No. 2 Circulating Pump	360.0	MGD	556.92	cfs	250,000	gpm	(Ref. 6)
Unit No. 2 Circulating Pump	360.0	MGD	556.92	cfs	250,000	gpm	(Ref. 6)
Unit No. 3 Circulating Pump	360.0	MGD	556.92	cfs	250,000	gpm	(Ref. 6)
Unit No. 3 Circulating Pump	360.0	MGD	556.92	cfs	250,000	gpm	(Ref. 6)
Unit No. 3 Circulating Pump	360.0	MGD	556.92	cfs	250,000	gpm	(Ref. 6)
Service Water Pumps	80.6	MGD	124.75	cfs	56,000	gpm	(Ref. 7)
TOTALs	**2240.6**	**MGD**	**3466.3**	**cfs**	**1,556,000**	**gpm**	

Nominal Width of Bar Rack Structure w/ Active Racks	450.0	ft	(Ref. 3)
Number of Bar Racks	29		(Ref. 3)
Width of Each Bar Rack	13.5	ft	(Ref. 3)
Blade thickness	0.25	in	(Ref. 3)
Spacing Between Blades	3.25	in	(Ref. 3)
Number of Spaces per Bar Rack	46		
Screenhouse Floor Elevation	84.0	feet	(Ref. 3)
Design Water Elevation	104.0	feet	(Ref. 8)
Water Height (Depth)	20.0	feet	

Assumptions:

1. The minimum reservoir level (below which Muddy Run would shut down) of 104.0 feet is used to calculate the design approach velocity even though the minimum permitted water height for the Conowingo Reservoir is 100.5 feet.
2. No changes to as-built configuration after dates of references used.
3. There are twenty-nine active bar racks normally in service and 100% clean.
4. All pumps normally operate at their design capacity ratings.
5. Assume that the design flow is split evenly across the bar racks.
6. Check velocity for worst-case scenario, with maximum no. of pumps for each unit operating.

References Used:

1. Page 78 and 79 of Screening Equipment Handbook, 2nd Edition, 1995. Tom M. Pankratz.
2. Drawing M-18-64_sht_00001, TWS Data Sheet, 1/15/93.
3. Drawing 6280, Sheets C-100-102, C.W. Screen Structure (Bottom Plan, Top Slab Plan, & Sections), Bechtel 1971-1976.
4. Standard Handbook for Mechanical Engineers, eight edition, p. 6-45
5. 40 CFR Part 125.94(a)(1)(ii) - Ref. In Calculation Methodology Section
6. Design Basis Document: Circulating Water and Cooling Tower System, P-S-22, Revision 14, PECO Nuclear
7. Design Basis Document: Service Water System, P-S-17, Revision 9, PECO Nuclear
8. Conowingo Pond Management Plan, April 2006, pg. 22.

Summary and Conclusions:

1. The calculated design through velocity at the bar racks for the Peach Bottom CWIS is **0.48 fps**

AECOM
Conshohocken, PA

EXELON GENERATION COMPANY
Peach Bottom Atomic Power Station 316(b) Project

PEACH BOTTOM SCREEN APPROACH VELOCITY

PREPARED FOR

Exelon

Prepared By: Mary Paskewicz, P.E.
Project Engineer

Date: 8/28/2018

Reviewed By: Susan Ambler, P.E.
Senior Engineer

Date: 8/31/2018

Approved By: Joella Posey, P.E.
Project Manager

Date: 9/4/2018

Rev.	Date	Prepared by	Rev'wd by	Approved by
0	9/17/07	TAJ	JLP	JMD
1	8/28/2018	MEP	SEA	JLP
2				
3				

Peach Bottom Atomic Power Station 316b Project

APPROACH VELOCITY CALCULATION

Calculation Purpose:

1. Calculate the design approach velocity for the Peach Bottom outer screens to assess area of influence.

Calculation Objectives:

1. Identify the outer screens physical parameters and design intake flow rate.
2. Calculate the wetted area immediately in front of the outer screens.
3. Calculate the design approach velocity under the listed assumptions.

System Description:
The Exelon Peach Bottom Atomic Power Station is a 2,304 MW boiling water reactor atomic generating station with two active operating units (Units 2 and 3). Cooling water for the once-through condenser cooling system is withdrawn from the Conowingo Reservoir of the Susquehanna River by six CW pumps and discharged after use to the Conowingo Reservoir downstream of the CWIS. The cooling water intake is located on the shoreline of the Conowingo Reservoir. The water flows through the outer screen structure into two 3-acre intake basins and then through the original, inner intake structure. 29 active trash racks on the outer screen structure prevent ice and large objects from entering the outer screenhouse structure. There are 24 through-flow traveling water screens in the outer screenhouse and 10 traveling water screens, 6 dual-flow screens for the cooling water and 4 through-flow screens for the service water, in the inner screenhouse.

Calculation Methodology:

The approach velocity will be calculated using the design flow through the area of the screen structure.

V = Q / A = Q / (WD * OSW)

where:

Q = flow rate in gallons per minute (gpm)
V = approach velocity in feet per second (fps)
WD = water depth in feet (ft)
OSW = nominal width of the outer screen structure through which water flows in ft

Peach Bottom Atomic Power Station 316b Project

APPROACH VELOCITY CALCULATION

Design Inputs:

Pump Design Capacities:

Unit No. 2 Circulating Pump	360.0	MGD	556.92	cfs	250,000	gpm	(Ref. 6)
Unit No. 2 Circulating Pump	360.0	MGD	556.92	cfs	250,000	gpm	(Ref. 6)
Unit No. 2 Circulating Pump	360.0	MGD	556.92	cfs	250,000	gpm	(Ref. 6)
Unit No. 3 Circulating Pump	360.0	MGD	556.92	cfs	250,000	gpm	(Ref. 6)
Unit No. 3 Circulating Pump	360.0	MGD	556.92	cfs	250,000	gpm	(Ref. 6)
Unit No. 3 Circulating Pump	360.0	MGD	556.92	cfs	250,000	gpm	(Ref. 6)
Service Water Pumps	80.6	MGD	124.75	cfs	56,000	gpm	(Ref. 7)
TOTALs	**2240.6**	**MGD**	**3466.3**	**cfs**	**1,556,000**	**gpm**	

Nominal Width of Screen Structure incl support concrete	370.0	ft	(Ref. 3)
Number of screens	24		(Ref. 3)
Width of Each Screen	11.2	ft	(Ref. 3)
Wire thickness	0.08	in	(Ref. 3)
Mesh wire openings (square)	0.375	in	(Ref. 3)
Screenhouse Floor Elevation	84.0	feet	(Ref. 3)
Design Water Elevation	104.0	feet	(Ref. 8)
Water Height (Depth)	20.0	feet	

Assumptions:

1. The minimum reservoir level (below which Muddy Run would shut down) of 104.0 feet is used to calculate the design approach velocity even though the minimum permitted water height for the Conowingo Reservoir is 100.5 feet.
2. No changes to as-built configuration after dates of references used.
3. There are twenty-four active screens normally in service and 100% clean.
4. All pumps normally operate at their design capacity ratings.
5. Assume that the design flow is split evenly across the screens.
6. Check velocity for worst-case scenario, with maximum no. of pumps for each unit operating.

References Used:

1. Page 78 and 79 of Screening Equipment Handbook, 2nd Edition, 1995. Tom M. Pankratz.
2. Drawing M-18-64_sht_00001, TWS Data Sheet, 1/15/93.
3. Drawing 6280, Sheets C-100-102, C.W. Screen Structure (Bottom Plan, Top Slab Plan, & Sections), Bechtel 1971-1976.
4. Standard Handbook for Mechanical Engineers, eight edition, p. 6-45
5. 40 CFR Part 125.94(a)(1)(ii) - Ref. In Calculation Methodology Section
6. Design Basis Document: Circulating Water and Cooling Tower System, P-S-22, Revision 14, PECO Nuclear
7. Design Basis Document: Service Water System, P-S-17, Revision 9, PECO Nuclear
8. Conowingo Pond Management Plan, April 2006, pg. 22.

Summary and Conclusions:

1. The calculated design approach velocity at the outer screens for the Peach Bottom CWIS is **0.65 fps**

AECOM
Conshohocken, PA

EXELON GENERATION COMPANY
Peach Bottom Atomic Power Station 316(b) Project

PEACH BOTTOM THROUGH-SCREEN VELOCITY

PREPARED FOR

Exelon

Prepared By: Mary Paskewicz, P.E.
Project Engineer

Date: 8/8/2018

Reviewed By: Susan Ambler, P.E.
Senior Engineer

Date: 8/14/2018

Approved By: Joella Posey, P.E.
Project Manager

Date: 8/28/18

Rev.	Date	Prepared by	Rev'wd by	Approved by
0	10/3/07	TAJ	JLP	JMD
1	10/24/07	RdS	JLP	JMD
2	11/28/07	RdS	JLP	JMD
3	8/8/18	MEP	SEA	JLP

Peach Bottom Atomic Power Station 316(b) Project

THROUGH-SCREEN VELOCITY CALCULATION

Calculation Purpose:

Calculate the design through-screen velocity for the Peach Bottom Outer Cooling Water Intake Structure (CWIS).

Calculation Objectives:

1. Identify the screen physical parameters and design intake flow rate.
2. Calculate the proportion of open screen area to screen surface area.
3. Calculate the design through-screen velocity at the Outer CWIS under the listed assumptions.

System Description:

The Exelon Peach Bottom Atomic Power Station is a nominal 2,304 MW boiling water reactor atomic generating station with two active operating units (Units 2 and 3). Cooling water (CW) for the once-through condenser cooling system is withdrawn from the Conowingo Reservoir of the Susquehanna River by six CW pumps and discharged after use to the Conowingo Reservoir downstream of the CWIS. The cooling water intake is located on the shoreline of the Conowingo Reservoir. The water flows through the outer screen structure into two 3-acre intake basins and then through the original, inner intake structure. 29 active trash racks on the outer screen structure prevent ice and large objects from entering the outer screenhouse structure. There are 24 through-flow traveling water screens in the outer screenhouse.

Calculation Methodology:

The through-screen velocity will be calculated using formulas adapted from Pankratz, 1988.

$V = Q / (WD * OA * TW * K)$ **(Formula 1)**

where:

Q = flow rate in gallons per minute (gpm)
V = through-screen velocity in feet per second (fps)
WD = water depth in feet (ft)
OA = proportion of screen open area to total screen area
TW = nominal screen tray width in ft
K = constant = 396 for through-flow screen for unit conversion and reduction of screen open area due to typical screen features

and $OA = (W \times L) / ((W + D) * (L + d))$ **(Formula 2)**

where:

d = screen horizontal (shute) wire diameter in inches (in)
D = screen vertical (warp) wire diameter (in)
W = width of screen opening (in)
L = vertical length of screen opening (in)

Peach Bottom Atomic Power Station 316(b) Project

THROUGH-SCREEN VELOCITY CALCULATION

Design Inputs:

1. Pump Design Capacities:

Unit No. 2 Circulating Pump	360.0	MGD	556.92	cfs	250,000	gpm	(Ref. 5)
Unit No. 2 Circulating Pump	360.0	MGD	556.92	cfs	250,000	gpm	(Ref. 5)
Unit No. 2 Circulating Pump	360.0	MGD	556.92	cfs	250,000	gpm	(Ref. 5)
Unit No. 3 Circulating Pump	360.0	MGD	556.92	cfs	250,000	gpm	(Ref. 5)
Unit No. 3 Circulating Pump	360.0	MGD	556.92	cfs	250,000	gpm	(Ref. 5)
Unit No. 3 Circulating Pump	360.0	MGD	556.92	cfs	250,000	gpm	(Ref. 5)
Service Water Pumps	80.6	MGD	124.75	cfs	56,000	gpm	(Ref. 6)
TOTALs	**2,240.6**	**MGD**	**3,466.3**	**cfs**	**1,556,000**	**gpm**	
Peach Bottom Max Withdrawal Rate			2,240.6	MGD			

2. Number of screens	24		(Ref. 2)
3. Nominal Water Withdrawal Rate (per screen)	64,833	gpm	
4. Screen Width	10.00	feet	(Ref. 2)
5. Screenhouse Floor Elevation	84.0	feet	(Ref. 3)
6a. Minimum (Low) Design Water Elevation	104.0	feet	(Ref. 7)
6b. Normal Water Elevation	108.5	feet	(Ref. 7)
7a. Minimum (Low) Water Height (Depth)	20.0	feet	
7b. Normal Water Height (Depth)	24.5	feet	
8. Mesh Size (Square)	0.375	inch	(Ref. 2)
9. Wire Size	14	Gauge	(Ref. 2)
10. Wire Width (Avg)	0.0800	inch	(Ref. 4)

Assumptions:

1. The minimum reservoir level (below which Muddy Run would shut down) of 104.0 feet is used to calculate the design through-screen velocity even though the minimum permitted water height for the Conowingo Reservoir is 100.5 feet.
2. No changes to as-built configuration after dates of references used.
3. All twenty-four active intake screens are normally in service and 100% clean.
4. All pumps normally operate at their design capacity ratings.
5. Assume that the design flow is split evenly between all intake screens.
6. The constant for Formula 1 includes units conversion (gpm to cfs) and other screen factors.
7. Check velocity for worst-case scenario, with maximum no. of pumps for each unit operating.

References Used:

1. Page 78 and 79 of Screening Equipment Handbook, 2nd Edition, 1995. Tom M. Pankratz.
2. Drawing M-18-64_sht_00001, TWS Data Sheet, 1/15/93.
3. Drawing 6280, Sheets C-100-102, C.W. Screen Structure (Bottom Plan, Top Slab Plan, & Sections), Bechtel 1971-1976.
4. Standard Handbook for Mechanical Engineers, eight edition, p. 6-45
5. Design Basis Document: Circulating Water and Cooling Tower System, P-S-22, Revision 14, PECO Nuclear
6. Design Basis Document: Service Water System, P-S-17, Revision 9, PECO Nuclear
7. Conowingo Pond Management Plan, April 2006, pg. 22.
8. 316(b) Compliance Report with Source Waterbody Information, Impingement mortality Characterization Study, and Design and Construction Technology Plan: Peach Bottom Atomic Power Station. June 2008. URS Corporation.

Summary and Conclusions:

The calculated design through-screen velocity for the Peach Bottom Outer CWIS at the low water elevation is	**1.205 fps**
The calculated design through-screen velocity for the Peach Bottom Outer CWIS at the normal water elevation is	**0.984 fps**

Peach Bottom Atomic Power Station 316(b) Project

THROUGH-SCREEN VELOCITY CALCULATION

Calculations:

1. Screen Physical Parameters and Design Intake Flow Rate

Formulas Used:
none

Given:

Q=	64,833	gpm per screen
Screen (outer): D=d=	0.0800	in
W=L=	0.375	in
WD (low water elev.)=	20.0	ft
WD (normal water elev.)=	24.5	ft
K=	396	
TW=	10.0	ft

Calculate:
N/A

2. Proportion of Open Screen Area to Total Screen Area

Formulas Used:
Formula 2

Given:
screen parameters as above

Calculate:
Outer Screenhouse
OA = (W x L) / ((W + D) * (L + d)) = **0.6793**

Peach Bottom Atomic Power Station 316(b) Project

THROUGH-SCREEN VELOCITY CALCULATION

Calculations: cont.

3. Design Through-screen Velocity at Outer CWIS

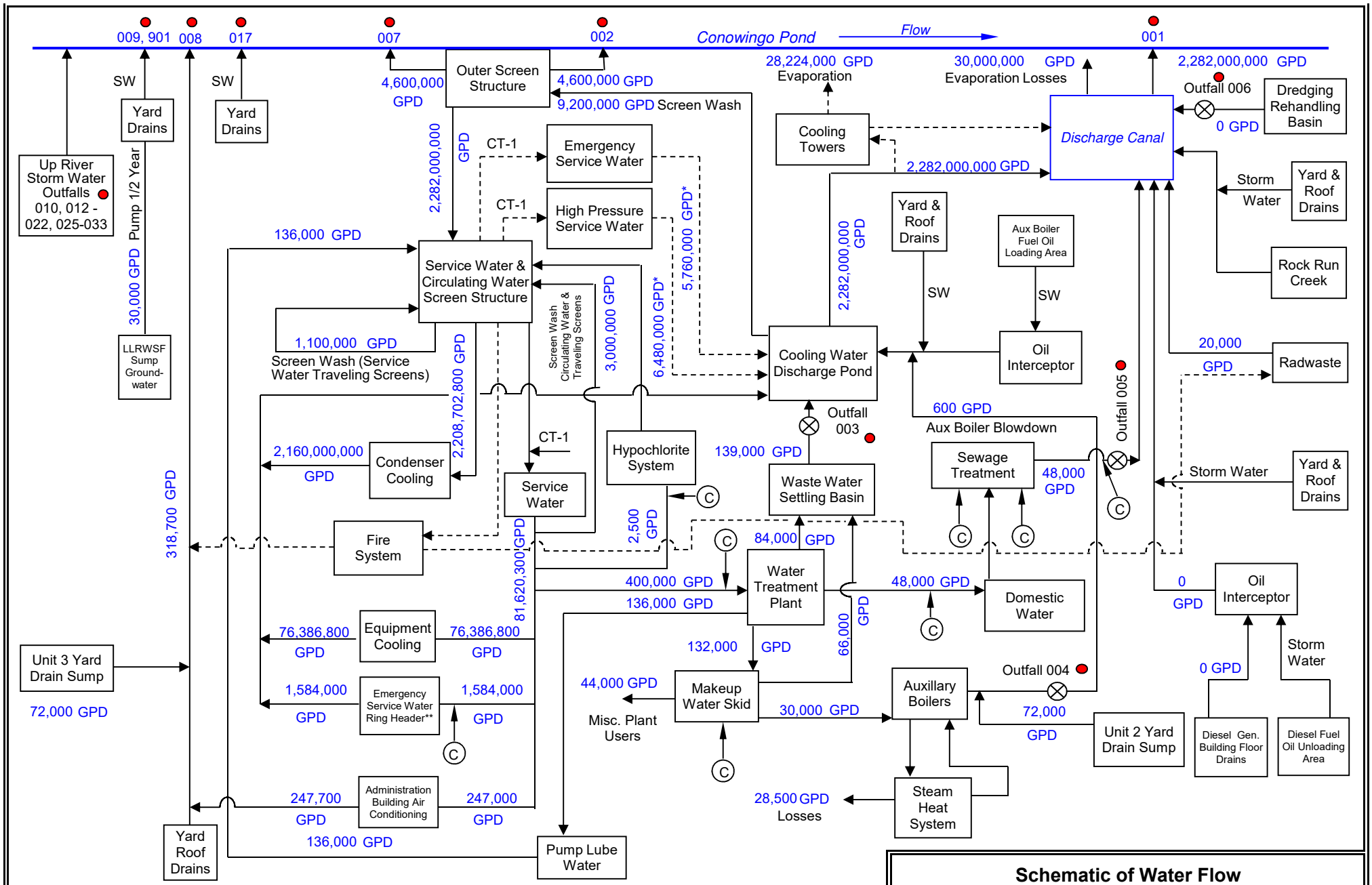
Formulas Used:
Formula 1

Given:
screen parameters as above and calculated screen open area proportion

Calculate:

V = Q / (WD * OA * TW * K) =	Low water elevation:	**1.205**	fps
	Normal water elevation:	**0.984**	fps

APPENDIX C
DRAWINGS AND SCHEMATICS



Legend

- Point of Chemical Addition
- Sampling Port
- Outfall Number
- Flowpath
- Alternate Route

Notes:
SW = Storm Water
CT = Cooling Tower
GPD = Gallons Per Day
LLRWSF = Low-level Radwaste Storage Facility
* Standby Safety Systems – not typically operated
** Emergency Service Water Ring Header flow estimates consist of service water supply during normal conditions.
Denotes point of chemical addition (additives listed in Module 1, Section 7 of the permit application).

Revision Dates
10/24/18

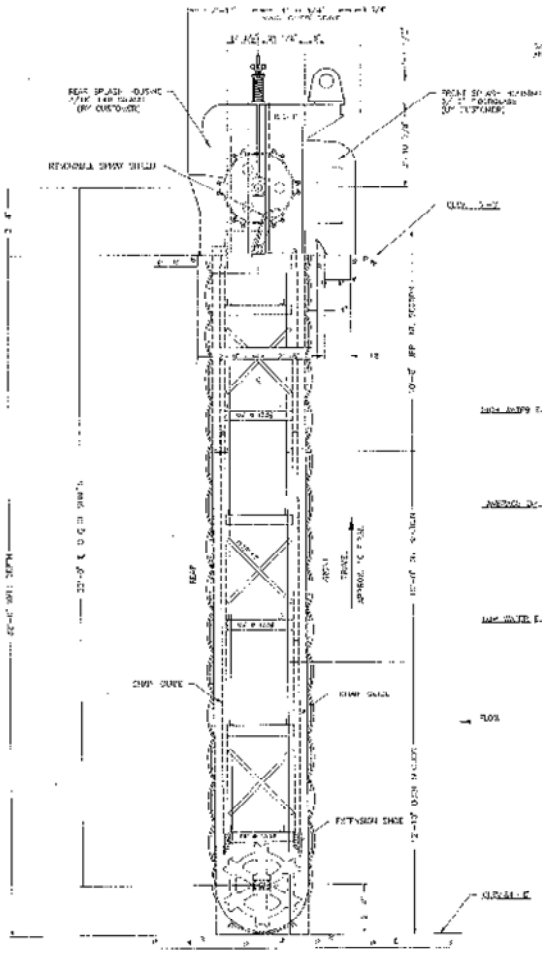
Schematic of Water Flow

Exelon Nuclear
Peach Bottom Atomic Power Station
Delta, York County, Pennsylvania

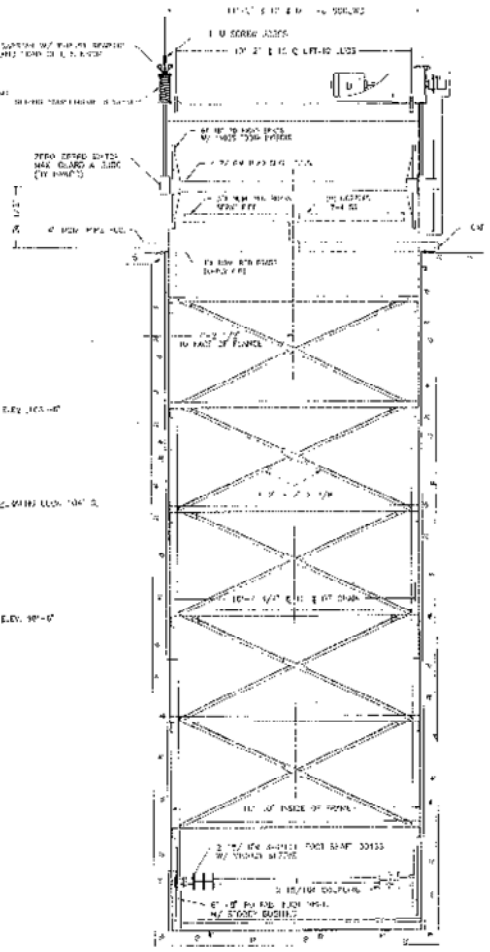
Line Drawing

NPDES Permit Number: PA 0009733

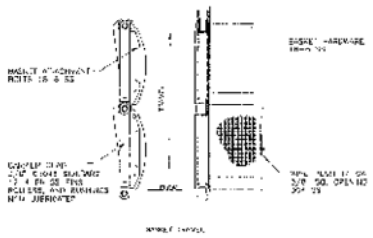
Date:	Job Number:	Figure Number:
12/11/2013	19999737.00001	NPDES - 1

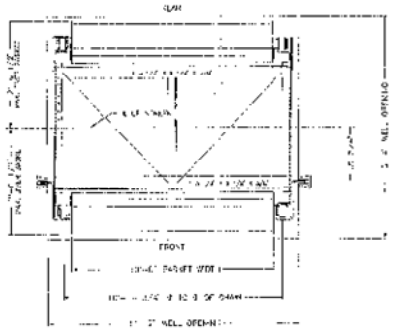


LEFT SIDE ELEVATION



FRONT ELEVATION





PHILADELPHIA ELECTRIC CO.
PEACH BOTTOM ATOMIC POWER STATION
DELTA, PA

G.A. 10' X 33' T.W.S.

DATE 08 25 82 | SCALE NONE
DRAWN BY KO | APP BY
CHECK BY | DRAWING NO. 486 D

PURCHASE ORDER # 8010001

STORAGE # 6280 N 18

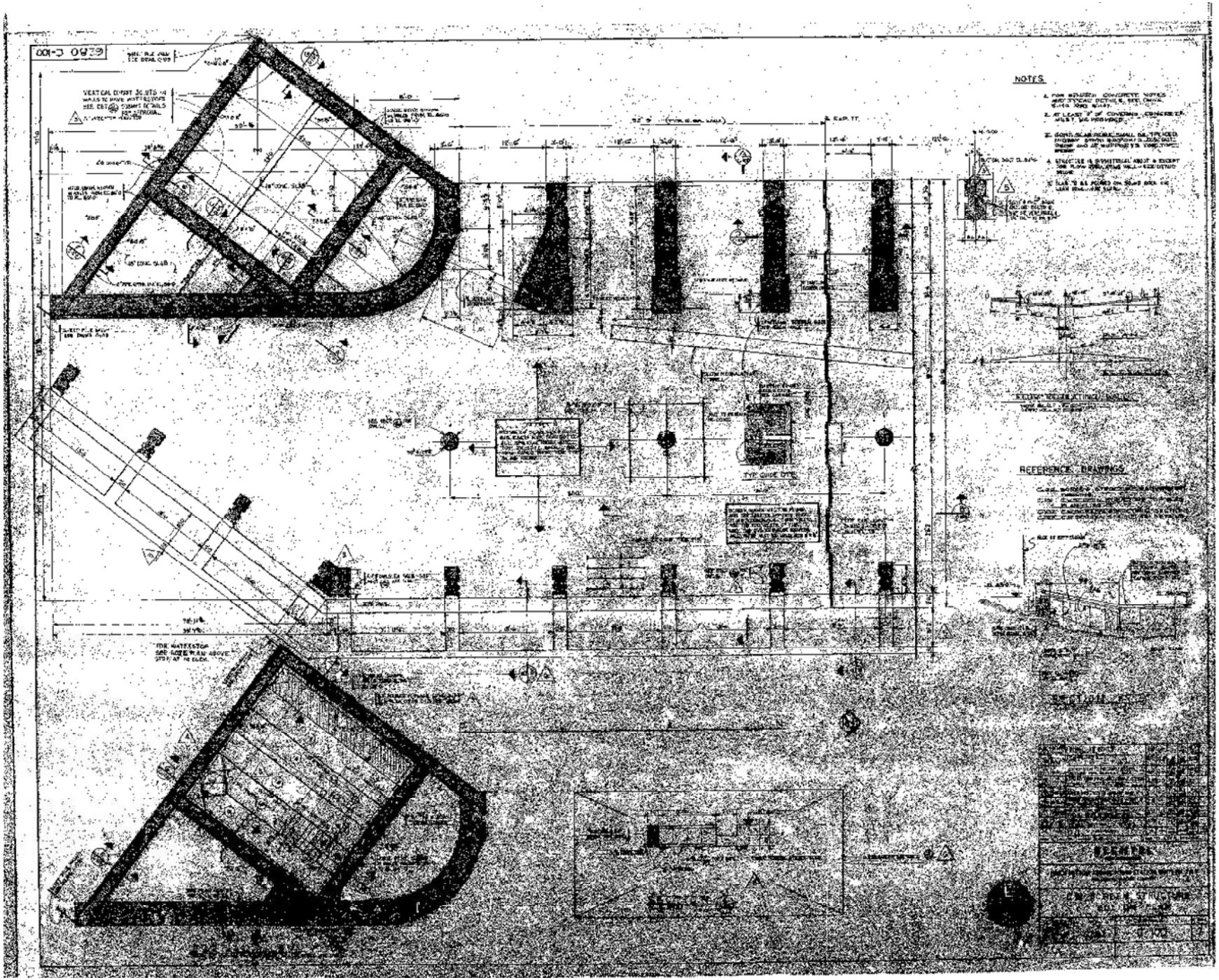
482-0D

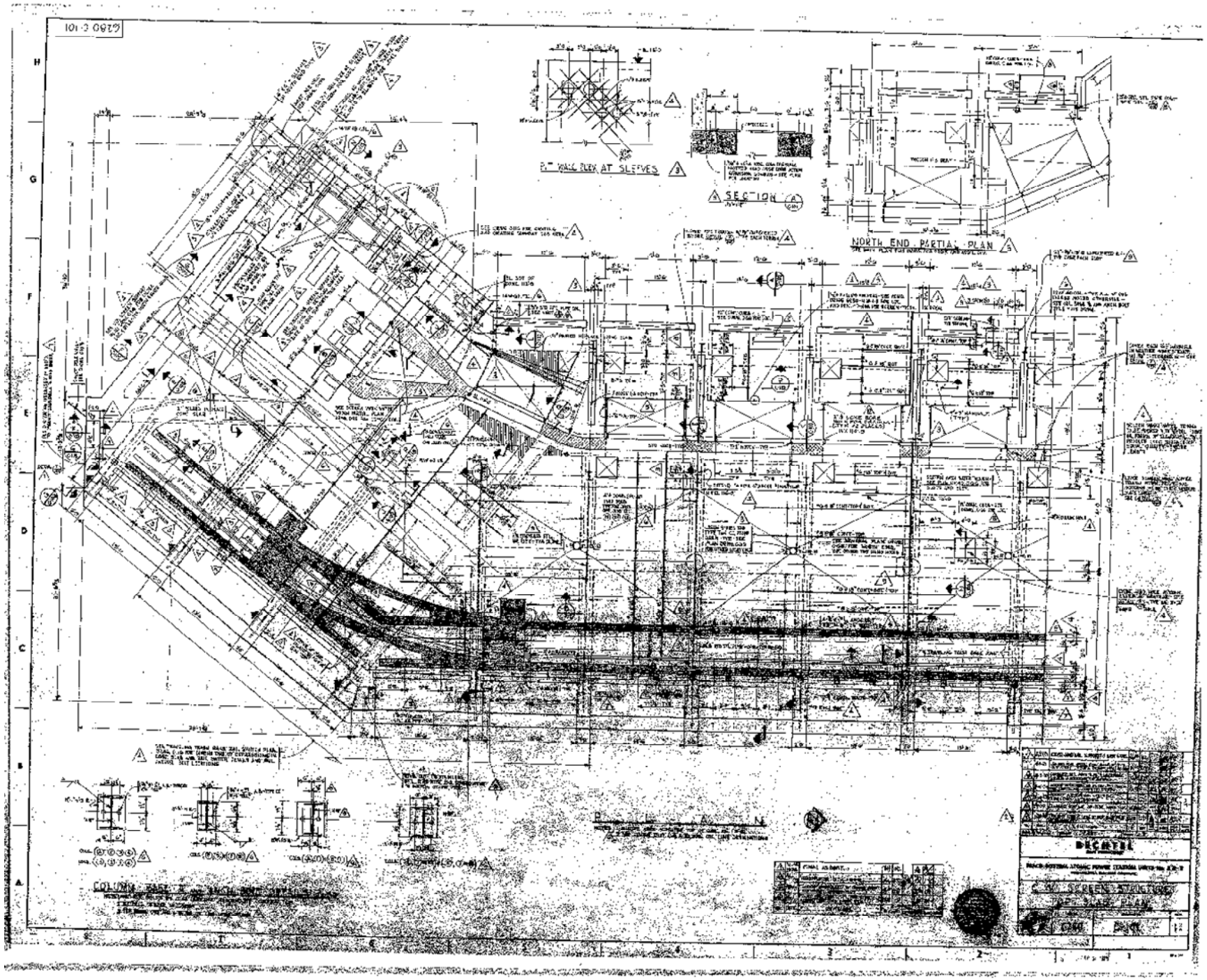
Hawco Screens, Inc.	DATE: 01-15-93	CHK'D BY: KT	TITLE: T.W.S. DATA SHEET
	DRAWN BY: RQ	APP BY:	

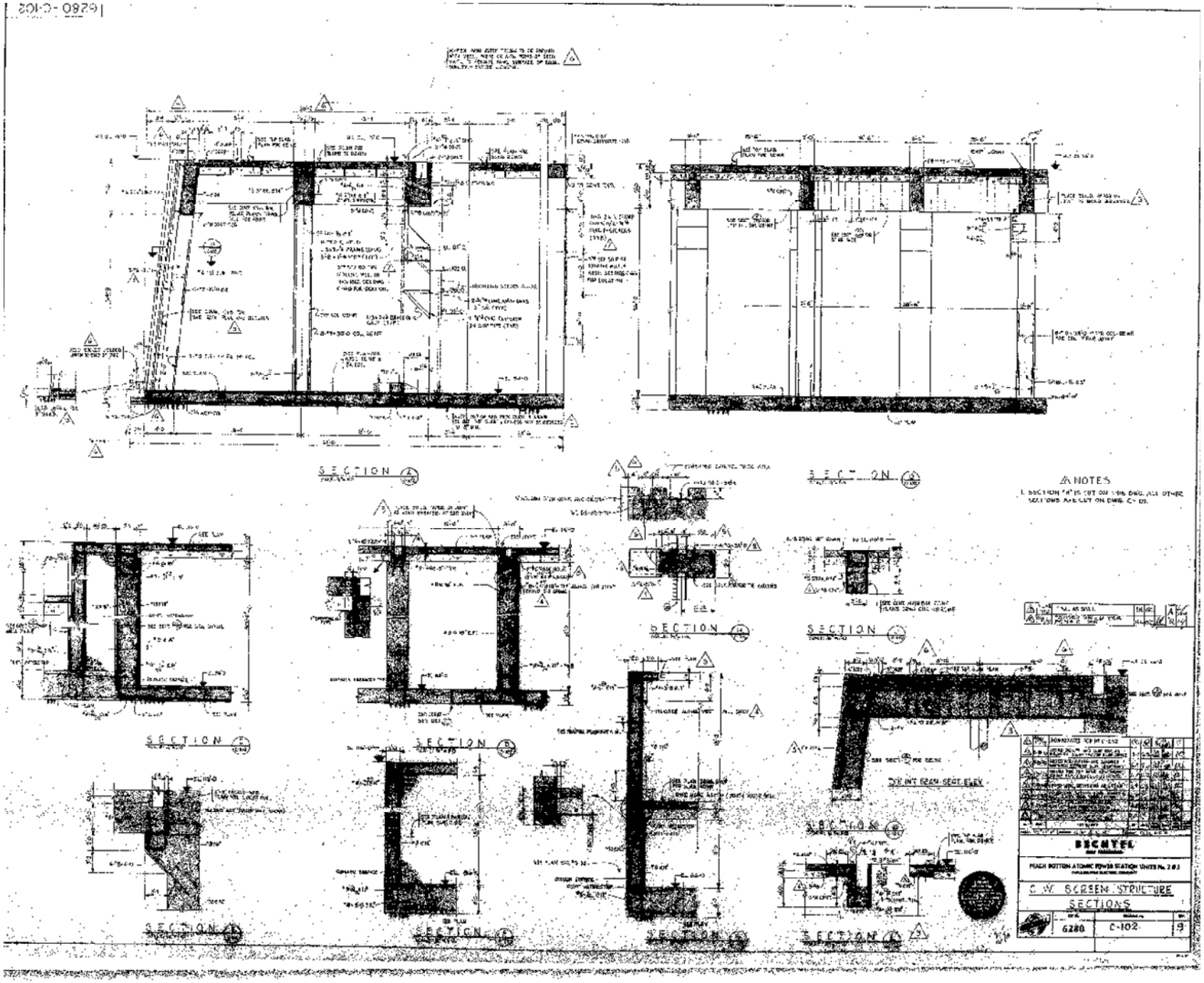
Station PBAPS		Unit(s) 2+3	
Drawing M-18-64		Sheet 1	Rev 0
Date	Description	EVAL	IR	APP
2/14/01	INCORPORATE DWG INTO DOCUMENT CONTROL REGISTER PER ECR 93-00727. INITIAL ISSUE OF DOCUMENT	TB	LA	MW

APPENDIX III.
TRAVELING WATER SCREEN DATA SHEET
PHILADELPHIA ELECTRIC COMPANY
PEACH BOTTOM ATOMIC POWER STATION
UNITS 2 AND 3
OUTER SCREEN STRUCTURE SCREENS
PURCHASE ORDER # BW660813
SPEC. # 6280-M-18

DESIGN FLOW	67,000 GPM
DIFFERENTIAL HEADLOSS:	
% OF CLEANLINESS	
100%	.04 FT.
75%	.08 FT.
50%	.21 FT.
25%	.88 FT.
WATER DEPTH AT DESIGN FLOW	20'-0"
NORMAL HIGH WATER DEPTH	24'-6"
MATERIALS:	
SHAFTS: HEAD/FOOT	ANSI C1018 / TYPE 304SS
FRAME WORK:	CARBON STEEL
CHAIN AND ROLLERS:	ANSI C1045 SIDEBARS/ NON-LUBED 17-4 Ph SS PINS, ROLLERS, AND BUSHINGS
SCREEN PANELS:	
NUMBER/ DIMENSIONS	39 PER SCREEN 24" X 10'-0"
MATERIALS:	
FRAME:	CARBON STEEL
MESH:	14 GA. 3/8" SQ. OPEN 304 SS
MAX. DEFLECTION AT 5' DIFF.	.482 IN.
GEAR REDUCER	BY PECO
MANUFACTURE:	WESTINGHOUSE
TYPE AND SIZE	HELICAL GEAR 54Q
SPEED RATIO:	304.1 : 1
SPROCKET RATIO:	8 : 55
SCREEN TRAVEL SPEED:	5/10 F.P.M
WASH WATER:	264 GPM @ 80 PSI 294 GPM @ 100 PSI
WEIGHT:	
COMPLETE ASSEMBLY:	27,800 LBS.
SCREEN PANEL:	229 LBS.
CHAIN:	20.2 LBS. PER FT.
DIMENSIONS:	
DEPTH OF WELL	32'-0"
WIDTH OF WELL	11'-2"
LENGTH BETWEEN SHAFTS	33'-0"
SCREEN TYPE AND SIZE	10' X 33' 6 TOOTH 24" PITCH
DRIVER:	BY PECO
MANUFACTURER	WESTINGHOUSE
RPM/HP	1800 RPM/ 2 HP 900 RPM/ 1 HP


NOTES
REFERENCE DRAWINGS
TYP GUIDE DTL


SECTION
NORTH END PARTIAL PLAN
COLUMN BASE
DECATUR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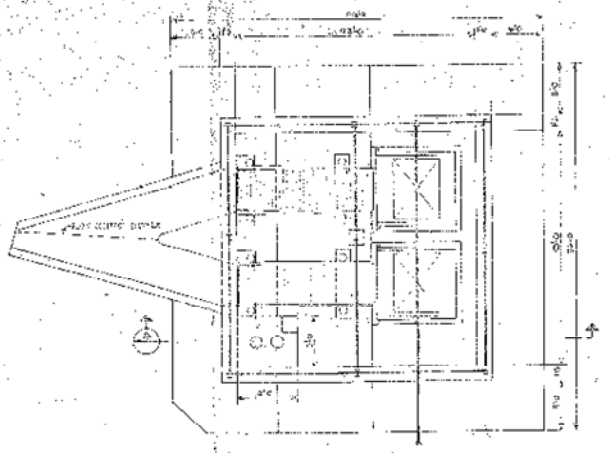
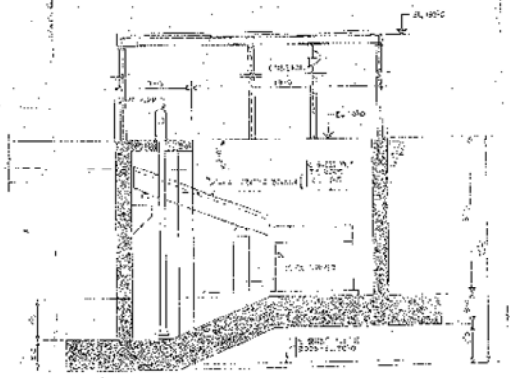
SECTION
SECTION
NOTES
BECHTEL
PEACH BOTTOM ATOMIC POWER STATION UNITS No. 2 & 3
C.W. SCREEN STRUCTURE
SECTIONS
6280
C-102
9



P L A N



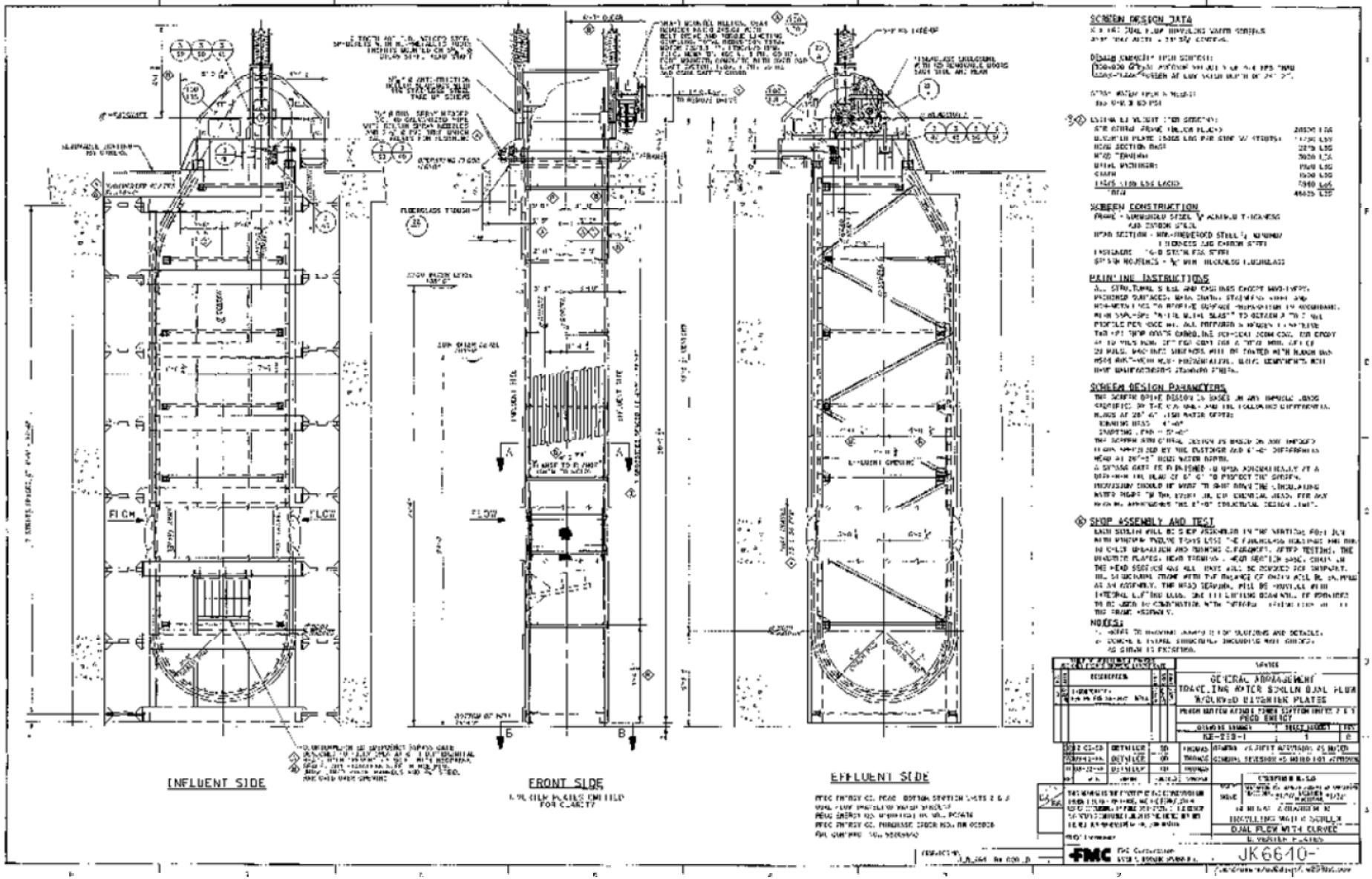
S E C T I O N

BECHTEL
SAN FRANCISCO

SCREEN STRUCTURE
TRASH COLLECTION AREA

6280

SKS 289


INFLUENT SIDE
FRONT SIDE
EFFLUENT SIDE
FLOW
SCREEN DESIGN DATA
SCREEN CONSTRUCTION
PAINTING INSTRUCTIONS
SCREEN DESIGN PARAMETERS
SHOP ASSEMBLY AND TEST
NOTES:
GENERAL ARRANGEMENT
TRAVELING WATER SCREEN DUAL FLOW
WALKWAY DETAILS PLATES
DUAL FLOW WITH CURVED
JK6610-

APPENDIX D
THREATENED AND ENDANGERED SPECIES INFORMATION

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Pennsylvania Ecological Services Field Office
110 Radnor Road Suite 101
State College, PA 16801-7987
Phone: (814) 234-4090 Fax: (814) 234-0748
http://www.fws.gov/northeast/pafo/

In Reply Refer To: May 14, 2018
Consultation Code: 05E2PA00-2018-SLI-1006
Event Code: 05E2PA00-2018-E-04421
Project Name: PBAPS 316(b) Compliance

Subject: List of threatened and endangered species that may occur in your proposed project location, and/or may be affected by your proposed project

To Whom It May Concern:

The enclosed species list identifies threatened, endangered, proposed and candidate species, as well as proposed and final designated critical habitat, that may occur within the boundary of your proposed project and/or may be affected by your proposed project. The species list fulfills the requirements of the U.S. Fish and Wildlife Service (Service) under section 7(c) of the Endangered Species Act (Act) of 1973, as amended (16 U.S.C. 1531 et seq.).

New information based on updated surveys, changes in the abundance and distribution of species, changed habitat conditions, or other factors could change this list. Please feel free to contact us if you need more current information or assistance regarding the potential impacts to federally proposed, listed, and candidate species and federally designated and proposed critical habitat. Please note that under 50 CFR 402.12(e) of the regulations implementing section 7 of the Act, the accuracy of this species list should be verified after 90 days. This verification can be completed formally or informally as desired. The Service recommends that verification be completed by visiting the ECOS-IPaC website at regular intervals during project planning and implementation for updates to species lists and information. An updated list may be requested through the ECOS-IPaC system by completing the same process used to receive the enclosed list.

The purpose of the Act is to provide a means whereby threatened and endangered species and the ecosystems upon which they depend may be conserved. Under sections 7(a)(1) and 7(a)(2) of the Act and its implementing regulations (50 CFR 402 et seq.), Federal agencies are required to utilize their authorities to carry out programs for the conservation of threatened and endangered species and to determine whether projects may affect threatened and endangered species and/or designated critical habitat.

A Biological Assessment is required for construction projects (or other undertakings having similar physical impacts) that are major Federal actions significantly affecting the quality of the human environment as defined in the National Environmental Policy Act (42 U.S.C. 4332(2)(c)). For projects other than major construction activities, the Service suggests that a biological evaluation similar to a Biological Assessment be prepared to determine whether the project may affect listed or proposed species and/or designated or proposed critical habitat. Recommended contents of a Biological Assessment are described at 50 CFR 402.12.

If a Federal agency determines, based on the Biological Assessment or biological evaluation, that listed species and/or designated critical habitat may be affected by the proposed project, the agency is required to consult with the Service pursuant to 50 CFR 402. In addition, the Service recommends that candidate species, proposed species and proposed critical habitat be addressed within the consultation. More information on the regulations and procedures for section 7 consultation, including the role of permit or license applicants, can be found in the "Endangered Species Consultation Handbook" at:

http://www.fws.gov/endangered/esa-library/pdf/TOC-GLOS.PDF

Please be aware that bald and golden eagles are protected under the Bald and Golden Eagle Protection Act (16 U.S.C. 668 et seq.), and projects affecting these species may require development of an eagle conservation plan (http://www.fws.gov/windenergy/eagle_guidance.html). Additionally, wind energy projects should follow the wind energy guidelines (http://www.fws.gov/windenergy/) for minimizing impacts to migratory birds and bats.

Guidance for minimizing impacts to migratory birds for projects including communications towers (e.g., cellular, digital television, radio, and emergency broadcast) can be found at: http://www.fws.gov/migratorybirds/CurrentBirdIssues/Hazards/towers/towers.htm; http://www.towerkill.com; and http://www.fws.gov/migratorybirds/CurrentBirdIssues/Hazards/towers/comtow.html.

Any activity proposed on National Wildlife Refuge lands must undergo a "Compatibility Determination' conducted by the Refuge. Please contact the individual Refuge to discuss any questions or concerns.

We appreciate your concern for threatened and endangered species. The Service encourages Federal agencies to include conservation of threatened and endangered species into their project planning to further the purposes of the Act. Please include the Consultation Tracking Number in the header of this letter with any request for consultation or correspondence about your project that you submit to our office.

Attachment(s):

- Official Species List
- USFWS National Wildlife Refuges and Fish Hatcheries

Official Species List

This list is provided pursuant to Section 7 of the Endangered Species Act, and fulfills the requirement for Federal agencies to "request of the Secretary of the Interior information whether any species which is listed or proposed to be listed may be present in the area of a proposed action".

This species list is provided by:

Pennsylvania Ecological Services Field Office
110 Radnor Road Suite 101
State College, PA 16801-7987
(814) 234-4090

Project Summary

Consultation Code: 05E2PA00-2018-SLI-1006

Event Code: 05E2PA00-2018-E-04421

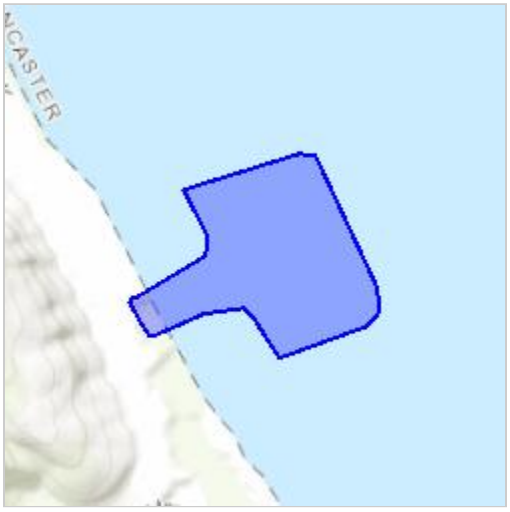
Project Name: PBAPS 316(b) Compliance

Project Type: POWER GENERATION

Project Description: Determination of any risk of impingement or entrainment to any federal threatened or endangered species that may occur in the vicinity of the Peach Bottom Atomic Power Station

Project Location:

Approximate location of the project can be viewed in Google Maps: https://www.google.com/maps/place/39.760873865370655N76.26389641251987W



Counties: Lancaster, PA

Endangered Species Act Species

There is a total of 4 threatened, endangered, or candidate species on this species list.

Species on this list should be considered in an effects analysis for your project and could include species that exist in another geographic area. For example, certain fish may appear on the species list because a project could affect downstream species.

IPaC does not display listed species or critical habitats under the sole jurisdiction of NOAA Fisheries[1], as USFWS does not have the authority to speak on behalf of NOAA and the Department of Commerce.

See the "Critical habitats" section below for those critical habitats that lie wholly or partially within your project area under this office's jurisdiction. Please contact the designated FWS office if you have questions.

---

1. NOAA Fisheries, also known as the National Marine Fisheries Service (NMFS), is an office of the National Oceanic and Atmospheric Administration within the Department of Commerce.

Mammals

NAME	STATUS
Indiana Bat Myotis sodalis There is final critical habitat for this species. Your location is outside the critical habitat. Species profile: https://ecos.fws.gov/ecp/species/5949	Endangered
Northern Long-eared Bat Myotis septentrionalis No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/9045	Threatened

Birds

NAME	STATUS
Red Knot Calidris canutus rufa No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/1864	Threatened

Reptiles

NAME	STATUS
Bog Turtle *Clemmys muhlenbergii*	Threatened

Population: Wherever found, except GA, NC, SC, TN, VA
No critical habitat has been designated for this species.
Species profile: https://ecos.fws.gov/ecp/species/6962

Critical habitats

THERE ARE NO CRITICAL HABITATS WITHIN YOUR PROJECT AREA UNDER THIS OFFICE'S JURISDICTION.

USFWS National Wildlife Refuge Lands And Fish Hatcheries

Any activity proposed on lands managed by the National Wildlife Refuge system must undergo a 'Compatibility Determination' conducted by the Refuge. Please contact the individual Refuges to discuss any questions or concerns.

REFUGE INFORMATION WAS NOT AVAILABLE WHEN THIS SPECIES LIST WAS GENERATED. PLEASE CONTACT THE FIELD OFFICE FOR FURTHER INFORMATION.

1. PROJECT INFORMATION

Project Name: **PBAPS_DraftER2016**
Date of Review: **9/21/2017 02:26:19 PM**
Project Category: **Energy Storage, Production, and Transfer, Energy Production (generation), Other**
Project Area: **774.51 acres**
County(s): **Lancaster; York**
Township/Municipality(s): **DRUMORE; FULTON; PEACH BOTTOM**
ZIP Code: **17314**
Quadrangle Name(s): **DELTA; HOLTWOOD**
Watersheds HUC 8: **Lower Susquehanna**
Watersheds HUC 12: **Fishing Creek-Susquehanna River**
Decimal Degrees: **39.756246, -76.270233**
Degrees Minutes Seconds: **39° 45' 22.4849" N, 76° 16' 12.8400" W**

2. SEARCH RESULTS

Agency	Results	Response
PA Game Commission	No Known Impact	No Further Review Required
PA Department of Conservation and Natural Resources	**Potential Impact**	**FURTHER REVIEW IS REQUIRED, See Agency Response**
PA Fish and Boat Commission	**Potential Impact**	**FURTHER REVIEW IS REQUIRED, See Agency Response**
U.S. Fish and Wildlife Service	**Potential Impact**	**MORE INFORMATION REQUIRED, See Agency Response**

As summarized above, Pennsylvania Natural Diversity Inventory (PNDI) records indicate there may be potential impacts to threatened and endangered and/or special concern species and resources within the project area. If the response above indicates "No Further Review Required" no additional communication with the respective agency is required. If the response is "Further Review Required" or "See Agency Response," refer to the appropriate agency comments below. Please see the DEP Information Section of this receipt if a PA Department of Environmental Protection Permit is required.

Note that regardless of PNDI search results, projects requiring a Chapter 105 DEP individual permit or GP 5, 6, 7, 8, 9 or 11 must comply with the bog turtle habitat screening requirements of the PASPGP.

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Project Boundary

Buffered Project Boundary

Service Layer Credits: Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community
Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user

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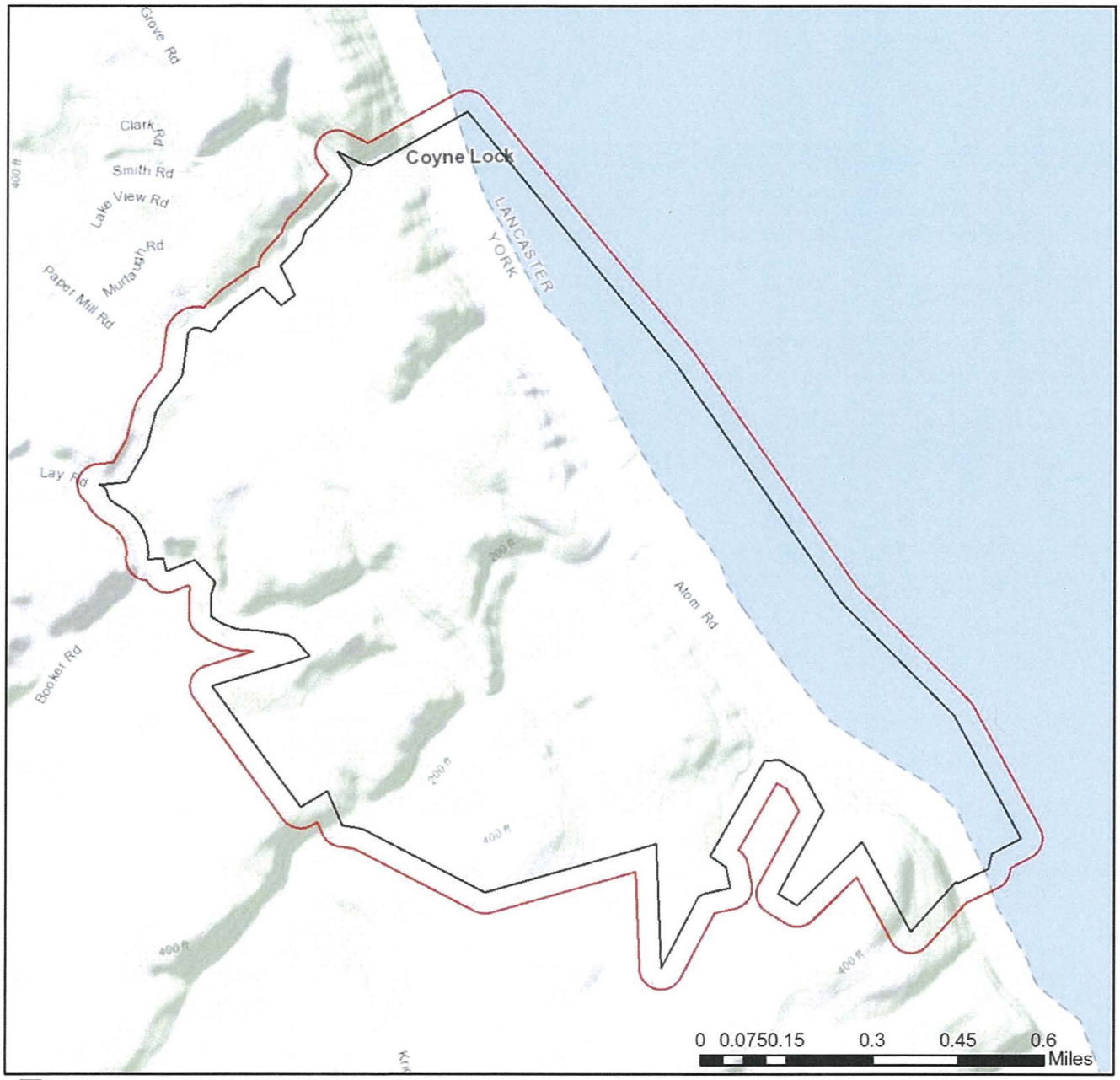

Project Boundary

Buffered Project Boundary

Service Layer Credits: Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

RESPONSE TO QUESTION(S) ASKED

Q1: Which of the following closest describes the proposed project?
Your answer is: A well or other groundwater extraction (e.g., groundwater pumping to facilitate mining, pump-and-treat operation) is proposed as part of this project, or in order to support some aspect of the project, but less than 1000 gallons per day will be extracted.

Q2: Are there any perennial or intermittent waterways (rivers, streams, creeks, tributaries) in or near the project area, or on the land parcel?
Your answer is: Yes

Q3: Describe how wastewater (effluent) will be handled (select one). For the purpose of this question, wastewater/effluent does not include stormwater runoff. If the project involves solely the renewal or modification of an existing discharge permit (e.g., NPDES permit), select from options 3, 4, 5, or 6 below.
Your answer is: Some or all wastewater/effluent from this project/activity will be discharged to a waterway (river or stream), and the discharge (including the existing discharge, plus any additional discharge) will exceed 5000 gallons/day.

Q4: Accurately describe what is known about wetland presence in the project area or on the land parcel by selecting ONE of the following. "Project" includes all features of the project (including buildings, roads, utility lines, outfall and intake structures, wells, stormwater retention/detention basins, parking lots, driveways, lawns, etc.), as well as all associated impacts (e.g., temporary staging areas, work areas, temporary road crossings, areas subject to grading or clearing, etc.). Include all areas that will be permanently or temporarily affected -- either directly or indirectly -- by any type of disturbance (e.g., land clearing, grading, tree removal, flooding, etc.). Land parcel = the lot(s) on which some type of project(s) or activity(s) are proposed to occur.
Your answer is: The project area (or land parcel) has not been investigated by someone qualified to identify and delineate wetlands, or it is currently unknown if the project or project activities will affect wetlands.

Q5: The proposed project is in the range of the Indiana bat. Describe how the project will affect bat habitat (forests, woodlots and trees) and indicate what measures will be taken in consideration of this. Round acreages up to the nearest acre (e.g., 0.2 acres = 1 acre).
Your answer is: The project will affect 1 to 39 acres of forests, woodlots and trees.

Q6: Is tree removal, tree cutting or forest clearing of 40 acres or more necessary to implement all aspects of this project?
Your answer is: No

3. AGENCY COMMENTS

Regardless of whether a DEP permit is necessary for this proposed project, any potential impacts to threatened and endangered species and/or special concern species and resources must be resolved with the appropriate jurisdictional agency. In some cases, a permit or authorization from the jurisdictional agency may be needed if adverse impacts to these species and habitats cannot be avoided.

These agency determinations and responses are **valid for two years** (from the date of the review), and are based on the project information that was provided, including the exact project location; the project type, description, and features; and any responses to questions that were generated during this search. If any of the following change: 1) project location, 2) project size or configuration, 3) project type, or 4) responses to the questions that were asked during the online review, the results of this review are not valid, and the review must be searched again via the PNDI Environmental Review Tool and resubmitted to the jurisdictional agencies. The PNDI tool is a primary screening tool, and a desktop review may reveal more or fewer impacts than what is listed on this PNDI receipt. The jursidictional agencies **strongly advise against** conducting surveys for the species listed on the receipt prior to consultation with the agencies.

PA Game Commission
RESPONSE:
No Impact is anticipated to threatened and endangered species and/or special concern species and resources.

PA Department of Conservation and Natural Resources
RESPONSE:
Further review of this project is necessary to resolve the potential impact(s). Please send project information to this agency for review (see WHAT TO SEND).

DCNR Species: (Note: The Pennsylvania Conservation Explorer tool is a primary screening tool, and a desktop review may reveal more or fewer species than what is listed below. After desktop review, if a botanical survey is required by DCNR, we recommend the DCNR Botanical Survey Protocols, available here: https://conservationexplorer.dcnr.pa.gov/content/survey-protocols)

Scientific Name	Common Name	Current Status	Proposed Status	Survey Window
Asplenium pinnatifidum	Lobed Spleenwort	Special Concern Species*	Special Concern Species*	Year-round (evergreen)
Erigenia bulbosa	Harbinger-of-spring	Threatened	Special Concern Species*	Flowers March - April
Ilex opaca	American Holly	Threatened	Threatened	Flowers May - early June, fruits October - winter; evergreen leaves
Sensitive Species**		Special Concern Species*	Threatened	

PA Fish and Boat Commission
RESPONSE:
Further review of this project is necessary to resolve the potential impact(s). Please send project information to this agency for review (see WHAT TO SEND).

PFBC Species: (Note: The Pennsylvania Conservation Explorer tool is a primary screening tool, and a desktop review may reveal more or fewer species than what is listed below.)

Scientific Name	Common Name	Current Status
Percina bimaculata	Chesapeake Logperch	Threatened

U.S. Fish and Wildlife Service
RESPONSE:
Information Request: Conduct a Bog Turtle Habitat (Phase 1) Survey in accordance with USFWS Guidelines for Bog Turtle Surveys (April 2006). Evaluate all wetlands within 300 feet of the project area, which includes all areas that will be impacted by earth disturbance or project features (e.g., roads, structures, utility lines, lawns, detention basins, staging areas, etc.). IF THE PHASE 1 SURVEY IS DONE BY A QUALIFIED BOG TURTLE SURVEYOR (see https://www.fws.gov/northeast/pafo/endangered/surveys.html): 1) Send positive results to USFWS for concurrence, along with a project description documenting how impacts will be avoided. OR, conduct a Phase 2 survey and send Phase 1 and 2 results to USFWS for concurrence. 2) Send a courtesy copy of negative results to USFWS (label as "Negative Phase 1 Survey Results by Qualified Bog Turtle Surveyor: USFWS Courtesy Copy"). USFWS approval of negative results is not necessary when a qualified surveyor does the survey in full accordance with USFWS guidelines. IF THE PHASE 1 SURVEY IS NOT DONE BY A QUALIFIED SURVEYOR: Send ALL Phase 1 results to USFWS for concurrence, and if potential habitat is found, also send a project description documenting how impacts will be avoided. As a qualified bog turtle surveyor, I _____ (name) certify that I conducted a Phase 1 survey of all wetlands in and within 300 feet of the project area on _____(date) and determined that bog turtle habitat is absent.

_____ (Signature)

* Special Concern Species or Resource - Plant or animal species classified as rare, tentatively undetermined or candidate as well as other taxa of conservation concern, significant natural communities, special concern populations (plants or animals) and unique geologic features.
** Sensitive Species - Species identified by the jurisdictional agency as collectible, having economic value, or being susceptible to decline as a result of visitation.

WHAT TO SEND TO JURISDICTIONAL AGENCIES

If project information was requested by one or more of the agencies above, upload* or email* the following information to the agency(s). Instructions for uploading project materials can be found here. This option provides the applicant with the convenience of sending project materials to a single location accessible to all three state agencies. Alternatively, applicants may email or mail their project materials (see AGENCY CONTACT INFORMATION).
***Note:** U.S.Fish and Wildlife Service requires applicants to mail project materials to the USFWS PA field office (see AGENCY CONTACT INFORMATION). USFWS will not accept project materials submitted electronically (by upload or email).

Check-list of Minimum Materials to be submitted:
____Project narrative with a description of the overall project, the work to be performed, current physical characteristics of the site and acreage to be impacted.
____A map with the project boundary and/or a basic site plan(particularly showing the relationship of the project to the physical features such as wetlands, streams, ponds, rock outcrops, etc.)
In addition to the materials listed above, USFWS REQUIRES the following
____**SIGNED** copy of a Final Project Environmental Review Receipt

The inclusion of the following information may expedite the review process.
____Color photos keyed to the basic site plan (i.e. showing on the site plan where and in what direction each photo was taken and the date of the photos)
____Information about the presence and location of wetlands in the project area, and how this was determined (e.g., by a qualified wetlands biologist), if wetlands are present in the project area, provide project plans showing the location of all project features, as well as wetlands and streams.

4. DEP INFORMATION

The Pa Department of Environmental Protection (DEP) requires that a signed copy of this receipt, along with any required documentation from jurisdictional agencies concerning resolution of potential impacts, be submitted with applications for permits requiring PNDI review. Two review options are available to permit applicants for handling PNDI coordination in conjunction with DEP's permit review process involving either T&E Species or species of special concern. Under sequential review, the permit applicant performs a PNDI screening and completes all coordination with the appropriate jurisdictional agencies prior to submitting the permit application. The applicant will include with its application, both a PNDI receipt and/or a clearance letter from the jurisdictional agency if the PNDI Receipt shows a Potential Impact to a species or the applicant chooses to obtain letters directly from the jurisdictional agencies. Under concurrent review, DEP, where feasible, will allow technical review of the permit to occur concurrently with the T&E species consultation with the jurisdictional agency. The applicant must still supply a copy of the PNDI Receipt with its permit application. The PNDI Receipt should also be submitted to the appropriate agency according to directions on the PNDI Receipt. The applicant and the jurisdictional agency will work together to resolve the potential impact(s). See the DEP PNDI policy at https://conservationexplorer.dcnr.pa.gov/content/resources.

5. ADDITIONAL INFORMATION

The PNDI environmental review website is a preliminary screening tool. There are often delays in updating species status classifications. Because the proposed status represents the best available information regarding the conservation status of the species, state jurisdictional agency staff give the proposed statuses at least the same consideration as the current legal status. If surveys or further information reveal that a threatened and endangered and/or special concern species and resources exist in your project area, contact the appropriate jurisdictional agency/agencies immediately to identify and resolve any impacts.

For a list of species known to occur in the county where your project is located, please see the species lists by county found on the PA Natural Heritage Program (PNHP) home page (www.naturalheritage.state.pa.us). Also note that the PNDI Environmental Review Tool only contains information about species occurrences that have actually been reported to the PNHP.

6. AGENCY CONTACT INFORMATION

PA Department of Conservation and Natural Resources
Bureau of Forestry, Ecological Services Section
400 Market Street, PO Box 8552
Harrisburg, PA 17105-8552
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U.S. Fish and Wildlife Service
Pennsylvania Field Office
Endangered Species Section
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State College, PA 16801
NO Faxes Please

PA Fish and Boat Commission
Division of Environmental Services
595 E. Rolling Ridge Dr., Bellefonte, PA 16823
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PA Game Commission
Bureau of Wildlife Habitat Management
Division of Environmental Planning and Habitat Protection
2001 Elmerton Avenue, Harrisburg, PA 17110-9797
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NO Faxes Please

7. PROJECT CONTACT INFORMATION

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Phone: (610)832-3651 Fax: (610)832-3501
Email: emily.phelan@aecom.com

8. CERTIFICATION

I certify that ALL of the project information contained in this receipt (including project location, project size/configuration, project type, answers to questions) is true, accurate and complete. In addition, if the project type, location, size or configuration changes, or if the answers to any questions that were asked during this online review change, I agree to re-do the online environmental review.

Phelan, Emily Digitally signed by Phelan, Emily Date: 2017.09.21 15:00:36 -04'00' 9/21/2017
applicant/project proponent signature date

ENCLOSURE 04

Normandeau Associates, Inc. 2019. Entrainment Characterization Study at Peach Bottom Atomic Power Station. Clean Water Act 316(b) Compliance Report for 40 CFR 122.21(r)(9), NPDES Permit No. PA 0009733. January 19, 2019. 384 p.

Entrainment Characterization Study at Peach Bottom Atomic Power Station

Clean Water Act §316(b) Compliance Report for 40 CFR §122.21(r)(9), NPDES Permit No. PA 0009733

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Executive Summary

Exelon Generation Company, LLC, owns and operates Peach Bottom Atomic Power Station (PBAPS) located in Delta, Pennsylvania, on the western shore of the impounded portion of Susquehanna River called Conowingo Pond. PBAPS uses a once-through cooling intake system for both units (Unit 2 and Unit 3). Cooling water is withdrawn through an outer intake structure located on the shoreline of the Pond, and flows through two separate three-acre intake ponds and inner intake structures (one serving each unit). Actual intake flow (AIF) for Unit 2 and 3 combined at PBAPS exceeds 125 million gallons per day with at least 25% used exclusively for cooling purposes, and therefore PBAPS is required to submit an Entrainment Characterization Study that includes a minimum of two years of entrainment data collection as specified by §122.21(r)(9) of the §316(b) regulations. Entrainment characterization studies conducted at PBAPS during 2012 and 2016 were used to address the three components of §122.21(r)(9): (i) Entrainment Data Collection Method, (ii) Biological Entrainment Characterization, and (iii) Analysis and Supporting Documentation.

Entrainment characterization studies were conducted at PBAPS for 30 consecutive weeks during 2012 (weeks 10 through 39, beginning Monday 5 March and ending Sunday 30 September) and for 28 consecutive weeks in 2016 (weeks 12 through 39, beginning Monday 21 March and ending Sunday 2 October). Samples were collected from three locations in 2016: the Outer Intake Structure (Location 1); the Circulating Water Discharge Outfall for Units 2 and 3 (Location 2); and the Discharge Canal Outfall (Location 3). The Circulating Water Discharge Outfall (Location 2) was previously sampled for entrainment abundance in 2012. Collection methods were consistent between years with the use of an electric pump to withdraw 100-m^3 samples that were filtered through a 500-micron plankton net suspended in a barrel during two hours of pumping at each location. Location 1 samples were collected from the Unit 2 side of the Outer Intake Structure immediately downstream from traveling screen 2G and Location 2 samples were collected in the discharge basin as close as feasible to the discharge structure outfall.

Ichthyoplankton entrainment samples collected from the Outer Intake Structure (Location 1; 2016 only) and the Circulating Water Discharge Outfall (Location 2; 2012 and 2016) were used to address §122.21(r)(9). Data collected at or adjusted to the Outer Intake Structure (Location 1) were used to characterize organisms entrained from the source water body by PBAPS. In the 2016 study, the annual total entrainment abundance estimate based on ichthyoplankton densities at the Circulating Water Discharge Outfall (Location 2) and Discharge Canal Outfall (Location 3) was higher than the estimate based on densities from the Outer Intake Structure (Location 1) by 47% and 61%, respectively, which suggests a contribution from ichthyoplankton production from spawning activity within the discharge canal and intake ponds between the two locations.

Synchronized sampling at Locations 1 and 2 in 2016 allowed for a paired, design-based comparison of weekly diel-averaged ichthyoplankton densities between location pairs using a

generalized linear mixed model (GLMM) approach. A location conversion factor (LCF) for each ichthyoplankton taxon and life stage group was estimated from the model coefficient for the location effect in the GLMM if there was a significant difference in density between Locations 2 and 1. The LCF derived from the 2016 data was then used to adjust the 2012 density estimates from pump sampling at Location 2 to the expected densities at Location 1. Additionally, ichthyoplankton having a limiting body dimension ≥14.2 mm (0.56 inches) were considered not entrainable as defined in §125.92(h) and were excluded from analysis. The adjustment for significant sample location differences and exclusion of non-entrainable ichthyoplankton provided a standardized two-year time series (2012 and 2016) of entrainment density at the Outer Intake Structure (Location 1) to characterize the composition and variability of entrainment abundance at the point at which water is first withdrawn from the source water body.

Samples collected at Location 2 in 2012 comprised 8 taxa identified to species, one taxon to genus, and three taxa to family in addition to an unidentified classification. For Locations 1 and 2 combined in 2016, 24 taxa were identified: 15 species, two genera, two groupings of multiple genera, and four families in addition to an unidentified classification. Larval life stages (yolk-sac, post yolk-sac, and unidentified larval stage) contributed the highest proportion to the total number of ichthyoplankton collected at Location 2, making up 93% of the total in 2012 and 97% of the total in 2016. Alewife/Gizzard Shad and Gizzard Shad together were the dominant taxa during both years, representing 71% of the total number collected in 2012 and 96% of the total in 2016 total. Alewife and Gizzard Shad are both identified as fragile species in 40 CFR §125.92(m) due to a low likelihood of surviving any form of impingement.

The sampled periods March through September (2012) and April through September (2016) were intended to encompass the season of entrainable life stages of fish within each year, and entrainment density estimates at the Outer Intake Structure were assumed to be representative of entrainment at both Unit 2 and 3. Density peaked in June during both years, with Alewife/Gizzard Shad larvae (yolk-sac larvae "YSL", post yolk-sac larvae "PYSL", and unidentified larval stage "UNID") as the dominant taxonomic and life stage group. For the full sampling period each year, mean ichthyoplankton density of all taxonomic groups and life stages combined was highest during the 2100-0300 diel period.

Total entrainment abundance for both units combined was estimated using weekly total AIF and weekly mean ichthyoplankton densities. Entrainment survival data were not available for the PBAPS circulating water discharge outfall for the combined Units 2 and 3 during 2012 and 2016, so 100% mortality of eggs and larvae was assumed when estimating entrainment mortality based on entrainment abundance, even though entrainment mortality is typically less than 100%. Total AIF volumes of circulating and service water withdrawn from the Susquehanna River during the entrainment sampling periods were 454,047 million gallons in 2012 and 442,325 million gallons in 2016. The estimated mean total annual entrainment abundance of all ichthyoplankton taxa and life stages at PBAPS Units 2 and 3 combined was 551.7 million individuals based on annual entrainment abundance estimates of 140.7 million individuals in 2012 and 962.7 million individuals in 2016.

The difference in estimated annual entrainment abundance between years was a result of the much higher observed densities of Alewife/Gizzard Shad larvae (YSL, PYSL, and UNID) during 2016 compared to 2012, particularly during June. In 2012, 87% (122.3 million individuals) of the estimated total annual entrainment abundance of 140.7 million occurred during May through July, with <1% of the total having occurred during March, August, and September. A similar temporal pattern in entrainment abundance was observed in 2016, when April, August, and September each accounted for <1% of the estimated total, and 88% (849.5 million individuals) of the annual total of 962.7 million having occurred in June. Fragile species (Alewife and Gizzard Shad) represented 49% (68.6 million individuals) of the estimated total entrainment abundance of 140.7 million individuals in 2012 and 95% (913.0 million individuals) of the total abundance of 962.7 million individuals in 2016.

1.0 Introduction

Exelon Generation Company, LLC, owns and operates Peach Bottom Atomic Power Station (PBAPS) located in Delta, Pennsylvania, on the western shore of the impounded portion of Susquehanna River called Conowingo Pond (the "Pond"). The station is a nuclear-fueled power generating facility consisting of two units (Unit 2 and Unit 3) with a combined nominal generating capacity of 2,304 megawatts of electricity. The U.S. Environmental Protection Agency (EPA) has delegated the authority and responsibility for administering the National Pollutant Discharge Elimination System (NPDES) permitting and Clean Water Act Section 316(b) Regulations for Cooling Water Intake Structures at Existing Facilities (79 Federal Register 48300-48439; August 15, 2014; "§316(b) regulations") for PBAPS to Pennsylvania Department of Environmental Protection (PA DEP). A renewed NPDES Permit No. PA 0009733, effective 1 October 2014 and expiring 30 September 2019 was issued by PA DEP to PBAPS.

Two agency approved annual entrainment characterization studies were conducted during the period when ichthyoplankton were present in Conowingo Pool to describe the weekly (March through September) entrainment densities and the taxon and life stage composition of ichthyoplankton present in the combined Circulating Water Discharge Outfall for Units 2 and 3, one in 2012 (Normandeau 2013) and the other in 2016 (Normandeau 2018). Data and results from each of these two entrainment characterization studies were used to address §122.21(r)(9) when applied to the actual intake flow (AIF) of cooling water withdrawal at PBAPS. Total AIF at PBAPS (Units 2 and 3 combined) from 1 January through 31 December 2016 was approximately 2,150 million gallons per day (mgd). Existing facilities that withdraw greater than 125 mgd AIF and use at least 25% of water withdrawn exclusively for cooling purposes are required to submit an Entrainment Characterization Study that includes a minimum of two years of entrainment data collection as described by §122.21(r)(9) of the §316(b) regulations. The entrainment characterization studies conducted at PBAPS during 2012 and 2016 were used to address each of the following components of §122.21(r)(9):

§122.21(r)(9)(i) Entrainment Data Collection Method

- identify and document the data collection period and frequency
- identify and document organisms collected to the lowest taxon possible of all life stages of fish and shellfish that are in the vicinity of the cooling water intake structure(s) and are susceptible to entrainment
- collect biological data representative of the entrainment at the intakes subject to this provision
- identify and document how the location of the cooling water intake structure in the waterbody and the water column are accounted for by the data collection locations

§122.21(r)(9)(ii) Biological Entrainment Characterization

- characterize all life stages of fish, shellfish, and any species protected under Federal, State, or Tribal law (including threatened or endangered species), including a

description of their abundance and their temporal and spatial characteristics in the vicinity of the cooling water intake structure(s)

- characterize annual, seasonal, and diel variations in entrainment, including but not limited to variations related to climate and weather differences, spawning, feeding, and water column migration
- identify all life stages of fish and shellfish to include identification of any surrogate species used
- identify data representing both motile and non-motile life stages of organisms

§122.21(r)(9)(iii) Analysis and Supporting Documentation

- document the current entrainment of all life stages of fish, shellfish, and any species protected under Federal, State, or Tribal law (including threatened or endangered species)
- collect entrainment data to support the facility's calculations during periods of representative operational flows for the cooling water intake structure
- document flows associated with the data collection
- identify the method used to determine latent mortality along with data for specific organism mortality or survival that is applied to other life stages or species
- identify and document all assumptions and calculations used to determine the total entrainment for that facility together with all methods and quality assurance/quality control procedures for data collection and data analysis
- ensure that data collection and data analysis methods are appropriate for a quantitative survey

2.0 Entrainment Data Collection Method (§122.21(r)(9)(i))

2.1 Entrainment Sampling Schedule

Entrainment characterization studies were conducted at PBAPS for 30 consecutive weeks during 2012 (weeks 10 through 39, beginning Monday 5 March and ending Sunday 30 September; Table 2-1) and for 28 consecutive weeks in 2016 (weeks 12 through 39, beginning Monday 21 March and ending Sunday 2 October; Table 2-1). Sampling effort completed for the 2012 and 2016 entrainment characterization studies (Normandeau 2013, 2018) are provided in Table 2-2 and Table 2-3. Each sample was assigned a use code under a variable ("Status" in 2012, "USE_CD" in 2016) that defined availability of that sample for subsequent use in analytical tasks (Note: "USE_CD" is used in both Tables 2-2 and 2-3 for consistency between years). A use code = 1 sample was one in which valid data were collected and no sampling problems were encountered. A use code = 2 sample was one in which a sample or portion of a sample was collected but sampling problems were encountered such that the sample was not collected as specified by the standard operating procedures (SOP), and a use code = 5 indicated a void sample (Normandeau 2012, Normandeau 2016). In 2016 when multiple sites were sampled, a sample narrative ("SAM_NAR") classification was added to describe if the sample

was collected in a manner that was synchronized with the time of travel lag times of intake water through the circulating water system, or if the sample deviated from the specified lag between locations. A SAM_NAR = 1 indicated the sample was collected with appropriate lag time for that location (lag of 0 minutes for Location 1, 25 minutes for Location 2, and 85 minutes for Location 3), and SAM_NAR = 2 indicated that lag time differed by more than ten minutes from specified lag time for that location. All sample coding details are described in Appendices A and B of this document for the 2012 and 2016 studies, respectively (Normandeau 2013, 2018).

2.2 Sampling Locations

PBAPS uses a once-through cooling intake system to remove waste heat from the station's condensers. The cooling water for both units (Unit 2 and Unit 3) is withdrawn through an outer intake structure (Location 1, the point at which water is first withdrawn from the source water body) located on the shoreline of the Pond, through two separate three-acre intake ponds (one serving each unit), and then through an inner intake structure as shown in Figure 2-1. Location 1 samples were collected from the Unit 2 side of the Outer Intake Structure immediately downstream from traveling screen 2G. Entrainment sampling Location 2 is the combined Circulating Water Discharge Outfall for Units 2 and 3 (Figure 2-1), and was sampled in both 2012 and 2016. Location 1 and Location 3 (Discharge Canal Outfall) were only sampled in 2016 (Figure 2-1). Therefore, Location 2 provided data for direct comparison of year to year variation in entrainment densities between the two years required by §122.21(r)(9).

Ichthyoplankton entrainment sampling at Location 2 during 2012 and 2016 was conducted using a 3-inch electric pump to withdraw samples through a 3-inch diameter pipe positioned vertically in the discharge basin as close as feasible to the discharge structure outfall (Figure 2-2). The sampling pipe had a 3-inch round distal end opening set at 101 feet of Pond elevation and each 100 m^3 sample was filtered through a 500-micron plankton net suspended in a barrel during approximately two hours of pumping.

The 2016 entrainment characterization study consisted of time-synchronized entrainment sampling performed at the Outer Intake Structure (Location 1), the Circulating Water Discharge Outfall (Location 2), and the Discharge Canal Outfall (Location 3) using the same sampling methods used in 2012 as described above. Entrainment samples collected from the Outer Intake Structure (Location 1; 2016 only) and the Circulating Water Discharge Outfall (Location 2; 2012 and 2016) were used to address §122.21(r)(9). Data collected at or adjusted to the Outer Intake Structure (Location 1) were used to characterize organisms entrained from the source water body by PBAPS. The 2016 annual total entrainment abundance estimate based on densities at the Circulating Water Discharge Outfall (Location 2) and Discharge Canal Outfall (Location 3) was higher than the estimate based on densities from the Outer Intake Structure (Location 1) by 47% and 61%, respectively, which suggests a contribution from ichthyoplankton production from spawning activity within the discharge canal and intake ponds between the two locations (Normandeau 2018).

The availability of synchronized weekly diel-averaged densities at three locations sampled during 2016 allowed for a paired design-based comparison of ichthyoplankton density differences between location pairs using a generalized linear mixed model (GLMM) approach. If a significant location effect was present between the Circulating Water Discharge Outfall (Location 2) and the Outer Intake Structure (Location 1), then a location conversion factor (LCF) was estimated. This LCF was then used to adjust the 2012 density estimates from pump sampling at the Circulating Water Discharge Outfall (Location 2) to the expected densities at the Outer Intake Structure (Location 1). This adjustment provided a standardized two-year time series (2012 and 2016) to characterize the composition and variability of entrainment abundance at the point at which water is first withdrawn from the source water body.

Because the Outer Intake Structure withdraws water for both Unit 2 and Unit 3 from the same source waterbody location along the shoreline, it was assumed that ichthyoplankton samples collected at Location 1 were representative of entrainment at Unit 2 and Unit 3. Entrainment samples collected at Location 2 represent the combined discharge for Units 2 and 3, and therefore represent the entrainment of both intakes.

The Outer Intake Structure (Location 1) has a length of approximately 480 feet along the shoreline with a fixed vertical trash rack on the face of the intake followed by a set of conventional vertical traveling screens. The vertical trash rack and traveling screens extend from above the high water surface elevation to the pond bottom, and therefore the water withdrawn is representative of the full water column of the source waterbody in the shoreline region of PBAPS. Entrainment samples in 2016 were collected at the Outer Intake Structure (Location 1) using a vertical pipe located immediately inboard of the traveling screen (Figure 2-3). This sampling pipe had three intake ports: one near bottom, one at mid-water column, and one near the surface. The surface intake port was approximately 1 ft below the low water elevation to ensure the collection of near-surface entrainment samples during all water level stages.

2.3 Field Sampling Procedures

2.3.1 Ichthyoplankton Field Sampling Procedure

Prior to the first sample of each scheduled sampling day, the measured flow rate in gallons per minute (gpm) from a calibration test was compared to the observed flow rate from the corresponding flowmeter gauge during the calibration test (gauge gpm/calibration gpm). A deviation of ±10% between the two readings was considered acceptable, and a deviation of >10% resulted in the replacement of the flowmeter and subsequent recalibration test procedure.

During 2012, entrainment samples were collected at Location 2 beginning at the start of each diel period. For the 2016 study, the start of each diel period sample collection on a given sampling day from the Outer Intake Structure (Location 1) to Discharge Canal Outfall (Location 3) was offset to take into consideration the estimated transit time of water through the plant from Conowingo Pool The start time of the first diel period (0900–1500) sample at the Outer Intake Structure (Location 1) established the offset times for sampling at the Circulating Water

Discharge Outfall for Units 2 and 3 (Location 2 started 25 minutes after Location 1) and at the Discharge Canal Outfall (Location 3 started 85 minutes after Location 1). These offset collection times for each diel period ended at each location when 100 m^3 + 10 m^3 of circulating water were filtered through the collection net. This same offset was maintained for each subsequent diel period and location within each scheduled sampling day (24 hours).

Clogging of the sampling net mesh during periods of high debris loads required switching to a clean 500-micron net during collection of an ≈100 m^3 sample (±10%). In these situations, the sampling net was switch out every 20 to 30 minutes to minimize the effects of clogging and egg or larval damage. Each time a net was switched out, it was done by moving one net to the side, placing a second clean net under the sampling flow, and removing the original net in a manner to collect a subsample without interrupting sample collection. When filtering the ≈100 m^3 sample volume (±10%) was completed, and any time plankton nets were exchanged during a sample due to clogging, the net surface was washed into the cod end bucket by using a wash-down pump. Wash water was obtained by a sump pump set into the bottom of the entrainment tank that supplied previously filtered water (i.e., filtered through the 500-micron plankton net) so additional ichthyoplankton were not added to the sample from raw (unfiltered) water during wash-down. The sample material from the cod end bucket was washed into a sample container, preserved with sufficient formalin to make a final concentration of 6% (60 ml of full-strength formalin per liter of sample) with the container completely filled, and Rose Bengal vital stain was added to each sample to turn the live ichthyoplankton red in each preserved sample. For adequate preservation, each one-liter sample container had no more than 25% of the settled volume of organisms and debris, and multiple containers were used if needed to insure adequate preservation. Each sample container was taped shut with black electric tape to prevent spillage; labeled with date, time, period, location, and a unique sample number; and packed in a spill-proof crate for delivery to the biological laboratory.

2.3.2 Field Water Quality Sampling Procedure

Temperature (to 0.1°C), dissolved oxygen (nearest 0.1 mg/l), pH (to the nearest 0.1 pH unit), and conductivity (nearest µS/cm; 2016 only) were recorded with a YSI Professional Plus water quality meter for each diel sample collection period and location. Meters were calibrated prior to each day of use and again after each day of use (or before the next day of use), as specified in the YSI Professional Plus water quality meter manual. Water quality of the cooling water was measured in each entrainment sampling tank at each location within the first hour of pumping for each 100 m^3 sample.

2.4 Laboratory Methods

Ichthyoplankton samples from the entrainment characterization studies at PBAPS in 2012 and 2016 were received and inventoried in Normandeau's biological laboratory in Stowe, Pennsylvania, and sorting occurred in biological laboratories located in Stowe laboratory and Bedford, New Hampshire. All identification, enumeration, and measurement data were performed and the Bedford biological laboratory.

Samples with high numbers of eggs or larvae were subsampled in the laboratory with a minimum of 200 specimens of fish eggs and larvae (combined) to be analyzed. This 200 specimen quota applied to the total count of all species combined, not to individual species. Samples containing low numbers of ichthyoplankton and a high volume of detritus and other plankton (more than 400 ml settled volume) were processed for sorting following a Volume Split Option (VSO), which allowed for sorting to be discontinued before the numeric quotas for eggs or larvae are met. The VSO required at least 200 ml of settled solids to be sorted (unless the 200 specimen quotas were met in a smaller fraction) for all processed samples. If at least half (50%) of the sample container volume was sorted but the 200 specimen quota for eggs or larvae was not been met, sorting was discontinued and the proportion of the total sample sorted was recorded.

Samples requiring splitting were processed in a manner to eliminate any bias. Typically some steps in the procedure were performed by an assistant so that the sorter had no prior knowledge of which samples were subjected to quality control inspection. All sample splitting (if needed) was performed using a Motoda or Folsom splitter after all large fish and excessive amounts of filamentous algae were removed to allow free mixing of the sample but not so great as to promote clumping due to over dilution. Any large fish removed were set aside, identified, enumerated, and added to the tally sheet as originating from the entire sample and not from the split fraction.

Fish eggs and larvae that were dead prior to capture and preservation were identified based on changes in their physical characteristics observed under microscopic examination so that only ichthyoplankton eggs and larvae that were alive at the time of collection and preservation were included in further processing. Fish eggs, larvae, and juveniles were isolated (sorted) from each sample processed in the laboratory by pouring the sample contents into a sieve with a mesh equivalent to, or finer than, 0.500 mm. Sample contents retained on the sieve were placed into a sorting tray for examination under magnification. Fish eggs, larvae, and juveniles were stored in vials with 6% buffered formalin for subsequent identification and enumeration. If larvae were damaged, only those fragments that include the head were removed for subsequent processing.

The sorted ichthyoplankton from each sample were assigned a life stage, identified to the lowest practical taxon, and measured using a binocular microscope with an ocular micrometer. The life stage of each specimen was determined based on the criteria described within the project-specific SOPs. The life stages (and abbreviations) used for the entrainment characterization studies in 2012 and 2016 were egg, yolk-sac larvae (YSL), post yolk-sac larvae (PYSL), young of the year (YOY), and yearling or older (YROL). Larvae that had one or more distinguishing anatomical features missing were classified as unidentified life stage (UNID). For each sample, the total number of each taxon within each life stage was recorded. A maximum of 20 individuals from each fish taxon and life stage were measured for total length, greatest soft tissue body depth, or width to the nearest 0.1 mm. A maximum of 20 eggs per taxon per sample were measured to the nearest 0.1 mm along the major and minor axes. If more than 20 eggs or larvae were present, a random selection of specimens was measured. Only whole (intact) ichthyoplankton were used for measurements, and all measurements were made with a

calibrated ocular micrometer. Each ocular micrometer was calibrated at least weekly using a stage micrometer.

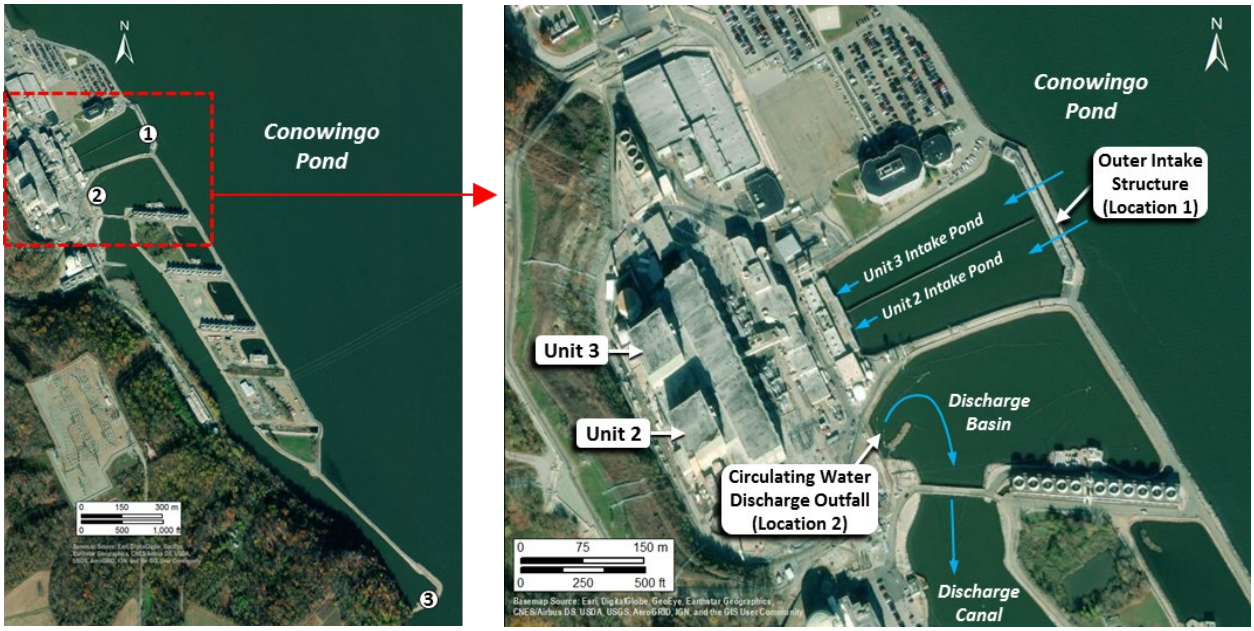

Figure 2-1. Entrainment sample collection locations at PBAPS during 2012 (Location 2), and 2016 (Locations 1, 2 and 3). Locations 1 and 2 are shown in detail in the right panel. Blue arrows indicate the direction of source waterbody flow from the intake ponds to the discharge canal.

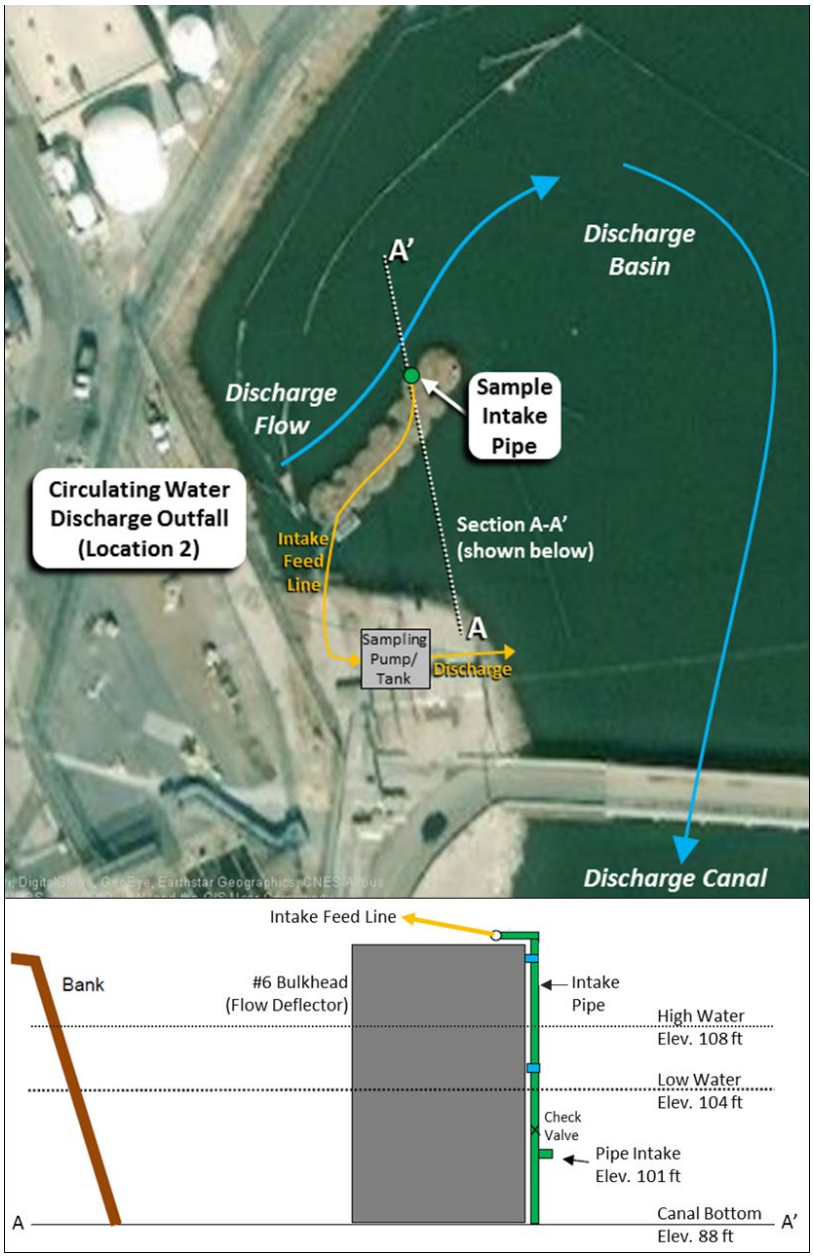

Figure 2-2. Aerial (upper panel) and cross-sectional (lower panel, not to scale) views of the Circulating Water Discharge Outfall sampling site (Location 2) used for entrainment characterization studies at Peach Bottom Atomic Power Station during 2012 and 2016.

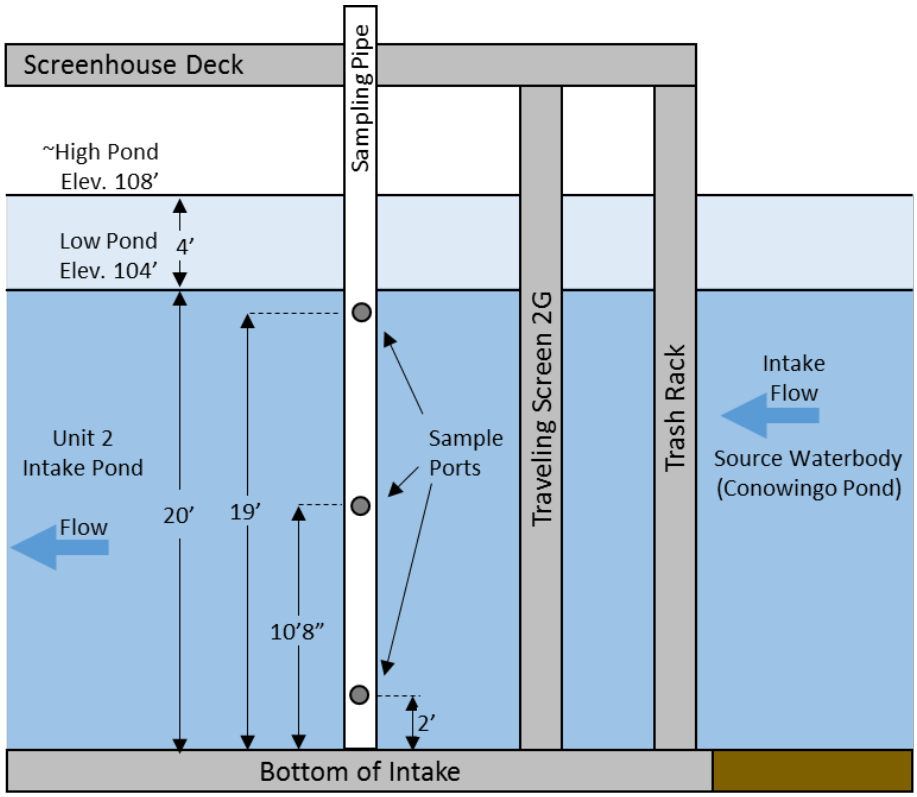

Figure 2-3. Cross-sectional schematic of the three-port entrainment sampling piped deployed immediately downstream of the traveling screen at the Outer Intake Structure (Location 1) that was used to sample the full water column for estimating entrainment abundance at Peach Bottom Atomic Power Station during 2016.

Table 2-1. Nominal month and calendar week number (beginning Monday) designations for entrainment samples collected at PBAPS during 2012 and 2016. Green highlights indicate dates of pump sampling at Location 2 (2012) and Locations 1, 2, and 3 (2016). Orange highlight indicates net sampling conducted at alternative Location 2 (2012 only).

2012								
Nominal Month	Week No.	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Mar	10	5-Mar	6-Mar	7-Mar	8-Mar	9-Mar	10-Mar	11-Mar
	11	12-Mar	13-Mar	14-Mar	15-Mar	16-Mar	17-Mar	18-Mar
	12	19-Mar	20-Mar	21-Mar	22-Mar	23-Mar	24-Mar	25-Mar
	13	26-Mar	27-Mar	28-Mar	29-Mar	30-Mar	31-Mar	1-Apr
Apr	14	2-Apr	3-Apr	4-Apr	5-Apr	6-Apr	7-Apr	8-Apr
	15	9-Apr	10-Apr	11-Apr	12-Apr	13-Apr	14-Apr	15-Apr
	16	16-Apr	17-Apr	18-Apr	19-Apr	20-Apr	21-Apr	22-Apr
	17	23-Apr	24-Apr	25-Apr	26-Apr	27-Apr	28-Apr	29-Apr
May	18	30-Apr	1-May	2-May	3-May	4-May	5-May	6-May
	19	7-May	8-May	9-May	10-May	11-May	12-May	13-May
	20	14-May	15-May	16-May	17-May	18-May	19-May	20-May
	21	21-May	22-May	23-May	24-May	25-May	26-May	27-May
Jun	22	28-May	29-May	30-May	31-May	1-Jun	2-Jun	3-Jun
	23	4-Jun	5-Jun	6-Jun	7-Jun	8-Jun	9-Jun	10-Jun
	24	11-Jun	12-Jun	13-Jun	14-Jun	15-Jun	16-Jun	17-Jun
	25	18-Jun	19-Jun	20-Jun	21-Jun	22-Jun	23-Jun	24-Jun
	26	25-Jun	26-Jun	27-Jun	28-Jun	29-Jun	30-Jun	1-Jul
Jul	27	2-Jul	3-Jul	4-Jul	5-Jul	6-Jul	7-Jul	8-Jul
	28	9-Jul	10-Jul	11-Jul	12-Jul	13-Jul	14-Jul	15-Jul
	29	16-Jul	17-Jul	18-Jul	19-Jul	20-Jul	21-Jul	22-Jul
	30	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul
Aug	31	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug
	32	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug
	33	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug
	34	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug	26-Aug
	35	27-Aug	28-Aug	29-Aug	30-Aug	31-Aug	1-Sep	2-Sep
Sep	36	3-Sep	4-Sep	5-Sep	6-Sep	7-Sep	8-Sep	9-Sep
	37	10-Sep	11-Sep	12-Sep	13-Sep	14-Sep	15-Sep	16-Sep
	38	17-Sep	18-Sep	19-Sep	20-Sep	21-Sep	22-Sep	23-Sep
	39	24-Sep	25-Sep	26-Sep	27-Sep	28-Sep	29-Sep	30-Sep

2016								
Nominal Month)	Week No.	Mon	Tue	Wed	Thu	Fri	Sat	Sun
	10	7-Mar	8-Mar	9-Mar	10-Mar	11-Mar	12-Mar	13-Mar
	11	14-Mar	15-Mar	16-Mar	17-Mar	18-Mar	19-Mar	20-Mar
Apr	12[a]	21-Mar	22-Mar	23-Mar	24-Mar	25-Mar	26-Mar	27-Mar
	13	28-Mar	29-Mar	30-Mar	31-Mar	1-Apr	2-Apr	3-Apr
	14	4-Apr	5-Apr	6-Apr	7-Apr	8-Apr	9-Apr	10-Apr
	15	11-Apr	12-Apr	13-Apr	14-Apr	15-Apr	16-Apr	17-Apr
	16	18-Apr	19-Apr	20-Apr	21-Apr	22-Apr	23-Apr	24-Apr
	17	25-Apr	26-Apr	27-Apr	28-Apr	29-Apr	30-Apr	1-May
May	18	2-May	3-May	4-May	5-May	6-May	7-May	8-May
	19	9-May	10-May	11-May	12-May	13-May	14-May	15-May
	20	16-May	17-May	18-May	19-May	20-May	21-May	22-May
	21	23-May	24-May	25-May	26-May	27-May	28-May	29-May
Jun	22	30-May	31-May	1-Jun	2-Jun	3-Jun	4-Jun	5-Jun
	23	6-Jun	7-Jun	8-Jun	9-Jun	10-Jun	11-Jun	12-Jun
	24	13-Jun	14-Jun	15-Jun	16-Jun	17-Jun	18-Jun	19-Jun
	25	20-Jun	21-Jun	22-Jun	23-Jun	24-Jun	25-Jun	26-Jun
	26	27-Jun	28-Jun	29-Jun	30-Jun	1-Jul	2-Jul	3-Jul
Jul	27	4-Jul	5-Jul	6-Jul	7-Jul	8-Jul	9-Jul	10-Jul
	28	11-Jul	12-Jul	13-Jul	14-Jul	15-Jul	16-Jul	17-Jul
	29	18-Jul	19-Jul	20-Jul	21-Jul	22-Jul	23-Jul	24-Jul
	30	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul
Aug	31	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug
	32	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug
	33	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug
	34	22-Aug	23-Aug	24-Aug	25-Aug	26-Aug	27-Aug	28-Aug
	35	29-Aug	30-Aug	31-Aug	1-Sep	2-Sep	3-Sep	4-Sep
Sep	36	5-Sep	6-Sep	7-Sep	8-Sep	9-Sep	10-Sep	11-Sep
	37	12-Sep	13-Sep	14-Sep	15-Sep	16-Sep	17-Sep	18-Sep
	38	19-Sep	20-Sep	21-Sep	22-Sep	23-Sep	24-Sep	25-Sep
	39	26-Sep	27-Sep	28-Sep	29-Sep	30-Sep	1-Oct	2-Oct

[a] 2016 week 12—Samples collected at Locations 1 and 2 only

Table 2-2. Number of samples planned and collected in the field and enumerated in the laboratory for the entrainment abundance sampling program at PBAPS Location 2 from 5 March through 30 September 2012.

Sampling Start Date	Week Number	Location	Diel Period	USE_CD	Gear	Field Planned	Field Collected	Lab Sort	Lab ID	Sample volume (gallons)	Sample volume (m^3)
8-Mar-12	10	Circulating Water Discharge (Location 2)	0300-0900	1	Pump	1	1	1	1	27374	104
			0900-1500	1	Pump	1	1	1	1	27240	103
			1500-2100	1	Pump	1	1	1	1	27007	102
			2100-0300	1	Pump	1	1	1	1	27036	102
14-Mar-12	11	Circulating Water Discharge (Location 2)	0300-0900	1	Pump	1	1	1	1	27099	103
			0900-1500	1	Pump	1	1	1	1	27071	102
			1500-2100	1	Pump	1	1	1	1	27121	103
			2100-0300	1	Pump	1	1	1	1	27671	105
21-Mar-12	12	Circulating Water Discharge (Location 2)	0300-0900	1	Pump	1	1	1	1	27042	102
			0900-1500	1	Pump	1	1	1	1	27060	102
			1500-2100	1	Pump	1	1	1	1	27409	104
			2100-0300	1	Pump	1	1	1	1	27592	104
n/a	13	Circulating Water Discharge (Location 2)	0300-0900	n/a	Pump	1	0	0	0	n/a	n/a
			0900-1500	n/a	Pump	1	0	0	0	n/a	n/a
			1500-2100	n/a	Pump	1	0	0	0	n/a	n/a
			2100-0300	n/a	Pump	1	0	0	0	n/a	n/a
5-Apr-12	14	Bridge (Alternative Location 2)	0900-1500	1	net	1	1	1	1	40339	153
			0900-1500	1	net	1	1	1	1	51108	193
11-Apr-12	15	Bridge (Alternative Location 2)	0900-1500	1	net	1	1	1	1	44746	169
			0900-1500	1	net	1	1	1	1	41842	158
			1500-2100	1	net	1	1	1	1	38202	145
			1500-2100	1	net	1	1	1	1	28019	106
19-Apr-12	16	Bridge (Alternative Location 2)	0900-1500	1	net	1	1	1	1	33230	126
			0900-1500	1	net	1	1	1	1	34480	131
			1500-2100	1	net	1	1	1	1	19729	75
			1500-2100	1	net	1	1	1	1	21725	82

(continued)

Table 2-2. (Continued)

Sampling Start Date	Week Number	Location	Diel Period	USE_CD	Gear	Field Planned	Field Collected	Lab Sort	Lab ID	Sample volume (gallons)	Sample volume (m^3)
25-Apr-12	17	Bridge (Alternative Location 2)	0900-1500	1	net	1	1	1	1	25354	96
			0900-1500	1	net	1	1	1	1	44850	170
			1500-2100	1	net	1	1	1	1	25665	97
			1500-2100	1	net	1	1	1	1	29191	110
2-May-12	18	Bridge (Alternative Location 2)	0900-1500	1	net	1	1	1	1	42879	162
			0900-1500	1	net	1	1	1	1	42827	162
			1500-2100	1	net	1	1	1	1	45161	171
			1500-2100	1	net	1	1	1	1	34479	131
9-May-12	19	Circulating Water Discharge (Location 2)	0300-0900	1	Pump	1	1	1	1	27218	103
			0900-1500	1	Pump	1	1	1	1	28350	107
			1500-2100	1	Pump	1	1	1	1	27000	102
			2100-0300	1	Pump	1	1	1	1	27000	102
16-May-12	20	Circulating Water Discharge (Location 2)	0900-1500	1	Pump	1	1	1	1	27000	102
			1500-2100	1	Pump	1	1	1	1	27000	102
			2100-0300	1	Pump	1	1	1	1	27000	102
			0300-0900	1	Pump	1	1	1	1	27000	102
23-May-12	21	Circulating Water Discharge (Location 2)	0300-0900	1	Pump	1	1	1	1	31122	118
			0900-1500	1	Pump	1	1	1	1	30384	115
			1500-2100	1	Pump	1	1	1	1	34200	129
			2100-0300	1	Pump	1	1	1	1	34380	130
30-May-12	22	Circulating Water Discharge (Location 2)	0300-0900	1	Pump	1	1	1	1	30240	114
			0900-1500	1	Pump	1	1	1	1	30240	114
6-Jun-12	23	Bridge (Alternative Location 2)	0300-0900	1	Pump	1	1	1	1	30240	114
			0900-1500	1	Pump	1	1	1	1	30240	114
			1500-2100	1	net	1	1	1	1	30747	116
			1500-2100	1	net	1	1	1	1	35620	135
13-Jun-12	24	Circulating Water Discharge (Location 2)	0300-0900	1	Pump	1	1	1	1	32400	123
			0900-1500	1	Pump	1	1	1	1	32040	121
			1500-2100	1	Pump	1	1	1	1	31770	120
			2100-0300	1	Pump	1	1	1	1	31140	118

(continued)

Table 2-2. (Continued)

Sampling Start Date	Week Number	Location	Diel Period	USE_CD	Gear	Field Planned	Field Collected	Lab Sort	Lab ID	Sample volume (gallons)	Sample volume (m^3)
20-Jun-12	25	Circulating Water Discharge (Location 2)	0300-0900	1	Pump	1	1	1	1	33311	126
			0900-1500	1	Pump	1	1	1	1	27064	102
			1500-2100	1	Pump	1	1	1	1	27065	102
			2100-0300	1	Pump	1	1	1	1	27006	102
27-Jun-12	26	Circulating Water Discharge (Location 2)	0300-0900	1	Pump	1	1	1	1	27019	102
			0900-1500	1	Pump	1	1	1	1	27049	102
			1500-2100	1	Pump	1	1	1	1	27085	103
			2100-0300	1	Pump	1	1	1	1	27042	102
5-Jul-12	27	Circulating Water Discharge (Location 2)	0300-0900	1	Pump	1	1	1	1	27163	103
			0900-1500	1	Pump	1	1	1	1	27078	103
			1500-2100	1	Pump	1	1	1	1	34211	130
			2100-0300	1	Pump	1	1	1	1	28689	109
11-Jul-12	28	Circulating Water Discharge (Location 2)	0300-0900	1	Pump	1	1	1	1	28168	107
			0900-1500	1	Pump	1	1	1	1	27156	103
			1500-2100	1	Pump	1	1	1	1	27555	104
			2100-0300	1	Pump	1	1	1	1	27038	102
18-Jul-12	29	Circulating Water Discharge (Location 2)	0300-0900	1	Pump	1	1	1	1	27377	104
			0900-1500	1	Pump	1	1	1	1	27025	102
			1500-2100	1	Pump	1	1	1	1	27045	102
			2100-0300	1	Pump	1	1	1	1	28260	107
25-Jul-12	30	Circulating Water Discharge (Location 2)	0300-0900	2	Pump	1	1	1	1	27040	102
			0900-1500	2	Pump	1	1	1	1	27722	105
			1500-2100	2	Pump	1	1	1	1	26895	102
			2100-0300	2	Pump	1	1	1	1	27880	106
1-Aug-12	31	Bridge (Alternative Location 2)	0900-1500	1	net	1	1	1	1	15063	57
			0900-1500	1	net	1	1	1	1	17095	65
			1500-2100	1	net	1	1	1	1	22855	87
			1500-2100	1	net	1	1	1	1	16455	62
8-Aug-12	32	Circulating Water Discharge (Location 2)	0300-0900	1	Pump	1	1	1	1	28937	110
			0900-1500	1	Pump	1	1	1	1	28370	107
			1500-2100	1	Pump	1	1	1	1	27531	104
			2100-0300	1	Pump	1	1	1	1	27030	102

Table 2-2. (Continued)

Sampling Start Date	Week Number	Location	Diel Period	USE_CD	Gear	Field Planned	Field Collected	Lab Sort	Lab ID	Sample volume (gallons)	Sample volume (m^3)
15-Aug-12	33	Circulating Water Discharge (Location 2)	0300-0900	1	Pump	1	1	1	1	27222	103
			0900-1500	1	Pump	1	1	1	1	27121	103
			1500-2100	1	Pump	1	1	1	1	27559	104
			2100-0300	1	Pump	1	1	1	1	27018	102
22-Aug-12	34	Circulating Water Discharge (Location 2)	0300-0900	1	Pump	1	1	1	1	27080	103
			0900-1500	1	Pump	1	1	1	1	27488	104
			1500-2100	1	Pump	1	1	1	1	27258	103
			2100-0300	1	Pump	1	1	1	1	27064	102
29-Aug-12	35	Circulating Water Discharge (Location 2)	0300-0900	1	Pump	1	1	1	1	27102	103
			0900-1500	1	Pump	1	1	1	1	27094	103
			1500-2100	1	Pump	1	1	1	1	27153	103
			2100-0300	1	Pump	1	1	1	1	27013	102
5-Sep-12	36	Circulating Water Discharge (Location 2)	0300-0900	1	Pump	1	1	1	1	27033	102
			0900-1500	1	Pump	1	1	1	1	27050	102
			1500-2100	1	Pump	1	1	1	1	27118	103
			2100-0300	1	Pump	1	1	1	1	27044	102
12-Sep-12	37	Circulating Water Discharge (Location 2)	0300-0900	1	Pump	1	1	1	1	27208	103
			0900-1500	1	Pump	1	1	1	1	27012	102
			1500-2100	1	Pump	1	1	1	1	27109	103
			2100-0300	1	Pump	1	1	1	1	27012	102
19-Sep-12	38	Circulating Water Discharge (Location 2)	0300-0900	1	Pump	1	1	1	1	27474	104
			0900-1500	1	Pump	1	1	1	1	27049	102
			1500-2100	1	Pump	1	1	1	1	27057	102
			2100-0300	1	Pump	1	1	1	1	27017	102
26-Sep-12	39	Circulating Water Discharge (Location 2)	0300-0900	1	Pump	1	1	1	1	27104	103
			0900-1500	1	Pump	1	1	1	1	27106	103
			1500-2100	1	Pump	1	1	1	1	27406	104
			2100-0300	1	Pump	1	1	1	1	27178	103

Table 2-3. Number of samples planned and collected in the field and enumerated in the laboratory for the entrainment abundance sampling program at PBAPS Locations 1, 2 and 3 from 24 March through 30 September 2016.

Date	Week Number	Location	Diel Period	USE_ CD	SAM_ NAR	Gear	Field Planned	Field Collected	Lab Sort	Lab ID	Sample volume (gallons)	Sample volume (m^3)
24-Mar-16	12	Outer Intake Structure (Location 1)	0900-1500	2	1	Net	1	1	1	1	33,733	128
			1500-2100	2	1	Net	1	1	1	1	48,597	184
			2100-0300	2	1	Net	1	1	1	1	104,933	397
			0300-0900	2	1	Net	1	1	1	1	103,528	392
		Circulating Water Discharge (Location 2)	0900-1500	1	2	Pump	1	1	1	1	27,106	103
			1500-2100	1	2	Pump	1	1	1	1	27,564	104
			2100-0300	1	2	Pump	1	1	1	1	28,444	108
			0300-0900	1	2	Pump	1	1	1	1	28,117	106
		Discharge Canal (Location 3)	0900-1500			Pump	1	0	0	0		
			1500-2100			Pump	1	0	0	0		
			2100-0300			Pump	1	0	0	0		
			0300-0900			Pump	1	0	0	0		
31-Mar-16	13	Outer Intake Structure (Location 1)	0900-1500	1	1	Pump	1	1	1	1	27,009	102
			1500-2100	1	1	Pump	1	1	1	1	27,127	103
			2100-0300	1	1	Pump	1	1	1	1	27,018	102
			0300-0900	1	1	Pump	1	1	1	1	27,025	102
		Circulating Water Discharge (Location 2)	0900-1500	1	2	Pump	1	1	1	1	28,832	109
			1500-2100	2	2	Pump	1	1	1	1		
			2100-0300	1	1	Pump	1	1	1	1	27,025	102
			0300-0900	1	1	Pump	1	1	1	1	27,031	102
		Discharge Canal (Location 3)	0900-1500	1	2	Pump	1	1	1	1	27,018	102
			1500-2100	1	2	Pump	1	1	1	1	27,013	102
			2100-0300	1	1	Pump	1	1	1	1	27,142	103
			0300-0900	1	1	Pump	1	1	1	1	27,127	103
5-Apr-16	14	Outer Intake Structure (Location 1)	0900-1500	1	1	Pump	1	1	1	1	27,021	102
			1500-2100	1	1	Pump	1	1	1	1	27,038	102
			2100-0300	1	1	Pump	1	1	1	1	27,530	104
			0300-0900	1	1	Pump	1	1	1	1	27,027	102

(continued)

Table 2-3. (Continued)

Date	Week Number	Location	Diel Period	USE_CD	SAM_NAR	Gear	Field Planned	Field Collected	Lab Sort	Lab ID	Sample volume (gallons)	Sample volume (m^3)
5-Apr-16 (cont'd)	14 (cont'd)	Circulating Water Discharge (Location 2)	0900-1500	1	1	Pump	1	1	1	1	28,489	108
			1500-2100	1	1	Pump	1	1	1	1	26,169	99
			2100-0300	1	1	Pump	1	1	1	1	27,097	103
			0300-0900	1	1	Pump	1	1	1	1	27,132	103
		Discharge Canal (Location 3)	0900-1500	1	2	Pump	1	1	1	1	27,011	102
			1500-2100	1	1	Pump	1	1	1	1	27,016	102
			2100-0300	1	1	Pump	1	1	1	1	27,089	103
			0300-0900	1	1	Pump	1	1	1	1	27,681	105
12-Apr-16	15	Outer Intake Structure (Location 1)	0900-1500	1	1	Pump	1	1	1	1	27,212	103
			1500-2100	1	1	Pump	1	1	1	1	27,227	103
			2100-0300	1	1	Pump	1	1	1	1	31,886	121
			0300-0900	1	1	Pump	1	1	1	1	27,000	102
		Circulating Water Discharge (Location 2)	0900-1500	1	2	Pump	1	1	1	1	29,875	113
			1500-2100	1	1	Pump	1	1	1	1	27,160	103
			2100-0300	1	1	Pump	1	1	1	1	27,001	102
			0300-0900	1	1	Pump	1	1	1	1	27,529	104
		Discharge Canal (Location 3)	0900-1500	1	2	Pump	1	1	1	1	27,021	102
			1500-2100	1	1	Pump	1	1	1	1	27,019	102
			2100-0300	1	1	Pump	1	1	1	1	27,142	103
			0300-0900	1	1	Pump	1	1	1	1	27,006	102
19-Apr-16	16	Outer Intake Structure (Location 1)	0900-1500	1	1	Pump	1	1	1	1	28,149	107
			1500-2100	1	1	Pump	1	1	1	1	27,006	102
			2100-0300	2	1	Pump	1	1	1	1		
			0300-0900	1	1	Pump	1	1	1	1	27,032	102
		Circulating Water Discharge (Location 2)	0900-1500	1	2	Pump	1	1	1	1	28,849	109
			1500-2100	1	1	Pump	1	1	1	1	27,127	103
			2100-0300	1	1	Pump	1	1	1	1	27,197	103
			0300-0900	2	1	Pump	1	1	1	1		

(continued)

Table 2-3. (Continued)

Date	Week Number	Location	Diel Period	USE_CD	SAM_NAR	Gear	Field Planned	Field Collected	Lab Sort	Lab ID	Sample volume (gallons)	Sample volume (m^3)
19-Apr-16 (cont'd)	16 (cont'd)	Discharge Canal (Location 3)	0900-1500	1	1	Pump	1	1	1	1	27,004	102
			1500-2100	1	1	Pump	1	1	1	1	27,019	102
			2100-0300	1	1	Pump	1	1	1	1	27,242	103
			0300-0900	1	1	Pump	1	1	1	1	27,237	103
26-Apr-16	17	Outer Intake Structure (Location 12)	0900-1500	1	1	Pump	1	1	1	1	27,322	103
			1500-2100	1	1	Pump	1	1	1	1	27,086	103
			2100-0300	1	1	Pump	1	1	1	1	27,043	102
			0300-0900	1	1	Pump	1	1	1	1	27,045	102
		Circulating Water Discharge Outfall (Location 2)	0900-1500	1	1	Pump	1	1	1	1	27,011	102
			1500-2100	1	1	Pump	1	1	1	1	27,007	102
			2100-0300	1	1	Pump	1	1	1	1	27,796	105
			0300-0900	1	1	Pump	1	1	1	1	27,217	103
		Discharge Canal Outfall (Location 3)	0900-1500	1	1	Pump	1	1	1	1	27,005	102
			1500-2100	1	1	Pump	1	1	1	1	27,126	103
			2100-0300	1	1	Pump	1	1	1	1	26,971	102
3-May-16	18	Outer Intake Structure (Location 1)	0900-1500	1	1	Pump	1	1	1	1	27,025	102
			1500-2100	1	1	Pump	1	1	1	1	27,054	102
			2100-0300	1	1	Pump	1	1	1	1	27,212	103
			0300-0900	1	1	Pump	1	1	1	1	27,665	105
		Circulating Water Discharge (Location 2)	0900-1500	1	1	Pump	1	1	1	1	26,996	102
			1500-2100	1	1	Pump	1	1	1	1	27,053	102
			2100-0300	1	1	Pump	1	1	1	1	27,118	103
			0300-0900	1	1	Pump	1	1	1	1	27,023	102
		Discharge Canal (Location 3)	0900-1500	1	1	Pump	1	1	1	1	27,003	102
			1500-2100	1	1	Pump	1	1	1	1	27,008	102
			2100-0300	1	1	Pump	1	1	1	1	27,139	103
			0300-0900	1	1	Pump	1	1	1	1	27,092	103

(continued)

Table 2-3. (Continued)

Date	Week Number	Location	Diel Period	USE_CD	SAM_NAR	Gear	Field Planned	Field Collected	Lab Sort	Lab ID	Sample volume (gallons)	Sample volume (m^3)
10-May-16	19	Outer Intake Structure (Location 1)	0900-1500	1	1	Pump	1	1	1	1	27,027	102
			1500-2100	1	1	Pump	1	1	1	1	27,012	102
			2100-0300	1	1	Pump	1	1	1	1	29,591	112
			0300-0900	1	1	Pump	1	1	1	1	27,110	103
		Circulating Water Discharge (Location 2)	0900-1500	1	1	Pump	1	1	1	1	27,101	103
			1500-2100	1	1	Pump	1	1	1	1	27,272	103
			2100-0300	1	1	Pump	1	1	1	1	27,015	102
			0300-0900	1	1	Pump	1	1	1	1	27,010	102
		Discharge Canal (Location 3)	0900-1500	1	1	Pump	1	1	1	1	27,093	103
			1500-2100	1	1	Pump	1	1	1	1	27,005	102
			2100-0300	1	1	Pump	1	1	1	1	27,019	102
			0300-0900	1	1	Pump	1	1	1	1	27,402	104
17-May-16 (19 May 16 Location 3)	20	Outer Intake Structure (Location 1)	0900-1500	1	1	Pump	1	1	1	1	27,161	103
			1500-2100	1	1	Pump	1	1	1	1	27,211	103
			2100-0300	1	1	Pump	1	1	1	1	27,029	102
			0300-0900	1	1	Pump	1	1	1	1	27,019	102
		Circulating Water Discharge (Location 2)	0900-1500	1	1	Pump	1	1	1	1	28,388	107
			1500-2100	1	1	Pump	1	1	1	1	27,112	103
			2100-0300	1	1	Pump	1	1	1	1	27,022	102
			0300-0900	1	1	Pump	1	1	1	1	27,105	103
		Discharge Canal (Location 3)	0900-1500	1	2	Pump	1	1	1	1	27,008	102
			1500-2100	1	2	Pump	1	1	1	1	27,009	102
			2100-0300	1	2	Pump	1	1	1	1	31,880	121
			0300-0900	1	2	Pump	1	1	1	1	27,000	102
24-May-16	21	Outer Intake Structure (Location 1)	0900-1500	1	1	Pump	1	1	1	1	27,008	102
			1500-2100	1	1	Pump	1	1	1	1	27,023	102
			2100-0300	1	1	Pump	1	1	1	1	27,404	104
			0300-0900	1	1	Pump	1	1	1	1	27,506	104

(continued)

Table 2-3. (Continued)

Date	Week Number	Location	Diel Period	USE_CD	SAM_NAR	Gear	Field Planned	Field Collected	Lab Sort	Lab ID	Sample volume (gallons)	Sample volume (m^3)
24-May-16 (cont'd)	21 (cont'd)	Circulating Water Discharge (Location 2)	0900-1500	1	1	Pump	1	1	1	1	27,022	102
			1500-2100	1	1	Pump	1	1	1	1	27,072	102
			2100-0300	1	1	Pump	1	1	1	1	27,084	103
			0300-0900	1	1	Pump	1	1	1	1	27,208	103
		Discharge Canal (Location 3)	0900-1500	1	1	Pump	1	1	1	1	27,022	102
			1500-2100	1	1	Pump	1	1	1	1	27,048	102
			2100-0300	1	1	Pump	1	1	1	1	27,005	102
			0300-0900	1	1	Pump	1	1	1	1	27,009	102
31-May-16	22	Outer Intake Structure (Location 1)	0900-1500	1	1	Pump	1	1	1	1	27,146	103
			1500-2100	1	1	Pump	1	1	1	1	27,184	103
			2100-0300	1	1	Pump	1	1	1	1	27,073	102
			0300-0900	1	1	Pump	1	1	1	1	27,097	103
		Circulating Water Discharge (Location 2)	0900-1500	1	1	Pump	1	1	1	1	27,000	102
			1500-2100	1	1	Pump	1	1	1	1	27,573	104
			2100-0300	1	1	Pump	1	1	1	1	27,037	102
			0300-0900	1	1	Pump	1	1	1	1	27,000	102
		Discharge Canal (Location 3)	0900-1500	1	1	Pump	1	1	1	1	27,239	103
			1500-2100	1	1	Pump	1	1	1	1	27,059	102
			2100-0300	1	1	Pump	1	1	1	1	27,002	102
			0300-0900	1	1	Pump	1	1	1	1	27,004	102
7-Jun-16	23	Outer Intake Structure (Location 1)	0900-1500	1	1	Pump	1	1	1	1	27,153	103
			1500-2100	1	1	Pump	1	1	1	1	27,175	103
			2100-0300	1	1	Pump	1	1	1	1	27,017	102
			0300-0900	1	1	Pump	1	1	1	1	27,021	102
		Circulating Water Discharge (Location 2)	0900-1500	1	1	Pump	1	1	1	1	27,000	102
			1500-2100	1	1	Pump	1	1	1	1	27,605	104
			2100-0300	1	1	Pump	1	1	1	1	27,190	103
			0300-0900	1	1	Pump	1	1	1	1	32,307	122

(continued)

Table 2-3. (Continued)

Date	Week Number	Location	Diel Period	USE_CD	SAM_NAR	Gear	Field Planned	Field Collected	Lab Sort	Lab ID	Sample volume (gallons)	Sample volume (m^3)
7-Jun-16 (cont'd)	23 (cont'd)	Discharge Canal (Location 3)	0900-1500	1	1	Pump	1	1	1	1	27,005	102
			1500-2100	1	1	Pump	1	1	1	1	27,006	102
			2100-0300	1	1	Pump	1	1	1	1	27,029	102
			0300-0900	1	1	Pump	1	1	1	1	27,608	105
14-Jun-16	24	Outer Intake Structure (Location 1)	0900-1500	1	1	Pump	1	1	1	1	27,018	102
			1500-2100	1	1	Pump	1	1	1	1	27,048	102
			2100-0300	1	1	Pump	1	1	1	1	27,022	102
			0300-0900	1	1	Pump	1	1	1	1	27,020	102
		Circulating Water Discharge (Location 2)	0900-1500	1	1	Pump	1	1	1	1	27,118	103
			1500-2100	1	1	Pump	1	1	1	1	27,012	102
			2100-0300	1	1	Pump	1	1	1	1	27,176	103
			0300-0900	1	1	Pump	1	1	1	1	27,255	103
		Discharge Canal (Location 3)	0900-1500	1	2	Pump	1	1	1	1	27,227	103
			1500-2100	1	1	Pump	1	1	1	1	27,045	102
			2100-0300	1	1	Pump	1	1	1	1	27,007	102
			0300-0900	1	1	Pump	1	1	1	1	27,009	102
21-Jun-16	25	Outer Intake Structure (Location 1)	0900-1500	1	1	Pump	1	1	1	1	27,003	102
			1500-2100	1	1	Pump	1	1	1	1	26,997	102
			2100-0300	1	1	Pump	1	1	1	1	27,343	104
			0300-0900	1	1	Pump	1	1	1	1	27,189	103
		Circulating Water Discharge (Location 2)	0900-1500	1	1	Pump	1	1	1	1	27,121	103
			1500-2100	1	1	Pump	1	1	1	1	27,066	102
			2100-0300	1	1	Pump	1	1	1	1	27,062	102
			0300-0900	1	1	Pump	1	1	1	1	27,064	102
		Discharge Canal (Location 3)	0900-1500	1	1	Pump	1	1	1	1	27,282	103
			1500-2100	1	1	Pump	1	1	1	1	27,027	102
			2100-0300	1	1	Pump	1	1	1	1	27,010	102
			0300-0900	1	1	Pump	1	1	1	1	27,017	102

(continued)

Table 2-3. (Continued)

Date	Week Number	Location	Diel Period	USE_CD	SAM_NAR	Gear	Field Planned	Field Collected	Lab Sort	Lab ID	Sample volume (gallons)	Sample volume (m^3)
28-Jun-16	26	Outer Intake Structure (Location 1)	0900-1500	1	1	Pump	1	1	1	1	27,079	103
			1500-2100	1	1	Pump	1	1	1	1	27,090	103
			2100-0300	1	1	Pump	1	1	1	1	27,022	102
			0300-0900	1	1	Pump	1	1	1	1	27,015	102
		Circulating Water Discharge (Location 2)	0900-1500	1	1	Pump	1	1	1	1	27,087	103
			1500-2100	1	1	Pump	1	1	1	1	27,061	102
			2100-0300	1	1	Pump	1	1	1	1	27,000	102
			0300-0900	1	1	Pump	1	1	1	1	27,002	102
		Discharge Canal (Location 3)	0900-1500	1	1	Pump	1	1	1	1	27,020	102
			1500-2100	1	1	Pump	1	1	1	1	27,217	103
			2100-0300	1	1	Pump	1	1	1	1	33,230	126
			0300-0900	1	1	Pump	1	1	1	1	27,009	102
6-Jul-16	27	Outer Intake Structure (Location 1)	0900-1500	1	1	Pump	1	1	1	1	27,936	106
			1500-2100	1	1	Pump	1	1	1	1	27,018	102
			2100-0300	1	1	Pump	1	1	1	1	27,002	102
			0300-0900	1	1	Pump	1	1	1	1	27,023	102
		Circulating Water Discharge (Location 2)	0900-1500	1	1	Pump	1	1	1	1	27,035	102
			1500-2100	1	1	Pump	1	1	1	1	27,007	102
			2100-0300	1	1	Pump	1	1	1	1	27,008	102
			0300-0900	1	1	Pump	1	1	1	1	27,959	106
		Discharge Canal (Location 3)	0900-1500	1	1	Pump	1	1	1	1	27,014	102
			1500-2100	1	1	Pump	1	1	1	1	27,073	102
			2100-0300	1	1	Pump	1	1	1	1	27,080	103
			0300-0900	1	1	Pump	1	1	1	1	27,017	102
12-Jul-16	28	Outer Intake Structure (Location 1)	0900-1500	1	1	Pump	1	1	1	1	27,055	102
			1500-2100	1	1	Pump	1	1	1	1	27,070	102
			2100-0300	1	1	Pump	1	1	1	1	27,185	103
			0300-0900	1	1	Pump	1	1	1	1	27,019	102

(continued)

Table 2-3. (Continued)

Date	Week Number	Location	Diel Period	USE_CD	SAM_NAR	Gear	Field Planned	Field Collected	Lab Sort	Lab ID	Sample volume (gallons)	Sample volume (m^3)
12-Jul-16 (cont'd)	28 (cont'd)	Circulating Water Discharge (Location 2)	0900-1500	1	1	Pump	1	1	1	1	27,038	102
			1500-2100	1	1	Pump	1	1	1	1	27,018	102
			2100-0300	1	1	Pump	1	1	1	1	27,033	102
			0300-0900	1	1	Pump	1	1	1	1	27,005	102
		Discharge Canal (Location 3)	0900-1500	1	1	Pump	1	1	1	1	27,201	103
			1500-2100	1	1	Pump	1	1	1	1	27,011	102
			2100-0300	1	1	Pump	1	1	1	1	27,049	102
			0300-0900	1	1	Pump	1	1	1	1	27,014	102
19-Jul-16	29	Outer Intake Structure (Location 1)	0900-1500	1	1	Pump	1	1	1	1	27,232	103
			1500-2100	1	1	Pump	1	1	1	1	27,007	102
			2100-0300	1	1	Pump	1	1	1	1	27,006	102
			0300-0900	1	1	Pump	1	1	1	1	27,107	103
		Circulating Water Discharge (Location 2)	0900-1500	1	1	Pump	1	1	1	1	27,072	102
			1500-2100	1	1	Pump	1	1	1	1	27,045	102
			2100-0300	1	1	Pump	1	1	1	1	27,028	102
			0300-0900	1	1	Pump	1	1	1	1	27,125	103
		Discharge Canal (Location 3)	0900-1500	1	1	Pump	1	1	1	1	27,009	102
			1500-2100	1	1	Pump	1	1	1	1	27,062	102
			2100-0300	1	1	Pump	1	1	1	1	27,461	104
			0300-0900	1	1	Pump	1	1	1	1	27,004	102
26-Jul-16	30	Outer Intake Structure (Location 1)	0900-1500	1	1	Pump	1	1	1	1	26,907	102
			1500-2100	1	1	Pump	1	1	1	1	28,557	108
			2100-0300	1	1	Pump	1	1	1	1	28,077	106
			0300-0900	1	1	Pump	1	1	1	1	27,015	102
		Circulating Water Discharge (Location 2)	0900-1500	1	1	Pump	1	1	1	1	27,125	103
			1500-2100	1	1	Pump	1	1	1	1	27,028	102
			2100-0300	1	1	Pump	1	1	1	1	27,232	103
			0300-0900	1	1	Pump	1	1	1	1	27,064	102

(continued)

Table 2-3. (Continued)

Date	Week Number	Location	Diel Period	USE_CD	SAM_NAR	Gear	Field Planned	Field Collected	Lab Sort	Lab ID	Sample volume (gallons)	Sample volume (m^3)
26-Jul-16 (cont'd)	30 (cont'd)	Discharge Canal (Location 3)	0900-1500	1	1	Pump	1	1	1	1	27,008	102
			1500-2100	1	1	Pump	1	1	1	1	27,017	102
			2100-0300	1	1	Pump	1	1	1	1	27,020	102
			0300-0900	1	1	Pump	1	1	1	1	27,770	105
2-Aug-16	31	Outer Intake Structure (Location 1)	0900-1500	1	1	Pump	1	1	1	1	27,870	105
			1500-2100	1	1	Pump	1	1	1	1	28,103	106
			2100-0300	1	1	Pump	1	1	1	1	27,036	102
			0300-0900	1	1	Pump	1	1	1	1	27,013	102
		Circulating Water Discharge (Location 2)	0900-1500	1	1	Pump	1	1	1	1	27,001	102
			1500-2100	1	1	Pump	1	1	1	1	27,184	103
			2100-0300	1	1	Pump	1	1	1	1	27,244	103
			0300-0900	1	1	Pump	1	1	1	1	27,002	102
		Discharge Canal (Location 3)	0900-1500	1	1	Pump	1	1	1	1	27,015	102
			1500-2100	1	1	Pump	1	1	1	1	27,019	102
			2100-0300	1	1	Pump	1	1	1	1	27,014	102
			0300-0900	1	1	Pump	1	1	1	1	27,130	103
9-Aug-16	32	Outer Intake Structure (Location 1)	0900-1500	1	1	Pump	1	1	1	1	27,115	103
			1500-2100	1	1	Pump	1	1	1	1	27,650	105
			2100-0300	1	1	Pump	1	1	1	1	27,029	102
			0300-0900	1	1	Pump	1	1	1	1	27,028	102
		Circulating Water Discharge (Location 2)	0900-1500	1	1	Pump	1	1	1	1	27,007	102
			1500-2100	1	1	Pump	1	1	1	1	27,153	103
			2100-0300	1	1	Pump	1	1	1	1	27,114	103
			0300-0900	1	1	Pump	1	1	1	1	27,010	102
		Discharge Canal (Location 3)	0900-1500	1	1	Pump	1	1	1	1	27,001	102
			1500-2100	1	1	Pump	1	1	1	1	27,018	102
			2100-0300	1	1	Pump	1	1	1	1	27,024	102
			0300-0900	1	1	Pump	1	1	1	1	27,003	102

(continued)

Table 2-3. (Continued)

Date	Week Number	Location	Diel Period	USE_CD	SAM_NAR	Gear	Field Planned	Field Collected	Lab Sort	Lab ID	Sample volume (gallons)	Sample volume (m^3)
16-Aug-16	33	Outer Intake Structure (Location 1)	0900-1500	1	1	Pump	1	1	1	1	27,045	102
			1500-2100	1	1	Pump	1	1	1	1	27,120	103
			2100-0300	1	1	Pump	1	1	1	1	28,659	108
			0300-0900	1	1	Pump	1	1	1	1	27,017	102
		Circulating Water Discharge (Location 2)	0900-1500	1	1	Pump	1	1	1	1	27,158	103
			1500-2100	1	1	Pump	1	1	1	1	27,117	103
			2100-0300	1	1	Pump	1	1	1	1	27,353	104
			0300-0900	1	1	Pump	1	1	1	1	27,013	102
		Discharge Canal (Location 3)	0900-1500	1	1	Pump	1	1	1	1	27,002	102
			1500-2100	1	1	Pump	1	1	1	1	27,022	102
			2100-0300	1	1	Pump	1	1	1	1	27,075	102
			0300-0900	1	1	Pump	1	1	1	1	27,010	102
23-Aug-16	34	Outer Intake Structure (Location 1)	0900-1500	1	1	Pump	1	1	1	1	28,186	107
			1500-2100	1	1	Pump	1	1	1	1	27,008	102
			2100-0300	1	1	Pump	1	1	1	1	27,008	102
			0300-0900	1	1	Pump	1	1	1	1	27,045	102
		Circulating Water Discharge (Location 2)	0900-1500	1	1	Pump	1	1	1	1	27,067	102
			1500-2100	1	1	Pump	1	1	1	1	27,050	102
			2100-0300	1	1	Pump	1	1	1	1	27,051	102
			0300-0900	1	1	Pump	1	1	1	1	27,123	103
		Discharge Canal (Location 3)	0900-1500	1	1	Pump	1	1	1	1	27,034	102
			1500-2100	1	1	Pump	1	1	1	1	27,034	102
			2100-0300	1	1	Pump	1	1	1	1	27,054	102
			0300-0900	1	1	Pump	1	1	1	1	27,608	105
30-Aug-16	35	Outer Intake Structure (Location 1)	0900-1500	1	1	Pump	1	1	1	1	27,020	102
			1500-2100	1	1	Pump	1	1	1	1	27,064	102
			2100-0300	1	1	Pump	1	1	1	1	27,169	103
			0300-0900	1	1	Pump	1	1	1	1	27,022	102

(continued)

Table 2-3. (Continued)

Date	Week Number	Location	Diel Period	USE_CD	SAM_NAR	Gear	Field Planned	Field Collected	Lab Sort	Lab ID	Sample volume (gallons)	Sample volume (m^3)
30-Aug-16 (cont'd)	35 (cont'd)	Circulating Water Discharge (Location 2)	0900-1500	1	1	Pump	1	1	1	1	27,163	103
			1500-2100	1	1	Pump	1	1	1	1	27,014	102
			2100-0300	1	1	Pump	1	1	1	1	27,024	102
			0300-0900	1	1	Pump	1	1	1	1	27,116	103
		Discharge Canal (Location 3)	0900-1500	1	1	Pump	1	1	1	1	27,026	102
			1500-2100	1	1	Pump	1	1	1	1	27,312	103
			2100-0300	1	1	Pump	1	1	1	1	27,342	104
			0300-0900	1	1	Pump	1	1	1	1	27,000	102
6-Sep-16	36	Outer Intake Structure (Location 1)	0900-1500	1	1	Pump	1	1	1	1	27,008	102
			1500-2100	1	1	Pump	1	1	1	1	26,997	102
			2100-0300	1	1	Pump	1	1	1	1	27,010	102
			0300-0900	1	1	Pump	1	1	1	1	27,025	102
		Circulating Water Discharge (Location 2)	0900-1500	1	1	Pump	1	1	1	1	27,321	103
			1500-2100	1	1	Pump	1	1	1	1	27,360	104
			2100-0300	1	1	Pump	1	1	1	1	27,371	104
			0300-0900	1	1	Pump	1	1	1	1	27,133	103
		Discharge Canal (Location 3)	0900-1500	1	1	Pump	1	1	1	1	27,001	102
			1500-2100	1	1	Pump	1	1	1	1	27,113	103
			2100-0300	1	1	Pump	1	1	1	1	27,118	103
			0300-0900	1	1	Pump	1	1	1	1	27,024	102
13-Sep-16	37	Outer Intake Structure (Location 1)	0900-1500	1	1	Pump	1	1	1	1	27,009	102
			1500-2100	1	1	Pump	1	1	1	1	27,046	102
			2100-0300	1	1	Pump	1	1	1	1	27,022	102
			0300-0900	1	1	Pump	1	1	1	1	27,058	102
		Circulating Water Discharge (Location 2)	0900-1500	1	1	Pump	1	1	1	1	27,203	103
			1500-2100	1	1	Pump	1	1	1	1	27,011	102
			2100-0300	1	1	Pump	1	1	1	1	27,003	102
			0300-0900	1	1	Pump	1	1	1	1	27,133	103

(continued)

Table 2-3. (Continued)

Date	Week Number	Location	Diel Period	USE_CD	SAM_NAR	Gear	Field Planned	Field Collected	Lab Sort	Lab ID	Sample volume (gallons)	Sample volume (m^3)
13-Sep-16 (cont'd)	37 (cont'd)	Discharge Canal (Location 3)	0900-1500	1	1	Pump	1	1	1	1	27,084	103
			1500-2100	1	1	Pump	1	1	1	1	27,192	103
			2100-0300	1	1	Pump	1	1	1	1	27,093	103
			0300-0900	1	1	Pump	1	1	1	1	27,274	103
20-Sep-16	38	Outer Intake Structure (Location 1)	0900-1500	1	1	Pump	1	1	1	1	27,017	102
			1500-2100	1	1	Pump	1	1	1	1	27,068	102
			2100-0300	1	1	Pump	1	1	1	1	27,446	104
			0300-0900	1	1	Pump	1	1	1	1	27,042	102
		Circulating Water Discharge (Location 2)	0900-1500	1	1	Pump	1	1	1	1	27,206	103
			1500-2100	1	1	Pump	1	1	1	1	27,801	105
			2100-0300	1	1	Pump	1	1	1	1	27,003	102
			0300-0900	1	1	Pump	1	1	1	1	27,157	103
		Discharge Canal (Location 3)	0900-1500	1	1	Pump	1	1	1	1	27,091	103
			1500-2100	1	1	Pump	1	1	1	1	27,081	103
			2100-0300	1	1	Pump	1	1	1	1	27,034	102
			0300-0900	1	1	Pump	1	1	1	1	27,023	102
27-Sep-16	39	Outer Intake Structure (Location 1)	0900-1500	1	1	Pump	1	1	1	1	27,015	102
			1500-2100	1	1	Pump	1	1	1	1	27,735	105
			2100-0300	1	1	Pump	1	1	1	1	27,038	102
			0300-0900	1	1	Pump	1	1	1	1	27,014	102
		Circulating Water Discharge (Location 2)	0900-1500	1	1	Pump	1	1	1	1	27,058	102
			1500-2100	1	1	Pump	1	1	1	1	27,135	103
			2100-0300	1	1	Pump	1	1	1	1	27,064	102
			0300-0900	1	1	Pump	1	1	1	1	27,018	102
		Discharge Canal (Location 3)	0900-1500	1	1	Pump	1	1	1	1	27,000	102
			1500-2100	1	1	Pump	1	1	1	1	27,036	102
			2100-0300	1	1	Pump	1	1	1	1	27,055	102
			0300-0900	1	1	Pump	1	1	1	1	27,002	102

Notes:
Use codes: 1 = valid sample; 2 = collected with sampling problems; 5 = void
Sample Narrative (used only in 2016): 1 = collected with appropriate time lag from location 12 to location 3; 2 = out of time lag synchrony
Week 20 has 2 dates because location 3 was use code 5, then redone on 5/19/16 as use code 2 and sam nar 2

3.0 Biological Entrainment Characterization (§122.21(r)(9)(ii))

3.1 Endangered and Threatened Species

No federally listed endangered or threatened species are known to occur in Conowingo Pond. However, a state listed species, Chesapeake Logperch (*Percina bimaculata*), and a species of concern, American Eel (*Anguilla rostrata*), are known to occur within the Pond; a brief discussion of these species follows.

The Chesapeake Logperch is listed as a threatened species in Pennsylvania and is also listed as threatened in Maryland. The Chesapeake Logperch range includes the lower Susquehanna River and several tributaries including Fishing Creek, Muddy Creek, Peters Creek, Michael Run, and Octoraro Creek. This species only occurs in approximately 30 combined stream and river miles within Pennsylvania. No Chesapeake Logperch were collected during entrainment sampling in 2012 (Normandeau 2013). However, a total of four Chesapeake Logperch were collected among the 331 entrainment samples processed in the 2016 entrainment abundance samples from PBAPS (Normandeau 2018). These four Chesapeake Logperch individuals, two at the Outer Intake Structure (Location 1) and two at the Circulating Water Discharge Outfall (Location 2), were reported to the PA Fish and Boat Commission by email when identified during laboratory processing and retained in Normandeau's biological laboratory reference collection.

The American Eel population is in apparent decline and is considered a species of concern. In 2011 the U.S. Fish and Wildlife Service initiated a new status review for the American Eel as a result of a 90-day finding on the Council for Endangered Species Act Reliability's petition to list the American Eel as threatened under the authority of the Endangered Species Act. However, a recently initiated trap and transport program at Conowingo Dam has begun stocking American Eel in the Pond (USFWS 2015). This program has increased the number of American Eels present in the Pond. A single juvenile American Eel was collected during entrainment sampling in 2012 (Normandeau 2013).

3.3 Entrainment Characterization

3.3.1 Taxonomic Composition

All ichthyoplankton collected during entrainment characterization studies in 2012 and 2016 at PBAPS were identified to the lowest possible taxon and life stage. Samples collected at Location 2 in 2012 comprised 8 taxa identified to species, one taxon to genus, and three taxa to family in addition to an unidentified classification (Table 3-1). The taxonomic composition of samples collected at Location 2 in 2016 consisted of 14 taxa identified to species, one taxa identified to species group, two taxa identified to genus, one taxa identified to group of genera, five taxa identified to family, and one taxon with an unidentified classification. During 2016, samples collected at the Outer Intake Structure (Location 1) consisted of 13 taxa identified to species, two taxa identified to genus, one taxon identified to a group of two species, two taxa identified to family, and one unidentified taxon. For all three sampling locations combined in

2016, 26 taxa were identified: 16 species, three genera, two groupings of multiple genera, and five families in addition to an unidentified classification. Taxon nomenclature used by the Normandeau laboratory for taxonomic identification changed between 2012 and 2016, which required taxon names to be standardized to allow comparisons between years (Table 3-1). Nine of the 25 standardized taxa were collected in entrainment samples at the comparable Location 2 during both 2012 and 2016, four taxa were unique to 2012, and 12 were unique to 2016. The presence of each taxon and life stage by year and sampling location is shown in Table 3-2. By life stage, unidentified larval stage contributed the highest proportion of the total at each site during both survey years, with all larval stages (YSL, PYSL, Unid) making up 93% of the total in 2012 (Location 2) and 96%, 97%, and 98% of the totals in 2016 at Locations 1, 2, and 3 respectively (Figure 3-1).

3.3.2 Number of Ichthyoplankton Collected

Entrainment samples collected at the Circulating Water Discharge Outfall (Location 2) contained an overall lower number of ichthyoplankton in 2012 (n=1,106) compared to 2016 (n=9,789; Table 3-3). The total for 2012 includes all Use Code 1 samples from pump sampling at Location 2 (Table 3-3; n=88 samples). The difference between years was driven by the high number of Alewife/Gizzard Shad larvae (YSL, PYSL, and UNID) collected in 2016 (n=8,959) compared to 2012 (n=725). Although there was a large difference between years in the actual number of ichthyoplankton collected, Alewife/Gizzard Shad and Gizzard Shad together were the dominant taxon groups during both years, representing 71% of the total in 2012 and 96% of the 2016 total.

3.3.3 Data Exclusions and Adjustments

During 2012, each individual ichthyoplankton collected from Location 2 had a limiting body dimension <14.2 mm. All larvae (YSL, PYSL, and UNID) collected in 2016 had a limiting dimension of <14.2 mm, while 67% of YOY Gizzard Shad, 50% of YROL Flathead Catfish, and 83% of YROL Tessellated Darters had limiting dimensions ≥14.2 mm. The statistically significant location correction factors used to adjust the Location 2 densities to Location 1 are listed in Table 3-4. Applying the location correction factor to estimate densities at Location 1 for 2012 and including only ichthyoplankton with a limiting body dimension of <14.2 mm for the 2016 data allowed for a two-year comparison of the density of entrainable fish where cooling water is first withdrawn by PBAPS from the source waterbody.

3.4 Variations in Entrainment

3.4.1 Annual Variability

The adjusted (to Location 1) overall mean entrainment density at the PBAPS Outer Intake Structure was lower during 2012 (7.6 fish/100 m^3) than 2016 (59.8 fish/100 m^3) when the LCF for each taxon groups by life stages was applied (Table 3-5). The total estimated annual entrainment abundance based on those densities and respective annual AIF was 140.7 million individuals in 2012 and 962.7 million individuals in 2016 (Table 3-6). Using the LCF of each taxon with all life stages combined, the overall mean entrainment density during 2012 was 8.8 fish/100 m^3 and the total estimated entrainment was 158.9 million individuals (Table 3-7). Using

the LCF for all taxa combined for each life stage, the overall mean density was 8.8 fish/100 m^3 and the total entrainment was 156.8 million individuals (Table 3-8).

3.4.2 Seasonal Variability

Although the overall entrainment density was higher in 2016, the seasonal pattern was similar between 2012 and 2016 with the highest entrainment at the Outer Intake Structure occurring during the late spring into summer (May-July; Figure 3-2, Table 3-9). For all life stages combined, the Alewife/Gizzard Shad and Gizzard Shad taxon groups dominated the total entrainment abundance during the May–July period (Table 3-10). For each life stage with all taxonomic groups combined, larvae contributed the most to entrainment density and abundance during the May–July period (Tables 3-11 and 3-12).

3.4.3 Diel Variability

For all taxon groups and life stages combined, the diel pattern of entrainment at the Outer Intake Structure was similar between 2012 and 2016, with the highest ichthyoplankton entrainment density observed during the 2100–0300 period and the lowest observed during the 1500–2100 period (Figure 3-3). This pattern was mainly driven by high densities of unidentified larvae of Darters in 2012 and Alewife/Gizzard Shad in 2016, during the 2100–0300 period (Table 3-13).

3.4.4 Variability Related to Water Quality

The period of highest entrainment density occurred when water temperatures at the sampled location ranged from 24.4°C to 36.6°C (2012) and from 26.5°C to 39.4°C (2016; Table 3-14). Dissolved oxygen levels were >5.7 mg/l during the peak entrainment period in 2012 and >7.2 mg/l in 2016.

3.4.4 Variability Related to Spawning, Feeding, and Vertical Migration

During the 2012 entrainment characterization study, PBAPS operated under NPDES Permit No. PA 0009733, which was issued 30 November 2010 with an effective date of 1 January 2011. The permit contained a requirement for an entrainment characterization study to be conducted over at least one fish spawning season as described in the permit within the following relevant sections of Part C, section II.D.1:

> *Entrainment data collections shall occur for a period of at least one fish spawning season, approximately March through September, at a sampling frequency sufficient to characterize the entrainment occurring.*

The entrainment characterization study conducted at PBAPS during 5 March through 30 September 2012 was designed to satisfy the sampling period requirement of the NPDES permit and encompass the time period during which ichthyoplankton of entrainable size were expected to be present. The entrainment characterization study subsequently conducted 21 March through 2 October 2016 was designed to cover the same spawning period. Over the duration of each survey, the weekly sampling events during each study were scheduled for approximately the same day each week to ensure regular spacing of the events. This sampling

frequency for the entrainment characterization studies was based on guidance provided in the *Entrainment Abundance Monitoring Technical Support Document* by the Electric Power Research Institute (EPRI 2005a) and based on similar PA DEP-approved entrainment studies conducted recently at other generating stations in Pennsylvania (Normandeau 2008a, 2008b).

Because the intake structure extended from the reservoir bottom to the surface and each entrainment sample comprised three locations within the water column, the ichthyoplankton densities estimated from sampling at Location 1 are representative of ichthyoplankton densities within the full water column of the Pond adjacent to the intake structure (see Figure 2-3). Additionally, for each sampling week of 2012 and 2016, samples were collected during each of four diel periods (0900–1500, 1500–2100, 2100–0300, and 0300–0900). Because the sampling pipe represented the full water column and sampling was conducted during all diel periods, any variation in ichthyoplankton density throughout the water column related to diel period, feeding behavior, or habitat preferences were accounted for by the study design.

3.5 Total Entrainment Abundance and Entrainment Mortality

Entrainment mortality for all species combined was estimated to be 85 to 93% in a 1975 study at PBAPS, with Gizzard Shad experiencing the highest entrainment mortality at 98 to 100% (Philadelphia Electric Company 1977). Entrainment survival data were not available for the PBAPS circulating water discharge outfall for the combined Units 2 and 3 during 2012 and 2016, so 100% mortality of eggs and larvae was assumed when estimating entrainment mortality based on entrainment abundance, even though entrainment mortality is typically less than 100% (EPRI 2000, 2005b). The similarity of species composition (i.e., dominance by Gizzard Shad larvae) between the 1975 study and the 2012 and 2016 entrainment characterization studies suggests the assumption of 100% entrainment mortality remains appropriate for the current operations at PBAPS. Entrainment abundance and mortality was assumed to be zero for months outside of the sampled periods during both 2012 and 2016.

The annual estimate of entrainment abundance of ichthyoplankton from cooling water withdrawal by the Unit 2 and Unit 3 Outer Intake Structure at PBAPS was 551.7 million individuals, based on the average of the annual entrainment abundance estimates of 140.7 million individuals in 2012 and 962.7 million individuals in 2016 (Table 3-6). The annual entrainment abundance estimate for 2012, when only the Circulating Water Discharge Outfall was sampled, was adjusted by taxon and life stage groups, where appropriate, to account for significant sampling location differences between the Circulating Water Discharge Outfall and Outer Intake Structure. When densities from 2012 were adjusted to expected densities at the Outer Intake Structure by using either life stage or taxon-aggregated LCFs rather than by taxon and life stage specific LCFs, the entrainment abundance estimate was 158.9 million using LCFs for each taxon and all life stages combined (Table 3-7) and 156.8 million using LCFs for all taxa combined and each life stage (Table 3-8). While location adjustments made to the taxon- or life stage-aggregated entrainment densities in 2012 increased the entrainment abundance estimate by 11 to 13%, the two annual estimates (140.7 million individuals in 2012 and 962.7 million individuals in 2016) differed by a factor of five (584%) which was largely explained by higher

observed entrainment densities of Alewife/Gizzard Shad larvae in 2016, particularly in June. Fragile species (Alewife and Gizzard Shad) represented 49% (68.6 million individuals) of the estimated total entrainment mortality of 140.7 million individuals in 2012 and 95% (913.0 million individuals) of the total mortality of 962.7 million individuals in 2016 (Table 3-6).

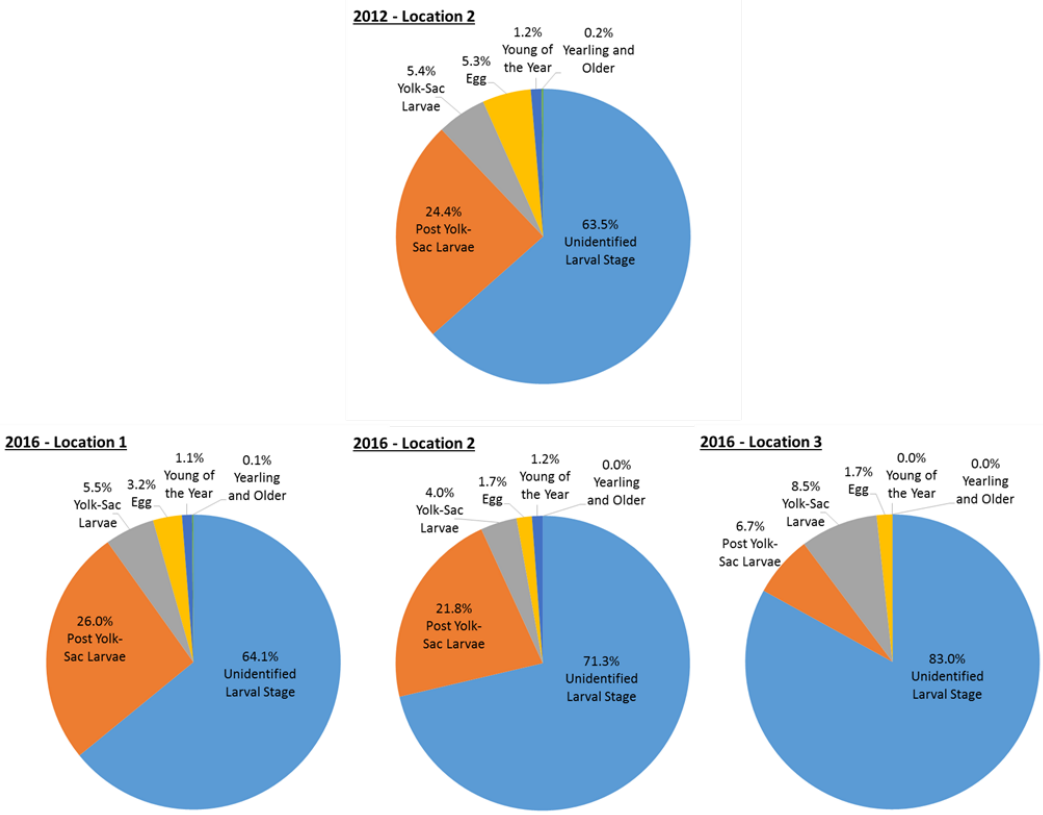

Figure 3-1. Contribution of each life stage to the total number of ichthyoplankton collected at each location sampled during entrainment characterization studies at PBAPS in 2012 (Location 2 only) and 2016 (Locations 1, 2, and 3).

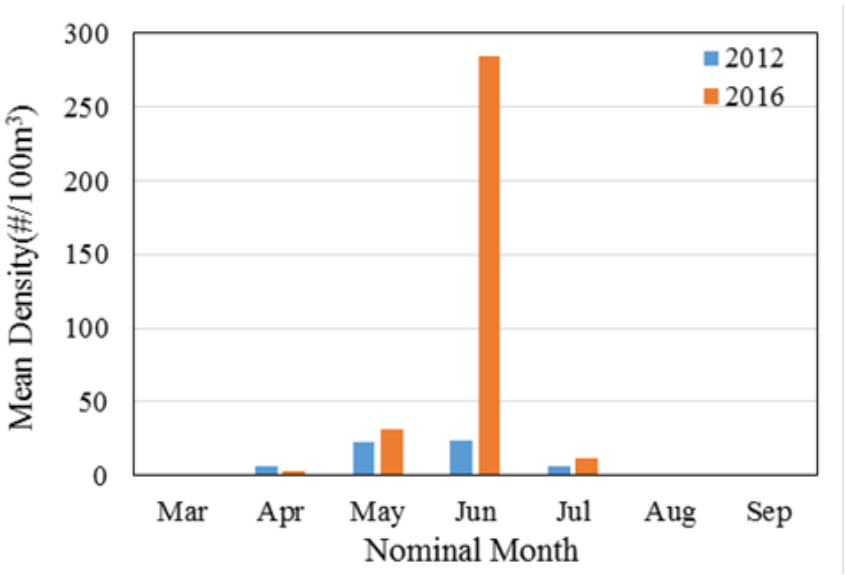

Figure 3-2. Monthly mean ichthyoplankton density (all taxa and life stages combined) at the PBAPS outer intake structure (Location 1) for 2012 (estimated from Location 2 densities) and 2016 (actual Location 1 densities).

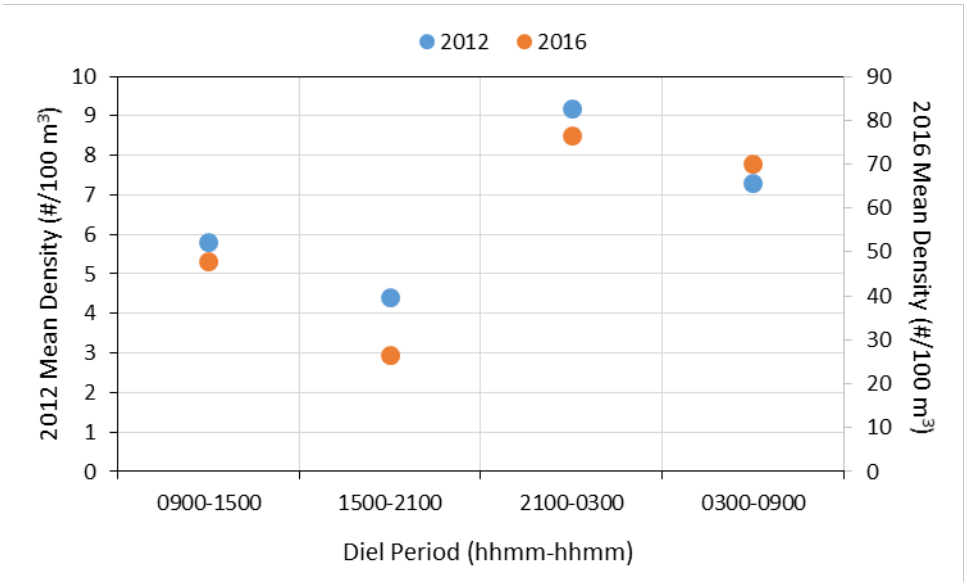

Figure 3-3. Overall mean ichthyoplankton density (all taxa and life stages combined) for each of the four sampled diel periods at the PBAPS Outer Intake Structure (Location 1) during 2012 (estimated from Location 2 densities) and 2016 (actual Location 1 densities).

Table 3-1. Ichthyoplankton taxa identified from entrainment samples collected during the entrainment season from 5 March through 30 September 2012 and 24 March through 2 October 2016 at PBAPS. Changes in taxonomic nomenclature between 2012 and 2016 were standardized for analysis.

Family	Taxon	Species (if applicable)	Identified in Entrainment Samples (Year & Location)				Standardized for 2012 & 2016	
			2012	2016				
			2	1	2	3	Taxon	Taxon Group
Anguillidae	American Eel	*Anguilla rostrata*	X				American Eel	Other
Catostomidae	Sucker Family				X	X	Sucker Family	
	Quillback	*Carpiodes cyprinus*		X	X	X	Quillback	
	White Sucker	*Catostomus olmstedi*	X				White Sucker	
Centrarchidae	Sunfish Family		X		X		Sunfish Family	Sunfishes
	Lepomis Species	*Lepomis sp.*		X	X	X	Lepomis Species	
	Lepomis Species/ Crappie Species	*Lepomis sp.*/ *Pomoxis sp.*			X	X	Lepomis Species/ Crappie Species	
	Bluegill	*Lepomis macrochirus*		X			Bluegill	
Clupeidae	Herring Family		X[1]	X[2]	X[2]		Alewife/Gizzard Shad	Alewife/ Gizzard Shad
	Alewife/ Gizzard Shad	*A. pseudoharengus*/ *D. cepedianum*		X	X	X	Alewife/Gizzard Shad	
	Alewife	*Alosa pseudoharengus*		X	X	X	Alewife	
	American Shad	*Alosa sapidissima*			X		American Shad	Other
	Gizzard Shad	*Dorosoma cepedianum*	X	X	X	X	Gizzard Shad	Gizzard Shad
Cyprinidae	Carp and Minnow Family		X	X	X	X	Carp and Minnow Family	Carps and Minnows
	Common Carp	*Cyprinus carpio*		X	X	X	Common Carp	
	Spottail Shiner	*Notropis hudsonius*	X				Spottail Shiner	
Ictaluridae	Bullhead Catfish Family				X		Bullhead Catfish	Catfishes
	Ictalurus Species	*Ictalurus sp.*				X	Ictalurus Species	
	Brown Bullhead	*Ameiurus nebulosus*			X		Brown Bullhead	
	Channel Catfish	*Ictalurus punctatus*	X	X	X		Channel Catfish	
	Flathead Catfish	*Pylodictis olivaris*		X	X		Flathead Catfish	
	White Catfish	*Ameiurus catus*			X		White Catfish	
Moronidae	White Perch	*Morone americana*		X	X	X	White Perch	Other
Percidae	Darter Species			X	X	X	Darter Species	Darters
	Etheostoma species	*Etheostoma sp.*	X[3]				Darter Species	
	Banded Darter	*Etheostoma zonale*	X	X	X	X	Banded Darter	
	Greenside Darter	*Etheostoma blennioides*	X				Greenside Darter	
	Shield Darter	*Percina peltata*		X			Shield Darter	
	Tessellated Darter	*Etheostoma olmstedi*	X	X	X	X	Tessellated Darter	
	Chesapeake Logperch	*Percina bimaculata*		X	X		Chesapeake Logperch	Other
	Yellow Perch	*Perca flavescens*		X	X		Yellow Perch	
Unidentified	Unidentified		X[4]				Unidentified	Unidentified Osteichthyes
	Unidentified Osteichthyes			X	X	X	Unidentified Osteichthyes	

1. The "Alewife/Gizzard Shad" taxon was not used in 2012; "Herring Family" specimens from 2012 would have been classified as "Alewife/Gizzard Shad" in 2016.
2. The single "Herring Family" specimen (PYSL) collected in 2016 was assigned to "Alewife/Gizzard Shad" (in 2016, >99.9% of PYSL clupeids were classified as Alewife/Gizzard Shad, Gizzard Shad, or Alewife)
3. "Etheostoma species" (used in 2012) and "Darter Family" (used in 2016) are identical classifications.
4. All "Unidentified" in 2012 were re-classified as "Unidentified Osteichthyes" which was added in 2016 to specify bony fishes.

Table 3-2. Ichthyoplankton life stages[1] present within each standardized taxon identified from entrainment samples collected at each location during the entrainment season from 5 March through 30 September 2012 and 24 March through 2 October 2016 at Peach Bottom Atomic Power Station.

	2012						2016																	
	Location 2						Location 1						Location 2						Location 3					
Standardized Taxon	UNID	Egg	YSL	PYSL	YOY	YROL	UNID	Egg	YSL	PYSL	YOY	YROL	UNID	Egg	YSL	PYSL	YOY	YROL	UNID	Egg	YSL	PYSL	YOY	YROL
Alewife									X	X				X	X	X					X			
Alewife/Gizzard Shad	X		X	X			X		X	X	X		X		X	X			X		X	X		
American Eel						X																		
American Shad																X								
Banded Darter	X		X	X						X						X						X		
Bluegill											X													
Brown Bullhead																	X							
Bullhead Catfish Family																	X							
Carp and Minnow Family				X						X				X		X					X	X		
Channel Catfish				X	X						X						X							
Chesapeake Logperch										X						X		X						
Common Carp								X		X				X		X				X		X		
Darter Species	X			X					X				X		X	X			X		X	X		
Flathead Catfish												X					X							
Gizzard Shad		X	X					X	X	X	X		X	X	X	X	X		X	X	X	X		
Greenside Darter				X																				
Ictalurus sp.																							X	
Lepomis sp.							X			X			X			X					X	X		
Lepomis sp./Crappie sp.																X						X		
Quillback										X					X	X						X		
Shield Darter											X													
Spottail Shiner					X	X																		
Sucker Family																X						X		
Sunfish family				X												X								
Tessellated Darter	X		X	X	X				X	X	X	X	X		X	X	X				X	X		
Unidentified Osteichthyes	X	X		X			X			X			X	X		X			X	X		X		
White Catfish																	X							
White Perch								X						X						X				
White Sucker	X			X																				

1. YSL=yolk-sac larvae, PYSL= post yolk-sac larvae, YOY =young of the year, YROL=yearling or older, and Unid=unidentified larval stage

Table 3-3. Total number of ichthyoplankton by taxon group and life stage collected in entrainment samples from the PBAPS circulating water discharge outfall (Location 2) during 2012 and 2016. Life stage "UNID" is unidentified larval stage, "Larvae" includes yolk-sac and post yolk-sac larvae, and "YROL" is young of the year and older.

Taxon Group	Life Stage Group	Circulating Water Discharge Outfall (Location 2)			
		2012 N samples = 88 Total Volume Sampled[b] = 9,326 m³		2016 N samples = 110 Total Volume Sampled = 11,356 m³	
		N collected	Percentage of 2012 Total	N collected	Percentage of 2016 Total
Alewife/Gizzard Shad	UNID	540	48.8	6919	70.7
Alewife/Gizzard Shad	Egg	0	0.0	1	<0.1
Alewife/Gizzard Shad	Larvae	185	16.7	2039	20.8
Alewife/Gizzard Shad	YROL	0	0.0	0	0.0
Gizzard Shad	UNID	0	0.0	4	<0.1
Gizzard Shad	Egg	57	5.2	150	1.5
Gizzard Shad	Larvae	1	0.1	326	3.3
Gizzard Shad	YROL	0	0.0	3	<0.1
Darters	UNID	30	2.7	18	0.2
Darters	Egg	0	0.0	0	0.0
Darters	Larvae	86	7.8	62	0.6
Darters	YROL	4	0.4	95	1.0
Unidentified	UNID	131	11.8	40	0.4
Unidentified	Egg	2	0.2	2	<0.1
Unidentified	Larvae	51	4.6	11	0.1
Unidentified	YROL	0	0.0	0	0.0
Carps and Minnows	UNID	0	0.0	0	0.0
Carps and Minnows	Egg	0	0.0	8	0.1
Carps and Minnows	Larvae	1	0.1	35	0.4
Carps and Minnows	YROL	2	0.2	0	0.0
Sunfishes	UNID	0	0.0	3	<0.1
Sunfishes	Egg	0	0.0	0	0.0
Sunfishes	Larvae	1	0.1	42	0.4
Sunfishes	YROL	0	0.0	0	0.0
Catfishes	UNID	0	0.0	0	0.0
Catfishes	Egg	0	0.0	0	0.0
Catfishes	Larvae	3	0.3	0	0.0
Catfishes	YROL	8	0.7	17	0.2
Other	UNID	1	0.1	0	0.0
Other	Egg	0	0.0	4	<0.1
Other	Larvae	2	0.2	9	0.1
Other	YROL	1	0.1	1	<0.1
Alewife/Gizzard Shad	All	725	65.6	8959	91.5
Gizzard Shad		58	5.2	483	4.9
Darters		120	10.8	175	1.8
Unidentified		184	16.6	53	0.5
Carps and Minnows		3	0.3	43	0.4
Sunfishes		1	0.1	45	0.5
Catfishes		11	1.0	17	0.2
Other		4	0.4	14	0.1
All	UNID	702	63.5	6984	71.3
	Egg	59	5.3	165	1.7
	Larvae	330	29.8	2524	25.8
	YROL	15	1.4	116	1.2
All	**All**	1106	100.0	9789	100.0

Table 3-4. Location Conversion Factors (LCF) estimated by the generalized linear mixed model (GLMM) method for adjusting densities at Circulating Water (CW) Discharge Outfall (Location 2) to densities at the Outer Intake Structure (Location 1) for taxonomic and life stage groups with significant location effects determined by the GLMM, based on paired sampling design[1] between locations at PBAPS during the entrainment season from the week beginning 21 March through 2 October 2016.

Fish Taxon	Life Stage	GLMM[2]			Applied to Estimates in:
		Location Effect (±β)	Location Effect Standard Error (SE)	LCF (Location 1:2)	
Alewife/Gizzard Shad	UNID	0.55	0.20	0.33	Tables 3-5 and 3-12
Gizzard Shad	Egg	0.33	0.09	0.51	
Gizzard Shad	Larvae	-0.30	0.11	1.84	
Carp and Minnows	Egg	-0.72	0.16	4.28	
Sunfishes	Older	-0.16	0.05	1.38	
Unidentified	Larvae	0.15	0.03	0.74	
Alewife/Gizzard Shad	All Stages	0.26	0.10	0.59	Tables 3-6, 3-8, and 3-9
Darters	All Stages	0.15	0.05	0.74	
Carp and Minnows	All Stages	-0.39	0.17	2.22	
All Taxa	UNID	0.27	0.09	0.58	Tables 3-7, 3-10, and 3-11

[1] Weekly location pairs were excluded if the density was zero at both locations for a given week for that taxonomic and life stage group.

[2] $\widehat{LCF}_{ts} = \frac{\widehat{D_{ts,ref}}}{\widehat{D_{ts,alt}}} = 1/e^{2\beta(1+0.5SE^2)}$

Table 3-5. Ichthyoplankton density estimates for Location 1 during entrainment season from 5 March through 30 September 2012 and 21 March through 3 October 2016. Estimates for 2012 are based on adjusted densities at Location 2 using Location Correction Factors for taxon group and life stages only (see Table 3-4).

Taxonomic Group	Life Stage Group	Mean Density (#/100 m³) 2012 (Adjusted to Location 1)	2016 (Location 1 actual)
Alewife/ Gizzard Shad	UNID	2.0	38.0
	Eggs	0	0
	Larvae	1.5	15.0
	Older	0	<0.1
Gizzard Shad	UNID	0	0
	Eggs	0.3	0.6
	Larvae	<0.1	3.0
	Older	0	<0.1
Darters	UNID	0.3	0
	Eggs	0	0
	Larvae	1.1	0.3
	Older	<0.1	0.5
Carps and Minnows	UNID	0	0
	Eggs	0	1.3
	Larvae	<0.1	<0.1
	Older	<0.1	0
Sunfishes	UNID	0	<0.1
	Eggs	0	0
	Larvae	<0.1	0.3
	Older	0	<0.1
Catfishes	UNID	0	0
	Eggs	0	0
	Larvae	<0.1	0
	Older	<0.1	0.1
Other	UNID	<0.1	0
	Eggs	0	<0.1
	Larvae	<0.1	<0.1
	Older	<0.1	0
Unidentified	UNID	2.1	0.3
	Eggs	<0.1	0
	Larvae	0.3	<0.1
	Older	0	0
Alewife/ Gizzard Shad	All	3.5	53.1
Gizzard Shad	All	1.5	3.6
Darters	All	1.8	0.8
Carps and Minnows	All	0.3	1.4
Sunfishes	All	0.3	0.4
Catfishes	All	0.6	0.1
Other	All	0.3	<0.1
Unidentified	All	1.4	0.4
All	UNID	4.4	38.4
	Eggs	0.3	1.9
	Larvae	2.9	18.8
	Older	0.0	0.8
All	All	7.6	59.8

Table 3-6. Ichthyoplankton entrainment abundance estimates for Location 1 during the entrainment season from 5 March through 30 September 2012 and 21 March through 3 October 2016. Estimates for 2012 are based on adjusted densities at Location 2 using Location Correction Factors for taxon group and life stages only (see Table 3-4).

Taxonomic Group	Life Stage Group	Abundance (N fish)					
		2012 (Adjusted to Location 1)			2016 (Location 1 actual)		
		Unit 2	Unit 3	Total	Unit 2	Unit 3	Total
Alewife/ Gizzard Shad	UNID	17,906,778	17,906,778	35,813,555	307,479,896	304,739,524	612,219,420
	Eggs	0	0	0	0	0	0
	Larvae	13,046,829	12,957,214	26,004,043	122,100,055	120,666,609	242,766,664
	Older	0	0	0	73,884	73,884	147,769
Gizzard Shad	UNID	0	0	0	0	0	0
	Eggs	2,858,233	2,858,233	5,716,466	4,585,853	4,599,375	9,185,227
	Larvae	530,154	530,154	1,060,307	24,175,922	23,908,724	48,084,647
	Older	0	0	0	288,600	288,600	577,201
Darters	UNID	2,616,366	2,616,366	5,232,732	0	0	0
	Eggs	0	0	0	0	0	0
	Larvae	10,211,449	10,211,050	20,422,499	2,230,491	2,215,654	4,446,145
	Older	243,992	243,992	487,984	4,187,153	4,145,323	8,332,476
Carps and Minnows	UNID	0	0	0	0	0	0
	Eggs	0	0	0	10,256,538	10,181,824	20,438,361
	Larvae	62,960	62,960	125,919	658,271	653,214	1,311,485
	Older	141,392	138,073	279,465	0	0	0
Sunfishes	UNID	0	0	0	73,822	73,822	147,643
	Eggs	0	0	0	0	0	0
	Larvae	57,326	57,326	114,653	2,789,814	2,756,557	5,546,371
	Older	0	0	0	363,495	362,200	725,695
Catfishes	UNID	0	0	0	0	0	0
	Eggs	0	0	0	0	0	0
	Larvae	217,378	217,378	434,757	0	0	0
	Older	598,820	598,271	1,197,090	882,613	868,150	1,750,763
Other	UNID	129,667	129,667	259,333	0	0	0
	Eggs	0	0	0	288,732	281,600	570,332
	Larvae	145,227	145,227	290,453	426,533	424,916	851,449
	Older	1,298	73,436	74,734	0	0	0
Unidentified	UNID	18,697,851	18,696,020	37,393,871	2,576,824	2,599,970	5,176,794
	Eggs	122,222	122,222	244,444	0	0	0
	Larvae	2,789,220	2,752,093	5,541,313	221,571	218,543	440,115
	Older	0	0	0	0	0	0
Alewife/ Gizzard Shad	All	30,953,607	30,863,992	61,817,598	429,653,835	425,480,017	855,133,853
Gizzard Shad	All	3,388,387	3,388,387	6,776,773	29,050,375	28,796,699	57,847,075
Darters	All	13,071,807	13,071,408	26,143,215	6,417,644	6,360,977	12,778,621
Carps and Minnows	All	204,352	201,033	405,384	10,914,809	10,835,038	21,749,846
Sunfishes	All	57,326	57,326	114,653	3,227,131	3,192,579	6,419,709
Catfishes	All	816,198	815,649	1,631,847	882,613	868,150	1,750,763
Other	All	276,192	348,330	624,520	715,265	706,516	1,421,781
Unidentified	All	21,609,293	21,570,335	43,179,628	2,798,395	2,818,513	5,616,909
All	UNID	39,350,662	39,348,831	78,699,491	310,130,542	307,413,316	617,543,857
	Eggs	2,980,455	2,980,455	5,960,910	15,131,123	15,062,799	30,193,920
	Larvae	27,060,543	26,933,402	53,993,944	152,602,657	150,844,217	303,446,876
	Older	985,502	1,053,772	2,039,273	5,795,745	5,738,157	11,533,904
All	All	70,377,162	70,316,460	140,693,618	483,660,067	479,058,489	962,718,557

Table 3-7. Density and abundance estimates for Location 1 during the entrainment season from 5 March through 30 September 2012 and 21 March through 3 October 2016. Estimates for 2012 are based on adjusted densities from Location 2 using Location Correction Factors for taxon group and all life stages combined (see Table 3-4).

Taxon Group	Life Stage Group	2012 (Adjusted to Location 1)				2016 (Location 1 actual)			
		Mean Density (#/100 m^3)	Abundance (N fish)			Mean Density (#/100 m^3)	Abundance (N fish)		
			Unit 2	Unit 3	Total		Unit 2	Unit 3	Total
Alewife/ Gizzard Shad	All	4.5	39,712,777	39,659,904	79,372,681	53.1	429,653,835	425,480,017	855,133,853
Gizzard Shad	All	0.7	5,892,505	5,892,505	11,785,010	3.6	29,050,375	28,796,699	57,847,075
Darters	All	1.1	9,673,137	9,672,842	19,345,979	0.8	6,417,644	6,360,977	12,778,621
Carps and Minnows	All	<0.1	453,659	446,292	899,952	1.4	10,914,809	10,835,038	21,749,846
Sunfishes	All	<0.1	57,326	57,326	114,653	0.4	3,227,131	3,192,579	6,419,709
Catfishes	All	<0.1	816,198	815,649	1,631,847	0.1	882,613	868,150	1,750,763
Other	All	<0.1	276,191	348,329	624,521	<0.1	715,265	706,516	1,421,781
Unidentified	All	2.5	22,589,290	22,537,287	45,126,576	0.4	2,798,395	2,818,513	5,616,909
All	All	8.8	79,471,083	79,430,134	158,901,219	59.8	483,660,067	479,058,489	962,718,557

Table 3-8. Density and abundance estimates for Location 1 during the entrainment season from 5 March through 30 September 2012 and 21 March through 3 October 2016. Estimates for 2012 are based on adjusted densities at Location 2 using Location Correction Factors for each life stage with all taxon groups combined (see Table 3-4).

Taxon Group	Life Stage Group	2012 (Adjusted to Location 1)				2016 (Location 1 actual)			
		Mean Density (#/100 m^3)	Abundance (N fish)			Mean Density (#/100 m^3)	Abundance (N fish)		
			Unit 2	Unit 3	Total		Unit 2	Unit 3	Total
All	UNID	4.9	43,909,971	43,908,909	87,818,880	38.4	310,130,542	307,413,316	617,543,857
	Eggs	0.6	5,726,600	5,726,600	11,453,200	1.9	15,131,123	15,062,799	30,193,920
	Larvae	3.1	27,798,512	27,658,326	55,456,838	18.8	152,602,657	150,844,217	303,446,876
	Older	0.1	985,501	1,053,772	2,039,273	0.8	5,795,745	5,738,157	11,533,904
	All	8.8	78,420,585	78,347,607	156,768,192	59.8	483,660,067	479,058,489	962,718,557

Table 3-9. Monthly (nominal month) mean density estimates by taxonomic group for Location 1 during the entrainment season from 5 March through 30 September 2012 and 21 March through 3 October 2016. Estimates for 2012 are adjusted densities from Location 2 using Location Correction Factors for each taxonomic group with all life stages combined (see Table 3-4).

Year	Taxonomic Group	Outer Intake Structure (Location 1) Density (#/100 m^3)						
		Mar	Apr	May	Jun	Jul	Aug	Sep
2012	Alewife/Gizzard Shad	0	0	7.3	18.3	3.2	<0.1	0
	Gizzard Shad	<0.1	0.8	3.4	0.5	0	0	0
	Darters	0.1	1.7	5.6	0.5	<0.1	0	0
	Carps and Minnows	0.1	0	0	<0.1	0	0.1	0
	Sunfishes	0	0	<0.1	0	0	0	0
	Catfishes	0	0	0	0.4	0.2	<0.1	0
	Other	0	0	0.1	<0.1	0	0	<0.1
	Unidentified	0.3	4.0	6.2	4.1	3.2	<0.1	0
2016	Alewife/Gizzard Shad		0	7.0	273.1	9.7	0.1	0
	Gizzard Shad		1.6	17.5	3.7	0.1	0.3	0
	Darters		0.4	1.1	3.0	0.1	<0.1	0
	Carps and Minnows		0	4.7	3.5	0	<0.1	0
	Sunfishes		0	0.1	0.6	1.1	0.6	0
	Catfishes		0	0.1	0.4	0.2	0	0.1
	Other		0	0.5	<0.1	0	0	0
	Unidentified		1.0	0.3	0.3	0.4	<0.1	0

Table 3-10. Monthly (nominal month) total (Unit 2 + Unit 3) entrainment abundance estimates by taxonomic group for Location 1 during the entrainment season from 5 March through 30 September 2012 and 21 March through 3 October 2016. Estimates for 2012 are adjusted densities from Location 2 using Location Correction Factors for each taxonomic group with all life stages combined (see Table 3-4).

Year	Taxonomic Group	Outer Intake Structure (Location 1) Entrainment Abundance (N fish)						
		Mar	Apr	May	Jun	Jul	Aug	Sep
2012	Alewife/Gizzard Shad	0	0	17,363,263	54,264,631	7,657,691	87,097	0
	Gizzard Shad	143,906	2,014,690	8,070,414	1,556,000	0	0	0
	Darters	290,598	4,068,374	13,350,182	1,529,707	107,117	0	0
	Carps and Minnows	298,864	0	0	279,540	0	321,548	0
	Sunfishes	0	0	114,653	0	0	0	0
	Catfishes	0	0	0	1,138,957	421,304	71,587	0
	Other	0	0	290,453	259,333	0	0	74,734
	Unidentified	684,474	9,582,634	14,718,986	12,233,580	7,685,471	221,432	0
2016	Alewife/Gizzard Shad		0	16,617,055	814,975,436	23,245,911	295,450	0
	Gizzard Shad		4,709,601	41,342,447	11,076,300	141,527	577,201	0
	Darters		949,526	2,647,925	8,895,934	145,955	139,282	0
	Carps and Minnows		0	11,109,261	10,492,838	0	147,747	0
	Sunfishes		0	141,578	1,905,238	2,624,110	1,748,782	0
	Catfishes		0	72,319	1,166,270	366,406	0	145,768
	Other		0	1,276,073	145,708	0	0	0
	Unidentified		2,851,162	717,914	874,246	1,025,790	147,796	0

Table 3-11. Monthly (nominal month) mean density estimates by life stage (all taxa combined) for Location 1 during the entrainment season from 5 March through 30 September 2012 and 21 March through 3 October 2016. Estimates for 2012 are adjusted densities from Location 2 using Location Correction Factors for each life stage with all taxonomic groups combined (see Table 3-4).

Year	Life Stage	Outer Intake Structure (Location 1) Density (#/100 m^3)						
		Mar	Apr	May	Jun	Jul	Aug	Sep
2012	UNID	0.2	2.4	11.7	18.0	0.2	0	0
	Egg	<0.1	0.7	3.3	0.6	0	0	0
	Larvae	0.2	2.3	6.0	5.0	8.4	0.1	0
	Older	<0.1	0	0.2	0.2	0.2	<0.1	<0.1
	All	0.5	5.5	21.3	23.8	8.7	0.2	<0.1
2016	UNID		1.0	3.9	202.7	0.2	0.1	0
	Egg		0.5	8.1	3.2	0	0	0
	Larvae		1.3	19.1	75.9	11.0	0.4	0
	Older		0.2	0.1	2.8	0.3	0.5	<0.1
	All		2.9	31.3	284.6	11.5	1.1	<0.1

Table 3-12. Monthly (nominal month) total (Unit 2 + Unit 3) entrainment abundance estimates by life stage (all taxa combined) for Location 1 during the entrainment season from 5 March through 30 September 2012 and 21 March through 3 October 2016. Estimates for 2012 are adjusted densities from Location 2 using Location Correction Factors for each life stage with all taxonomic groups combined (see Table 3-4).

Year	Life Stage	Outer Intake Structure (Location 1) Entrainment Abundance (N fish)						
		Mar	Apr	May	Jun	Jul	Aug	Sep
2012	UNID	409,028	5,726,390	27,858,817	53,438,662	385,982	0	0
	Egg	123,326	1,726,563	7,802,868	1,800,444	0	0	0
	Larvae	392,534	5,495,477	14,341,256	14,714,643	20,143,874	369,053	0
	Older	134,623	0	487,984	704,200	421,304	216,428	74,734
	All	1,059,511	12,948,430	50,490,925	70,657,950	20,951,161	585,481	74,734
2016	UNID		2,851,162	9,355,508	604,456,072	585,675	295,439	0
	Egg		1,419,868	19,153,989	9,620,065	0	0	0
	Larvae		3,718,829	45,102,752	227,002,758	26,306,379	1,316,157	0
	Older		520,430	312,323	8,453,075	657,646	1,444,662	145,768
	All		8,510,289	73,924,572	849,531,970	27,549,700	3,056,258	145,768

Table 3-13. Mean of all weekly densities during each diel period for Location 1 during the entrainment season from 5 March through 30 September 2012 and 21 March through 3 October 2016. Estimates for 2012 are adjusted densities from Location 2 using Location Correction Factors for each taxonomic group and life stage (see Table 3-4).

Taxonomic Group	Life Stage	Outer Intake Structure (Location 1) Density (#/100 m^3) by Diel Period (hhmm)							
		2012 (Adjusted to Location 1)				2016 (Actual)			
		0900–1500	1500–2100	2100–0300	0300–0900	0900–1500	1500–2100	2100–0300	0300–0900
Alewife / Gizzard Shad	UNID	2.4	0	0.2	2.2	32.5	8.9	62.4	33.5
	Eggs	0	0	0	0	0	0	0	0
	Larvae	1.4	2.2	1.0	1.0	6.0	13.7	7.8	28.2
	Older	0	0	0	0	0	0	0	0
Gizzard Shad	UNID	0	0	0	0	0	0	0	0
	Eggs	0.4	0.3	0.2	0.4	1.0	0.4	0.3	0.8
	Larvae	0	0	0	0.3	5.1	2.0	2.1	3.8
	Older	0	0	0	0	<0.1	<0.1	0	<0.1
Darters	UNID	0.1	<0.1	0.6	0.4	0	0	0	0
	Eggs	0	0	0	0	0	0	0	0
	Larvae	0.5	1.0	2.3	1.0	<0.1	<0.1	0.6	0.4
	Older	0	<0.1	<0.1	0	<0.1	0	1.5	0.4
Carps and Minnows	UNID	0	0	0	0	0	0	0	0
	Eggs	0	0	0	0	1.5	0.9	0.9	1.9
	Larvae	0	0	<0.1	0	0	0	0.3	<0.1
	Older	0	<0.1	0	0	0	0	0	0
Sunfishes	UNID	0	0	0	0	0	0	<0.1	0
	Eggs	0	0	0	0	0	0	0	0
	Larvae	0	<0.1	0	0	0.5	<0.1	0.2	0.6
	Older	0	0	0	0	0.1	<0.1	0	0
Catfishes	UNID	0	0	0	0	0	0	0	0
	Eggs	0	0	0	0	0	0	0	0
	Larvae	0	<0.1	<0.1	0	0	0	0	0
	Older	0	<0.1	0.3	0	0	0	0.2	0.2
Other	UNID	<0.1	0	0	0	0	0	0	0
	Eggs	0	0	0	0	0.2	0	0	0
	Larvae	0	0	<0.1	0	0.2	<0.1	0.1	<0.1
	Older	0	0	<0.1	0	0	0	0	<0.1
Unidentified	UNID	0.9	0.4	4.4	1.7	0.4	0.6	0.3	0
	Eggs	0	<0.1	0	<0.1	0	0	0	0
	Larvae	0.1	0.5	0.2	0.3	0	0	0	0.1
	Older	0	0	0	0	0	0	0	0
All	UNID	3.4	0.4	5.2	4.3	32.9	9.5	62.7	33.5
	Eggs	0.4	0.3	0.2	0.4	2.7	1.3	1.2	2.7
	Larvae	2.0	3.7	3.5	2.6	11.9	15.9	11.0	33.3
	Older	0.0	0.0	0.3	0.0	0.3	<0.1	1.7	0.7
All	All	5.8	4.4	9.2	7.3	47.8	26.7	76.6	70.2

Table 3-14. Monthly summary statistics for water quality parameter measurements taken during entrainment sample collecting at PBAPS during the entrainment season from 5 March through 30 September 2012 and 21 March through 3 October 2016.

		Location 2 Circulating Water Discharge Outfall										Location 3 Discharge Canal Outfall					Location 1 Outer Intake Structure				
		2012					2016					2016					2016				
Parameter	Month	n	Mean	SD	Min	Max	n	Mean	SD	Min	Max	n	Mean	SD	Min	Max	n	Mean	SD	Min	Max
Temperature (°C)	Mar	12	23.0	1.7	20.7	25.5	*n/a*					*n/a*					*n/a*				
	Apr	14	25.2	1.5	23.5	27.1	24	24.4	3.3	20.7	30.8	19	24.8	3.1	20.3	30.4	23	12.4	3.2	8.6	18.1
	May	16	28.6	2.7	24.4	32.1	16	28.0	1.6	26.5	31.1	16	28.0	1.7	25.9	31.1	16	16.2	1.8	14.4	19.5
	Jun	18	34.4	2.0	30.2	36.6	20	36.9	1.4	34.6	39.4	20	36.4	1.6	33.8	38.7	20	25.1	1.2	22.5	27.1
	Jul	20	39.6	0.9	38.2	41.1	16	41.0	1.2	38.6	42.8	16	38.8	0.7	37.5	39.7	16	28.7	1.3	26.5	30.5
	Aug	16	37.7	1.0	35.6	39.3	20	41.1	0.9	39.8	42.9	20	38.1	1.1	36.2	40.2	20	28.9	0.7	27.9	30.3
	Sep	16	33.2	2.2	30.5	37.1	16	38.7	1.5	35.8	40.1	16	38.6	1.4	35.4	39.7	16	26.5	1.5	23.2	28.0
	Mar-Sep	112	32.4	5.9	20.7	41.1	112	34.6	7.0	20.7	42.9	107	34.1	5.9	20.3	40.2	111	22.6	6.9	8.6	30.5
Dissolved Oxygen (mg/l)	Mar	12	11.7	1.7	8.2	13.6	*n/a*					*n/a*					*n/a*				
	Apr	14	10.4	1.6	8.4	13.2	24	9.8	0.5	8.8	10.5	19	10.0	0.5	9.1	10.7	23	9.6	0.6	8.5	10.6
	May	16	9.2	3.9	7.2	23.3	16	9.0	0.3	8.5	9.5	16	9.3	0.4	8.8	10.0	16	8.7	0.3	8.1	9.1
	Jun	18	7.1	1.0	5.7	9.2	20	8.0	0.5	7.2	8.8	20	8.0	0.5	7.1	8.8	20	7.4	0.5	6.7	8.3
	Jul	20	7.6	2.3	0.0	9.9	16	7.3	0.5	6.3	8.0	16	7.4	0.5	6.5	8.2	16	7.9	0.7	7.0	9.2
	Aug	16	7.5	1.4	5.1	10.6	20	6.7	0.4	6.2	7.8	20	6.8	0.3	6.4	7.2	20	7.6	0.5	6.8	8.4
	Sep	16	7.0	0.8	5.0	8.1	16	6.7	0.4	5.9	7.6	16	6.8	0.5	5.9	7.8	16	7.6	0.6	6.5	8.8
	Mar-Sep	112	8.4	2.6	0.0	23.3	112	8.0	1.3	5.9	10.5	107	8.1	1.3	5.9	10.7	111	8.2	1.0	6.5	10.6
pH	Mar	12	8.1	0.5	7.2	8.9	*n/a*					*n/a*					*n/a*				
	Apr	*n/a*					24	7.9	0.2	7.6	8.2	19	7.9	0.2	7.5	8.2	23	7.7	0.2	7.3	8.1
	May	10	7.7	0.3	7.1	8.1	16	7.7	0.2	7.5	8.1	16	7.7	0.1	7.5	7.9	16	7.5	0.2	7.1	7.9
	Jun	16	8.1	0.1	7.8	8.4	20	7.7	0.2	7.4	8.1	19	7.6	0.2	7.4	8.2	20	7.5	0.2	7.2	7.9
	Jul	16	8.3	0.2	8.0	8.7	16	8.4	0.4	7.6	8.8	16	8.4	0.4	7.7	8.8	16	8.3	0.5	7.5	8.9
	Aug	16	8.2	0.1	8.0	8.4	20	8.3	0.2	8.1	8.7	20	8.3	0.1	8.1	8.5	20	8.3	0.2	8.0	8.6
	Sep	16	8.2	0.2	7.9	8.4	16	8.2	0.2	7.9	8.7	16	8.1	0.2	7.8	8.6	16	8.1	0.2	7.8	8.7
	Mar-Sep	86	8.1	0.3	7.1	8.9	112	8.0	0.4	7.4	8.8	106	8.0	0.4	7.4	8.8	111	7.9	0.4	7.1	8.9
Specific Conductance (µs/cm)	Apr	*n/a*					23	222.8	12.3	203.0	241.2	19	225.3	12.6	203.4	243.5	23	217.5	12.3	198.0	237.0
	May						16	214.6	27.6	188.0	261.0	16	217.5	26.3	190.0	261.0	15	211.8	28.4	185.0	261.0
	Jun						20	260.7	26.7	217.0	295.0	20	262.2	25.3	218.0	297.1	20	258.7	25.3	215.0	293.0
	Jul						16	293.9	12.2	275.0	313.0	16	295.3	12.7	277.0	313.0	15	295.1	11.2	276.0	311.0
	Aug						20	311.5	13.5	285.0	328.0	20	311.4	15.6	284.2	330.0	20	311.2	14.1	285.0	327.0
	Sep						16	294.9	12.5	285.0	320.0	16	296.0	13.0	286.0	320.0	16	293.4	12.9	283.0	317.0
	Apr-Sep						111	265.1	41.5	188.0	328.0	107	268.1	40.4	190.0	330.0	109	263.3	42.9	185.0	327.0

SD = standard deviation

4.0 Analysis and Supporting Documentation (§122.21(r)(9)(iii))

4.1 Operational Intake Flows

Daily AIF for representative year 1 January through 31 December at PBAPS Units 2 and 3 during 2012 and 2016 are shown in Appendix A. Total weekly, sampling period, and annual AIF is summarized for 2012 in Table 4-1 (as 1,000 m^3) and Table 4-2 (as millions of gallons) and for 2016 in Table 4-3 (as 1,000 m^3) and Table 4-4 (as millions of gallons). Annual total water withdrawal volume for circulating and service water at Units 2 and 3 combined was similar between 2012 (740,867 million gallons; Table 4-2) and 2016 (787,594 million gallons; Table 4-4). In 2012, Units 2 and 3 were both operating during the weeks 10 through 38 of the entrainment sampling period, with only Unit 3 operating during the final sampling week (39). In 2016, Units 2 and 3 were both operating during the entire entrainment sampling period of weeks 12 through 39. Total AIF volumes during entrainment sampling periods were 454,047 million gallons in 2012 (weeks 10 through 39; Table 4-2), and 442,325 million gallons in 2016 (weeks 12 through 39; Table 4-4).

4.2 Quality Assurance/Quality Control

During the 2012 entrainment characterization study, PBAPS operated under the previous NPDES Permit No. PA 0009733 with an effective date of 1 January 2011. The permit requires qualified personnel and a formal QA/QC plan for an entrainment characterization study as described within Part C. section II.D.1 of the permit:

> *Entrainment data collection shall be performed by qualified consultants and/or trained professionals with the skills and knowledge appropriate for producing valid samples and evaluations under a formal QA/QC plan.*

The SOP, including a description of all field sampling and laboratory methods and all quality assurance/quality control (QA/QC) procedures for the 2012 entrainment characterization study are described in the document "Peach Bottom Atomic Power Station 2012 Entrainment Study Standard Operating Procedure and Quality Assurance Plan, Revision 1" dated March 2012 (Appendix B).

The SOP, including a description of all QA/QC procedures for the 2016 entrainment characterization study are described in the document "Standard Operating Procedures for Entrainment Abundance Sampling at Peach Bottom Atomic Power Station, Revision 1" dated 21 April 2016 (Appendix C).

4.2 Entrainment Data Analysis

Entrainment abundance, weekly and monthly densities, and limiting dimensions were tabulated for each taxon and life stage from the samples collected at PBAPS during 2012 and 2016. Body dimension measurement data were used to identify the proportion of each ichthyoplankton taxon and life stage expected to have a limiting dimension ≥14.2 mm (0.56 inches) and therefore be excluded from entrainment as defined by the §316(b) regulations. All

individuals measured from entrainment samples collected in 2012 had a limiting body dimension <14.2 mm, and therefore no proportion of any taxon or life stage was excluded from entrainment calculations. In 2016, three taxa were collected that had at least one individual with a limiting body dimension ≥14.2 mm. Only ichthyoplankton that were considered alive at the time of collection (methodology described in the SOP) were analyzed for entrainment density and abundance. The weekly entrainment abundances (i.e., total numbers) were determined using AIFs of cooling water at PBAPS. Weekly abundance estimates were summed into monthly and annual estimates of entrainment abundance by species using the methods described below.

Density (number per 100 m^3) in each sample from each of the three sampled locations at PBAPS (Outer Intake Structure, Location 1 [2016]; Circulating Water Discharge Outfall, Location 2 [2012 and 2016]; and the Discharge Canal Outfall Location 3 [2016]) were calculated by taxon and life stage as follows:

$$D_{sti} = C_{sti} \ / \ V_i \qquad \text{[Eq. 1]}$$

where D_{sti} = density for stage s of taxon t in sample i (number per 100 m^3),

C_{sti} = count for stage s of taxon t in sample i (scaled up to represent the whole sample if subsampling occurred), and

V_i = volume filtered in collecting sample i (in thousands of cubic meters).

Density for each six-hour diel period sample was averaged by taxon and life stage within each completed sampling day and considered representative of each sampling week as follows:

$$D_{stw} = [\Sigma_{i=1 \ to \ n} (D_{sti})]/n \qquad \text{[Eq. 2]}$$

where D_{stw} = density for stage s of taxon t in week w (number per 100 m^3),

D_{sti} = density for stage s of taxon t in six-hour sample i (number per 100 m^3), and

n = number of six-hour samples (=4) in week w.

Weekly densities were adjusted to only include the proportion of each taxa having a limiting body dimension <14.2 mm:

$$D_{LD,stw} = D_{stw} * P_{LD,st} \qquad \text{[Eq. 3]}$$

where

$D_{LD,st}$ = density for stage s of taxon t in week w with a limiting body dimension (LD) <14.2 mm,

$P_{LD,st}$ = proportion of stage s of taxon t with a limiting body dimension (LD) <14.2 mm

Total weekly entrainment abundance was estimated by multiplying weekly densities by weekly AIF volumes at PBAPS (Units 2 and 3 separately, and both combined), and then summed to estimate the total annual entrainment (number of fish) by taxon and life stage:

$$E_{st} = \sum_{w=1,52} (D_{LD,stw} F_w) \qquad \text{[Eq. 4]}$$

where E_{st} = annual number of life stage s of taxon t entrained,

$D_{LD,stw}$ = density for stage s of taxon t with LD<14.2 mm in week w (number per 100 m^3), and

F_w = total flow withdrawn from Conowingo Pond during week w (100s of m^3).

For the purpose of presenting some summarized results, selected taxa and life stages were grouped together into higher taxa and life stages and successive weeks were clustered into "months." Weekly densities were summed by life stage group (*i*) within each taxon group (*j*) for each week (*w*):

$$D_{LD,s_i t_j w} = \sum_{i,j} \left(D_{LD,stw}\right)_{i,j} \qquad \text{[Eq. 5]}$$

For 2012 data only, the location correction factor (LCF) was applied to Location 2 density estimates to estimate the density at Location 1:

$$D_{(Location\ 1),LD,s_i t_j w} = D_{(Location\ 2),LD,s_i t_j w} * LCF_{s_i t_j} \qquad \text{[Eq. 6]}$$

With all subscript notations as described above.

The monthly mean entrainment density for each taxon group (*i*) and life stage group (*j*) was then calculated as the average of the weekly densities (with P_{LD} and LCF applied where necessary) within each month:

$$D_{LD,s_i t_j m} = [\sum_{w=1\ to\ n} (D_{LD,s_i t_j w})]/n \qquad \text{[Eq. 7]}$$

where

$D_{LD,s_i t_j m}$ = density for stage group i of taxon group j in month m, having LD <14.2 mm

$D_{LD,s_i t_j w}$ = density for stage group i of taxon group j in week w, having LD <14.2 mm, and

n = number samples in week w

The overall mean entrainment density for each taxon group (*i*) and life stage group (*j*) was calculated using the weekly mean densities from Equation 5 (for 2016) and Equation 6 (for 2012):

$$D_{LD,s_i t_j} = [\Sigma_{w=1 \text{ to } n} (D_{LD,s_i t_j w})]/n \qquad \text{[Eq. 8]}$$

where

$D_{LD,s_i t_j w}$ = density for stage group i of taxon group j in week w (number per 100 m^3), and

n = total number of sampling weeks

The availability of synchronized weekly diel-averaged densities at three locations sampled during 2016 allowed for a paired design-based comparison of ichthyoplankton density differences between location pairs using a GLMM approach. If a significant location effect was present between the Circulating Water Discharge Outfall (Location 2) and the Outer Intake Structure (Location 1) then an LCF was estimated. This LCF was then used to adjust the 2012 density estimates from pump sampling at the Circulating Water Discharge Outfall (Location 2) to the expected densities at the Outer Intake Structure (Location 1). This adjustment provided a standardized two-year time series (2012 and 2016) to characterize the composition and variability of entrainment abundance at PBAPS.

A GLMM approach commonly used in paired-tow calibration studies of different vessels or gear types (Wilderbruer and Kappenman 1998; Cadigan and Dowden 2009; Milliken and Fogarty 2009; Braccini et al. 2012) to determine if significant differences in densities exist between two sampling locations at PBAPS.

For those taxonomic and life groups with significant differences in density between location pairs, an LCF analogous to fishing power correction factors used to calibrate trawl survey indices from multi-vessel surveys was estimated by the GLMM (i.e., randomized block analysis of variance in Wilderbruer et al. 1998). The LCF (also a ratio of the reference-to-alternate location) was estimated by the coefficient estimates from the GLMM via maximum pseudo-likelihood method using the "*fitglme*" function in Matlab software (version R2016b). Weekly mean densities for taxon *t* and stage *s* at location *i* (D_{stwi}) were natural log transformed as $\log_e(D_{stwi}+1)$ to approximate or meet normality and to accommodate zero densities at one location in a location pair. As such the GLMM was fitted assuming a normal distribution with an identity link function. Following Wilderbruer et al. (1998), the estimated $\log_e(D_{stwi}+1)$ at location *i* (reference =1, alternate = 2) during week *j* was the grand mean (μ) plus the estimated fixed effect of location (±β) and the estimated random effect of week (w_w) as a blocking variable and expressed by the following model formula:

$$\log_e(D_{stwi}+1) = \mu + \beta_i + w_w + \varepsilon_{iw} \qquad \text{[Eq. 9]}$$

where ε_{iw} is a normally distributed random variable. The LCF estimator for taxon group *t* and life stage group *s* was then estimated as

$$\widehat{LCF}_{ts} = \frac{\widehat{D_{ts,ref}}}{\widehat{D_{ts,alt}}} = 1/e^{2\beta(1+0.5SE^2)} \qquad \text{[Eq. 10]}$$

where $\widehat{D_{ts,\,ref}}$ and $\widehat{D_{ts,\,alt}}$ = estimated density for taxon group *t* and life stage group *s* at the reference and alternate location, respectively, independent of week effects (=$e^{(\mu+\beta)}$), $\beta_{alt} = +\beta$, $\beta_{ref} = -\beta$, and SE^2 = squared standard error for β as estimate of the variance. Week was considered a random blocking variable because sampling date represented only a fraction of all the possible sampling times (Underwood 1994). The *fitglme* function by default sets the coefficient for the first category (i.e., reference location) to zero so the parameter estimates provided in the output were given for the alternative location relative to the reference location instead of the grand mean; therefore, the parameter estimates ($\beta_{alt:ref}$ and $SE(\beta_{alt:ref})$) were halved to adjust to the grand mean and the inverse of the back-transformation to adjust the ratio to the reference location relative to the alternative location (i.e., ratios of Location 1 to Location 2, Location 1 to Location 3, and Location 2 to Location 3).

Table 4-1. Weekly water withdrawal volume (1000 m^3) based on AIF of circulating water and service water for Units 2 and 3 and both units combined at PBAPS during 1 January through 31 December 2012. Entrainment sample collection dates are in bold.

Week	Start Date	Unit 2 AIF (1,000 m^3)			Unit 3 AIF (1,000 m^3)			Unit 2 + Unit 3 AIF (1,000 m^3)
		Circulating Water	Service Water	Total	Circulating Water	Service Water	Total	
0	26-Dec-2011	2,725	153	2,878	4,088	153	4,241	7,119
1	02-Jan-2012	19,078	1,068	20,147	20,441	1,068	21,510	41,656
2	09-Jan-2012	19,078	1,068	20,147	21,804	1,068	22,872	43,019
3	16-Jan-2012	19,078	1,068	20,147	19,078	1,068	20,147	40,294
4	23-Jan-2012	20,441	1,068	21,510	19,078	1,068	20,147	41,656
5	30-Jan-2012	24,529	1,068	25,598	19,078	1,068	20,147	45,745
6	06-Feb-2012	19,078	1,068	20,147	19,078	1,068	20,147	40,294
7	13-Feb-2012	19,078	1,068	20,147	19,078	1,068	20,147	40,294
8	20-Feb-2012	19,078	1,068	20,147	19,078	1,068	20,147	40,294
9	27-Feb-2012	19,078	1,068	20,147	19,078	1,068	20,147	40,294
10	**05-Mar-2012**	**19,078**	**1,068**	**20,147**	**19,078**	**1,068**	**20,147**	**40,294**
11	**12-Mar-2012**	**27,255**	**1,068**	**28,323**	**25,892**	**1,068**	**26,961**	**55,284**
12	**19-Mar-2012**	**28,618**	**1,068**	**29,686**	**28,618**	**1,068**	**29,686**	**59,372**
13	**26-Mar-2012**	**28,618**	**1,068**	**29,686**	**28,618**	**1,068**	**29,686**	**59,372**
14	**02-Apr-2012**	**28,618**	**1,068**	**29,686**	**28,618**	**1,068**	**29,686**	**59,372**
15	**09-Apr-2012**	**28,618**	**1,068**	**29,686**	**28,618**	**1,068**	**29,686**	**59,372**
16	**16-Apr-2012**	**28,618**	**1,068**	**29,686**	**28,618**	**1,068**	**29,686**	**59,372**
17	**23-Apr-2012**	**28,618**	**1,068**	**29,686**	**28,618**	**1,068**	**29,686**	**59,372**
18	**30-Apr-2012**	**28,618**	**1,068**	**29,686**	**28,618**	**1,068**	**29,686**	**59,372**
19	**07-May-2012**	**28,618**	**1,068**	**29,686**	**28,618**	**1,068**	**29,686**	**59,372**
20	**14-May-2012**	**28,618**	**1,068**	**29,686**	**28,618**	**1,068**	**29,686**	**59,372**
21	**21-May-2012**	**28,618**	**1,068**	**29,686**	**28,618**	**1,068**	**29,686**	**59,372**
22	**28-May-2012**	**28,618**	**1,068**	**29,686**	**28,618**	**1,068**	**29,686**	**59,372**
23	**04-Jun-2012**	**28,618**	**1,068**	**29,686**	**28,618**	**1,068**	**29,686**	**59,372**
24	**11-Jun-2012**	**28,618**	**1,068**	**29,686**	**28,618**	**1,068**	**29,686**	**59,372**
25	**18-Jun-2012**	**28,618**	**1,068**	**29,686**	**28,618**	**1,068**	**29,686**	**59,372**
26	**25-Jun-2012**	**28,618**	**1,068**	**29,686**	**28,618**	**1,068**	**29,686**	**59,372**
27	**02-Jul-2012**	**28,618**	**1,232**	**29,850**	**28,618**	**1,068**	**29,686**	**59,536**
28	**09-Jul-2012**	**28,618**	**1,603**	**30,220**	**28,618**	**1,068**	**29,686**	**59,906**
29	**16-Jul-2012**	**28,618**	**1,603**	**30,220**	**28,618**	**1,529**	**30,147**	**60,367**
30	**23-Jul-2012**	**28,618**	**1,603**	**30,220**	**28,618**	**1,603**	**30,220**	**60,441**

(continued)

Table 4-1. Continued.

Week	Start Date	Unit 2 AIF (1000 m³)			Unit 3 AIF (1000 m³)			Unit 2 + Unit 3 AIF (1000 m³)
		Circulating Water	Service Water	Total	Circulating Water	Service Water	Total	
31	**30-Jul-2012**	**28,618**	**1,603**	**30,220**	**28,618**	**1,603**	**30,220**	**60,441**
32	**06-Aug-2012**	**28,618**	**1,603**	**30,220**	**28,618**	**1,603**	**30,220**	**60,441**
33	**13-Aug-2012**	**28,618**	**1,603**	**30,220**	**28,618**	**1,603**	**30,220**	**60,441**
34	**20-Aug-2012**	**28,618**	**1,603**	**30,220**	**28,618**	**1,603**	**30,220**	**60,441**
35	**27-Aug-2012**	**28,618**	**1,603**	**30,220**	**28,618**	**1,603**	**30,220**	**60,441**
36	**03-Sep-2012**	**28,618**	**1,603**	**30,220**	**28,618**	**1,603**	**30,220**	**60,441**
37	**10-Sep-2012**	**28,618**	**1,132**	**29,749**	**28,618**	**1,603**	**30,220**	**59,970**
38	**17-Sep-2012**	**8,176**	**580**	**8,757**	**28,618**	**1,603**	**30,220**	**38,977**
39	**24-Sep-2012**	**0**	**534**	**534**	**28,618**	**1,603**	**30,220**	**30,755**
40	01-Oct-2012	0	534	534	28,618	1,603	30,220	30,755
41	08-Oct-2012	0	534	534	28,618	1,603	30,220	30,755
42	15-Oct-2012	9,539	710	10,249	28,618	1,603	30,220	40,470
43	22-Oct-2012	28,618	1,068	29,686	28,618	1,603	30,220	59,906
44	29-Oct-2012	28,618	1,068	29,686	28,618	1,417	30,034	59,720
45	05-Nov-2012	28,618	1,068	29,686	28,618	1,068	29,686	59,372
46	12-Nov-2012	28,618	1,068	29,686	28,618	1,068	29,686	59,372
47	19-Nov-2012	28,618	1,068	29,686	28,618	1,068	29,686	59,372
48	26-Nov-2012	28,618	1,068	29,686	28,618	1,068	29,686	59,372
49	03-Dec-2012	28,618	1,068	29,686	28,618	1,068	29,686	59,372
50	10-Dec-2012	28,618	1,068	29,686	28,618	1,068	29,686	59,372
51	17-Dec-2012	28,618	1,068	29,686	28,618	1,068	29,686	59,372
52	24-Dec-2012	28,618	1,068	29,686	28,618	1,068	29,686	59,372
53	31-Dec-2012	4,088	153	4,241	4,088	153	4,241	8,482
0-53	1-Jan to 31-Dec	1,279,621	58,447	1,338,068	1,402,268	64,149	1,466,418	2,804,486
Sampled Weeks 10-39	**5-Mar to 30-Sep**	**798,577**	**36,061**	**834,630**	**846,274**	**37,851**	**884,117**	**1,718,756**

Table 4-2. Weekly water withdrawal volume (millions of gallons) based on AIF of circulating water (CW) and service water (SW) for Units 2 and 3 and both units combined at PBAPS during 1 January through 31 December 2012. Entrainment sample collection dates are in bold.

Week	Start Date	Unit 2 AIF (million gallons)			Unit 3 AIF (million gallons)			Unit 2 + Unit 3 AIF (million gallons)
		Circulating Water	Service Water	Total	Circulating Water	Service Water	Total	
0	26-Dec-2011	720	40	760	1,080	40	1,120	1,881
1	02-Jan-2012	5,040	282	5,322	5,400	282	5,682	11,004
2	09-Jan-2012	5,040	282	5,322	5,760	282	6,042	11,364
3	16-Jan-2012	5,040	282	5,322	5,040	282	5,322	10,645
4	23-Jan-2012	5,400	282	5,682	5,040	282	5,322	11,004
5	30-Jan-2012	6,480	282	6,762	5,040	282	5,322	12,085
6	06-Feb-2012	5,040	282	5,322	5,040	282	5,322	10,645
7	13-Feb-2012	5,040	282	5,322	5,040	282	5,322	10,645
8	20-Feb-2012	5,040	282	5,322	5,040	282	5,322	10,645
9	27-Feb-2012	5,040	282	5,322	5,040	282	5,322	10,645
10	**05-Mar-2012**	5,040	282	5,322	5,040	282	5,322	10,645
11	**12-Mar-2012**	7,200	282	7,482	6,840	282	7,122	14,604
12	**19-Mar-2012**	7,560	282	7,842	7,560	282	7,842	15,684
13	**26-Mar-2012**	7,560	282	7,842	7,560	282	7,842	15,684
14	**02-Apr-2012**	7,560	282	7,842	7,560	282	7,842	15,684
15	**09-Apr-2012**	7,560	282	7,842	7,560	282	7,842	15,684
16	**16-Apr-2012**	7,560	282	7,842	7,560	282	7,842	15,684
17	**23-Apr-2012**	7,560	282	7,842	7,560	282	7,842	15,684
18	**30-Apr-2012**	7,560	282	7,842	7,560	282	7,842	15,684
19	**07-May-2012**	7,560	282	7,842	7,560	282	7,842	15,684
20	**14-May-2012**	7,560	282	7,842	7,560	282	7,842	15,684
21	**21-May-2012**	7,560	282	7,842	7,560	282	7,842	15,684
22	**28-May-2012**	7,560	282	7,842	7,560	282	7,842	15,684
23	**04-Jun-2012**	7,560	282	7,842	7,560	282	7,842	15,684
24	**11-Jun-2012**	7,560	282	7,842	7,560	282	7,842	15,684
25	**18-Jun-2012**	7,560	282	7,842	7,560	282	7,842	15,684
26	**25-Jun-2012**	7,560	282	7,842	7,560	282	7,842	15,684
27	**02-Jul-2012**	7,560	325	7,886	7,560	282	7,842	15,728
28	**09-Jul-2012**	7,560	423	7,983	7,560	282	7,842	15,825
29	**16-Jul-2012**	7,560	423	7,983	7,560	404	7,964	15,947
30	**23-Jul-2012**	7,560	423	7,983	7,560	423	7,983	15,967

(Continued)

Table 4-2. Continued.

Week	Start Date	Unit 2 AIF (million gallons)			Unit 3 AIF (million gallons)			Unit 2 + Unit 3 AIF (million gallons)
		Circulating Water	Service Water	Total	Circulating Water	Service Water	Total	
31	**30-Jul-2012**	7,560	423	7,983	7,560	423	7,983	15,967
32	**06-Aug-2012**	7,560	423	7,983	7,560	423	7,983	15,967
33	**13-Aug-2012**	7,560	423	7,983	7,560	423	7,983	15,967
34	**20-Aug-2012**	7,560	423	7,983	7,560	423	7,983	15,967
35	**27-Aug-2012**	7,560	423	7,983	7,560	423	7,983	15,967
36	**03-Sep-2012**	7,560	423	7,983	7,560	423	7,983	15,967
37	**10-Sep-2012**	7,560	299	7,859	7,560	423	7,983	15,842
38	**17-Sep-2012**	2,160	153	2,313	7,560	423	7,983	10,297
39	**24-Sep-2012**	0	141	141	7,560	423	7,983	8,125
40	01-Oct-2012	0	141	141	7,560	423	7,983	8,125
41	08-Oct-2012	0	141	141	7,560	423	7,983	8,125
42	15-Oct-2012	2,520	188	2,707	7,560	423	7,983	10,691
43	22-Oct-2012	7,560	282	7,842	7,560	423	7,983	15,825
44	29-Oct-2012	7,560	282	7,842	7,560	374	7,934	15,776
45	05-Nov-2012	7,560	282	7,842	7,560	282	7,842	15,684
46	12-Nov-2012	7,560	282	7,842	7,560	282	7,842	15,684
47	19-Nov-2012	7,560	282	7,842	7,560	282	7,842	15,684
48	26-Nov-2012	7,560	282	7,842	7,560	282	7,842	15,684
49	03-Dec-2012	7,560	282	7,842	7,560	282	7,842	15,684
50	10-Dec-2012	7,560	282	7,842	7,560	282	7,842	15,684
51	17-Dec-2012	7,560	282	7,842	7,560	282	7,842	15,684
52	24-Dec-2012	7,560	282	7,842	7,560	282	7,842	15,684
53	31-Dec-2012	1,080	40	1,120	1,080	40	1,120	2,241
0-53	1-Jan to 31-Dec	338,040	15,440	353,480	370,440	16,946	387,387	740,867
Sampled Weeks 10-39	**5-Mar to 30-Sep**	210,962	9,526	220,486	223,562	9,999	233,559	454,047

Table 4-3. Weekly water withdrawal volume (1000 m^3) based on AIF of circulating water (CW) and service water (SW) for Units 2 and 3 and both units combined at PBAPS during 1 January through 31 December 2016. Entrainment sample collection dates are in bold.

Week	Start Date	Unit 2 AIF (1000 m^3)			Unit 3 AIF (1000 m^3)			Unit 2 + Unit 3 AIF (1000 m^3)
		Circulating Water	Service Water	Total	Circulating Water	Service Water	Total	
0	01-Jan-2016	12,268	458	12,725	12,268	458	12,725	25,451
1	04-Jan-2016	28,618	1,068	29,686	27,969	1,069	29,038	58,724
2	11-Jan-2016	28,618	1,068	29,686	28,618	1,068	29,686	59,372
3	18-Jan-2016	22,346	1,069	23,415	22,375	1,069	23,443	46,858
4	25-Jan-2016	19,078	1,068	20,147	19,481	1,069	20,549	40,696
5	01-Feb-2016	22,317	1,069	23,385	23,523	1,069	24,592	47,977
6	08-Feb-2016	28,618	1,068	29,686	26,501	1,069	27,569	57,255
7	15-Feb-2016	28,618	1,068	29,686	25,194	1,069	26,262	55,948
8	22-Feb-2016	28,618	1,068	29,686	28,618	1,068	29,686	59,372
9	29-Feb-2016	28,618	1,068	29,686	28,618	1,068	29,686	59,372
10	07-Mar-2016	28,618	1,068	29,686	28,121	1,069	29,190	58,876
11	14-Mar-2016	28,618	1,068	29,686	28,618	1,068	29,686	59,372
12	**21-Mar-2016**	**28,618**	**1,068**	**29,686**	**28,618**	**1,068**	**29,686**	**59,372**
13	**28-Mar-2016**	**28,618**	**1,068**	**29,686**	**28,618**	**1,068**	**29,686**	**59,372**
14	**04-Apr-2016**	**28,462**	**1,069**	**29,530**	**28,618**	**1,068**	**29,686**	**59,216**
15	**11-Apr-2016**	**28,618**	**1,068**	**29,686**	**28,618**	**1,068**	**29,686**	**59,372**
16	**18-Apr-2016**	**28,618**	**1,068**	**29,686**	**28,618**	**1,068**	**29,686**	**59,372**
17	**25-Apr-2016**	**27,813**	**1,069**	**28,882**	**28,618**	**1,068**	**29,686**	**58,568**
18	**02-May-2016**	**28,618**	**1,068**	**29,686**	**28,551**	**1,069**	**29,620**	**59,306**
19	**09-May-2016**	**28,618**	**1,068**	**29,686**	**28,618**	**1,068**	**29,686**	**59,372**
20	**16-May-2016**	**28,618**	**1,068**	**29,686**	**27,884**	**1,069**	**28,953**	**58,639**
21	**23-May-2016**	**28,618**	**1,068**	**29,686**	**28,618**	**1,068**	**29,686**	**59,372**
22	**30-May-2016**	**28,618**	**1,327**	**29,945**	**28,618**	**1,068**	**29,686**	**59,631**
23	**06-Jun-2016**	**28,618**	**1,603**	**30,220**	**28,618**	**1,068**	**29,686**	**59,906**
24	**13-Jun-2016**	**28,543**	**1,603**	**30,146**	**28,618**	**1,068**	**29,686**	**59,832**
25	**20-Jun-2016**	**28,618**	**1,603**	**30,220**	**28,618**	**1,068**	**29,686**	**59,906**
26	**27-Jun-2016**	**28,618**	**1,603**	**30,220**	**28,618**	**1,420**	**30,037**	**60,258**
27	**04-Jul-2016**	**28,618**	**1,603**	**30,220**	**28,618**	**1,190**	**29,807**	**60,028**
28	**11-Jul-2016**	**28,618**	**1,603**	**30,220**	**28,618**	**1,068**	**29,686**	**59,906**
29	**18-Jul-2016**	**28,618**	**1,603**	**30,220**	**28,618**	**1,068**	**29,686**	**59,906**
30	**25-Jul-2016**	**28,618**	**1,603**	**30,220**	**28,547**	**1,401**	**29,947**	**60,168**

(Continued)

Table 4-3. Continued.

Week	Start Date	Unit 2 AIF (1000 m³)			Unit 3 AIF (1000 m³)			Unit 2 + Unit 3 AIF (1000 m³)
		Circulating Water	Service Water	Total	Circulating Water	Service Water	Total	
31	**01-Aug-2016**	**28,618**	**1,603**	**30,220**	**28,618**	**1,603**	**30,220**	**60,441**
32	**08-Aug-2016**	**28,618**	**1,603**	**30,220**	**28,618**	**1,603**	**30,220**	**60,441**
33	**15-Aug-2016**	**28,618**	**1,603**	**30,220**	**28,618**	**1,603**	**30,220**	**60,441**
34	**22-Aug-2016**	**28,618**	**1,603**	**30,220**	**28,618**	**1,603**	**30,220**	**60,441**
35	**29-Aug-2016**	**28,367**	**1,603**	**29,970**	**28,618**	**1,603**	**30,220**	**60,190**
36	**05-Sep-2016**	**28,618**	**1,603**	**30,220**	**27,826**	**1,603**	**29,428**	**59,649**
37	**12-Sep-2016**	**28,618**	**1,603**	**30,220**	**28,572**	**1,603**	**30,175**	**60,395**
38	**19-Sep-2016**	**28,618**	**1,603**	**30,220**	**28,618**	**1,603**	**30,220**	**60,441**
39	**26-Sep-2016**	**28,618**	**1,603**	**30,220**	**28,618**	**1,603**	**30,220**	**60,441**
40	03-Oct-2016	28,618	1,261	29,879	28,618	1,266	29,884	59,763
41	10-Oct-2016	28,618	1,068	29,686	27,960	1,069	29,029	58,715
42	17-Oct-2016	28,355	1,069	29,423	28,618	1,068	29,686	59,109
43	24-Oct-2016	1,749	367	2,116	28,618	1,289	29,907	32,023
44	31-Oct-2016	0	376	376	28,618	1,227	29,845	30,220
45	07-Nov-2016	16,271	793	17,063	28,618	1,068	29,686	46,749
46	14-Nov-2016	28,618	1,068	29,686	28,618	1,068	29,686	59,372
47	21-Nov-2016	28,618	1,068	29,686	28,618	1,068	29,686	59,372
48	28-Nov-2016	26,179	1,069	27,247	28,618	1,068	29,686	56,934
49	05-Dec-2016	19,078	1,068	20,147	28,618	1,068	29,686	49,833
50	12-Dec-2016	24,607	1,069	25,676	28,618	1,068	29,686	55,362
51	19-Dec-2016	28,618	1,068	29,686	28,618	1,068	29,686	59,372
52	26-Dec-2016	24,529	916	25,445	24,529	916	25,445	50,890
0-52	1-Jan to 31-Dec	1,388,828	63,728	1,452,537	1,466,785	62,052	1,528,821	2,981,369
Sampled Weeks 12-39	**21-Mar to 2 Oct**	**800,017**	**39,260**	**839,261**	**799,594**	**35,528**	**835,111**	**1,674,382**

Table 4-4. Weekly water withdrawal volume (millions of gallons) based on AIF of circulating water (CW) and service water (SW) for Units 2 and 3 and both units combined at PBAPS during 1 January through 31 December 2016. Entrainment sample collection dates are in bold.

Week	Start Date	Unit 2 AIF (million gallons)			Unit 3 AIF (million gallons)			Unit 2 + Unit 3 AIF (million gallons)
		Circulating Water	Service Water	Total	Circulating Water	Service Water	Total	
0	01-Jan-2016	3,241	121	3,362	3,241	121	3,362	6,723
1	04-Jan-2016	7,560	282	7,842	7,389	282	7,671	15,513
2	11-Jan-2016	7,560	282	7,842	7,560	282	7,842	15,684
3	18-Jan-2016	5,903	282	6,186	5,911	282	6,193	12,379
4	25-Jan-2016	5,040	282	5,322	5,146	282	5,428	10,751
5	01-Feb-2016	5,896	282	6,178	6,214	282	6,497	12,674
6	08-Feb-2016	7,560	282	7,842	7,001	282	7,283	15,125
7	15-Feb-2016	7,560	282	7,842	6,656	282	6,938	14,780
8	22-Feb-2016	7,560	282	7,842	7,560	282	7,842	15,684
9	29-Feb-2016	7,560	282	7,842	7,560	282	7,842	15,684
10	07-Mar-2016	7,560	282	7,842	7,429	282	7,711	15,553
11	14-Mar-2016	7,560	282	7,842	7,560	282	7,842	15,684
12	**21-Mar-2016**	7,560	282	7,842	7,560	282	7,842	15,684
13	**28-Mar-2016**	7,560	282	7,842	7,560	282	7,842	15,684
14	**04-Apr-2016**	7,519	282	7,801	7,560	282	7,842	15,643
15	**11-Apr-2016**	7,560	282	7,842	7,560	282	7,842	15,684
16	**18-Apr-2016**	7,560	282	7,842	7,560	282	7,842	15,684
17	**25-Apr-2016**	7,347	282	7,630	7,560	282	7,842	15,472
18	**02-May-2016**	7,560	282	7,842	7,542	282	7,825	15,667
19	**09-May-2016**	7,560	282	7,842	7,560	282	7,842	15,684
20	**16-May-2016**	7,560	282	7,842	7,366	282	7,649	15,491
21	**23-May-2016**	7,560	282	7,842	7,560	282	7,842	15,684
22	**30-May-2016**	7,560	351	7,911	7,560	282	7,842	15,753
23	**06-Jun-2016**	7,560	423	7,983	7,560	282	7,842	15,825
24	**13-Jun-2016**	7,540	423	7,964	7,560	282	7,842	15,806
25	**20-Jun-2016**	7,560	423	7,983	7,560	282	7,842	15,825
26	**27-Jun-2016**	7,560	423	7,983	7,560	375	7,935	15,918
27	**04-Jul-2016**	7,560	423	7,983	7,560	314	7,874	15,858
28	**11-Jul-2016**	7,560	423	7,983	7,560	282	7,842	15,825
29	**18-Jul-2016**	7,560	423	7,983	7,560	282	7,842	15,825
30	**25-Jul-2016**	7,560	423	7,983	7,541	370	7,911	15,895

(Continued)

Table 4-4. Continued.

Week	Start Date	Unit 2 AIF (million gallons)			Unit 3 AIF (million gallons)			Unit 2 + Unit 3 AIF (million gallons)
		Circulating Water	Service Water	Total	Circulating Water	Service Water	Total	
31	**01-Aug-2016**	7,560	423	7,983	7,560	423	7,983	15,967
32	**08-Aug-2016**	7,560	423	7,983	7,560	423	7,983	15,967
33	**15-Aug-2016**	7,560	423	7,983	7,560	423	7,983	15,967
34	**22-Aug-2016**	7,560	423	7,983	7,560	423	7,983	15,967
35	**29-Aug-2016**	7,494	423	7,917	7,560	423	7,983	15,901
36	**05-Sep-2016**	7,560	423	7,983	7,351	423	7,774	15,758
37	**12-Sep-2016**	7,560	423	7,983	7,548	423	7,971	15,955
38	**19-Sep-2016**	7,560	423	7,983	7,560	423	7,983	15,967
39	**26-Sep-2016**	7,560	423	7,983	7,560	423	7,983	15,967
40	03-Oct-2016	7,560	333	7,893	7,560	334	7,895	15,788
41	10-Oct-2016	7,560	282	7,842	7,386	282	7,669	15,511
42	17-Oct-2016	7,491	282	7,773	7,560	282	7,842	15,615
43	24-Oct-2016	462	97	559	7,560	341	7,901	8,460
44	31-Oct-2016	0	99	99	7,560	324	7,884	7,983
45	07-Nov-2016	4,298	209	4,508	7,560	282	7,842	12,350
46	14-Nov-2016	7,560	282	7,842	7,560	282	7,842	15,684
47	21-Nov-2016	7,560	282	7,842	7,560	282	7,842	15,684
48	28-Nov-2016	6,916	282	7,198	7,560	282	7,842	15,040
49	05-Dec-2016	5,040	282	5,322	7,560	282	7,842	13,164
50	12-Dec-2016	6,500	282	6,783	7,560	282	7,842	14,625
51	19-Dec-2016	7,560	282	7,842	7,560	282	7,842	15,684
52	26-Dec-2016	6,480	242	6,722	6,480	242	6,722	13,444
0-52	1-Jan to 31-Dec	366,889	16,835	383,720	387,484	16,392	403,872	787,594
Sampled Weeks 12-39	**21-Mar to 2 Oct**	211,342	10,371	221,709	211,230	9,386	220,613	442,325

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Appendix A: Daily AIF for Representative Year from 1 January through 31 December, Peach Bottom Atomic Power Station Units 2 and 3 during 2012 and 2016

Table A-1. Daily and weekly Actual Intake Flow (AIF) of circulating water (CW) and service water (SW) in millions of gallons for Units 2 and 3 and Both Units Combined at PBAPS during 1 January through 31 December 2012. Entrainment sample collection dates are highlighted in light green.

Week Number (Beginning Mon.)	Date	Unit 2			Unit 3			Both Units Combined		
		CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)
0	01-Jan-12	720	40	760	1,080	40	1,120	1,800	81	1,881
(26DEC2011)	Week Total	720	40	760	1,080	40	1,120	1,800	81	1,881
1	02-Jan-12	720	40	760	1,080	40	1,120	1,800	81	1,881
(02JAN2012)	03-Jan-12	720	40	760	720	40	760	1,440	81	1,521
	04-Jan-12	720	40	760	720	40	760	1,440	81	1,521
	05-Jan-12	720	40	760	720	40	760	1,440	81	1,521
	06-Jan-12	720	40	760	720	40	760	1,440	81	1,521
	07-Jan-12	720	40	760	720	40	760	1,440	81	1,521
	08-Jan-12	720	40	760	720	40	760	1,440	81	1,521
	Week Total	5,040	282	5,322	5,400	282	5,682	10,440	564	11,004
2	09-Jan-12	720	40	760	720	40	760	1,440	81	1,521
(09JAN2012)	10-Jan-12	720	40	760	720	40	760	1,440	81	1,521
	11-Jan-12	720	40	760	720	40	760	1,440	81	1,521
	12-Jan-12	720	40	760	1,080	40	1,120	1,800	81	1,881
	13-Jan-12	720	40	760	1,080	40	1,120	1,800	81	1,881
	14-Jan-12	720	40	760	720	40	760	1,440	81	1,521
	15-Jan-12	720	40	760	720	40	760	1,440	81	1,521
	Week Total	5,040	282	5,322	5,760	282	6,042	10,800	564	11,364

(continued)

Table A-1 (continued).

Week Number (Beginning Mon.)	Date	Unit 2			Unit 3			Both Units Combined		
		CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)
3 (16JAN2012)	16-Jan-12	720	40	760	720	40	760	1,440	81	1,521
	17-Jan-12	720	40	760	720	40	760	1,440	81	1,521
	18-Jan-12	720	40	760	720	40	760	1,440	81	1,521
	19-Jan-12	720	40	760	720	40	760	1,440	81	1,521
	20-Jan-12	720	40	760	720	40	760	1,440	81	1,521
	21-Jan-12	720	40	760	720	40	760	1,440	81	1,521
	22-Jan-12	720	40	760	720	40	760	1,440	81	1,521
	Week Total	5,040	282	5,322	5,040	282	5,322	10,080	564	10,644
4 (23JAN2012)	23-Jan-12	720	40	760	720	40	760	1,440	81	1,521
	24-Jan-12	720	40	760	720	40	760	1,440	81	1,521
	25-Jan-12	720	40	760	720	40	760	1,440	81	1,521
	26-Jan-12	720	40	760	720	40	760	1,440	81	1,521
	27-Jan-12	720	40	760	720	40	760	1,440	81	1,521
	28-Jan-12	720	40	760	720	40	760	1,440	81	1,521
	29-Jan-12	1,080	40	1,120	720	40	760	1,800	81	1,881
	Week Total	5,400	282	5,682	5,040	282	5,322	10,440	564	11,004
5 (30JAN2012)	30-Jan-12	1,080	40	1,120	720	40	760	1,800	81	1,881
	31-Jan-12	1,080	40	1,120	720	40	760	1,800	81	1,881
	01-Feb-12	1,080	40	1,120	720	40	760	1,800	81	1,881
	02-Feb-12	1,080	40	1,120	720	40	760	1,800	81	1,881
	03-Feb-12	720	40	760	720	40	760	1,440	81	1,521
	04-Feb-12	720	40	760	720	40	760	1,440	81	1,521
	05-Feb-12	720	40	760	720	40	760	1,440	81	1,521
	Week Total	6,480	282	6,762	5,040	282	5,322	11,520	564	12,084

(continued)

Table A-1 (continued).

Week Number (Beginning Mon.)	Date	Unit 2			Unit 3			Both Units Combined		
		CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)
6	06-Feb-12	720	40	760	720	40	760	1,440	81	1,521
(06FEB2012)	07-Feb-12	720	40	760	720	40	760	1,440	81	1,521
	08-Feb-12	720	40	760	720	40	760	1,440	81	1,521
	09-Feb-12	720	40	760	720	40	760	1,440	81	1,521
	10-Feb-12	720	40	760	720	40	760	1,440	81	1,521
	11-Feb-12	720	40	760	720	40	760	1,440	81	1,521
	12-Feb-12	720	40	760	720	40	760	1,440	81	1,521
	Week	5,040	282	5,322	5,040	282	5,322	10,080	564	10,644
7	13-Feb-12	720	40	760	720	40	760	1,440	81	1,521
(13FEB2012)	14-Feb-12	720	40	760	720	40	760	1,440	81	1,521
	15-Feb-12	720	40	760	720	40	760	1,440	81	1,521
	16-Feb-12	720	40	760	720	40	760	1,440	81	1,521
	17-Feb-12	720	40	760	720	40	760	1,440	81	1,521
	18-Feb-12	720	40	760	720	40	760	1,440	81	1,521
	19-Feb-12	720	40	760	720	40	760	1,440	81	1,521
	Week	5,040	282	5,322	5,040	282	5,322	10,080	564	10,644
8	20-Feb-12	720	40	760	720	40	760	1,440	81	1,521
(20FEB2012)	21-Feb-12	720	40	760	720	40	760	1,440	81	1,521
	22-Feb-12	720	40	760	720	40	760	1,440	81	1,521
	23-Feb-12	720	40	760	720	40	760	1,440	81	1,521
	24-Feb-12	720	40	760	720	40	760	1,440	81	1,521
	25-Feb-12	720	40	760	720	40	760	1,440	81	1,521
	26-Feb-12	720	40	760	720	40	760	1,440	81	1,521
	Week	5,040	282	5,322	5,040	282	5,322	10,080	564	10,644

(continued)

Table A-1 (continued).

Week Number (Beginning Mon.)	Date	Unit 2			Unit 3			Both Units Combined		
		CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)
9 (27FEB2012)	27-Feb-12	720	40	760	720	40	760	1,440	81	1,521
	28-Feb-12	720	40	760	720	40	760	1,440	81	1,521
	29-Feb-12	720	40	760	720	40	760	1,440	81	1,521
	01-Mar-12	720	40	760	720	40	760	1,440	81	1,521
	02-Mar-12	720	40	760	720	40	760	1,440	81	1,521
	03-Mar-12	720	40	760	720	40	760	1,440	81	1,521
	04-Mar-12	720	40	760	720	40	760	1,440	81	1,521
	Week Total	5,040	282	5,322	5,040	282	5,322	10,080	564	10,644
10 (05MAR2012)	05-Mar-12	720	40	760	720	40	760	1,440	81	1,521
	06-Mar-12	720	40	760	720	40	760	1,440	81	1,521
	07-Mar-12	720	40	760	720	40	760	1,440	81	1,521
	08-Mar-12	720	40	760	720	40	760	1,440	81	1,521
	09-Mar-12	720	40	760	720	40	760	1,440	81	1,521
	10-Mar-12	720	40	760	720	40	760	1,440	81	1,521
	11-Mar-12	720	40	760	720	40	760	1,440	81	1,521
	Week Total	5,040	282	5,322	5,040	282	5,322	10,080	564	10,644
11 (12MAR2012)	12-Mar-12	720	40	760	720	40	760	1,440	81	1,521
	13-Mar-12	1,080	40	1,120	720	40	760	1,800	81	1,881
	14-Mar-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	15-Mar-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	16-Mar-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	17-Mar-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	18-Mar-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	Week Total	7,200	282	7,482	6,840	282	7,122	14,040	564	14,604

(continued)

Table A-1 (continued).

Week Number (Beginning Mon.)	Date	Unit 2			Unit 3			Both Units Combined		
		CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)
12 (19MAR2012)	19-Mar-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	20-Mar-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	21-Mar-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	22-Mar-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	23-Mar-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	24-Mar-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	25-Mar-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	Week Total	7,560	282	7,842	7,560	282	7,842	15,120	564	15,684
13 (26MAR2012)	26-Mar-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	27-Mar-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	28-Mar-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	29-Mar-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	30-Mar-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	31-Mar-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	01-Apr-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	Week Total	7,560	282	7,842	7,560	282	7,842	15,120	564	15,684
14 (02APR2012)	02-Apr-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	03-Apr-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	04-Apr-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	05-Apr-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	06-Apr-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	07-Apr-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	08-Apr-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	Week Total	7,560	282	7,842	7,560	282	7,842	15,120	564	15,684

(continued)

Table A-1 (continued).

Week Number (Beginning Mon.)	Date	Unit 2			Unit 3			Both Units Combined		
		CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)
15 (09APR2012)	09-Apr-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	10-Apr-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	11-Apr-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	12-Apr-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	13-Apr-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	14-Apr-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	15-Apr-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	Week Total	7,560	282	7,842	7,560	282	7,842	15,120	564	15,684
16 (16APR2012)	16-Apr-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	17-Apr-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	18-Apr-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	19-Apr-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	20-Apr-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	21-Apr-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	22-Apr-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	Week Total	7,560	282	7,842	7,560	282	7,842	15,120	564	15,684
17 (23APR2012)	23-Apr-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	24-Apr-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	25-Apr-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	26-Apr-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	27-Apr-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	28-Apr-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	29-Apr-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	Week Total	7,560	282	7,842	7,560	282	7,842	15,120	564	15,684

(continued)

Table A-1 (continued).

Week Number (Beginning Mon.)	Date	Unit 2			Unit 3			Both Units Combined		
		CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)
18 (30APR2012)	30-Apr-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	01-May-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	02-May-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	03-May-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	04-May-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	05-May-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	06-May-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	Week Total	7,560	282	7,842	7,560	282	7,842	15,120	564	15,684
19 (07MAY2012)	07-May-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	08-May-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	09-May-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	10-May-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	11-May-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	12-May-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	13-May-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	Week Total	7,560	282	7,842	7,560	282	7,842	15,120	564	15,684
20 (14MAY2012)	14-May-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	15-May-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	16-May-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	17-May-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	18-May-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	19-May-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	20-May-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	Week Total	7,560	282	7,842	7,560	282	7,842	15,120	564	15,684

(continued)

Table A-1 (continued).

Week Number (Beginning Mon.)	Date	Unit 2			Unit 3			Both Units Combined		
		CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)
21 (21MAY2012)	21-May-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	22-May-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	23-May-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	24-May-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	25-May-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	26-May-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	27-May-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	Week Total	7,560	282	7,842	7,560	282	7,842	15,120	564	15,684
22 (28MAY2012)	28-May-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	29-May-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	30-May-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	31-May-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	01-Jun-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	02-Jun-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	03-Jun-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	Week Total	7,560	282	7,842	7,560	282	7,842	15,120	564	15,684
23 (04JUN2012)	04-Jun-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	05-Jun-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	06-Jun-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	07-Jun-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	08-Jun-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	09-Jun-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	10-Jun-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	Week Total	7,560	282	7,842	7,560	282	7,842	15,120	564	15,684

(continued)

Table A-1 (continued).

Week Number (Beginning Mon.)	Date	Unit 2			Unit 3			Both Units Combined		
		CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)
24 (11JUN2012)	11-Jun-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	12-Jun-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	13-Jun-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	14-Jun-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	15-Jun-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	16-Jun-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	17-Jun-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	Week Total	7,560	282	7,842	7,560	282	7,842	15,120	564	15,684
25 (18JUN2012)	18-Jun-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	19-Jun-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	20-Jun-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	21-Jun-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	22-Jun-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	23-Jun-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	24-Jun-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	Week Total	7,560	282	7,842	7,560	282	7,842	15,120	564	15,684
26 (25JUN2012)	25-Jun-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	26-Jun-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	27-Jun-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	28-Jun-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	29-Jun-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	30-Jun-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	01-Jul-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	Week Total	7,560	282	7,842	7,560	282	7,842	15,120	564	15,684

(continued)

Table A-1 (continued).

Week Number (Beginning Mon.)	Date	Unit 2			Unit 3			Both Units Combined		
		CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)
27 (02JUL2012)	02-Jul-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	03-Jul-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	04-Jul-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	05-Jul-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	06-Jul-12	1,080	43	1,123	1,080	40	1,120	2,160	84	2,244
	07-Jul-12	1,080	60	1,140	1,080	40	1,120	2,160	101	2,261
	08-Jul-12	1,080	60	1,140	1,080	40	1,120	2,160	101	2,261
	Week Total	7,560	326	7,886	7,560	282	7,842	15,120	608	15,728
28 (09JUL2012)	09-Jul-12	1,080	60	1,140	1,080	40	1,120	2,160	101	2,261
	10-Jul-12	1,080	60	1,140	1,080	40	1,120	2,160	101	2,261
	11-Jul-12	1,080	60	1,140	1,080	40	1,120	2,160	101	2,261
	12-Jul-12	1,080	60	1,140	1,080	40	1,120	2,160	101	2,261
	13-Jul-12	1,080	60	1,140	1,080	40	1,120	2,160	101	2,261
	14-Jul-12	1,080	60	1,140	1,080	40	1,120	2,160	101	2,261
	15-Jul-12	1,080	60	1,140	1,080	40	1,120	2,160	101	2,261
	Week Total	7,560	423	7,983	7,560	282	7,842	15,120	706	15,826
29 (16JUL2012)	16-Jul-12	1,080	60	1,140	1,080	41	1,121	2,160	102	2,262
	17-Jul-12	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	18-Jul-12	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	19-Jul-12	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	20-Jul-12	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	21-Jul-12	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	22-Jul-12	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	Week Total	7,560	423	7,983	7,560	404	7,964	15,120	827	15,947

(continued)

Table A-1 (continued).

Week Number (Beginning Mon.)	Date	Unit 2			Unit 3			Both Units Combined		
		CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)
30 (23JUL2012)	23-Jul-12	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	24-Jul-12	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	25-Jul-12	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	26-Jul-12	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	27-Jul-12	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	28-Jul-12	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	29-Jul-12	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	Week Total	7,560	423	7,983	7,560	423	7,983	15,120	847	15,967
31 (30JUL2012)	30-Jul-12	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	31-Jul-12	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	01-Aug-12	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	02-Aug-12	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	03-Aug-12	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	04-Aug-12	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	05-Aug-12	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	Week Total	7,560	423	7,983	7,560	423	7,983	15,120	847	15,967
32 (06AUG2012)	06-Aug-12	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	07-Aug-12	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	08-Aug-12	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	09-Aug-12	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	10-Aug-12	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	11-Aug-12	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	12-Aug-12	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	Week Total	7,560	423	7,983	7,560	423	7,983	15,120	847	15,967

(continued)

Table A-1 (continued).

Week Number (Beginning Mon.)	Date	Unit 2			Unit 3			Both Units Combined		
		CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)
33 (13AUG2012)	13-Aug-12	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	14-Aug-12	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	15-Aug-12	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	16-Aug-12	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	17-Aug-12	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	18-Aug-12	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	19-Aug-12	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	Week Total	7,560	423	7,983	7,560	423	7,983	15,120	847	15,967
34 (20AUG2012)	20-Aug-12	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	21-Aug-12	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	22-Aug-12	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	23-Aug-12	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	24-Aug-12	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	25-Aug-12	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	26-Aug-12	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	Week Total	7,560	423	7,983	7,560	423	7,983	15,120	847	15,967
35 (27AUG2012)	27-Aug-12	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	28-Aug-12	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	29-Aug-12	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	30-Aug-12	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	31-Aug-12	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	01-Sep-12	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	02-Sep-12	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	Week Total	7,560	423	7,983	7,560	423	7,983	15,120	847	15,967

(continued)

Table A-1 (continued).

Week Number (Beginning Mon.)	Date	Unit 2			Unit 3			Both Units Combined		
		CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)
36 (03SEP2012)	03-Sep-12	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	04-Sep-12	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	05-Sep-12	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	06-Sep-12	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	07-Sep-12	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	08-Sep-12	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	09-Sep-12	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	Week Total	7,560	423	7,983	7,560	423	7,983	15,120	847	15,967
37 (10SEP2012)	10-Sep-12	1,080	57	1,137	1,080	60	1,140	2,160	117	2,277
	11-Sep-12	1,080	40	1,120	1,080	60	1,140	2,160	101	2,261
	12-Sep-12	1,080	40	1,120	1,080	60	1,140	2,160	101	2,261
	13-Sep-12	1,080	40	1,120	1,080	60	1,140	2,160	101	2,261
	14-Sep-12	1,080	40	1,120	1,080	60	1,140	2,160	101	2,261
	15-Sep-12	1,080	40	1,120	1,080	60	1,140	2,160	101	2,261
	16-Sep-12	1,080	40	1,120	1,080	60	1,140	2,160	101	2,261
	Week Total	7,560	299	7,859	7,560	423	7,983	15,120	722	15,842
38 (17SEP2012)	17-Sep-12	1,080	32	1,112	1,080	60	1,140	2,160	93	2,253
	18-Sep-12	1,080	20	1,100	1,080	60	1,140	2,160	81	2,241
	19-Sep-12	-	20	20	1,080	60	1,140	1,080	81	1,161
	20-Sep-12	-	20	20	1,080	60	1,140	1,080	81	1,161
	21-Sep-12	-	20	20	1,080	60	1,140	1,080	81	1,161
	22-Sep-12	-	20	20	1,080	60	1,140	1,080	81	1,161
	23-Sep-12	-	20	20	1,080	60	1,140	1,080	81	1,161
	Week Total	2,160	153	2,313	7,560	423	7,983	9,720	577	10,297

(continued)

Table A-1 (continued).

Week Number (Beginning Mon.)	Date	Unit 2			Unit 3			Both Units Combined		
		CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)
39 (24SEP2012)	24-Sep-12	-	20	20	1,080	60	1,140	1,080	81	1,161
	25-Sep-12	-	20	20	1,080	60	1,140	1,080	81	1,161
	26-Sep-12	-	20	20	1,080	60	1,140	1,080	81	1,161
	27-Sep-12	-	20	20	1,080	60	1,140	1,080	81	1,161
	28-Sep-12	-	20	20	1,080	60	1,140	1,080	81	1,161
	29-Sep-12	-	20	20	1,080	60	1,140	1,080	81	1,161
	30-Sep-12	-	20	20	1,080	60	1,140	1,080	81	1,161
	Week Total	-	141	141	7,560	423	7,983	7,560	564	8,124
40 (01OCT2012)	01-Oct-12	-	20	20	1,080	60	1,140	1,080	81	1,161
	02-Oct-12	-	20	20	1,080	60	1,140	1,080	81	1,161
	03-Oct-12	-	20	20	1,080	60	1,140	1,080	81	1,161
	04-Oct-12	-	20	20	1,080	60	1,140	1,080	81	1,161
	05-Oct-12	-	20	20	1,080	60	1,140	1,080	81	1,161
	06-Oct-12	-	20	20	1,080	60	1,140	1,080	81	1,161
	07-Oct-12	-	20	20	1,080	60	1,140	1,080	81	1,161
	Week Total	-	141	141	7,560	423	7,983	7,560	564	8,124
41 (08OCT2012)	08-Oct-12	-	20	20	1,080	60	1,140	1,080	81	1,161
	09-Oct-12	-	20	20	1,080	60	1,140	1,080	81	1,161
	10-Oct-12	-	20	20	1,080	60	1,140	1,080	81	1,161
	11-Oct-12	-	20	20	1,080	60	1,140	1,080	81	1,161
	12-Oct-12	-	20	20	1,080	60	1,140	1,080	81	1,161
	13-Oct-12	-	20	20	1,080	60	1,140	1,080	81	1,161
	14-Oct-12	-	20	20	1,080	60	1,140	1,080	81	1,161
	Week Total	-	141	141	7,560	423	7,983	7,560	564	8,124

(continued)

Table A-1 (continued).

Week Number (Beginning Mon.)	Date	Unit 2			Unit 3			Both Units Combined		
		CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)
42 (15OCT2012)	15-Oct-12	-	20	20	1,080	60	1,140	1,080	81	1,161
	16-Oct-12	-	20	20	1,080	60	1,140	1,080	81	1,161
	17-Oct-12	-	20	20	1,080	60	1,140	1,080	81	1,161
	18-Oct-12	-	20	20	1,080	60	1,140	1,080	81	1,161
	19-Oct-12	720	26	746	1,080	60	1,140	1,800	87	1,887
	20-Oct-12	720	40	760	1,080	60	1,140	1,800	101	1,901
	21-Oct-12	1,080	40	1,120	1,080	60	1,140	2,160	101	2,261
	Week Total	2,520	188	2,708	7,560	423	7,983	10,080	611	10,691
43 (22OCT2012)	22-Oct-12	1,080	40	1,120	1,080	60	1,140	2,160	101	2,261
	23-Oct-12	1,080	40	1,120	1,080	60	1,140	2,160	101	2,261
	24-Oct-12	1,080	40	1,120	1,080	60	1,140	2,160	101	2,261
	25-Oct-12	1,080	40	1,120	1,080	60	1,140	2,160	101	2,261
	26-Oct-12	1,080	40	1,120	1,080	60	1,140	2,160	101	2,261
	27-Oct-12	1,080	40	1,120	1,080	60	1,140	2,160	101	2,261
	28-Oct-12	1,080	40	1,120	1,080	60	1,140	2,160	101	2,261
	Week Total	7,560	282	7,842	7,560	423	7,983	15,120	706	15,826
44 (29OCT2012)	29-Oct-12	1,080	40	1,120	1,080	60	1,140	2,160	101	2,261
	30-Oct-12	1,080	40	1,120	1,080	60	1,140	2,160	101	2,261
	31-Oct-12	1,080	40	1,120	1,080	60	1,140	2,160	101	2,261
	01-Nov-12	1,080	40	1,120	1,080	60	1,140	2,160	101	2,261
	02-Nov-12	1,080	40	1,120	1,080	52	1,132	2,160	92	2,252
	03-Nov-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	04-Nov-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	Week Total	7,560	282	7,842	7,560	374	7,934	15,120	656	15,776

(continued)

Table A-1 (continued).

Week Number (Beginning Mon.)	Date	Unit 2			Unit 3			Both Units Combined		
		CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)
45 (05NOV2012)	05-Nov-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	06-Nov-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	07-Nov-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	08-Nov-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	09-Nov-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	10-Nov-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	11-Nov-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	Week Total	7,560	282	7,842	7,560	282	7,842	15,120	564	15,684
46 (12NOV2012)	12-Nov-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	13-Nov-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	14-Nov-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	15-Nov-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	16-Nov-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	17-Nov-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	18-Nov-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	Week Total	7,560	282	7,842	7,560	282	7,842	15,120	564	15,684
47 (19NOV2012)	19-Nov-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	20-Nov-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	21-Nov-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	22-Nov-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	23-Nov-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	24-Nov-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	25-Nov-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	Week Total	7,560	282	7,842	7,560	282	7,842	15,120	564	15,684

(continued)

Table A-1 (continued).

Week Number (Beginning Mon.)	Date	Unit 2			Unit 3			Both Units Combined		
		CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)
48 (26NOV2012)	26-Nov-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	27-Nov-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	28-Nov-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	29-Nov-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	30-Nov-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	01-Dec-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	02-Dec-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	Week Total	7,560	282	7,842	7,560	282	7,842	15,120	564	15,684
49 (03DEC2012)	03-Dec-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	04-Dec-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	05-Dec-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	06-Dec-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	07-Dec-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	08-Dec-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	09-Dec-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	Week Total	7,560	282	7,842	7,560	282	7,842	15,120	564	15,684
50 (10DEC2012)	10-Dec-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	11-Dec-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	12-Dec-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	13-Dec-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	14-Dec-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	15-Dec-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	16-Dec-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	Week Total	7,560	282	7,842	7,560	282	7,842	15,120	564	15,684

(continued)

Table A-1 (continued).

Week Number (Beginning Mon.)	Date	Unit 2			Unit 3			Both Units Combined		
		CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)
51 (17DEC2012)	17-Dec-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	18-Dec-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	19-Dec-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	20-Dec-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	21-Dec-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	22-Dec-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	23-Dec-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	Week Total	7,560	282	7,842	7,560	282	7,842	15,120	564	15,684
52 (24DEC2012)	24-Dec-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	25-Dec-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	26-Dec-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	27-Dec-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	28-Dec-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	29-Dec-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	30-Dec-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	Week Total	7,560	282	7,842	7,560	282	7,842	15,120	564	15,684
53 (31DEC2012)	31-Dec-12	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	Week Total	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241

Table A-2. Daily and weekly Actual Intake Flow (AIF) of circulating water (CW) and service water (SW) in millions of gallons for Units 2 and 3 and Both Units Combined at PBAPS during 1 January through 31 December 2016. Entrainment sample collection dates are highlighted.

Week (beginning Monday)	Date	Unit 2			Unit 3			Both Units Combined		
		CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)
0 (01JAN2016)	1-Jan-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	2-Jan-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	3-Jan-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	Week Total	3,240	121	3,361	3,240	121	3,361	6,480	242	6,722
1 (04JAN2016)	4-Jan-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	5-Jan-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	6-Jan-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	7-Jan-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	8-Jan-16	1,080	40	1,120	1,036	40	1,076	2,116	81	2,196
	9-Jan-16	1,080	40	1,120	953	40	993	2,033	81	2,114
	10-Jan-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	Week Total	7,560	282	7,842	7,389	282	7,671	14,949	565	15,513
2 (11JAN2016)	11-Jan-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	12-Jan-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	13-Jan-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	14-Jan-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	15-Jan-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	16-Jan-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	17-Jan-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	Week Total	7,560	282	7,842	7,560	282	7,842	15,120	564	15,684

(continued)

Table A-2 (continued).

Week (beginning Monday)	Date	Unit 2			Unit 3			Both Units Combined		
		CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)
3 (18JAN2016)	18-Jan-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	19-Jan-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	20-Jan-16	863	40	904	871	40	911	1,734	81	1,815
	21-Jan-16	720	40	760	720	40	760	1,440	81	1,521
	22-Jan-16	720	40	760	720	40	760	1,440	81	1,521
	23-Jan-16	720	40	760	720	40	760	1,440	81	1,521
	24-Jan-16	720	40	760	720	40	760	1,440	81	1,521
	Week Total	5,903	282	6,186	5,911	282	6,193	11,814	565	12,379
4 (25JAN2016)	25-Jan-16	720	40	760	720	40	760	1,440	81	1,521
	26-Jan-16	720	40	760	720	40	760	1,440	81	1,521
	27-Jan-16	720	40	760	720	40	760	1,440	81	1,521
	28-Jan-16	720	40	760	720	40	760	1,440	81	1,521
	29-Jan-16	720	40	760	826	40	867	1,546	81	1,627
	30-Jan-16	720	40	760	720	40	760	1,440	81	1,521
	31-Jan-16	720	40	760	720	40	760	1,440	81	1,521
	Week Total	5,040	282	5,322	5,146	282	5,429	10,186	565	10,751
5 (01FEB2016)	1-Feb-16	720	40	760	720	40	760	1,440	81	1,521
	2-Feb-16	720	40	760	720	40	760	1,440	81	1,521
	3-Feb-16	720	40	760	720	40	760	1,440	81	1,521
	4-Feb-16	720	40	760	814	40	855	1,534	81	1,615
	5-Feb-16	856	40	896	1,080	40	1,120	1,936	81	2,016
	6-Feb-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	7-Feb-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	Week Total	5,896	282	6,178	6,214	282	6,497	12,110	565	12,674

(continued)

Table A-2 (continued).

Week (beginning Monday)	Date	Unit 2			Unit 3			Both Units Combined		
		CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)
6 (08FEB2016)	8-Feb-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	9-Feb-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	10-Feb-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	11-Feb-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	12-Feb-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	13-Feb-16	1,080	40	1,120	881	40	921	1,961	81	2,041
	14-Feb-16	1,080	40	1,120	720	40	760	1,800	81	1,881
	Week Total	7,560	282	7,842	7,001	282	7,283	14,561	565	15,125
7 (15FEB2016)	15-Feb-16	1,080	40	1,120	720	40	760	1,800	81	1,881
	16-Feb-16	1,080	40	1,120	720	40	760	1,800	81	1,881
	17-Feb-16	1,080	40	1,120	896	40	936	1,976	81	2,056
	18-Feb-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	19-Feb-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	20-Feb-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	21-Feb-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	Week Total	7,560	282	7,842	6,656	282	6,938	14,216	565	14,780
8 (22FEB2016)	22-Feb-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	23-Feb-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	24-Feb-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	25-Feb-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	26-Feb-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	27-Feb-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	28-Feb-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	Week Total	7,560	282	7,842	7,560	282	7,842	15,120	564	15,684

(continued)

Table A-2 (continued).

Week (beginning Monday)	Date	Unit 2			Unit 3			Both Units Combined		
		CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)
9 (29FEB2016)	29-Feb-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	1-Mar-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	2-Mar-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	3-Mar-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	4-Mar-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	5-Mar-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	6-Mar-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	Week Total	7,560	282	7,842	7,560	282	7,842	15,120	564	15,684
10 (07MAR2016)	7-Mar-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	8-Mar-16	1,080	40	1,120	999	40	1,039	2,079	81	2,159
	9-Mar-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	10-Mar-16	1,080	40	1,120	1,030	40	1,070	2,110	81	2,191
	11-Mar-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	12-Mar-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	13-Mar-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	Week Total	7,560	282	7,842	7,429	282	7,711	14,989	565	15,553
11 (14MAR2016)	14-Mar-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	15-Mar-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	16-Mar-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	17-Mar-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	18-Mar-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	19-Mar-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	20-Mar-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	Week Total	7,560	282	7,842	7,560	282	7,842	15,120	564	15,684

(continued)

Table A-2 (continued).

Week (beginning Monday)	Date	Unit 2			Unit 3			Both Units Combined		
		CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)
12 (21MAR2016)	21-Mar-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	22-Mar-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	23-Mar-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	24-Mar-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	25-Mar-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	26-Mar-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	27-Mar-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	Week Total	7,560	282	7,842	7,560	282	7,842	15,120	564	15,684
13 (28MAR2016)	28-Mar-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	29-Mar-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	30-Mar-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	31-Mar-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	1-Apr-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	2-Apr-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	3-Apr-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	Week Total	7,560	282	7,842	7,560	282	7,842	15,120	564	15,684
14 (04APR2016)	4-Apr-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	5-Apr-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	6-Apr-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	7-Apr-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	8-Apr-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	9-Apr-16	1,039	40	1,079	1,080	40	1,120	2,119	81	2,199
	10-Apr-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	Week Total	7,519	282	7,801	7,560	282	7,842	15,079	565	15,643

(continued)

Table A-2 (continued).

Week (beginning Monday)	Date	Unit 2			Unit 3			Both Units Combined		
		CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)
15 (11APR2016)	11-Apr-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	12-Apr-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	13-Apr-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	14-Apr-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	15-Apr-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	16-Apr-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	17-Apr-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	Week Total	7,560	282	7,842	7,560	282	7,842	15,120	564	15,684
16 (18APR2016)	18-Apr-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	19-Apr-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	20-Apr-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	21-Apr-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	22-Apr-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	23-Apr-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	24-Apr-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	Week Total	7,560	282	7,842	7,560	282	7,842	15,120	564	15,684
17 (25APR2016)	25-Apr-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	26-Apr-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	27-Apr-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	28-Apr-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	29-Apr-16	1,072	40	1,112	1,080	40	1,120	2,152	81	2,233
	30-Apr-16	876	40	916	1,080	40	1,120	1,956	81	2,036
	1-May-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	Week Total	7,348	282	7,630	7,560	282	7,842	14,908	565	15,472

(continued)

Table A-2 (continued).

Week (beginning Monday)	Date	Unit 2			Unit 3			Both Units Combined		
		CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)
18 (02MAY2016)	2-May-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	3-May-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	4-May-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	5-May-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	6-May-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	7-May-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	8-May-16	1,080	40	1,120	1,063	40	1,103	2,143	81	2,223
	Week Total	7,560	282	7,842	7,543	282	7,825	15,103	565	15,667
19 (09MAY2016)	9-May-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	10-May-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	11-May-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	12-May-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	13-May-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	14-May-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	15-May-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	Week Total	7,560	282	7,842	7,560	282	7,842	15,120	564	15,684
20 (16MAY2016)	16-May-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	17-May-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	18-May-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	19-May-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	20-May-16	1,080	40	1,120	1,078	40	1,118	2,158	81	2,238
	21-May-16	1,080	40	1,120	889	40	929	1,969	81	2,049
	22-May-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	Week Total	7,560	282	7,842	7,366	282	7,649	14,926	565	15,491

(continued)

Table A-2 (continued).

Week (beginning Monday)	Date	Unit 2			Unit 3			Both Units Combined		
		CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)
21 (23MAY2016)	23-May-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	24-May-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	25-May-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	26-May-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	27-May-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	28-May-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	29-May-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	Week Total	7,560	282	7,842	7,560	282	7,842	15,120	564	15,684
22 (30MAY2016)	30-May-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	31-May-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	1-Jun-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	2-Jun-16	1,080	48	1,128	1,080	40	1,120	2,160	89	2,249
	3-Jun-16	1,080	60	1,140	1,080	40	1,120	2,160	101	2,261
	4-Jun-16	1,080	60	1,140	1,080	40	1,120	2,160	101	2,261
	5-Jun-16	1,080	60	1,140	1,080	40	1,120	2,160	101	2,261
	Week Total	7,560	351	7,911	7,560	282	7,842	15,120	633	15,753
23 (06JUN2016)	6-Jun-16	1,080	60	1,140	1,080	40	1,120	2,160	101	2,261
	7-Jun-16	1,080	60	1,140	1,080	40	1,120	2,160	101	2,261
	8-Jun-16	1,080	60	1,140	1,080	40	1,120	2,160	101	2,261
	9-Jun-16	1,080	60	1,140	1,080	40	1,120	2,160	101	2,261
	10-Jun-16	1,080	60	1,140	1,080	40	1,120	2,160	101	2,261
	11-Jun-16	1,080	60	1,140	1,080	40	1,120	2,160	101	2,261
	12-Jun-16	1,080	60	1,140	1,080	40	1,120	2,160	101	2,261
	Week Total	7,560	423	7,983	7,560	282	7,842	15,120	706	15,826

(continued)

Table A-2 (continued).

Week (beginning Monday)	Date	Unit 2			Unit 3			Both Units Combined		
		CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)
24 (13JUN2016)	13-Jun-16	1,080	60	1,140	1,080	40	1,120	2,160	101	2,261
	14-Jun-16	1,080	60	1,140	1,080	40	1,120	2,160	101	2,261
	15-Jun-16	1,080	60	1,140	1,080	40	1,120	2,160	101	2,261
	16-Jun-16	1,080	60	1,140	1,080	40	1,120	2,160	101	2,261
	17-Jun-16	1,060	61	1,121	1,080	40	1,120	2,140	101	2,241
	18-Jun-16	1,080	60	1,140	1,080	40	1,120	2,160	101	2,261
	19-Jun-16	1,080	60	1,140	1,080	40	1,120	2,160	101	2,261
	Week Total	7,540	423	7,964	7,560	282	7,842	15,100	706	15,806
25 (20JUN2016)	20-Jun-16	1,080	60	1,140	1,080	40	1,120	2,160	101	2,261
	21-Jun-16	1,080	60	1,140	1,080	40	1,120	2,160	101	2,261
	22-Jun-16	1,080	60	1,140	1,080	40	1,120	2,160	101	2,261
	23-Jun-16	1,080	60	1,140	1,080	40	1,120	2,160	101	2,261
	24-Jun-16	1,080	60	1,140	1,080	40	1,120	2,160	101	2,261
	25-Jun-16	1,080	60	1,140	1,080	40	1,120	2,160	101	2,261
	26-Jun-16	1,080	60	1,140	1,080	40	1,120	2,160	101	2,261
	Week Total	7,560	423	7,983	7,560	282	7,842	15,120	706	15,826
26 (27JUN2016)	27-Jun-16	1,080	60	1,140	1,080	40	1,120	2,160	101	2,261
	28-Jun-16	1,080	60	1,140	1,080	40	1,120	2,160	101	2,261
	29-Jun-16	1,080	60	1,140	1,080	52	1,132	2,160	113	2,273
	30-Jun-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	1-Jul-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	2-Jul-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	3-Jul-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	Week Total	7,560	423	7,983	7,560	375	7,935	15,120	798	15,918

(continued)

Table A-2 (continued).

Week (beginning Monday)	Date	Unit 2			Unit 3			Both Units Combined		
		CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)
27 (04JUL2016)	4-Jul-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	5-Jul-16	1,080	60	1,140	1,080	52	1,132	2,160	113	2,273
	6-Jul-16	1,080	60	1,140	1,080	40	1,120	2,160	101	2,261
	7-Jul-16	1,080	60	1,140	1,080	40	1,120	2,160	101	2,261
	8-Jul-16	1,080	60	1,140	1,080	40	1,120	2,160	101	2,261
	9-Jul-16	1,080	60	1,140	1,080	40	1,120	2,160	101	2,261
	10-Jul-16	1,080	60	1,140	1,080	40	1,120	2,160	101	2,261
	Week Total	7,560	423	7,983	7,560	314	7,874	15,120	738	15,858
28 (11JUL2016)	11-Jul-16	1,080	60	1,140	1,080	40	1,120	2,160	101	2,261
	12-Jul-16	1,080	60	1,140	1,080	40	1,120	2,160	101	2,261
	13-Jul-16	1,080	60	1,140	1,080	40	1,120	2,160	101	2,261
	14-Jul-16	1,080	60	1,140	1,080	40	1,120	2,160	101	2,261
	15-Jul-16	1,080	60	1,140	1,080	40	1,120	2,160	101	2,261
	16-Jul-16	1,080	60	1,140	1,080	40	1,120	2,160	101	2,261
	17-Jul-16	1,080	60	1,140	1,080	40	1,120	2,160	101	2,261
	Week Total	7,560	423	7,983	7,560	282	7,842	15,120	706	15,826
29 (18JUL2016)	18-Jul-16	1,080	60	1,140	1,080	40	1,120	2,160	101	2,261
	19-Jul-16	1,080	60	1,140	1,080	40	1,120	2,160	101	2,261
	20-Jul-16	1,080	60	1,140	1,080	40	1,120	2,160	101	2,261
	21-Jul-16	1,080	60	1,140	1,080	40	1,120	2,160	101	2,261
	22-Jul-16	1,080	60	1,140	1,080	40	1,120	2,160	101	2,261
	23-Jul-16	1,080	60	1,140	1,080	40	1,120	2,160	101	2,261
	24-Jul-16	1,080	60	1,140	1,080	40	1,120	2,160	101	2,261
	Week Total	7,560	423	7,983	7,560	282	7,842	15,120	706	15,826

(continued)

Table A-2 (continued).

Week (beginning Monday)	Date	Unit 2			Unit 3			Both Units Combined		
		CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)
30 (25JUL2016)	25-Jul-16	1,080	60	1,140	1,080	40	1,120	2,160	101	2,261
	26-Jul-16	1,080	60	1,140	1,080	40	1,120	2,160	101	2,261
	27-Jul-16	1,080	60	1,140	1,080	47	1,127	2,160	108	2,268
	28-Jul-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	29-Jul-16	1,080	60	1,140	1,061	61	1,122	2,141	121	2,262
	30-Jul-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	31-Jul-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	Week Total	7,560	423	7,983	7,541	370	7,911	15,101	793	15,895
31 (01AUG2016)	1-Aug-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	2-Aug-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	3-Aug-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	4-Aug-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	5-Aug-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	6-Aug-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	7-Aug-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	Week Total	7,560	423	7,983	7,560	423	7,983	15,120	847	15,967
32 (08AUG2016)	8-Aug-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	9-Aug-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	10-Aug-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	11-Aug-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	12-Aug-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	13-Aug-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	14-Aug-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	Week Total	7,560	423	7,983	7,560	423	7,983	15,120	847	15,967

(continued)

Table A-2 (continued).

Week (beginning Monday)	Date	Unit 2			Unit 3			Both Units Combined		
		CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)
33 (15AUG2016)	15-Aug-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	16-Aug-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	17-Aug-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	18-Aug-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	19-Aug-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	20-Aug-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	21-Aug-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	Week Total	7,560	423	7,983	7,560	423	7,983	15,120	847	15,967
34 (22AUG2016)	22-Aug-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	23-Aug-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	24-Aug-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	25-Aug-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	26-Aug-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	27-Aug-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	28-Aug-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	Week Total	7,560	423	7,983	7,560	423	7,983	15,120	847	15,967
35 (29AUG2016)	29-Aug-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	30-Aug-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	31-Aug-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	1-Sep-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	2-Sep-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	3-Sep-16	1,014	61	1,074	1,080	60	1,140	2,094	121	2,215
	4-Sep-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	Week Total	7,494	423	7,917	7,560	423	7,983	15,054	847	15,901

(continued)

Table A-2 (continued).

Week (beginning Monday)	Date	Unit 2			Unit 3			Both Units Combined		
		CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)
36 (05SEP2016)	5-Sep-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	6-Sep-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	7-Sep-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	8-Sep-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	9-Sep-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	10-Sep-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	11-Sep-16	1,080	60	1,140	871	61	931	1,951	121	2,072
	Week Total	7,560	423	7,983	7,351	423	7,774	14,911	847	15,758
37 (12SEP2016)	12-Sep-16	1,080	60	1,140	1,068	61	1,129	2,148	121	2,269
	13-Sep-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	14-Sep-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	15-Sep-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	16-Sep-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	17-Sep-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	18-Sep-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	Week Total	7,560	423	7,983	7,548	423	7,971	15,108	847	15,955
38 (19SEP2016)	19-Sep-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	20-Sep-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	21-Sep-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	22-Sep-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	23-Sep-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	24-Sep-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	25-Sep-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	Week Total	7,560	423	7,983	7,560	423	7,983	15,120	847	15,967

(continued)

Table A-2 (continued).

Week (beginning Monday)	Date	Unit 2			Unit 3			Both Units Combined		
		CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)
39 (26SEP2016)	26-Sep-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	27-Sep-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	28-Sep-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	29-Sep-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	30-Sep-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	1-Oct-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	2-Oct-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	Week Total	7,560	423	7,983	7,560	423	7,983	15,120	847	15,967
40 (03OCT2016)	3-Oct-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	4-Oct-16	1,080	60	1,140	1,080	60	1,140	2,160	121	2,281
	5-Oct-16	1,080	51	1,131	1,080	52	1,132	2,160	103	2,263
	6-Oct-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	7-Oct-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	8-Oct-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	9-Oct-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	Week Total	7,560	333	7,893	7,560	334	7,894	15,120	668	15,788
41 (10OCT2016)	10-Oct-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	11-Oct-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	12-Oct-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	13-Oct-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	14-Oct-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	15-Oct-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	16-Oct-16	1,080	40	1,120	906	40	947	1,986	81	2,067
	Week Total	7,560	282	7,842	7,386	282	7,669	14,946	565	15,511

(continued)

Table A-2 (continued).

Week (beginning Monday)	Date	Unit 2			Unit 3			Both Units Combined		
		CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)
42 (17OCT2016)	17-Oct-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	18-Oct-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	19-Oct-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	20-Oct-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	21-Oct-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	22-Oct-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	23-Oct-16	1,011	40	1,051	1,080	40	1,120	2,091	81	2,171
	Week Total	7,491	282	7,773	7,560	282	7,842	15,051	565	15,615
43 (24OCT2016)	24-Oct-16	391	40	431	1,080	40	1,120	1,471	81	1,551
	25-Oct-16	72	34	105	1,080	40	1,120	1,152	74	1,226
	26-Oct-16	0	20	20	1,080	40	1,120	1,080	60	1,140
	27-Oct-16	0	3	3	1,080	40	1,120	1,080	43	1,123
	28-Oct-16	0	0	0	1,080	58	1,138	1,080	58	1,138
	29-Oct-16	0	0	0	1,080	60	1,140	1,080	60	1,140
	30-Oct-16	0	0	0	1,080	60	1,140	1,080	60	1,140
	Week Total	462	97	559	7,560	341	7,901	8,022	438	8,460
44 (31OCT2016)	31-Oct-16	0	0	0	1,080	60	1,140	1,080	60	1,140
	1-Nov-16	0	0	0	1,080	60	1,140	1,080	60	1,140
	2-Nov-16	0	19	19	1,080	42	1,122	1,080	60	1,140
	3-Nov-16	0	20	20	1,080	40	1,120	1,080	60	1,140
	4-Nov-16	0	20	20	1,080	40	1,120	1,080	60	1,140
	5-Nov-16	0	20	20	1,080	40	1,120	1,080	60	1,140
	6-Nov-16	0	20	20	1,080	40	1,120	1,080	60	1,140
	Week Total	0	99	99	7,560	324	7,884	7,560	423	7,983

(continued)

Table A-2 (continued).

Week (beginning Monday)	Date	Unit 2			Unit 3			Both Units Combined		
		CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)
45 (07NOV2016)	7-Nov-16	30	20	50	1,080	40	1,120	1,110	60	1,170
	8-Nov-16	360	20	380	1,080	40	1,120	1,440	60	1,500
	9-Nov-16	360	20	380	1,080	40	1,120	1,440	60	1,500
	10-Nov-16	713	28	741	1,080	40	1,120	1,793	68	1,861
	11-Nov-16	720	40	760	1,080	40	1,120	1,800	81	1,881
	12-Nov-16	1,036	40	1,076	1,080	40	1,120	2,116	81	2,196
	13-Nov-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	Week Total	4,298	209	4,508	7,560	282	7,842	11,858	492	12,350
46 (14NOV2016)	14-Nov-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	15-Nov-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	16-Nov-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	17-Nov-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	18-Nov-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	19-Nov-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	20-Nov-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	Week Total	7,560	282	7,842	7,560	282	7,842	15,120	564	15,684
47 (21NOV2016)	21-Nov-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	22-Nov-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	23-Nov-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	24-Nov-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	25-Nov-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	26-Nov-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	27-Nov-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	Week Total	7,560	282	7,842	7,560	282	7,842	15,120	564	15,684

(continued)

Table A-2 (continued).

Week (beginning Monday)	Date	Unit 2			Unit 3			Both Units Combined		
		CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)
48 (28NOV2016)	28-Nov-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	29-Nov-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	30-Nov-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	1-Dec-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	2-Dec-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	3-Dec-16	796	40	836	1,080	40	1,120	1,876	81	1,956
	4-Dec-16	720	40	760	1,080	40	1,120	1,800	81	1,881
	Week Total	6,916	282	7,198	7,560	282	7,842	14,476	565	15,040
49 (05DEC2016)	5-Dec-16	720	40	760	1,080	40	1,120	1,800	81	1,881
	6-Dec-16	720	40	760	1,080	40	1,120	1,800	81	1,881
	7-Dec-16	720	40	760	1,080	40	1,120	1,800	81	1,881
	8-Dec-16	720	40	760	1,080	40	1,120	1,800	81	1,881
	9-Dec-16	720	40	760	1,080	40	1,120	1,800	81	1,881
	10-Dec-16	720	40	760	1,080	40	1,120	1,800	81	1,881
	11-Dec-16	720	40	760	1,080	40	1,120	1,800	81	1,881
	Week Total	5,040	282	5,322	7,560	282	7,842	12,600	564	13,164
50 (12DEC2016)	12-Dec-16	720	40	760	1,080	40	1,120	1,800	81	1,881
	13-Dec-16	720	40	760	1,080	40	1,120	1,800	81	1,881
	14-Dec-16	741	40	781	1,080	40	1,120	1,821	81	1,901
	15-Dec-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	16-Dec-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	17-Dec-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	18-Dec-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	Week Total	6,501	282	6,783	7,560	282	7,842	14,061	565	14,625

(continued)

Table A-2 (continued).

Week (beginning Monday)	Date	Unit 2			Unit 3			Both Units Combined		
		CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)	CW Flow (10^6 gal)	SW Flow (10^6 gal)	Total (10^6 gal)
51 (19DEC2016)	19-Dec-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	20-Dec-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	21-Dec-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	22-Dec-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	23-Dec-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	24-Dec-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	25-Dec-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	Week Total	7,560	282	7,842	7,560	282	7,842	15,120	564	15,684
52 (26DEC2016)	26-Dec-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	27-Dec-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	28-Dec-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	29-Dec-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	30-Dec-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	31-Dec-16	1,080	40	1,120	1,080	40	1,120	2,160	81	2,241
	Week Total	6,480	242	6,722	6,480	242	6,722	12,960	484	13,444

Appendix B: Peach Bottom Atomic Power Station 2012 Entrainment Study Standard Operating Procedure and Quality Assurance Plan, Revision 1 dated March 2012

PEACH BOTTOM ATOMIC POWER STATION
2012 ENTRAINMENT STUDY STANDARD OPERATING PROCEDURE AND QUALITY ASSURANCE PLAN

Revision 1
March 2012

Prepared by
NORMANDEAU ASSOCIATES INC.
400 Old Reading Pike
Stowe, Pennsylvania 19464

Project 22176.000

1.0 INTRODUCTION
- 1.1 OBJECTIVES
- 1.2 ORGANIZATION
- 1.3 SITE ORIENTATION AND CHECK IN/ CHECK OUT

2.0 ENTRAINMENT FIELD SOP
- 2.1 SAMPLING SCHEDULE AND LOCATION
- 2.2 EQUIPMENT
- 2.3 PROCEDURES
  - 2.3.1 Operation of the Entrainment Sampling Pumps
  - 2.3.2 Flowmeter Calibration
  - 2.3.3 Sample Collection
- 2.4 SAMPLE HANDLING
  - 2.4.1 Chain of Custody for Collected Samples
- 2.5 DATA HANDLING
  - 2.5.1 Data Sheets and Handling
  - 2.5.2 Storage and Chain of Custody of Data Sheets
  - 2.5.3 Monthly Progress Report
- 2.6 HAZARDOUS SUBSTANCES LOG
- 2.7 EQUIPMENT MAINTENANCE

3.0 ENTRAINMENT PROCESSING LAB SOP
- 3.1 SAMPLES TO BE ANALYZED
- 3.2 EQUIPMENT
- 3.3 PROCEDURES
  - 3.3.1 Subsampling
    - 3.3.1.1 Restrictions and Quotas
    - 3.3.1.2 Sequence
    - 3.3.1.3 Splitting Technique
  - 3.3.2 Sorting
  - 3.3.3 Identification
    - 4.3.3.1 Ichthyoplankton
    - 4.3.3.2 Aquatic and Semi-Aquatic Organisms
- 3.4 SAMPLE HANDLING
  - 3.4.1 Sample Control
  - 3.4.2 Chain of Custody Records
  - 3.4.3 Preservation and Storage
  - 3.4.4 Disposal
- 3.5 DATA HANDLING
  - 3.5.1 Data Sheets and Coding Instructions
    - 3.5.1.1 Count Data
    - 3.5.1.2 Measurement Data
  - 3.5.2 Storage and Chain of Custody of Data Sheets
- 3.6 QUALITY CONTROL
  - 3.6.1 Tasks Subject to Quality Control
  - 3.6.2 Inspection Plans
  - 3.6.3 Acceptance/Rejection Criteria

3.6.3.1 Sorting
3.6.3.2 Identification
3.6.4 Quality Control Records
3.6.5 Quality Control Personnel
3.7 REFERENCE COLLECTION
3.8 INSTRUMENT CALIBRATION

4.0 DATA PROCESSING
4.1 DATA ENTRY VERIFICATION AND DATA SHEET CHAIN OF CUSTODY
4.2 SYSTEMATIC ERROR CHECKS
4.3 DATA FILE FORMAT
4.4 QUALITY CONTROL OF DATA FILES

5.0 TRAINING

6.0 QUALITY ASSURANCE
6.1 NONCONFORMANCE REPORTS AND CORRECTIVE ACTION
6.2 QA INSPECTIONS

APPENDIX A: Forms

APPENDIX B: Pre-Job Brief Checklist (HU-AA-1211, Attachment 1)

1.0 INTRODUCTION

1.1 STATION DESCRIPTION

Peach Bottom Atomic Power Station (PBAPS) is located in York County, Pennsylvania, on the west shore of Conowingo Reservoir (Pond), approximately 3 miles upstream from the Pennsylvania-Maryland border. PBAPS is a two-unit nuclear-fueled power generating facility with a nominal generating capacity of 2,304 megawatts electrical (MWe). The Station operates as a base-load facility with both units normally generating at full capacity. Unit 2 began commercial operation in June 1974 and Unit 3 entered commercial service in December 1974. Conowingo Pond was formed in 1928 with the construction of Conowingo Hydroelectric Station.

PBAPS utilizes a once-through cooling system to remove waste heat from the station's condensers. The cooling water for both units is withdrawn from the Pond through an outer intake structure located on the shoreline of Conowingo Pond, through two 3-acre intake ponds (one serving each unit), and then through an inner intake structure.

The outer intake is approximately 480 ft long with a fixed vertical trash rack on the face of the intake followed by a set of 24 vertical traveling screens which have 3/8-inch mesh openings. The trash rack consists of 0.25-inch by 3-inch steel bars spaced 3.5 inches on center and is designed to prevent large debris and ice from entering the intake. The trash rack is cleaned periodically based on the Station's preventative maintenance program.

After passing through the outer intake, the cooling water flows through the intake ponds to the inner intake. Fish live and grow in the ponds and can enter the ponds through the outer screens when they are small, by being carried over the screens if they are not removed during the screen cleaning process, and through the cross-tie gate from the discharge canal in winter. During cold weather and on an as-needed basis, a cross-tie gate between the discharge basin and the intake ponds is opened to re-circulate some of the heated discharge water.

1.2 OBJECTIVES

Entrainment sampling will be performed once per week from 4 March through September 2012. The objective of the proposed entrainment sampling program is to identify and quantify the ichthyoplankton currently entrained through the PBAPS Units 1 and 2 Cooling Water Intake Structure (CWIS) during plant operations.

This Standard Operating Procedure (SOP) and Quality Assurance Plan includes the SOPs for field, laboratory, and data processing tasks of the PBAPS entrainment study, including requirements for data coding, voucher specimens, and instrument calibrations. The functions of the SOPs are (1) to ensure that consistent and appropriate procedures are followed, (2) to provide documentation of the procedures used, and (3) to enable a Quality Assurance auditor to observe project activities and determine whether the required procedures are being followed. In addition to project activities described in the SOPs, this Quality Assurance Plan also describes the system for training project personnel, the method for documenting problems or unusual events (nonconformities), and procedures used in conducting Quality Assurance audits. Safety procedures are covered in a separate document entitled "Site-Specific Health and Safety Plan for Exelon Nuclear's Peach Bottom Atomic Power Station Entrainment Study" dated February 2012.

1.3 ORGANIZATION

Separate stand-alone SOPs are included for entrainment field procedures (Section 2.0), and entrainment laboratory procedures (Section 3.0). Within each of these two SOPs, subsections from the following list that are applicable to that SOP include: sampling schedule and location, equipment, procedures, sample handling, data handling, quality control, reference collection, and instrument calibration and maintenance. Procedures for data processing, from receipt of completed data sheets to the final data files, are described in Section 4.0. Normandeau's system for providing the appropriate training for project personnel is described in Section 5.0. Quality Assurance procedures are described in Section 6.0.

1.3 SITE ORIENTATION AND CHECK IN/CHECK OUT

Prior to arrival at PBAPS, each individual must ensure that they have been approved for site access by Security through prior request to the Exelon POC. A minimum twelve hour prior notice to Security is required for access to the site. Plan to arrive at PBAPS approximately one half hour before the first sample is to be run. Check in at the security gate by (1) telling security that you are with Normandeau Associates, Inc., (2) that you are here for the weekly entrainment sampling, and (3) are proceeding to the sample station at the discharge canal. After parking near the sample station and prior to entry at the sample station area contact Security at 717-456-4277 to inform them that they are entering the discharge canal area for sampling. Also, a call shall be made to the Operations Work Execution Supervisor at 717-456-4423 prior to entry into the sample station area informing the individual of the sampling activity to be performed and the expected duration of the sampling for that shift. A call shall be made to Joe Brozonis on his office phone (717-456-3795) to inform him that sampling will be performed. A return call shall be placed to the Operations Work Execution Supervisor and Joe Brozonis at the completion of the sampling activity for that shift. A job specific Pre-Job Brief Checklist (HU-AA-1211, Attachment 1) will be reviewed by the sampler each shift and a 2-minute drill performed by the sampler each entry to the sampling area. The Normandeau TM and Exelon POC will establish the key points within the job specific Pre-Job Brief Checklist.

2.0 ENTRAINMENT FIELD SOP

2.1 SAMPLING SCHEDULE AND LOCATION

Entrainment sampling will be performed once per week from the first week of March 2012 through September 2012 (approximately 30 sample events). Sample collections will be obtained at the combined discharge from Units 2 and 3. Each weekly collection consists of four samples collected at 6-hour intervals over a 24-hour period. If either planned or unanticipated events (outages, maintenance, or failure) prevent the operation of both generating units, the sampling will be terminated or cancelled for the day at the discretion of the Project Manager.

2.2 EQUIPMENT

Collection gear for PBAPS entrainment sampling consists of an electric "trash" pump with 3-inch intake and discharge hose, and plankton net suspended in a tank. The net is 500-micron mesh. The following additional equipment is required for entrainment field sampling (see Appendix A):

- copy of SOP and Health & Safety Plan,
- cell phone,

- flowmeter,
- data sheets, chain of custody, clipboard, and pencils,
- watch,
- flashlight,
- net washdown pump,
- sieve, plastic basin, and funnel,
- sample jars,
- formalin,
- personal protection equipment as required by the HASP
- protective gear for using the formalin: gloves, goggles, face shield and secondary container, and
- labels and waterproof pens.

2.3 PROCEDURES

2.3.1 Operation of the Entrainment Sampling Pump

Procedure for starting the electric entrainment pump:

1. Open the front and remove the top portion of the plastic housing of the containment shed.

2. Check to ensure that the oil level is full. If the oil level is low, add the manufacturer specified oil and bring it to a safe operating level.

3. Turn the on/off switch to the on position.

4. Monitor the entrainment tank for water flow. If there is no flow within 5 minutes stop the pump, check for air leaks, prime the pump, and then turn on/off switch to on position.

To stop and secure the pump:

1. Turn the on/off switch to off.

2. Allow sufficient time for the electric pump to cool and then reinstall the containment shed plastic housing.

2.3.2 Flowmeter Calibration

Prior to the first sample each month or on another monthly frequency, measure the flow rate delivered by the sampling pump by filling to overflowing a calibration vessel of known volume (the sampling tank holds 300-gallons) and note the time required to the nearest 0.1 second. During this test, the pump should be operating in the typical RPM range used for sampling. Record the flow rate (gpm) indicated on the flowmeter gauge during the calibration test. Calculate the observed flow rate as follows:

calibration gpm = calibration gallons / (calibration seconds/60)

Then calculate the percent error indicated by the calibration trial as follows:

Percent error = 100 x (gauge gpm – calibration gpm) / calibration gpm

The percent error can be positive or negative depending on whether the gauge gpm was larger or smaller than the calibration gpm. Record the results on the Entrainment Field Data Sheet, *including the minus sign* if the percent error was negative. If the absolute value of the percent error is **less than 3%** then no further action is necessary.

If the absolute value of the percent error is **more than 3%** then repeat the calibration trial two more times and average the three results, recording the results on the Entrainment Field Data Sheet. Keep the minus signs, if any, in calculating the average (if there are both positive and negative percent errors, they will partially cancel each other out). If the absolute value of the **average** percent error is **less than 10%** then no further action is necessary.

If the absolute value of the average percent error is **more than 10%** then replace the flowmeter and return it to the manufacturer for servicing. If there is no replacement flowmeter available immediately, continue to collect samples with the one that failed calibration, but enter the code for "flowmeter problem" in the sample status box on the Entrainment Field Data Sheet. (It may be feasible to estimate the sample volume by comparing the duration to durations of samples with known volumes collected during similar conditions.)

2.3.3 Sample Collection

Upon arrival at PBAPS check the entire entrainment sampling system, ensure the pump is primed, and set collection nets next to the tank.

Start the pump and adjust the flow valve at the base of the entrainment tank as necessary to maintain the tank water level.

Once the tank is full, and the flow has stabilized, insert nets under the discharge pipes, record the time, and record the totalizer readings. Fill out the sample identification information at the top of the Entrainment Field Data Sheet (Appendix A).

At times, clogging of the net mesh may make it necessary to switch to a clean net during a sample (possibly as frequently as every 20 minutes). To switch nets, move one net to the side, placing the other net under the flow, and remove the original net to collect a subsample without interrupting sample collection. If subsamples are collected in this way before the sample is completed, concentrate and preserve the sample material after each net switch in the same manner as described below for the completed sample. More than one subsample may be preserved in the same jar, but if multiple jars are used, label each one with the same sample number and indicate that multiple jars were used (e.g. "1 of __").

During the warmer summer months subsampling will be required at an interval of 30 minutes to minimize damage to sample organisms. This subsampling procedure should be utilized during the months of June through September. Utilize the methods described above for switching nets and labeling and preserving subsamples.

Wait until the totalizer indicates 27,000 gallons to make sure that at least 100 cubic meters of water has been sampled before ending the sample. After the volume has reached at least 27,000 gallons, turn off the pump, and record the time and totalizer reading. At a pumping rate of150 gpm, a sample should take about 180 minutes or some 3 hours of pumping to complete.

When the samples are completed (and any time plankton nets are exchanged during a sample due to clogging), wash the sample (or subsample) from the <u>outside of the net only</u> into the cod end

bucket using the washdown pump and hose assembly. Collect the sample material from the cod end bucket and place it in a labeled sample container. A 0.425-mm or finer sieve may be used to remove excess water from the sample before transferring it to the sample jar. Take care that none of the sample is spilled, and that the contents of the net and cod end bucket are completely rinsed into the sample container or sieve. Pouring the sample into the jar should always be done over a larger container in case some sample is spilled. Sample containers and cod end buckets that are open should be set down only in a container or bucket, just in case the sample is spilled. Preserve the sample by adding sufficient formalin to make the final concentration 5 to 10% (100 mL of full-strength formalin per liter of sample for 10%).

Repeat the above procedures for three additional samples at approximately 6-hour intervals within the 24-hr collection period. The starting times of the four diel samples should be about 6 hours apart. Record the new totalizer reading on the flowmeters between samples.

2.4 SAMPLE HANDLING

Add enough 10% buffered formalin to the sample jar to preserve the volume of samples collected. Do not add any additional water to the sample jar, as this will further dilute the formalin. A full sample jar should be no more than 75% full of organisms and debris for adequate preservation. Label the jars externally with the sample number, location where the sample was collected, sample collectors initials, date and time of sample and the number of jars (e.g., 1 of 4, 2 of 4, etc.). Place an internal label in each jar giving the sample number, location the sample was collected, the date and time collected and the sample collectors initials. Wrap electrical tape around the lid of each sample jar in order to prevent formalin leakage.

2.4.1 Chain of Custody for Collected Samples

Check over the chain of custody sheet, to make sure it is completely and correctly filled out, and to be alert to any unusual or unexpected data values. When the relieving shift comes on site both first shift and second shift personnel must sign and date the chain of custody forms. When the second shift ends that person is responsible for transporting the original data sheets and sample jars to the Normandeau lab.

2.5 DATA HANDLING

2.5.1 Data Sheets and Handling

A unique sample number is assigned to each entrainment sample and consists of six-digits. Record the sample identification and status, collection times, flowmeter readings, and other required information on the Entrainment Field Data Sheet (Appendix A) according to the instructions provided with the data sheet. Use the space for comments at the bottom of the data sheet to explain any problems or unusual circumstances. Use a separate data sheet for each sample. Instructions for what to record on the data sheets and the appropriate coding conventions are provided on the reverse side of the data sheets.

At the conclusion of sampling, check over all data sheets to make sure they are completely and correctly filled out, and to be alert to any unusual or unexpected data values. Store the data sheets safely until they are taken to the Stowe office for data entry, safe keeping, and applicable QA/QC verification.

2.5.2 Storage and Chain of Custody of Data Sheets

Check over all data sheets, to make sure they are completely and correctly filled out, and to be alert to any unusual or unexpected data values. Transport the original data sheets to the Drumore office, file a photocopy of each data sheet there for safe keeping and QA/QC verification, and send the originals to the Stowe office with the samples.

2.5.3 Monthly Progress Report

Submit a monthly Progress Report to the Project Manager at Stowe concerning the progress of all field activities, i. e. samples collected for the month and any problems encountered.

2.6 HAZARDOUS SUBSTANCES LOG

Maintain a log of the amounts of formalin brought on site. Include in each log entry the date, the name of person making the log entry, and the volume in gallons of formalin brought on site on that date (Appendix A). Make the log available for inspection as requested by Exelon representatives. Provide the log to PBAPS's Environmental Health and Safety department or other designated person as needed.

2.7 EQUIPMENT MAINTENANCE

Maintain the entrainment-sampling pump by checking oil level prior to each sampling event. Periodically check for leaks in the lay flat hose and repair by replacing or wrapping electrical tape around any holes. Prior to each sampling event thoroughly inspect the ichthyoplankton nets and cod-ends for holes or signs of wear. Replace worn or damaged nets and cod-ends as appropriate prior to initiating sampling.

3.0 ENTRAINMENT PROCESSING LAB SOP

3.1 SAMPLES TO BE ANALYZED

Entrainment sampling at PBAPS is scheduled weekly from March through September. The samples are to be transported to the Stowe office/ laboratory periodically for processing.

3.2 EQUIPMENT

The following items are required for laboratory analysis of ichthyoplankton in entrainment samples:

- Sorting pans
- Lights
- Magnifiers
- Dissecting microscopes
- Motoda plankton splitter
- Sieves
- Rose Bengal at the discretion of the sorter
- Gridded Petri dishes
- Divided Petri dishes
- Jars, with lids
- Forceps
- Pipettes

- Multitally counters
- Squirt bottles
- Lab data sheets
- Pencils
- Vials, with caps
- Vial labels
- Taxonomic literature
- Copy of SOP
- Ocular micrometers
- Millimeter rulers
- Masking tape
- Rubber bands
- Random number table

3.3 PROCEDURES

3.3.1 Subsampling

3.3.1.1 Restrictions and Quotas

Samples with high numbers of eggs or larvae may be subsampled in the laboratory to produce a minimum of 200 eggs and larvae to be analyzed per sample. This quota applies to the total count of all species combined, not to individual species.

For each sample with a low ichthyoplankton concentration and a high total volume of detritus and other plankton (more than 400 ml settled volume), sort a maximum of one-half of the sample for eggs and larvae.

3.3.1.2 Sequence

Use the following sequence of procedures in processing a sample that is subsampled by splitting. To eliminate any chance of bias, some steps in the procedure are to be performed by an assistant, as indicated below, so that the sorter has no prior knowledge of which samples are to be subjected to quality control inspection.

This procedure also applies when a previously split sample is further subsampled, such as an "id. split" performed because the fraction sorted was larger than necessary to meet the quota. In this situation the term "sample" in the following procedure refers to the part of the original sample that is to be further subsampled, and the selected fraction(s) are "analyzed" rather than "sorted."

1. Examine the sample to estimate the smallest size fraction that is likely to contain at least 200 eggs and larvae.

2. Divide the sample material into two equal parts using the techniques in Section 3.3.1.3.

3. Randomly select one of the two divisions for processing (or for further subsampling, if a smaller fraction is needed). Selection should be done using a random number table or a coin toss, so that each of the two divisions has an equal chance of being selected. The person performing the division must not

know which of the two divisions will be analyzed before the division is completed (it is not acceptable to always select the division from the same chamber of the splitter).

4. Set aside the fractions not selected for further processing and label it to identify the sample number and fractional size.

5. If the fraction that was selected for further processing needs to be subsampled further, repeat steps 2-4 as many times as necessary to produce the desired fraction for analysis. When the desired fraction is obtained, label it to show the sample number and fractional size.

6. Sort the subsample by the procedures in Section 3.3.2. Organisms must be sorted from the entire subsample even if the quota is reached before finishing the subsample.

3.3.1.3 Splitting Technique

Perform all sample splitting using either a Motoda or Folsom splitter. The presence of filamentous algae or large items (including large juvenile fish, or older age classes) can interfere with the even distribution of material and organisms between the two chambers of the splitter. Therefore, to ensure successful results, observe the following techniques: (1) Adjust sample dilution to be great enough to allow free mixing of the sample but not so great as to promote clumping due to over dilution. (2) Remove large fish and excessive amounts of filamentous algae before splitting, returning any adhering ichthyoplankton to the sample. (3) Pull apart remaining clumps of algae before splitting. (4) Scrutinize detritus and organisms during the splitting process to see that they appear equally distributed before making the final division. (5) Remix and split again if the two resulting portions of a division do not appear equal. If a sample has so much algae that it cannot be satisfactorily split, sort the entire sample, and if numbers of ichthyoplankton are high splitting may be performed after sorting. Large juveniles that are removed from the whole sample before splitting must be kept separate from ichthyoplankton sorted from the sample after splitting, and they must be labeled to show they represent the whole sample.

3.3.2 Sorting

Remove fish eggs, larvae, and juveniles from the samples according to the following procedures:

- Samples may be stained with rose bengal to facilitate sorting.
- Pour the sample contents into a sieve with a mesh equivalent to, or finer than, 333 μm and rinse with water to remove the preservative.
- If the sample contains large numbers of eggs and larvae, prepare a subsample following the procedures in Section 3.3.1.
- Carefully wash the sample contents into a container making certain that nothing remains in the sieve. Pour portions of the sample from the container into a pan and examine them under a magnifying lens.
- Remove fish eggs, larvae, and juveniles from the sample using forceps, pipettes, and probes. Remove only those fragments that include the head.
- Maintain a combined total count for eggs and larvae that are removed from the sample (i.e., the combined total of eggs, yolk-sac larvae, post yolk-sac larvae, and juveniles).

- When sorting is completed, recheck the sample for organisms. After the sample has been rechecked, label vials containing the sorted organisms and place them in a box designated for sorted samples. Record the sorting results and date completed in a log.
- Carefully wash the remaining sample contents back into the original sample container, appropriately preserve,, and return it to the storage area.
- If a sample is not completed by the end of the work day, it may be left unpreserved overnight if adequate precautions are taken to prevent it from drying out. No sample or part of a sample, however, should remain unpreserved for more than 24 hours.
- Fill out Sample Log: Plankton (see Appendix A) and retain it with the vials of sorted eggs and larvae.

3.3.3 Identification

3.3.3.1 Ichthyoplankton

Identify, stage, count, and measure the sorted ichthyoplankton according to the following procedures:

- Obtain the sample vials containing the sorted organisms from the storage area and sign them out by initialing a status log.
- Rinse specimens free of preservative and submerge them in water in a Petri dish. Use a binocular microscope with an ocular micrometer to examine the specimens, and identify them to the lowest practical taxon (usually species) by referring to the literature, the reference collections, and by consulting with fellow identifiers.
- Determine the life stage of each specimen. Pertinent life stages for all larvae are defined and identified as follows:

  Egg: the embryonic developmental stage, from spawning until hatching. Eggs frequently become damaged during collection and sample processing. Damaged eggs are counted as the number of embryos (without regard to how many egg capsules are present). Do not count non-fertilized eggs if they are present.

  Yolk-sac larva (prolarva): the transition stage from hatching through the development of a complete, functional digestive system (regardless of the degree of yolk and/or oil globule retention)

  Post yolk-sac larva (postlarva): the transition stage from development of a complete, functional digestive system to transformation to juvenile form (regardless of the degree of yolk and/or oil globule retention), including the leptocephalus stage of eels

  Young-of-the year or juvenile: the stage from completed transformation to Age 1 (i.e., 12 months after hatching). A young-of-the-year has a full complement of fin rays identical to that of an adult. Eels are classified in this stage until Age 2.

  Yearling or older: a fish at least one year old

- For each sample a maximum of 20 individuals for each species and life stage category will be measured for total length to the nearest 0.1 mm (nearest 1.0 mm for juvenile fish).

- All ichthyoplankton specimens will be retained for the duration of the study. If any Federal or Pennsylvania endangered, threatened, or candidate fish species are collected,

notify the Project Manager so that the appropriate Federal and state authorities can be notified within 24 hours of making a confirmed identification of any of these important species. Specimens of the genus *Percina* will be retained for transfer to the PA DEP at a later date.

3.4 SAMPLE HANDLING

3.4.1 Sample Control

Each sample was given a unique sample number at the time of collection. Track each sample by that sample number throughout the laboratory and data processing functions.

3.4.2 Chain of Custody Records

The chain of custody documentation begins with the field office providing a list with the following information for each sample in a shipment delivered to the laboratory facilities in Stowe, Pennsylvania and Bedford, New Hampshire: sample collection date, sample collection time, sample identification number, and number of jars. Upon receipt of the samples, a laboratory representative verifies that all jars of all samples on the list are present, then signs and dates the chain of custody document.

After samples have been received in the laboratory, track their location and status during all phases of storage and laboratory analysis by means of sample control logs. The function of this system is to provide a paper trail of who performed each step in the analysis of a sample from collection to storage, when each step occurred, what condition the samples were in and where each step took place.

3.4.3 Preservation and Storage

Retain the original preservative (formalin solution) for reuse in preserving the residue of sorted samples, adding 10% formalin as needed to adequately fill the sample jars. Store processed samples (i.e., detritus and organisms not removed from split samples) until sorting quality control checks are completed. Keep sorted ichthyoplankton in vials in a heated storage area until disposal is authorized (up to one year after submittal of data files to Exelon). Tape the tops of jars and vials to prevent loss of preservative by evaporation.

3.4.4 Disposal

Disposal of sample residue remaining after sorting (detritus and organisms not removed from split samples) may proceed after sorting quality control has been completed. Disposal of vials of organisms from processed samples may proceed after receiving authorization from Exelon. Follow all applicable local, state and federal regulations for hazardous waste disposal.

3.5 DATA HANDLING

3.5.1 Data Sheets and Coding Instructions

Record ichthyoplankton counts and measurements on Entrainment Lab Count Data Sheets and Entrainment Lab Length Data Sheets (Appendix A). The Entrainment Lab Count Data Sheet is

for count data for all taxa. The Entrainment Lab Length Data Sheet is for measurements of all species. Indicate in the upper right-hand corner of each data sheet how many pages there are for the sample (use "1 of 1" for a one-page sample, "1 of 2" and "2 of 2" for a two-page sample, etc.). Record also in the upper right-hand section of the first page the identifier's initials, the date the sample was identified, and the number of vials.

3.5.1.1 Count Data

Record count data in the top ("Card Type L1") section of the data sheet according to the following instructions.

VARIABLE	INSTRUCTIONS
SAMPLE	Record the 6-digit sample number. Sample numbers will begin with **#171362.**
CARD TYPE	Preprinted: L1
CATCH_CD	Enter 1 for valid non-empty sample or 2 for valid empty sample (data sheets are not required for void samples)
SPL_FACT	Enter 1.00 if the whole sample is analyzed; if the sample is subsampled record the ratio of the whole sample to the subsample (e.g., 8.00 for a 1/8 split)
TAXON	Enter the TAXON code from the Susquehanna River Data Dictionary.
STAGE	Enter one of the following life stage codes: 0 = unknown 1 = eggs 2 = yolk-sac larvae 3 = post yolk-sac larvae 4 = young-of-the-year 5 = yearling or older
COUNT	Record the number of organisms of the indicated taxon and life stage in the sample (or subsample)
SPECIES NAME	Record the common name for the taxon

3.5.1.2 Measurement Data

Record measurement data for all species on one or more Entrainment Lab Length Data Sheets according to the following instructions. A maximum of 20 individuals for each species and life stage category will be measured for total length to the nearest 0.1 mm (nearest 1.0 mm for juvenile fish).

VARIABLE	INSTRUCTIONS
SAMPLE	Record the sample number

VARIABLE	INSTRUCTIONS
Card Type	Preprinted: L2
Conversion Factor	Record the number of millimeters per division for the optical micrometer used to measure larvae
TAXON	Enter the taxon codes for each species that is measured on Entrainment Lab Length Data Sheets.
FISH_ID	Pre-coded 1-20 for each taxon and life stage combination
STAGE (or "STG.")	Enter the life stage code for each larva or 2, 3, 4, or 5 for other species). Refer to the life stage code definitions used for count data (Section 3.3.3).
SCALE	Enter 6 if measurements are recorded in optical micrometer units; enter 7 if measurements are recorded directly in millimeters. (If optical micrometer units are recorded for a measurement, the actual length in millimeters will be obtained later by multiplying the measurement by the conversion factor.)
MEASUREMENT	Record the total length of larvae to the nearest 0.1 optical micrometer unit or to the nearest 0.1 mm.

3.5.2 Storage and Chain of Custody of Data Sheets

Maintain all completed data sheets in duplicate. Keep photocopies at the site of origin and transfer the originals as needed from the laboratory to the data center, quality control, and a master project file. Track the custody of data sheets by means of data control logs.

3.6 QUALITY CONTROL

3.6.1 Tasks Subject to Quality Control

The following tasks are subjected to quality control checks consisting of reanalysis of randomly selected samples or measurements:

- sorting
- identification, life stage determination, and enumeration

3.6.2 Inspection Plans

Items are inspected using a quality control (QC) procedure derived from MIL-STD (military-standard) 1235B (single and multiple level continuous sampling procedures and tables for inspection by attributes) to achieve a 10 percent or better AOQL (Average Outgoing Quality Limit). The QC procedure used is the CSP-1 continuous sampling plan, which is conducted in two modes as follows:

- Mode 1. Reinspect one hundred percent of the samples until "i" consecutive samples pass.

- Mode 2. After "i" consecutive samples pass QC reinspection, randomly choose (using a random numbers table) the fraction "f" of the samples for reinspection. If any QC sample fails then return to Mode 1.

For this application of CSP-1, **i=8** and **f=1/7**, because the total number of samples analyzed by an individual is less than 500. It is important that QC inspections are performed as soon as possible after the original analysis; work-up of QC samples must not be postponed to be done in batches. Keeping the QC program as current as possible insures that problems are detected and remedied quickly, minimizing the additional number of samples that are analyzed before the problem is addressed.

Select items for reanalysis according to the plan using a random number table. The original analyzer should not know whether a sample is to be checked before the analysis of that sample has been completed. Perform all quality control checks "blindly" (i.e., the individual performing the QC inspection should have no knowledge of the original analyst's results).

Apply the QC plan on an individual processor basis, so that each person's work is subjected to the QC plan independently of others, starting at 100% inspection.

A resolution (third person) value may be determined for any sample found defective. All errors found during the QC check, whether the sample is found to be defective or not, are to be corrected on the data sheets. (A difference between original and QC counts that is within acceptable limits is not considered to be an error). Results of the quality control program are to be presented to all sorters and identifiers and help is to be made available to anyone failing a QC check.

In some cases a QC inspection may be able to determine the taxon or life stage of damaged specimens when the original identifier has recorded them as unknown life stage, unidentified taxon, or a higher level taxon (genus or family). If a more general taxon or life stage used by the original identifier includes the more specific category used by the QC inspector, and that is the only reason for a count discrepancy, then that sample does not fail the QC inspection on the basis of that taxon. For example, damaged specimens recorded as *Morone* sp. by the original identifier and as striped bass by the QC inspector are to be considered in agreement because the category *Morone* sp. includes striped bass. In contrast, an original determination of unidentified gobiid would not be acceptable if the QC determination was striped bass, because striped bass is not included in the family Gobiidae. If substantial differences occur between the original and QC counts as a result of identifying or staging to different levels, then the identifier should be provided with additional guidance or training to minimize such differences in future samples.

3.6.3 Acceptance/Rejection Criteria

3.6.3.1 Sorting

A sample is considered defective if the sorter failed to remove 10 percent of the total organisms in the sample (or subsample). Percent error is calculated as follows (where "QC count" denotes the number missed by the sorter):

% error = 100% x QC count/(sorter's count + QC count)

When the total count (sorter's plus QC) is ≤20, then the sample is considered defective only if the sorter missed more than two organisms.

3.6.3.2 Identification

A sample is considered defective if an error of 10 percent or more is made in identifying, assigning a life stage, or counting any species. In determining whether a sample is defective, analyzer and QC results are compared within each taxon/life stage combination.

For each taxon (or for a life stage within a taxon) the percent error is calculated as follows (except where the QC count is ≤20, the percent error is considered to be zero if analyzer and QC counts differ by no more than two organisms):

$$\% \text{ error} = 100\% \times |\text{analyzer count} - \text{QC count}| / \text{QC count}$$

A sample with a percent error of greater than or equal to 10% for any life stage for any taxon is considered defective.

For each defective sample, a resolution may be determined in which a third person reanalyzes the sample (resolution value). The error for each species and life stage will then be calculated using the resolution counts as the divisor. This will be done for both identification and QC counts:

$$\% \text{ error} = 100\% \times |\text{identifier count} - \text{resolution count}| / \text{resolution count}$$

$$\% \text{ error} = 100\% \times |\text{QC count} - \text{resolution count}| / \text{resolution count}$$

If the resolution vs. identifier error is <10 percent, the sample passes. If they are not, the sample fails and identifier counts are replaced by QC counts for all cases, provided the QC vs. resolution error is <10 percent. If the resolution vs. identifier and the resolution vs. QC errors are both 10 percent or more, the sample will be thoroughly reviewed by all three people and the identifier's sample processing will not continue until agreement can be reached on the identification of the sample. Subsequent samples will be reanalyzed by the QC person until eight consecutive samples pass. Notify the Laboratory Manager of any identifier exceeding two failed samples.

3.6.4 Quality Control Records

Maintain quality control logs, documenting the samples analyzed, the samples selected for reanalysis according to the QC plan, the results of the QC analysis, and any corrective action performed. All QC logs will be 100% inspected monthly by the Laboratory Supervisors. A summary report of quality control results and follow-up corrective action will be submitted to the client upon request.

3.6.5 Quality Control Personnel

The QC of the sorting process is to be conducted under the direct supervision of the Sorting Supervisor. Only the Sorting Supervisor or individuals with a documented sorting QC record of superior performance may provide sort QC.

Regarding identification QC, only the Identification Supervisors will be performing the QC on ichthyoplankton identification.

3.7 REFERENCE COLLECTION

Make sure that each taxon and life stage identified in the PBAPS entrainment program is represented in the general ichthyoplankton reference collection at Normandeau's biology laboratory. Add to that reference collection as needed by removing specimens from PBAPS entrainment samples and storing them in vials in a designated area. If available, include several (e.g., 10) specimens per taxon per stage, displaying a variety of sizes. Label the vials with the scientific name, date of capture, capture location, and a reference collection catalog number. The catalog number identifies a card containing more detailed sampling information, identifier, comments, etc. File the cards alphabetically by family, genus, and species.

Voucher specimens (at least two individuals, if available) of federal and state threatened , endangered, and candidate fish species shall be retained and catalogued. This includes the Chesapeake logperch (*Percina bimaculata*) which is known to occur within the vicinity of the collection location.

3.8 INSTRUMENT CALIBRATION

Calibrate each ocular micrometer periodically (at least weekly) using a stage micrometer. After calibration of ocular micrometers on zoom microscopes, place a calibration mark on the microscope so that measurement accuracy is maintained. Ocular micrometers on microscopes that have been adjusted or moved must be recalibrated before use.

4.0 DATA PROCESSING

4.1 DATA ENTRY VERIFICATION AND DATA SHEET CHAIN OF CUSTODY

Provide a submittal form with each batch of data sheets submitted to the Technical Data Processing (TDP) department in the Stowe office for data entry. Information on the submittal form should include names of sender and recipient, date sent, and dates of entrainment collections included in the batch.

In Bedford, key all data twice, resolving discrepancies between the two versions as they are flagged by the data verification program. In Stowe, key data once and conduct an independent check of 100% of the keyed data against the data sheets. Correct any mistakes.

After data entry and verification are complete, transfer custody of the data sheets from TDP to the project file and notify the Project Manager in the Stowe office, where they are used in the error checking and quality control tasks, and finally stored in a project file. Document the transfer from TDP back to the Stowe Office by one or more submittal sheets containing the same information as those used to transfer custody to TDP. TDP is not required to maintain copies of the data sheets. After Exelon accepts the data files and final report, the original data sheets and paper copies of them may be discarded.

4.2 SYSTEMATIC ERROR CHECKS

Keyed data are subjected to a series of systematic error checking programs developed specifically for this project. These consist of univariate, bivariate, and multivariate checks specified by project personnel. Univariate range checks identify records for which one or more variables have values outside their valid or expected ranges. Bivariate and multivariate checks compare values of related variables. Additional checks scan the data for duplicate or missing observations. All records flagged by these programs are resolved, and corrections to both the data files and the data

sheets are made as necessary. After error checking is complete, data files are subjected to quality control inspection (refer to Section 4.4).

4.3 DATA FILE FORMAT

Error checked data files are assembled into a Microsoft Access or Excel database.

4.4 QUALITY CONTROL OF DATA FILES

Data files that have completed the systematic error checking process undergo a QC inspection to assure a 1% AOQL (Average Outgoing Quality Limit) according to a lot sampling plan (American Society for Quality Control. 1993. Sampling procedures and tables for inspection by attributes. ANSI/ASQC Z1.4-1993). This procedure ensures that ≥99% of the observations in a data file agree with the original data sheets. The number of observations to be checked, and the number of those that must be within tolerance are shown below. If more than the acceptable number of failures are found, then the data set must be inspected 100%.

LOT SAMPLING PLAN FOR QC INSPECTION AT LESS THAN 1% AOQL.

		NUMBER OF FAILURES	
LOT SIZE	**SAMPLE SIZE**	**ACCEPT IF ≤**	**REJECT IF ≥**
1-32	All	0	1
33-500	32	0	1
501-3,200	125	1	2
3,201-10,000	200	2	3
10,001-35,000	315	3	4
35,001-150,000	500	5	6
150,001-500,000	800	7	8
500,001 and over	1,250	10	11

5.0 TRAINING

In order to assure the standardization of field, laboratory, and data processing procedures, Normandeau has developed a two level system for training technicians: the first level being documented standard operating procedures; the second level being a training program for all new project personnel. At a minimum, this training program consists of the following steps:

- A complete reading and explanation of the project SOP and QA manual. This is documented by a sign-off sheet that is filed in the project file.
- Observation by the Project Manager, Field Site Supervisor or Laboratory Manager of the first two or more times a new procedure is performed. This is documented with a signed checklist.
- Direct supervision by an experienced technician of personnel assigned to unfamiliar tasks for their first two or more attempts.
- 100% quality control checks for at least the first five samples analyzed.
- On tasks requiring identification of fish and ichthyoplankton, the Project Manager will have final approval as to who is qualified to make these identifications. In some

cases special training will be required to participate in tasks, as set forth by the Project Manager.

6.0 QUALITY ASSURANCE

6.1 NONCONFORMANCE REPORTS AND CORRECTIVE ACTION

Documentation of problems or unusual events occurring during a project will be accomplished using Extraordinary Event/Nonconformity (EENC) forms. The EENC form (Appendix A) is designed to dispense information to the Project Manager and Quality Assurance department and to obtain necessary action on items that are critical to technical operations and management of projects. The report results from observations such as these:

- deviations from standard operating procedures
- losing a sample
- finding an endangered species in a sample
- noting samples that are grossly different from expected (content, preservation, labels)
- noting a phenomenon that may deserve continued monitoring in the interest of the client and therefore may require a change in the scope of work
- quality control samples that exceed acceptable limits.

Items, samples, data, or information not in conformity with specifications or which do not meet preconditions for the next step in processing or use, are set aside until the problem is resolved and documented via the EENC report procedure.

Any person who identifies a problem or discovers information that is germane to a project scope of work or the improvement or change of contract performance shall report the matter to the Project Manager with a copy to the Manager Quality Assurance. The Project Manager confers with appropriate parties and decides what corrective action will be required. Instructions are provided to the person responsible for carrying out the corrective action. After the problems is resolved, he reports back to the Project Manager to confirm that the corrective action has been completed. The Project Manager periodically reports to the Manager QA on the status of actionable items and the status of corrective actions.

6.2 QA INSPECTIONS

Verification of the achievement of quality objectives will be accomplished primarily by inspections or audits, tests, and self-assessments which will provide objective evidence that the quality control program and technical requirements, methods, and procedures as outlined in the study QA plan are being implemented. All field, laboratory, and data processing tasks will be subject to at least one inspection or audit.

APPENDIX A

Forms

PEACH BOTTOM ATOMIC POWER STATION

Entrainment Field Data Sheet

SAMPLE COLLECTOR

SAMPLE

sample number

status

comments

DATE & TIME

	month	day	year	hour	min
start				start	
				end	

VOLUME
(gallons)

end	
start	
difference	
flow	gpm

WATER QUALITY

temp.		°C
pH		std. units
D.O.		mg/l

WEATHER

sky

wind dir.

wind sp.

Data sheet QC

initials _____ date _____

COMMENTS

Peach Bottom Entrainment Data Sheet Instructions

VARIABLE	INSTRUCTIONS
Sample collector	Initial here when on site for sample collection
Sample Number	A six-digit number predetermined from the label
Status	Enter code for status of sample: 0 = void (no sample) 1 = valid sample 2 = sample is provisional due to flowmeter problem
Comments	If comments are written at the bottom of the data sheet, enter 1; If not, leave it blank
Start Month	Record the month that the **24-hr** sampling event began
Start Day	Record the day that the **24-hr** sampling event began
Start Hour	Record the hour that the 100-cubic-meter diel sample began, using 24-hr clock (0000-2359 hrs)
Start Minute	Record the minute that the 100-cubic-meter diel sample began, using 24-hr clock (0000-2359 hrs)
End Hour	Record the hour that a 100-cubic-meter diel sample (or a subsample) ended, using 24-hr clock (0000-2359 hrs)
End Minute	Record the minute that a 100-cubic-meter diel sample (or a subsample) ended, using 24-hr clock (0000-2359 hrs)
Gallons, end	Record the flowmeter reading for total gallons at the end of the sample
Gallons, start	Record the flowmeter reading for total gallons at the beginning of the sample
Gallons, difference	Subtract the starting flowmeter volume reading from the ending flowmeter volume reading
Flow (gpm)	Divide the difference in gallons by the duration of the sample in minutes
Temp.	Record the temperature to the nearest 0.1°C
pH	Record the pH to the nearest 0.1 standard unit
D.O.	Record the dissolved oxygen concentration to the nearest 0.1 mg/l (ppm)
Weather	Record the sky condition, wind direction and wind speed using the following codes: **Sky** 1= clear, 2= hazy, 3= partly cloudy, 4= mostly cloudy, 5= overcast, 6= fog **Wind Direction** 1= none, 2= N, 3= NW, 4= W, 5= SW, 6= S, 7= SE, 8= E, 9= NE **Wind Speed (mph)** 1= 0-5, 2= 5-10, 3= 10-15, 4= 15-20, 5= 20-30, 6= 30+
Comments	Insert any additional comments or notes

PEACH BOTTOM ATOMIC POWER STATION

Flowmeter Calibration Sheet

SAMPLER | | | | **DATE** | | | month | | day | | year | |

CALIBRATION pump serial number _____

	trial 1	trial 2	trial 3
gauge gpm			
calibration seconds			
calibration gallons			
calibration gpm			
percent error			

average % error | | | |

calibration gpm = calibration gallons / (calibration seconds/60)

percent error = 100 x (gauge gpm – calibration gpm) / calibration gpm

month day year

PEACH BOTTOM ATOMIC POWER STATION

Hazardous Substances Log, page ___

Amounts of formalin brought on site for entrainment sampling

Date	Name	Gallons of Formalin

APPENDIX B

Pre-job Safety Checklist

Exelon Nuclear

Ensure Positive Engagement by all participants

ATTACHMENT 1

Pre-Job Briefing Checklist

Encourage Use of Reverse Briefs

Activity Description **ENTRAINMENT SAMPLING** Briefing Leader: Joe Brozonis

Purpose

☐ Review task, scope, and nature of work

Complete weekly entrainment sampling which requires two 12-hr sampling events. Sampling requires use of electrical equipment including trash pump and sump pump. Pumped water will be washed through a plankton net and the contents of the sample will be preserved in formalin.

-Check rubber material covering the 480v line across rd, if pulled apart notify Exelon

Document Review

Review documentation that will be used to complete the task:

- ☐ Procedures- SOP, complete 2-minute drill prior to work
- ☐ Turnover Information-live time between day and night shifts

Task Assignments

Identify and understand:

- ☐ Roles and responsibilities-Mark Ross is task mgr
- ☐ Qualifications-properly trained in sampling techniques, read SOP and HASP
- ☐ Personal limitations

Hazards and Mitigating Methods

- ☐ Identification of safety hazards (**electrical- pumps, chemical- formalin**, **walking safety- safety barrier, layflat hose,** etc.), weather (icing, heat, wind), pinch points
- ☐ Work procedures involved
- ☐ Personal protective equipment (PPE)- hard hat, safety glasses, work boots, work gloves.

Human Performance

Address human performance tools for error precursors, hazards, and each critical step relevant to risks with nuclear, industrial, radiological, environmental safety, reactivity management and/or operational risk activities (ORA).

- ☐ 2-Minute Drill
- ☐ STAR
- ☐ Peer Check
- ☐ Review SOP and HASP for specific information

Special Requirements or Unusual Conditions

- ☐ Resources, tools, and material-sampling equipment
- ☐ Interfaces with other organizations-Security
- ☐ Interaction with other activities planned or in progress
- ☐ Communication methods and potential obstacles to their effectiveness

-stay away from security fence when working

Operating Experience

- ☐ Specify how similar errors, events, or the causes of similar events will be avoided

Contingencies / Stop-Work Criteria

Review contingencies, changes in task conditions or its scope regarding unexpected equipment response:

- ☐ OOPS, stop work criteria
- ☐ Event response – if mistake is made, misposition occurs, spill, etc.
- ☐ Who to contact if concerns/questions arise-unusual events contact Operations, Joe Brozonis

-wasps or other insects which impede sampling

THU – Validate Assumptions / Questioning Attitude

Oversight

- ☐ Define the degree of management involvement
- ☐ Industrial Safety / Operational / Reactivity / Environmental / Atmospheric Risk requirements

Joe Brozonis x3795 or Mark Ross x3452

Refer to SOP, pre-job checklist and 2-minute drill

Questions and Concerns

- ☐ Review questions and concerns workers may have with the job

-Safety topic of the week

-Success for this activity can be defined as no safety issues and the collection of all scheduled samples.

The 5 Key Questions

☐ Are there any **Critical Steps** in this task? Contact security/plant staff

☐ What are the **Error Likely Situations**? Spill sample

☐ What is the **Worst Thing** that can go wrong? voided sample

☐ What **Defenses** are we relying upon? Training, SOP, and PPE

Appendix C: Standard Operating Procedures for Entrainment Abundance Sampling at Peach Bottom Atomic Power Station, Revision 1, dated 21 April 2016

Standard Operating Procedures for Entrainment Abundance Sampling at Peach Bottom Atomic Power Station Revision 1

Prepared For:
Exelon Generation Company, LLC
200 Exelon Way
Kennett Square, PA 19348

Submitted On:
21 April 2016

Prepared By:
Normandeau Associates, Inc.
25 Nashua Road
Bedford, NH 03110

www.normandeau.com

Standard Operating Procedures for Entrainment Abundance Sampling at Peach Bottom Atomic Power Station Revision 1

Prepared For:
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200 Exelon Way
Kennett Square, PA 19348

Submitted On:
21 April 2016

Prepared By:
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25 Nashua Road
Bedford, NH 03110

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TECHNICAL REVIEW: _____

PROGRAM APPROVAL: _____

QA APPROVAL: _____

COPY NUMBER: _____

ISSUED TO: _____

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(Normandeau Field)	12
Hannah Proctor (Normandeau Laboratory)	13
Robert Hasevlat (Normandeau QA)	14
June Childs (Normandeau Data Center)	15
Linda Cable (Normandeau Publications Dept.)	Original

I have read and understand this document.

_____ Signature

_____ Date

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1.0 Introduction

Exelon Generation Company, LLC owns and operates Peach Bottom Atomic Power Station (PBAPS) located on the Susquehanna River in Delta, PA (Figure 1-1). A one-year entrainment abundance sampling program is proposed for PBAPS beginning in March 2016 and continuing through the end of September 2016 to provide a portion of the information to fulfill the requirements of §122.21(r)(9) of the Clean Water Act Section 316(b) Regulations for Cooling Water Intake Structures at Existing Facilities (79 Fed. Reg. 48300-48439; August 15 2014). The objective of this one-year entrainment study is to obtain weekly, monthly and annual density data describing the number of fish eggs and larvae per unit volume of cooling water sampled at PBAPS. A previous entrainment abundance study was performed during 2012 by sampling at the circulating water discharge outfall of PBAPS (Normandeau 2013), and this location (Figure 1-2) will also be sampled in 2016 by the same methods to provide a second year of entrainment abundance data as required by §122.21(r)(9) of the Clean Water Act Section 316(b) Regulations. Additionally, the 2016 entrainment abundance study at PBAPS will simultaneously (adjusted for time of travel) sampled at two new locations, one at the outer intake structure (Figure 1-2), and the other at the discharge canal outfall (Figure 1-2), to allow comparison of the entrainment abundance among all of the three locations sampled in 2016.

Comparison of entrainment density and abundance among the three locations sampled during 2016 is intended to evaluate the representativeness of entrainment abundance sampling at the circulating water discharge outfall location. The definition of a cooling water intake structure (CWIS) from §125.92(f) of the Clean Water Act Section 316(b) Regulations is:

> "*Cooling water intake structure* means the total physical structure and any associated constructed waterways used to withdraw cooling water from waters of the United States. The cooling water intake structure extends from the point at which water is first withdrawn from waters of the United States up to, and including, the intake pumps".

Therefore, entrainment sampling at the outer intake structure of PBAPS represents the entrainment abundance at "the point at which water is first withdrawn", and sampling at the circulating water discharge outfall represents entrainment abundance at the point of exit from the PBAPS CWIS just downstream from the intake pumps. Observing statistically significant ($p<0.05$) higher entrainment densities at the circulating water discharge outfall location compared to coincident samples taken from the outer intake structure would suggest fish eggs and larvae are produced in the two intake ponds or in the cooling ponds (Figure 1-3). Observing statistically significant ($p<0.05$) higher entrainment densities at the discharge canal outfall compared to the circulating water discharge outfall location would suggest fish eggs and larvae are produced in the discharge canal or in a small tributary stream entering the discharge canal (Figure 1-4). If statistically significant differences are observed among the three locations sampled for entrainment abundance in 2016, adjustment factors will be developed during data analysis and reporting to make the two years (2012

and 2016) of entrainment abundance data from the circulating water discharge outfall location comparable to the outer intake structure location.

1.1 Organization of this Document

This document is a project-specific Standard Operating Procedures (SOP) that describes the procedures to be used for the field, laboratory, and data file preparation activities for the 2016 PBAPS entrainment abundance characterization study. Following a narrative description of the CWIS at PBAPS (Section 2.0) are separate stand-alone SOP sections for entrainment field (Section 3.0), and entrainment laboratory activities (Section 4.0). Within each of these two SOP sections, subsections from the following list that are applicable to that portion of the study are included: sampling schedule and location, equipment, procedures, sample handling, data handling, quality control, reference collection, and instrument calibration and maintenance. Procedures for data processing, from receipt of completed data sheets to the final data files, are described in Section 5.0. A system for providing the appropriate training for project personnel is described in Section 6.0. Quality Control and Quality Assurance (QA/QC) procedures are described in Section 7.0.

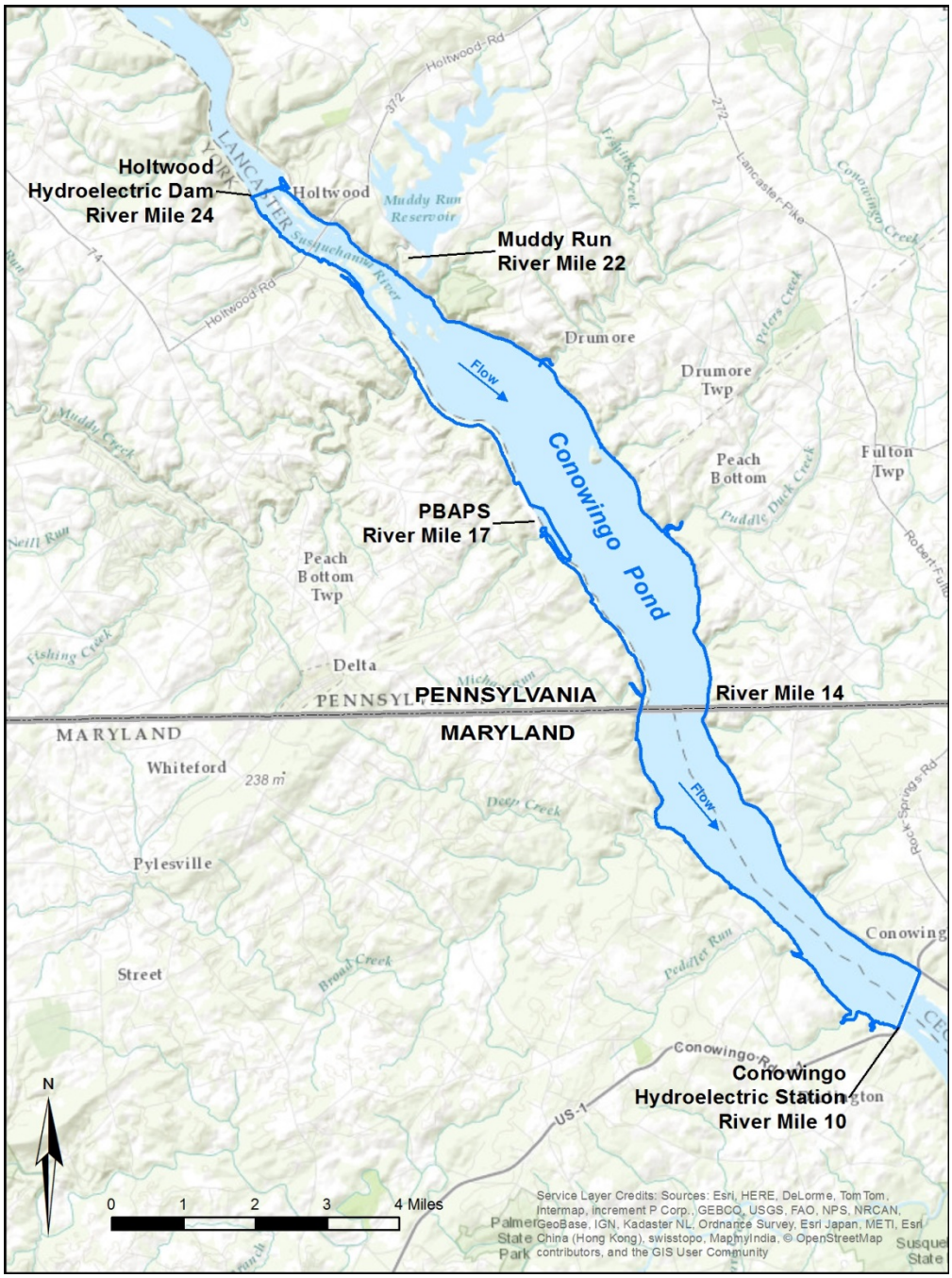


Figure 1-1. Map of Conowingo Reservoir showing locations of Peach Bottom Atomic Power Station and other power plants.

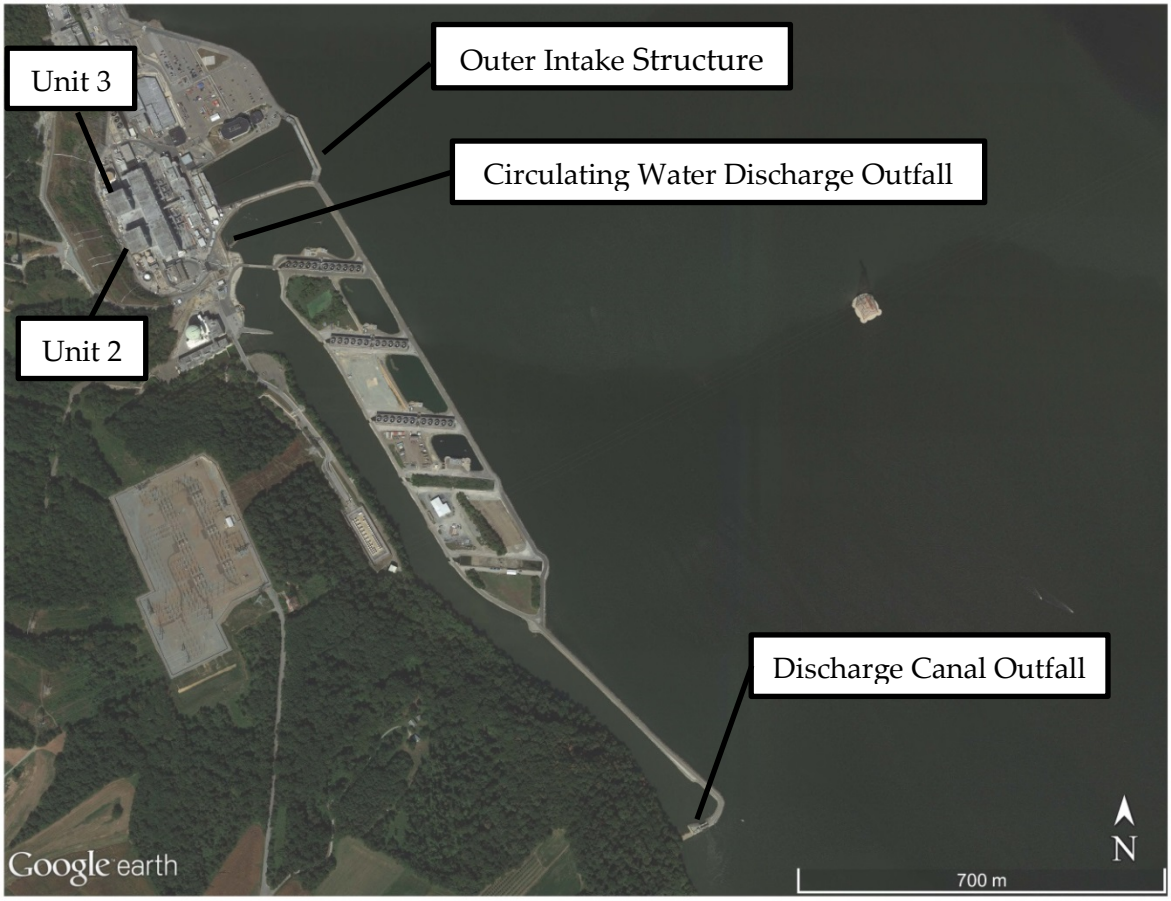


Figure 1-2. Three PBAPS cooling water intake and discharge structures selected for entrainment abundance sampling in 2016.

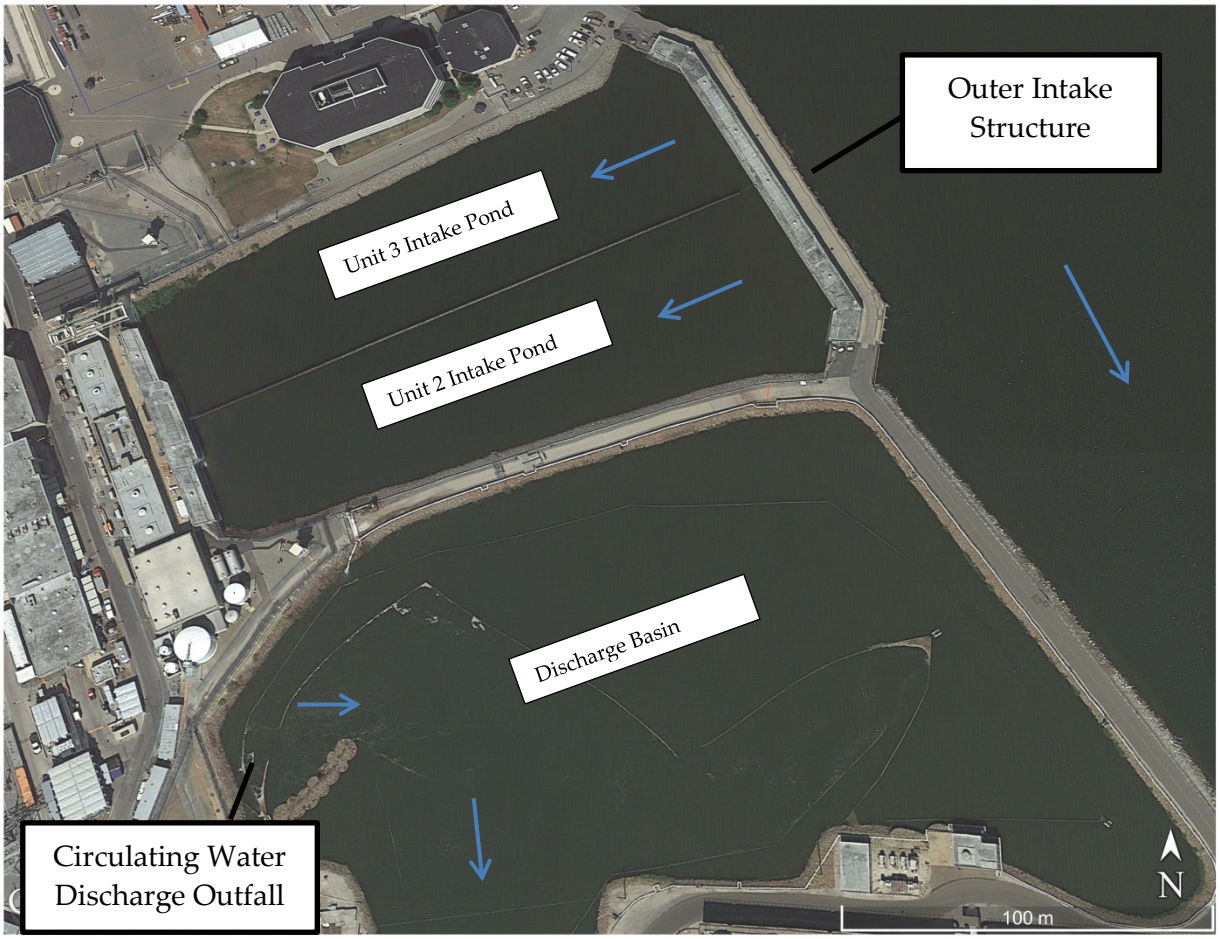


Figure 1-3. Close-up view of entrainment abundance sampling locations at outer intake structure and circulating water discharge outfall of PBAPS during 2016.

Figure 1-4. Close-up view of entrainment sampling location at discharge canal outfall of PBAPS during 2016.

2.0 Cooling Water Intake Structure Description

PBAPS is located in York County, Pennsylvania, on the west shore of Conowingo Reservoir (Pond), approximately 3 miles upstream from the Pennsylvania-Maryland border (Figure 1-1). The plant is located at approximate latitude 39° 45′ 35.82″ N and longitude 76° 16′ 07.20″ W (degrees minutes seconds). PBAPS is a nuclear-fueled power generating facility consisting of two units (Unit 2 and Unit 3) with a combined nominal generating capacity of 2,304 megawatts electrical (MWe). The PBAPS operates as a base-load facility with both units normally generating at full capacity. Unit 2 began commercial operation in June 1974 and Unit 3 entered commercial service in December 1974. A normal startup or shutdown sequence may take about six days. Scheduled maintenance and refueling outages occur every two years, but are staggered so that only one unit outage occurs annually. At the present time, outages last about 20 to 25 days.

Conowingo Pond was formed in 1928 with the construction of Conowingo Hydroelectric Station and has a surface area of about 9,000 acres and a storage capacity of 310,000 acre-feet. The pond is 14 miles long, averages 1 mile wide, and has an average depth of 20 feet at Pond elevation of 104.5 ft.

PBAPS uses a once-through cooling system to remove waste heat from the station's condensers. The cooling water for both units is withdrawn through an outer intake structure located on the shoreline of the Pond, through two 3-acre intake ponds (one serving each unit), and then through an inner intake structure as shown in Figure 1-2. Conowingo Pond refers to the portion of the Susquehanna River impounded by the Conowingo Dam; the boundaries of the Pond extend from the base of Holtwood Dam downstream to Conowingo Dam.

The outer intake is approximately 480 ft long with a fixed vertical trash rack on the face of the intake followed by a set of 24 vertical traveling screens which have 3/8-inch mesh openings. The trash rack consists of 0.25-inch by 3-inch steel bars spaced 3.5 inches on center and is designed to prevent large debris and ice from entering the intake. The trash rack is cleaned periodically per a preventative maintenance program.

After passing through the outer intake, the cooling water flows through the intake ponds to the inner intake (Figure 1-3). Fish live and grow in the ponds and can enter the ponds through the outer screens when they are small, by being carried over the screens if they are not removed during the screen cleaning process, and through the cross-tie gate from the discharge canal in winter. During cold weather and on an as-needed basis, a cross-tie gate between the discharge basin and the intake ponds is opened to re-circulate some of the heated discharge water.

At the inner intake, water enters the pumphouse through eight screen bays. Two bays are devoted to service water flows and six convey water to the circulating water pumps. Water flowing to the circulating water pumps is screened by 3/8-inch mesh dual-flow, or dual-entry single-exit, traveling screens. Approximately 47 ft downstream from the screens, there are six circulating water pumps, three per unit, each with a capacity of about 361 MGD (250,880 gpm) for a facility total of 2,168 MGD (3,360 cfs). The water travels from the circulating water pumps and then passes through the condensers and is discharged into a

common discharge basin (Figure 1-3). From the common discharge basin the discharge flows down a 4,700-ft long canal to the Conowingo Pond (Figure 1-4).

3.0 Entrainment Field Standard Operating Procedure

An entrainment abundance characterization study will be conducted at PBAPS from March through September 2016 with an option for the same time period in 2017 (Figure 3-1).

3.1 Sampling Location and Schedule

The abundance of entrained fish eggs and fish larvae (collectively, ichthyoplankton) will be determined by sampling the water withdrawn from Conowingo Pond through the PBAPS CWIS intake pumps and discharged through the discharge canal. Samples will be collected from three locations: (1) the outer intake structure; (2) the circulating water discharge outfall for Units 2 and 3; and (3) the discharge canal outfall (Figure 1-2). Entrainment abundance sampling at each of the three locations will be performed with a 3-inch electric pump to withdraw entrained cooling water from a suction pipe at each of the three sampling locations.

(Location 1) At the outer intake structure (Figure 1-3) entrainment abundance samples will be collected by pumping with a 3-inch electric pump from a location inboard from the traveling screens. Access for the suction pipe will be gained by deploying a 4-inch diameter schedule 40 aluminum multiport intake pipe vertically through a 4-inch square opening in a diamond plate hatch in the screenhouse deck near a 240v GFI protected temporary power supply. One multiport intake pipe will be deployed at Unit 2 immediately downstream from traveling screen 2G, and a second identical multiport intake pipe will be deployed at Unit 3 immediately downstream from traveling screen 3G to provide alternate sampling locations if Unit 2 or Unit 3 were not operating their circulating water intake pumps. This multiport intake pipe at the outer intake structure has three inlet openings, all facing upstream, one near the surface at elevation 103 feet that is 1.30 inches in diameter and located 19 feet above the bottom, the middle opening is at elevation 94.7 feet that is 2.26 inches in diameter and located 10.7 feet above the bottom, and the bottom opening is located at elevation 86 feet and is a rectangular opening 2.5 inches wide by 5.024 inches high and located 2 feet above the bottom at elevation 84 feet. Note that all elevations used in this SOP are measured with respect to Conowingo Pond full pond elevation reported as 108.5 Feet, and Conowingo Pond low water elevation reported as 104 feet.

(Location 2) At the combined circulating water discharge outfall for Units 2 and 3 (Figure 1-3), a 3-inch electric pump will be powered by a 240v GFI protected temporary power supply and used to withdraw entrainment abundance samples through a 3-inch aluminum suction pipe that is 12 feet long, with one 3-inch round opening at the distal end set at 101 feet of Conowingo Pond elevation, which is directly comparable to the suction pipe, equipment and procedures used in the 2012 entrainment abundance study (Normandeau 2013).

(Location 3) At the circulating water discharge outfall weir (Figure 1-4), entrainment abundance samples will be collected with a 3-inch electric pump powered by a 240v GFI protected temporary power supply. A 4-inch multiport schedule 80 aluminum suction pipe will be secured to the roadway curbing and suspended in the center of the discharge canal near the outfall weir. This multiport intake pipe at the discharge canal outfall structure has two inlet openings, the near surface one is 2.64 inches in diameter located at elevation 98.25 feet of Conowingo Pond elevation and facing upstream at 4.25 feet below the low water

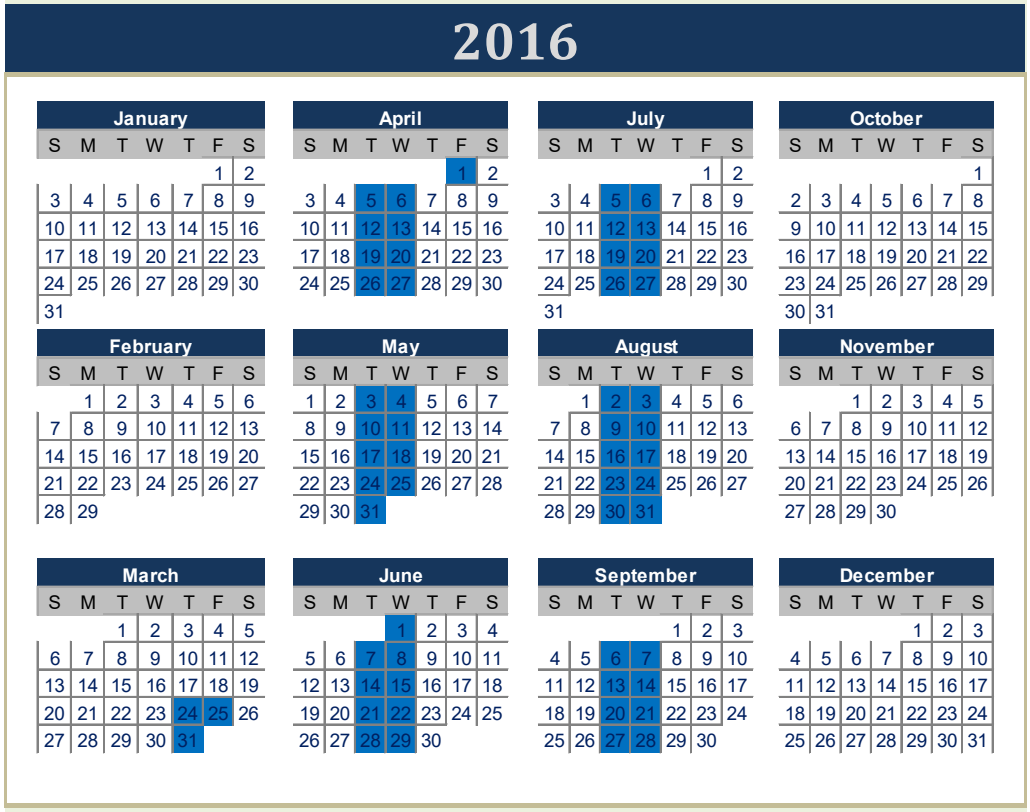
elevation of 102.5 feet in the canal, and the near-bottom opening is at the distal end of the pipe cut at a 45 degree angle and facing upstream, located at elevation 93.25 feet of Conowingo Pond elevation which is 9.25 feet below the low water elevation of 102.5 feet in the canal.

Entrainment abundance samples will be collected at these three locations weekly from March through September 2016 according to the schedule provided in the Work Plan (AECOM 2015) and incorporated into this SOP (Figure 3-1). During each weekly sampling event, four samples representing each of four consecutive 6-hour diel periods spanning 24-hours (i.e., one day) will be collected. These four diel sample periods are 2100-0300, 0300-0900, 0900-1500, and 1500-2100 (DST). The intention is to separate the collection of daytime, nighttime, and crepuscular periods (sunrise and sunset) entrainment samples symmetrically within the corresponding periods of each sampling date. In addition, the start of each diel period sample collection from the outer intake location to discharge canal outfall will be offset to take into consideration the estimated 85-minute transit time of water through the plant. A total of 336 samples are scheduled to be collected in 2016 (28 weeks x 4 diel periods/week x 3 locations = 336 samples).

Entrainment abundance samples will be collected in a barrel sampler (Figure 3-2) at each of the three locations. All entrainment abundance samples will have a target volume of 100 m^3 (27,000 m^3, acceptable range of 26,500 – 28,000 gallons) $\pm$ 10% obtained during about 2 hours and 30 minutes of pumping per sample. A calibrated, in-line flow meter will be used to quantify the actual volume of each entrainment abundance sample collected, and valid entrainment abundance samples will have a sample volume of 100 m^3 $\pm$ 10%. Each entrainment abundance sample will be pumped into a 500 µm mesh net suspended in a barrel sampler (Figure 3-2) filled with ambient water to buffer the flow and help ensure that ichthyoplankton will be in good condition for identification, targeting an overall percentage of damaged larvae of less than 15%. All samples will be preserved in 6% formalin with rose Bengal stain added, properly labeled and transported with chain-of-custody forms to Normandeau's biological laboratory in Bedford, NH, for sorting, identification and enumeration. Water quality data (dissolved oxygen, conductivity, water temperature, and pH) will be collected with each sample.

If for some reason the scheduled entrainment abundance samples cannot be collected at one or more locations, dates, or sampling periods, and at least one unit of PBAPS is operating, a USE CODE =2 sample may be substituted for the pumped sample by deploying a 0.5 m diameter by 3 m long hoop net with a 0.5 mm mesh plankton net and a calibrated General Oceanics flowmeter (G.O. Model 2030R) to collect a qualitative sample of approximately 100 m^3 from a near surface depth at each location. At location 1, the net samples would be deployed from the walkway on the intake pond side (east) of the outer intake structure for about 30 minutes to get a 100m^3 in the ~1 ft/sec current. At Location 2, a 0.5 m hoop net would be deployed from the road bridge over the head of the canal for about 20 minutes to get a 100m^3 in the ~1.5 ft/sec current, as was done in the 2012 study. At Location 3, a 0.5 m

Proposed sampling schedule for entrainment characterization study at PBAPS March 2016 through September 2016.



Each Scheduled Entrainment Sampling Event at Outer Intake Structure (Location 1), Condenser Discharge (Loca end of the Discharge Canal (Location 3) consists of four diel periods:

- **Period 1 = daytime (0900-1500)**
- **Period 2= sunset crepuscular (1500-2100)**
- **Period 3 = nighttime (2100-0300)**
- **Period 4 = sunrise crepuscular (0300-0900)**

Within each diel period, entrainment sample times at 185-200 gpm pumping rate are lagged to start and end as follows:

Time		
Start	**End**	**Daily Schedule**
9:00	11:25	Entrainment sampling at Outer Intake Structure Location 1
9:25	11:50	Entrainment sampling at Condenser Discharge Location 2
10:25	12:50	Entrainment sampling at end of Discharge Canal Location 3

Notes:

1. Entrainment abundance samples will be collected weekly at each location
2. Each sampling event will occur over a single 24-hr period
3. During each weekly sampling event, four samples representing four 6-hour diel periods will be collected
4. Sampling will start on Tuesday morning and end on Wednesday morning
5. the start time for entrainment samples collected within each diel period at each location are lagged with respec as follows: Location 1 = time 0; Location 2 = time 0 + 25 minutes; Location 3 = time 0 + 85 minutes.
6. A total of 28 weeks of sampling from March 2016 through September 2016

Figure 3-1. Entrainment abundance sampling schedule for Peach Bottom Atomic Power Station from March through September 2016.

Figure 3-2. Entrainment abundance sampling tank at the combined circulating water discharge outfall for Units 2 and 3 (Location = 2) for Peach Bottom Atomic Power Station.

hoop net would be deployed from the road bridge just upstream from the discharge weir for about 10minutes to get a 100m^3 in the ~ 3 ft/second current.

3.2 Equipment

Collection gear for PBAPS entrainment abundance sampling consists of an electric powered "trash" pump with 3-inch or 4-inch intake pipe and discharge hoses and a 0.500-mm mesh plankton net suspended in a tank (Figure 3-2).

In addition to the pumping system, the additional equipment listed below is required for entrainment field sampling at each of the three entrainment abundance sampling locations: (1) the outer intake structure; (2) the circulating water discharge outfall for Units 2 and 3; and (3) the discharge canal outfall (Figure 1-2).

- Copy of this SOP and copy of the site specific Health & Safety Plan (HASP; Appendix 4)
- Factory calibrated Signet in-line flow meter
- 0.500 mm mesh net with cod end
- Sampling tank
- Wash down pump
- 1-L wide mouth sample jars with associated internal and external labels
- 0.500 mm mesh (or smaller) sieves and squirt bottles

- Plastic basin for transferring sample material
- 6% formalin solution
- Rose Bengal vital stain
- Personal protection equipment (hard hat, safety glasses, safety boots, leather gloves, life vest, as specified by the HASP; Appendix 4)
- First aid kit and flashlights
- Disposable nitrile gloves
- Assorted plastic buckets
- Sample collection and calibration data sheets (Rite in the Rain paper)
- Chain-of-Custody forms
- Stopwatch
- Assorted binders with pens, pencils, SOP, labels, logbooks, cameras
- Clipboards
- YSI Professional Plus water quality meters (or equivalents) for measuring temperature to the nearest 0.1°C, dissolved oxygen to the nearest 0.1 mg/l, and conductivity to the nearest scale division (Appendix 2)
- pH pen
- Back up water quality meters
- Back up 0.5 m plankton net with 0.5 mm mesh net, calibrated GO flowmeter, line and cable depressor for alternate sampling if pumping system fails
- Calibration solutions as specified by water quality meter manual (Appendix 2)

3.3 Field Sampling Procedures

The planned schedule (Figure 3-1) for entrainment abundance sampling at the three PBAPs locations (1) the outer intake structure; (2) the circulating water discharge outfall for Units 2 and 3; and (3) the discharge canal outfall will be provided to the appropriate plant personnel prior to the onset of sampling in 2016, and plant personnel will be notified of any deviations from the planned sampling schedule as soon as we become aware of these deviations (if any). Project personnel will notify the Exelon point of contact (POC, typically Joseph Brozonis) the Friday prior to sampling of the intent to complete sampling the following week. The project specific Health and Safety Plan (HASP) provides a list of contact information for involved personnel from both Normandeau and PBAPS and is provided for reference as Appendix 4 of this SOP. Upon arriving at the plant the project personnel will call the Exelon POC and notify of their intent to complete entrainment sampling. The project personnel will provide the Exelon POC with their name, cell phone number, and sampling schedule for the event. The Exelon POC will need to tell the project personnel if no circulating water is being pumped at either unit. If no circulating water is being pumped from at least one unit, sampling will be suspended for that scheduled data and rescheduled for the next available date before the next planned sampling date.

Sampling will only occur if at least one circulating water pump is operating for Unit 2 or Unit 3. In addition, PBAPS has requested that the Normandeau crew performing entrainment sampling at the combined circulating water discharge outfall for Units 2 and 3 (Location 2) contact plant security each time during the 24-hour sampling date that they enter and leave the sampling location, unless arrangements are made with the Exelon POC or PBAPS security for less frequent notifications.

Once all four samples are collected at each of the three locations during the scheduled 24 hour sampling event, project personnel should notify the Exelon POC that the sampling event is complete.

3.3.1 Operation of the Electric Entrainment Sampling Pump

1. Remove the fill cap from the pump housing and fill the chamber with water to prime it.
2. Replace the fill cap.
3. Unlock the starter box switch and turn the power switch to on.
4. Monitor the entrainment tank for water flow. If there is no flow within 90 seconds stop the pump, check for air leaks, re-prime, and repeat steps 1 to 4.
5. Once a continuous flow is obtained, observe the flow rate at the flow meter to verify that the flow rate is 185-200 gallons per minute. Note: due to length of suction hose and head the maximum flow rate at Location 2 will be about 185 gpm, while the flow at Locations 1 and 3 may be 250 gpm or higher. Therefore, the flow valve at Locations 1 and 3 should be adjusted to 185 to 200 gpm to synchronize the sampling flow and durations needed to collect ~27,000 gallons at each of the three locations.
6. Check the flow meter calibration as described in Section 3.3.2 below.
7. Install the sampling net and begin collecting the sample as described in Section 3.3.3 below.

To stop and secure the pump:

1. Turn the power switch to off.
2. Drain the pump hosing using the drain valve located at the bottom of the housing.
3. Leave the valve open.
4. Wipe off any water that is on the pump motor.
5. Drain the sampling tank and secure the flow meter.

3.3.2 Flow Meter Calibration

Prior to the first sample of each scheduled sampling day, measure the flow rate delivered by the sampling pump by filling the calibration tank to known volume (Location 2) or filling to overflowing a calibration tank of known volume (Locations 1 and 3) (to the nearest gallon) and noting the time required to fill this tank to the nearest 1 second. The calibration on the next sampling date will provide the post-calibration of the previous sampling date. The

following calibration tank volumes are used for calibration of the entrainment pumping system installed at each of the three sampling locations at Peach Bottom:

Location 1 calibration tank volume = 202 gallons

Location 2 calibration tank volume = 200 gallons

Location 3 calibration tank volume = 262 gallons

During this calibration test, the pump should be operating at typical flow for sampling of 185 gpm to 200 gpm at each location. Record the measured flow rate in gallons per minute (gpm) indicated on the flowmeter gauge during the calibration test. Calculate the observed flow rate to fill the calibration tank as follows:

calibration flow rate gpm = calibration tank volume in gallons / (calibration seconds) * 60 seconds/minute

Then calculate the percent error of the observed calibration gpm compared to the expected flowmeter reading gpm as indicated by the calibration trial as follows:

percent error = 100 x (calibration gpm - flowmeter gauge gpm) / flowmeter gpm

The percent error can be positive or negative depending on whether the expected Signet flowmeter gauge gpm was larger or smaller than the observed calibration gpm. Record the results on the Entrainment Field Data Sheet in the Flowmeter Calibration section, *including the minus sign* if the percent error was negative. If the absolute value of the percent error is less than 10% then no further action is necessary. An example of the percent error calculations is shown below:

Tank Volume = 200 gallons for Location 2

Flowmeter gauge setting = 185 gpm

Time to fill calibration tank = 63 seconds

Calibration GPM to fill the tank = 200 gal/63 sec * 60 sec/minute = 190 gpm

Percent error = (190 gpm – 185 gpm)/190 gpm * 100 = +2.6%

If the absolute value of the percent error is more than 10% then repeat the calibration trial two more times and average the three results, recording the results on separate Entrainment Field Data Sheets for the same sample number and header information. Keep the minus signs, if any, in calculating the average of the three values (if there are both positive and negative percent errors, they will partially cancel each other out). If the absolute value of the average percent error is less than 10% then no further action is necessary. In the example above, since +2.8% is less than 10%, the flowmeter passed this calibration test.

If the absolute value of the average percent error is more than 10% then replace the flowmeter and return it to the manufacturer for servicing. If there is no replacement flowmeter available immediately, continue to collect samples with the one that failed calibration, but enter the code for "flowmeter problem" (USE CODE = 2) in the sample status box on the Entrainment Field Data Sheet. It may be feasible to estimate the sample volume by comparing the duration to durations of samples with known volumes collected

during similar conditions. See the Section 3.3.3.3 below for a description of use codes and sample collection narratives.

3.3.3 Sample Collection

The start of each diel period sample collection on a given sampling day from the outer intake location (Location 1) to discharge canal outfall will be offset to take into consideration the estimated 85-minute transit time of water through the plant. The start time of the first diel period (0900-1500) sample at the outer intake structure will establish the offset times for sampling at the circulating water discharge outfall for Units 2 and 3; and at the discharge canal outfall. Consider the start of the outer intake canal sample within each diel period to begin at Time = 0 minutes when the collection net is first deployed to filter the entrainment sample at that location. Then the offset time to deploy the collection net at the circulating water discharge outfall for Units 2 and 3 to collect the entrainment abundance sample there is Time 0 + 25 minutes, and the offset time to deploy the collection net at the discharge canal outfall to collect the entrainment abundance sample there is Time 0 + 85 minutes. For example, if the collection net is deployed to collect the entrainment abundance sample from the outer intake structure at 0900 DST to begin the first diel period (Period 1 = 0900-1500) sample there, then the entrainment abundance sample at the circulating water discharge outfall for Units 2 and 3 should begin collecting at 0925 DST; and the discharge canal outfall sample should begin collecting at 1025 DST. These offset collection times for each diel period will each end when 100 $m^3 \pm 10$ m^3 of circulating water has been filtered through the collection net at each location This same offset should be maintained for each subsequent diel period and location within each scheduled sampling day (24-hours).

If for some reason, the sampling times at any of the three locations deviate by more than ten minutes from the prescribed offset times of 0 minutes (Location 1), 25 minutes (Location 2) and 85 minutes (Location 3) within a sampling period, each sample collected out of synchrony with these specified times is assigned a Sample Narrative (SAM_NAR) of 2. See Section 3.3.3.3 below describing use codes and sample narratives below for more information.

Shortly before the scheduled start of the first 6-hour sampling period at each of the three locations, install the Signet probe in the T valve and secure it in place, taking care to protect the sensor cables. Then, start the pump and adjust the flow rate to approximately 185-200 gallons per minute (gpm). Record the time that water begins to enter the sampling net and also record the totalizer reading. Fill out the sample identification information at the top of the Entrainment Field Data Sheet (Section 3.5.1). Check the flowmeter gauge periodically and adjust the waste and sample valves if necessary to maintain a pumping rate similar to the start of the sample (i.e., 185-200 gpm).

At times, clogging of the net mesh may make it necessary to switch to a clean net during a sample. To insure clogging and egg or larval damage is minimized, be sure to switch out the collection net at each location every 20 to 30 minutes, and record each time the net is switched out in the appropriate section on the field data sheet To switch nets, move one net to the side, placing the other net under the flow, and remove the original net to collect a subsample without interrupting sample collection. If subsamples are collected in this way before the sample is completed, concentrate and preserve the sample material after each net

switch in the same manner as described below for the completed sample. More than one subsample may be preserved in the same jar, but if multiple jars are used, label each one with the same sample number and indicate that multiple jars were used (e.g. "1 of X").Wait until the totalizer indicates 27,000 gallons to make sure that at least 100 cubic meters of water has been sampled through the collection net before ending the sample. After the volume has reached at least 27,000 gallons, turn off the pump, and record the time and totalizer reading. At a constant pumping rate of 185 gpm, it should take about two hours and 25 minutes to collect 27,000 gallons (100 m^3). At a pumping rate of 200 gpm, it should take about two hours and 15 minutes to collect ~27,000 gallons (100 m^3).

When the ~100 m^3 sample volume is completed (and any time plankton nets are exchanged during a sample due to clogging), wash the sample (or subsample) into the cod end bucket using a washdown pump. Washing the net contents down should be done with water from a sump pump set into the bottom of the entrainment tank that supplies previously filtered water (i.e., filtered through the 0.500 mm plankton net) so additional ichthyoplankton are not added to the sample from raw (unfiltered) water. Collect the sample material from the cod end bucket and place it in a labeled sample container. A 0.500 mm or finer sieve may be used to remove excess water from the sample before transferring it to the sample jar. Take care that none of the sample is spilled, and that the contents of the net and cod end bucket are completely rinsed into the sample container or sieve. Pouring the sample into the jar should always be done over a larger container in case some sample is spilled. Sample containers and cod end buckets that are open should be set down only in a container or bucket, just in case the sample is spilled. Preserve the sample by adding sufficient formalin to make the final concentration 6% (60 ml of full-strength formalin per liter of sample). Add Rose Bengal vital stain to each sample to turn the live ichthyoplankton red in each preserved sample.

Repeat the above procedures for three additional diel samples within the 24-hr collection period. The starting times of the four diel samples should be approximately six hours apart. Reset the totalizer reading on the flowmeter to zero in between samples.

Before leaving the site at each of the three locations, disconnect and drain the system and pump housing and secure the pump system using the following procedures:

1. Turn the power switch to off.
2. Drain the pump hosing through the grating on the catwalk using the drain located at the bottom of the housing.
3. Leave the valve open.
4. Wipe off any water that is on the pump motor.
5. Drain the sampling tank and secure the flow meter.
6. Secure the starter box switch in the off position using a padlock when Normandeau staff are off site after completing each 24-hour sampling day.

Sample Use Code Status and Collection Narratives

Each field sample is assigned a unique sample number and a use code and sample narrative code at the time of collection defining its availability for use in analytical tasks. A use code 1 sample was one in which valid data was collected and no sampling problems were encountered. A use code 2 sample was one in which a sample or portion of a sample was collected but sampling problems were encountered so that the sample collection was not as specified by the procedures in Section 3.3 (and all subsections) of this SOP. Pumped entrainment sampling problems are generally related to gear deployment, flow measurement or timing that could affect the calculation of density (fish caught per unit volume of sample collected) and the comparison of fish density from sample to sample. Since density has two components, number of fish (numerator) and volume of water from which those fish were collected (denominator), deviations in either can result in a biased density estimate that might affect interpretation. For example, with respect to the numerator (number of fish), spilling a portion of a sample when washing it from the cod end of the net into the sample jar or noticing a hole in the net causes the sample collected to be classified as a Use code 2 sample. With respect to the denominator (sample volume), stopping the sample short of 100m^3 or having the flowmeter stop working during the collection interval means we don't have the sample collected with the specified (or know) volume, but some sample was collected, also causing it to be classified as a use code = 2 sample. A use code 5 sample is the same as a use code 2 sample but no fish or no volume measurement exists. Use code 1 samples are valid for all data analysis. Use code 2 samples may be used for length-frequency analysis or to describe the timing of seasonal occurrence of the ichthyoplankton entrained, but the final decision for its use will depend on the specific reason for the sample being classified as use code 2 and its relationship to the type of analysis. Use code 5 samples are excluded from all data analysis. Therefore, all use code 5 samples must be collected again until they are classified as use code 1 or use code 2 to satisfy the sampling requirements of PBAPS's entrainment program objectives.

The sample narrative code applies strictly to the synchrony or timing of each sample collection. For appropriate comparison of samples from all three sampling locations at PBAPS, without confounding effects of ichthyoplankton patchiness, our field procedures specify that sampling at Location 1 (outer intake structure) represents time 0 with respect to water withdrawal from Conowingo Pond into PBAPS. Since it takes an estimated 25 minutes for Conowingo Pond water first entering the outer intake structure at time 0 to travel to Location 2 (the circulating water discharge outfall for Units 2 and 3), and 85 minutes for this same water to travel from Location 1 to Location 3 (the discharge canal outfall), we have lagged the start of sample collection at each location to insure the same "slug" of water is sampled at all three locations within each of the four diel sampling periods. Each sample collected with the appropriate lag (0, 25, or 85 minutes, ±10 minutes for Locations 1, 2, and 3, respectively) for each location is assigned a SAM_NAR =1. If for some reason, any one or more of the three synchronized samples within a sampling period cannot be collected as use code = 1 (i.e., it is use code = 2 or use code = 5), rather than collect the entire set of three samples again to insure we have collected three use code = 1 samples in that period, if sufficient time within the 6-hour diel sampling period remains, a replacement use code =1 sample should be taken to represent the missing use code 2 sample. This replacement sample will be assigned a SAM_NAR = 2 indicating it was collected out of

lagged sequence specified in this SOP Section 3.3.3 above. For example, suppose the diel Period 1 sample at Location 1 is started at 0900 DST, Location 2 is started at 0925 DST, and Location 3 is started at 1025 DST. The Location 1 and Location 3 samples are collected as specified, each of these two samples represents 27,000 gallons, and therefore both samples are use code = 1, sample narrative = 1. A location 2, the flowmeter clogged after 90 minutes of collection (e.g, clogged at 1055). At 185 gpm, this 90 minute sample at location 1 represents just 16,650 gallons (63 m^3), which is more than 10% below the specified 27,000 gallons (100m^3). Therefore the Location 2 sample started at 0925 DST is classified as use code = 2 sample narrative = 1. Keep this sample and, since time remains within Period 1 to collect a make-up sample to replace the use code 2 sample, the flowmeter is fixed, calibrated, and a second sample is started at Location 2 at 1100 DST. The make-up sample from Location 2 is collected for 2 hours and 25 minutes at a pumping rate of 185 gpm, still within diel Period 1, providing a use code = 1 sample of 27,000 gallons (100m^3). This second sample is out of synchrony with the original set of three samples and is assigned a sample narrative = 2, but is still useful to describe the entrainment density for Location 2 during Period 1. This second sample from Location 2 will not be used for analysis of density differences between pairs of samples collected within diel Period 1 on that date, and assignment of SAM_NAR = 2 will be used in the data analysis to eliminate this sample from paired comparisons.

USE CODE DEFINITIONS

USE CODES	DEFINITION
1	Assigned to samples when there are no sampling problems with the gear and the deployment was as specified in the SOP.
2	Assigned to samples when sampling problems are encountered with the gear and/or volume measurements.
5	Assigned to samples when sampling problems are encountered and no fish or volume measurements are available.

SAMPLE NARRATIVE DEFINITIONS

1	Assigned to samples collected in the time-lagged sequence specified in the SOP (± 10 minutes). The time-lagged sequence is as follows: Location 1 = time 0; Location 2 = time 0+25 minutes; Location 3 = time 0+85 minutes.
2	Assigned to samples when sampling synchrony problems are encountered and one or more of each triplicate set of samples within the same date and period is out of time-lagged sequence by more than 10 minutes.

3.4 Sample Handling

Preserve each sample by adding sufficient formalin to make the final concentration 6% (60 ml of full-strength formalin per liter of sample). Each jar should be completely filled with filtered water and formalin. Rose Bengal should be added after preservative. Sample jars should be no more than 25% full of organisms and debris for adequate preservation. Label

the jars externally with a sticky label, and place an internal label in each jar. Both external and internal labels will contain the following information:

- Project number: 23754.001,
- Method: 01 = pump, 02 = net,
- Date: MMDDYY,
- Station: Location 1, 2 or 3,
- Time: Start time of the 100 m3 sample,
- Replicate Number: record number of jars representing each sample as 1 of 1, 1 of 2, etc. And
- Sample number: write the four digit unique sample number from the field data sheet.

The lids to the samples jars will be sealed with electrical tape to prevent spillage. Samples will be packed in a cooler with absorbent material and transported to the Normandeau Biological Laboratory in Stowe, Pa for sorting, and then on to Bedford, NH for identification and enumeration processing following the materials handling procedures specified in the HASP.

3.5 Water Quality

Temperature (to 0.1 °C), conductivity (nearest µS/cm), dissolved oxygen (nearest 0.1 mg/l), and pH (to the nearest 0.1 pH unit) will be recorded as one set of water quality measurements for each diel collection. Meters will be calibrated prior to each day of use, and again after each day of use (or before the next day of use), as specified in the YSI Professional Plus water quality meter manual (Appendix 2). All water quality meter calibrations will be recorded in a calibration log that is specific to each meter serial number and location the meter was used at. Water quality will be collected from the cooling water flow sampled within each entrainment sampling tank at each location within the first hour of pumping for each 100 m^3 sample.

3.6 Data Handling

3.6.1 Data Sheets and Coding Instructions

A data sheet and unique sample number will be assigned to each PBAPS entrainment abundance field sample. The sample number is a four-digit unique consecutive number. Record the sample identification and status, collection times, flowmeter readings, and flowmeter calibration data on the Entrainment Field Data Sheet (Appendix 1) according to the instructions below. Use the space for comments at the bottom of the data sheet to explain any problems or unusual circumstances. One data sheet is completed for each sample. The term "enter" appears in the data sheet coding instructions for all variables which require using the numeric codes specified below. The term "record" indicates a measurement or observational variable without a pre-specified numeric code required to complete the coding. The abbreviation N/A means the variable is not applicable to this study and is not entered or recorded.

Use the flowmeter calibration section of the Entrainment Field Data Sheet (Appendix 1) once per sampling day on the data sheet for the first entrainment sample at each of the three locations. Only one calibration trial is needed per location per day.

VARIABLE	INSTRUCTIONS
SAMPLE	Pre-coded four consecutive numbers unique to each sample
WEEK	Enter the week of the year (see entrainment schedule Figure 3-1)
YEAR	Precoded 16 = 2016
LOCATION	Enter the code for the entrainment sampling location: 12 = outer intake structure Unit 2 Screenwell 2G 13 = outer intake structure Unit 3 Screenwell 3G 2 = circulating water discharge outfall for Units 2 & 3 3 = discharge canal outfall
DIEL	Enter the code for diel period: 1= daytime (0900-1500) 2= sunset crepuscular (1500-2100) 3 = nighttime (2100-0300) 4 = sunrise crepuscular (0300-0900)
STATUS	Enter code for status of sample: 1 = valid sample 2 = sample is provisional due to collection problem 5 = void, no sample
SAM_NAR	Enter a sample narrative code describing if the sample was collected in a manner that was synchronized with the time of travel lag times, or if the sample deviated from the specified lag times from Location 1 (lag time = 0), Location 2 (lag time 25 minutes from Location 1), or Location 3 (lag time 85 minutes from Location 1): 1 = collected with appropriate lag time for that Location 2 = lag time different by more than ten minutes from specified lag time for that Location
COMMENTS	If comments are written at the bottom of the data sheet, enter 1; if not, leave it blank
START MONTH	Record the month that the diel collection began
START DAY	Record the day that the diel collection began
START YEAR	Enter year: 16 = 2016
END MONTH	Record the month that the diel collection ended
END DAY	Record the day that the diel collection ended
END YEAR	Enter year:

VARIABLE	INSTRUCTIONS
	16 = 2016
START HOUR	Record the hour that the diel collection began, using 24-hr clock (00-23 hrs). 24 hours is not valid
START MINUTE	Record the minute that the diel collection began (00-59 min)
END HOUR	Record the hour that the diel collection ended, using 24-hr clock (00-23 hrs) 24 is not valid
END MINUTE	Record the minute that the diel sample ended (00-59 min)
GALLONS END	Record the flowmeter reading for total gallons at the end of the sample
GALLONS START	Record the flowmeter reading for total gallons at the beginning of the sample
GALLONS, DIFFERENCE	Subtract the starting flowmeter volume reading from the ending flowmeter volume reading
FLOWMETER N	Record the 12 digit Signet flowmeter number used
FLOW CAL TANK VOL	Record volume of the calibration tank to the nearest 1 gallon
FLOWMETER GAUGE	Record pump flowmeter gauge rate to the nearest gallons per minute (GPM)
TANK FILL TIME	Record time to fill the calibration tank to the nearest 1 second
GPM TO FILL TANK	Record calculated flow rate into calibration tank in GPM
PERCENT ERROR	Record calculated percent error of flow rates to the nearest 0.1%
PASS/FAIL	Enter code for pass fail status of the flowmeter calibration 1 = pass 2 = fail
TEMPERATURE	Record the water temperature in to the nearest a 0.1 of a °C
CONDUCTIVITY	Record the conductivity in µS/cm to the nearest scale division
DISSOLVED OXYGEN	Record the dissolved oxygen to the nearest 0.1 of a mg/l
pH	Record pH to the nearest 0.1 of a unit

3.6.2 Storage and Chain-of-Custody of Data Sheets

Check over all data sheets, to make sure they are completely and correctly filled out, and to be alert to any unusual or unexpected data values. Initial the bottom of the data sheet. Transport the original data sheets to the Normandeau Stowe office and provide a copy to the project manager.

3.7 Hazardous Substances Log

Maintain a log of the amounts of formalin brought on site. Include in each log entry the date, the name of person making the log entry, and the volume in gallons of formalin brought on site on that date. Make the log available for inspection as requested by PBAPS representatives.

4.0 Entrainment Laboratory Standard Operating Procedures

4.1 Samples to be Analyzed

Samples for entrainment abundance characterization from PBAPS will be received and inventoried in our biological laboratory in Stowe, PA. If a large amount of detritus or large numbers of fish eggs and larvae are present in a sample it may be split down to a minimum of 200 specimens (eggs and larvae combined). All specimens in each sample will be identified to the lowest practical taxon. A maximum of 20 juveniles and 20 larvae per sample per taxon per lifestage will be measured for total length. Juveniles are measured to the nearest 1.0 mm total length, and larvae are measured to the nearest 0.1 mm total length. A maximum of 20 eggs per taxon per sample will be measured to the nearest 0.1 mm along the major and minor axes. Preserved specimens will be retained for one year after the completion of the study and then legally disposed of after written authorization to do so is received from Exelon.

Entrainment abundance samples for laboratory analysis will have been collected at three locations at PBAPS: (1) the outer intake structure; (2) the circulating water discharge outfall for Units 2 and 3; and (3) the discharge canal outfall (Figure 1-2). These three locations were sampled weekly from March through September 2016 at PBAPS according to the schedule incorporated into this SOP (Figure 3-1). During each weekly sampling event, four samples representing each of four consecutive 6-hour diel periods spanning 24-hours (i.e., one day) will be collected. These four diel sample periods are Period 1 = 0900-1500, Period 2 = 1500-2100, Period 3 = 2100-0300, and Period 4 = 0300-0900 (DST). The intention is to separate the collection of daytime, nighttime, and crepuscular periods (sunrise and sunset) entrainment samples symmetrically within the corresponding periods of each sampling date. In addition, the start of each diel period sample collection from the outer intake location to discharge canal outfall will be offset to take into consideration the estimated 85-minute transit time of water through the plant. A total of 336 samples are scheduled to be collected and processed in 2016 (28 weeks x 4 diel periods/week x 3 locations = 336 samples).

4.2 Equipment

The following items are required for laboratory analysis of ichthyoplankton and shellfish larvae in entrainment samples:

- Sorting trays
- Lights
- Magnifiers
- Dissection microscopes
- Folsom plankton splitter (or equivalent)
- Sieves
- Rose Bengal
- Gridded Petri dishes
- Divided Petri dishes
- Jars, with lids
- Forceps
- Pipettes

- Multi-tally counters
- Squirt bottles
- Lab data sheets
- Pencils
- Vials, with caps
- Vial labels
- Taxonomic literature
- Copy of SOP
- Ocular micrometers
- Millimeter rulers
- Masking tape
- Rubber bands
- Random number table
- Hensen-Stempel pipette

4.3 Procedures

4.3.1 Sample Preparation

Once the entrainment samples have been received by the laboratory, each depth-integrated sample will be analyzed as representative of the entrainment collection for the corresponding date and diel period. Samples will be logged into the laboratory and the Chain-of-Custody forms verified (See section 4.4.2 for Chain-of-Custody procedures). Samples will be washed with fresh water through a 0.500 mm mesh sieve, or smaller, to remove formalin and fine debris.

4.3.1.1 Subsampling Restrictions and Quotas

Samples with high numbers of eggs or larvae may be subsampled in the laboratory, with a minimum of 200 specimens of fish eggs and larvae (combined) to be analyzed. This quota applies to the total count of all species combined, not to individual species.

Samples containing low numbers of ichthyoplankton and a high volume of detritus and other plankton (more than 400 ml settled volume), may be sorted following the Volume Split Option (VSO), which allows for sorting to be discontinued before the numeric quotas for eggs or larvae are met. At least 200 ml of settled solids must be sorted (unless the quotas have been met in a smaller fraction) for all samples. If at least half the sample volume has been sorted but the quota for eggs or larvae has not been met, sorting may be discontinued.

4.3.1.2 Sample Splitting Sequence

Use the following sequence of procedures in processing a sample that is subsampled by splitting. To eliminate any chance of bias, some steps in the procedure are to be performed by an assistant so that the sorter has no prior knowledge of which samples are to be subjected to quality control inspection.

This procedure also applies when a previously split sample is further subsampled to meet the quota. In this situation the term “sample” in the following procedure refers to the part of the original sample that is to be further subsampled, and the selected fraction(s) are “analyzed” rather than “sorted.”

1. Examine the sample to estimate the smallest size fraction that is likely to contain at least 200 specimens of ichthyoplankton (eggs, larvae, small juveniles).
2. Divide the sample material into two equal parts using the techniques in Section 4.3.1.3.
3. Randomly select one of the two divisions for processing (or for further subsampling, if a smaller fraction is needed). Selection should be done using a random number table or a coin toss, so that each of the two divisions has an equal chance of being selected (it is not acceptable to always select the division from the same chamber of the splitter). The person performing the division must not know which of the two divisions will be analyzed before the division is completed.
4. Set aside the fraction not selected for further processing and label it to identify the sample number and fractional size.
5. If the fraction that was selected for further processing needs to be subsampled further, repeat steps 2-4 as many times as necessary to produce the desired fraction for analysis. When the desired fraction is obtained, label it to show the sample number and fractional size.
6. Sort the subsample by the procedures in Section 4.3.2. Organisms must be sorted from the entire subsample even if the quota is reached before finishing the subsample.

4.3.1.3 Sample Splitting Technique

Perform all sample splitting using a Folsom splitter. The presence of filamentous algae or large items (including large juvenile fish, or older age classes) can interfere with the even distribution of material and organisms between the two chambers of the splitter. Therefore, to ensure successful results, observe the following techniques: (1) Adjust sample dilution to be great enough to allow free mixing of the sample but not so great as to promote clumping due to over dilution. (2) Remove large fish and excessive amounts of filamentous algae before splitting, returning any adhering ichthyoplankton to the sample. (3) Pull apart remaining clumps of algae before splitting. (4) Scrutinize detritus and organisms during the splitting process to see that they appear equally distributed before making the final division. (5) Remix and split again if the two resulting portions of a division do not appear equal. If a sample has so much algae that it cannot be satisfactorily split, sort the entire sample, and if numbers of ichthyoplankton are high, splitting may be performed after sorting. Large juveniles that are removed from the whole sample before splitting must be kept separate from ichthyoplankton sorted from the sample after splitting, and they must be labeled to show they represent the whole sample.

4.3.2 Sample Processing

The enumeration of already dead organisms artificially inflates the densities of eggs and larvae found in entrainment samples. The exclusion of these dead organisms therefore is important when processing each ichthyoplankton sample, to provide the most accurate and representative estimates of entrainment abundance from source water body water withdrawn into a cooling water intake structure (CWIS). Fish eggs and larvae which were dead prior to capture and preservation exhibit changes in their physical characteristics that

can be observed under microscopic examination and therefore used by Normandeau's Biological Laboratory in the sorting and identification procedures to distinguish ichthyoplankton eggs and larvae that were alive at the time of collection and preservation from those that were dead. Only ichthyoplankton that were alive at the time of collection will be identified to the lowest practical taxon and enumerated. Specifically, the following criteria will be used to distinguish alive and dead ichthyoplankton:

Larvae:
Tend to decompose rapidly once dead resulting in a marked difference in the physical condition between decomposing larvae and live larvae. Alive larvae that are damaged by the collection method may exhibit decapitation, a severing at various points along the body, or an overall look of having been beaten. Severing may result from cavitation or contact with the joints in the piped connections in the pump sampling system or with various structures in the CWIS depending on where the samples were collected. Decomposing larvae that were dead at the time of collection and preservation exhibit an overall look of flesh deterioration. Additionally, once dead, larvae tend to settle out of the water column and are less susceptible to collection in entrainment samples. The swim bladder of dead larvae is not well developed and once they stop swimming, they sink. We generally do not see previously dead larvae in entrainment samples.

Eggs:
Dead eggs, while still spherical, will start to be form a hairy growth of fungus or bacteria. Normandeau colloquially identifies these eggs **"fuzz" eggs** and they are not removed from the detrital material during the sorting stage of sample processing. These "fuzz" eggs look different from adhesive eggs with aquatic vegetation attached to them. "Fuzz" eggs are predominantly freshwater species; the lab rarely observes this condition occurring in marine species.

Opaque eggs are always considered to have been alive at the time of capture, and are sorted, identified and enumerated as live eggs. They could either have turned opaque just before their capture (suggesting they were dead at the time of capture) or after collection at the time of preservation. It is not possible to tell the acute cause and time of death of opaque eggs. Opaque eggs are predominantly Clupeidae eggs, possibly due to the tendency of those eggs to have material inside the egg capsule that bursts apart from the stress of collection by pumped systems.

Immature eggs or **"polar bodies"** are the interstitial material or oocytes found between fertilized eggs that will never become fertilized. These individual irregular egg-shaped polar bodies are a bit more turgid (firm) and much smaller than the size range expected for fertilized eggs of species present. Polar bodies are not removed from the detrital material during the sorting stage of sample processing.

4.3.2.1 Sorting

Remove fish eggs, larvae, and juveniles from the samples according to the following procedures:

1. Samples may be stained with Rose Bengal to facilitate sorting if not previously stained in the field at the time of collection and initial preservation.

2. Pour the sample contents into a sieve with a mesh equivalent to, or finer than, 0.500 mm and rinse with water to remove the preservative.
3. If the sample contains large numbers of eggs and larvae, prepare a subsample following the procedures in Section 4.3.1.
4. Carefully wash the sample contents into a container making certain that nothing remains in the sieve. Pour portions of the sample from the container into a sorting tray and examine them under magnification.
5. Remove fish eggs, larvae, and juveniles from the sample using forceps, pipettes, or probes as appropriate and place in vials with 6% buffered formalin. Remove only those fragments that include the head.
6. Maintain a combined total count for eggs and larvae that are removed from the sample.
7. When sorting is completed, recheck the sample for organisms. After the sample has been rechecked, label vials containing the sorted organisms and place them in a box designated for sorted samples. Record the sorting results and date completed in a log.
8. Carefully wash the remaining sample contents back into the original sample container, appropriately preserved with the original preservative and return it to the storage area.
9. If a sample is not completed by the end of the work day, it may be left unpreserved overnight if adequate precautions are taken to prevent it from drying out. No sample or part of a sample, however, should remain unpreserved for more than 24 hours.

4.3.2.2 Identification

Identify, stage, count, and measure the sorted ichthyoplankton according to the following procedures:

- Obtain the sample vials containing the sorted organisms from the storage area and sign them out by initialing a status log.
- Rinse specimens free of preservative and submerge them in water in a Petri dish. Use a binocular microscope with an ocular micrometer to examine the specimens, and identify them to the lowest practical taxon (usually species) by referring to the literature, the reference collections, and by consulting with fellow identifiers.
- Determine the life stage of each specimen. Pertinent life stages are defined and identified as follows:

  Egg: the embryonic developmental stage, from spawning until hatching. Eggs frequently become damaged during collection and sample processing. Damaged eggs are counted as the number of embryos (without regard to how many egg capsules are present). Do not count non-fertilized eggs if they are present.

Yolk-sac larva: the transition stage from hatching through the development of a complete, functional digestive system (regardless of the degree of yolk and/or oil globule retention)

Post yolk-sac larva: the transition stage from development of a complete, functional digestive system to transformation to juvenile form (regardless of the degree of yolk and/or oil globule retention), including the leptocephalus stage of eels

Young-of-the year: the stage from completed transformation to Age 1 (i.e., 12 months after hatching). A young-of-the-year has a full complement of fin rays identical to that of an adult. Eels are classified in this stage until Age 2.

Yearling or older: a fish at least one year old.

- Count the specimens of each species by life stage. Record the counts by species and stage on the lab data sheet (refer to Section 4.5.1 for coding instructions).
- From each sample, measure a maximum of 10 individuals from each fish taxon and life stage for total length, greatest soft tissue body depth or width to the nearest 0.1 mm. For each sample also measure a maximum of 20 juveniles and 20 larvae per sample per taxon per lifestage to the nearest 0.1 mm total length. A maximum of 20 eggs per taxon per sample will be measured to the nearest 0.1 mm along the major and minor axes. If more than 20 eggs or larvae are present, randomize the selection of specimens for measuring by the following procedure. Spread them uniformly in a gridded container, select a starting point in the grid by means of a random number table, and then measure the first 20 measurable specimens encountered in a predetermined pattern commencing at the starting point. Every grid space must have an equal probability of being selected as the starting point, so that every specimen will have an equal probability of being included in the subsample.
- Place identified organisms in vials with an adequate amount of preservative for storage. Specimens may be removed for inclusion in the reference collection. For those removed, list the species, life stage, and numbers on the comments section of the data form and note their removal on a tag retained inside the appropriate vial. Label all vials for a single sample, initial them and band them together. Record the number of vials for the sample on the data form. For reference collection procedures refer to Section 4.7.

4.3.2.3 Morphometrics

For each sample, the following morphometric data will be collected:

- Up to 20 individuals from each fish taxon and life stage will be measured for total length and greatest body depth or width, all to the nearest 0.1 mm;
- Up to 20 eggs of each taxon will be measured for minimum and maximum diameter;

Only whole organisms will be subject to morphometric evaluations. Measurements will be performed with a calibrated ocular micrometer.

4.3.4 Species of Special Concern

No federally listed endangered or threatened species occur in Conowingo Pond. However, a state listed species, Chesapeake Logperch (*Percina bimaculata*), and a species of concern, American Eel (*Anguilla rostrata*), are known to occur within Conowingo Pond; a brief discussion of these species follows.

The Chesapeake Logperch is listed as a threatened species in Pennsylvania and is also listed as threatened in the state of Maryland. This species occurs and has been recently collected in Conowingo Pond (Normandeau 2014). The Chesapeake Logperch range includes the lower Susquehanna River and several tributaries including Fishing Creek, Muddy Creek, Peters Creek, Michael Run, and Octoraro Creek. This species only occurs in approximately 30 combined stream and river miles within Pennsylvania. No Chesapeake Logperch were collected during the most recent entrainment sampling in 2012.

The American Eel population is in apparent decline and is considered a species of concern. In 2011 the U.S. Fish and Wildlife Service initiated a new status review for the American Eel as a result of a 90-day finding on the Council for Endangered Species Act Reliability's petition to list the American Eel as threatened under the authority of the Endangered Species Act. Few American Eels are present within Conowingo Pond and none were collected during recent fish surveys in Conowingo Pond (Normandeau 2014). However, a recently initiated trap and transport program at Conowingo Dam has begun stocking American eel in Conowingo Pond. This program has increased the number of eels present in the Pond which may result in an increase in the rate of entrainment of the species. A single juvenile American Eel was collected during entrainment sampling in 2012 (Normandeau 2013).

4.4 Sample Handling

4.4.1 Sample Control

Each sample was given a unique sample number at the time of collection. Track each sample by that sample number throughout the laboratory and data processing functions.

4.4.2 Chain-of-Custody Records

The Chain-of-Custody documentation begins with the field office providing a list with the following information for each sample in a shipment delivered to the laboratory facility: sample collection date, sample collection time, sample identification number, and number of jars. Upon receipt of the samples, a laboratory representative verifies that all jars of all samples on the list are present, then signs and dates the Chain-of-Custody document.

After samples have been received in the laboratory, track their location and status during all phases of storage and laboratory analysis by means of sample control logs. The function of this system is to provide a paper trail of who performed each step in the analysis of a sample from collection to storage, when each step occurred, what condition the samples were in and where each step took place.

4.4.3 Preservation and Storage

Retain the original preservative (formalin solution) for reuse in preserving the residue of sorted samples. Store processed samples (i.e., detritus and organisms not removed from split samples) until sorting quality control checks are completed. Keep sorted ichthyoplankton in vials in a heated storage area until disposal is authorized (up to one years after submittal of data files and final report). Tape the tops of jars and vials to prevent loss of preservative by evaporation.

4.4.5 Disposal

Disposal of sample residue remaining after sorting (detritus and organisms not removed from split samples) may proceed after sorting quality control has been completed. Disposal of vials of organisms from processed samples may proceed after receiving written authorization from Exelon Power. Follow all applicable state and federal regulations for hazardous waste disposal.

4.5 Data Handling

4.5.1 Data Sheets and Coding Instructions

Record ichthyoplankton counts and measurements on Entrainment Lab Count Data Sheets and Entrainment Lab Length Data Sheets (Appendix 1). The Entrainment Lab Count Data Sheet is for the identification and count of eggs and larvae. The Entrainment Lab Length Data Sheet is for measurements of eggs and larvae. Indicate in the upper right-hand corner of each data sheet how many pages there are for the sample (use “1 of 1” for a one-page sample, “1 of 2” and “2 of 2” for a two-page sample, etc.). Record also in the upper right-hand section of the first page the identifier’s initials, the date the sample was identified, and the number of vials. The term "enter" appears in the data sheet coding instructions for all variables which require using the numeric codes specified below. The term "record" indicates a measurement or observational variable without a pre-specified numeric code required to complete the coding. The abbreviation N/A means the variable is not applicable to this study and is not entered or recorded.

4.5.1.1 Count Data

Record count data on the L1 data sheet according to the following instructions.

VARIABLE	INSTRUCTIONS
SAMPLE	Record the unique four digit sample number.
WEEK	Enter the week of the year (see data sheet for week number)
YEAR	Enter the year: 16 = 2016
LOCATION	Enter the code for the entrainment sampling location: 12 = outer intake structure Unit 2 Screenwell 2G 13 = outer intake structure Unit 3 Screenwell 3G 2 = circulating water discharge outfall for Units 2 and 3 3 = discharge canal outfall

VARIABLE	INSTRUCTIONS
CATCH_CD	Enter 1 for valid sample with ichthyoplankton present or 2 for valid sample with no ichthyoplankton caught (data sheets are not required for void (STATUS = 5 samples)
SPL_FACT	Enter 1.00 if the whole sample is analyzed; if the sample is subsampled record the ratio of the whole sample to the subsample (e.g., 8.00 for a 1/8 split)
TAXON	Enter the TAXON code from the Taxon Code List (A list of codes unique for each taxon is provided in Appendix 3).
STAGE	Enter one of the following life stage codes: 0 = unknown 1 = eggs 2 = yolk-sac larvae 3 = post yolk-sac larvae 4 = young-of-the-year 5 = yearling or older
COUNT	Record the number of organisms of the indicated taxon and life stage in the sample (or subsample)
SPECIES NAME	Record the common name for the taxon
COMMENT	Enter 1 if a comment is written on the sheet that might influence interpretation of the data. Blank if no comment.

4.5.1.2 Measurement Data

Record measurement data for all species on the Entrainment Lab Length Data Sheets (Appendix 1) according to the following instructions.

VARIABLE	INSTRUCTIONS
SAMPLE	Record the four digit unique sample number
WEEK	Enter the week of the year (see data sheet for week number)
YEAR	Enter the year: 16 = 2016
LOCATION	Enter the code for the entrainment sampling location: 12 = outer intake structure Unit 2 screenwell 2G 13 = outer intake structure Unit 3 screenwell 3G 2 = circulating water discharge outfall for Units 2 and 3 3 = discharge canal outfall
CONVERSION FACTOR	Record the number of millimeters per division for the optical micrometer used to measure larvae

VARIABLE	INSTRUCTIONS
TAXON	Enter the taxon codes for the species measured on Entrainment Lab Length Data Sheets.
STAGE (or "STG.")	Enter the life stage code for each larva measured: 1 = egg 2 = yolk-sac larvae 3 = post yolk-sac larvae 4 = young-of-the-year 5 = yearling or older
SCALE	Enter 6 if measurements are recorded in optical micrometer units; enter 7 if measurements are recorded directly in millimeters. (If optical micrometer units are recorded for a measurement, the actual length in millimeters will be obtained later by multiplying the measurement by the conversion factor.)
TL	Record the total length of larvae to the nearest 0.1 optical micrometer unit or to the nearest 0.1 mm.
BD	Record the body depth of larvae to the nearest 0.1 optical micrometer unit or to the nearest 0.1 mm.
BW	Record the body width of larvae to the nearest 0.1 optical micrometer unit or to the nearest 0.1 mm.
MIN (eggs only)	Record the minimum diameter of the egg
MAX (eggs only)	Record the maximum diameter of the egg
COMMENT	Enter 1 if a comment is written on the sheet that might influence interpretation of the data. Blank if no comment.

4.5.2 Storage and Chain-of-Custody of Data Sheets

Maintain all completed data sheets in duplicate. Keep photocopies at the site of origin and transfer the originals as needed from the laboratory to the data center, quality control, and a master project file. Track the custody of data sheets by means of data control logs.

4.6 Quality Control

4.6.1 Tasks Subject to Quality Control

The following tasks are subjected to quality control checks consisting of reanalysis of randomly selected samples or measurements:

- sorting
- identification, life stage determination, and enumeration

4.6.2 Inspection Plans

Items are inspected using a quality control (QC) procedure derived from MIL-STD (military-standard) 1235B (single and multiple level continuous sampling procedures and tables for inspection by attributes) to achieve a 10 percent or better AOQL (Average Outgoing Quality Limit). The QC procedure used is the CSP-1 continuous sampling plan, which is conducted in two modes as follows:

- ***Mode 1.*** Reinspect one hundred percent of the samples until "i" consecutive samples pass.
- ***Mode 2.*** After "i" consecutive samples pass QC re-inspection, randomly choose (using a random numbers table) the fraction "f" of the samples for re-inspection. If any QC sample fails then return to Mode 1.

For this application of CSP-1, **i=8** and **f=1/7**, because the total number of samples analyzed by an individual is less than 500. It is important that QC inspections are performed as soon as possible after the original analysis; work-up of QC samples must not be postponed to be done in batches. Keeping the QC program as current as possible insures that problems are detected and remedied quickly, minimizing the additional number of samples that are analyzed before the problem is addressed.

Select items for reanalysis according to the plan using a random number table. The original analyzer should not know whether a sample is to be checked before the analysis of that sample has been completed. Perform all quality control checks "blindly" (i.e., the individual performing the QC inspection should have no knowledge of the original analyst's results).

Apply the QC plan on an individual processor basis, so that each person's work is subjected to the QC plan independently of others, starting at 100% inspection.

A resolution (third person) value may be determined for any sample found defective. All errors found during the QC check, whether the sample is found to be defective or not, are to be corrected on the data sheets. (A difference between original and QC counts that is within acceptable limits is not considered to be an error). Results of the quality control program are to be presented to all sorters and identifiers and corrective actions will be provided for anyone failing a QC check.

In some cases a QC inspection may be able to determine the taxon or life stage of damaged specimens when the original identifier has recorded them as unknown life stage, unidentified taxon, or a higher level taxon (genus or family). If a more general taxon or life stage used by the original identifier includes the more specific category used by the QC inspector, and that is the only reason for a count discrepancy, then that sample does not fail the QC inspection on the basis of that taxon. For example, damaged specimens recorded as Gobiidae by the original identifier and as *Bembrops* sp. by the QC inspector are to be considered in agreement because the category Gobiidae includes *Bembrops* sp. In contrast, an original determination of Gobiidae would not be acceptable if the QC determination was Bay Anchovy, because Bay Anchovy is not included in the family Gobiidae. If substantial differences occur between the original and QC counts as a result of identifying or staging to different levels, then the identifier will be provided with additional guidance or training to minimize such differences in future samples.

4.6.3 Acceptance/Rejection Criteria

4.6.3.1 Sorting

A sample is considered defective if the sorter failed to remove 10 percent of the total organisms in the sample (or subsample). Percent error is calculated as follows (where "QC count" denotes the number of organisms missed by the sorter that the QC inspection found):

% error = 100% x QC count/(sorter's count + QC count)

When the total count (sorter's plus QC) is ≤20, then the sample is considered defective only if the sorter missed more than two organisms.

4.6.3.2 Identification

A sample is considered defective if an error of 10 percent or more is made in identifying, assigning a life stage, or counting any species. In determining whether a sample is defective, analyzer and QC results are compared within each taxon/life stage combination.

For each taxon (or for a life stage within a taxon) the percent error is calculated as follows (except where the QC count is ≤20, the percent error is considered to be zero if analyzer and QC counts differ by no more than two organisms):

% error = 100% x (analyzer count – QC count) /QC count

A sample with a percent error of greater than or equal to 10% for any life stage for any taxon is considered defective.

For each defective sample, a resolution may be determined in which a third person reanalyzes the sample (resolution value). The error for each species and life stage will then be calculated using the resolution counts as the divisor. This will be done for both identification and QC counts:

% error = 100% x (identifier count – resolution count) / resolution count

% error = 100% x (QC count – resolution count) / resolution count

If the resolution vs. identifier error is less than 10 percent, the sample passes. If they are not, the sample fails and identifier counts are replaced by QC counts for all cases, provided the QC vs. resolution error is less than 10 percent. If the resolution vs. identifier and the resolution vs. QC errors are both 10 percent or more, the sample will be thoroughly reviewed by all three people and the identifier's sample processing will not continue until agreement can be reached on the identification of the sample. Subsequent samples will be reanalyzed by the QC person until eight consecutive samples pass. Notify the Laboratory Manager of any identifier exceeding two failed samples.

4.6.4 Quality Control Records

Maintain quality control logs, documenting the samples analyzed, the samples selected for reanalysis according to the QC plan, the results of the QC analysis, and any corrective action performed. All QC logs will be 100% inspected monthly by the Laboratory Supervisors. A

summary report of quality control results and follow-up corrective action will be submitted to the client upon request.

4.6.5 Quality Control Personnel

The QC of the sorting process is to be conducted under the direct supervision of the Sorting Supervisor. Only the Sorting Supervisor or individuals with a documented sorting QC record of superior performance may provide sort QC.

Regarding identification QC, only the Identification Supervisors will be performing the QC on ichthyoplankton identification.

4.7 Reference Collection

Make sure that each taxon and life stage identified in the PBAPS entrainment program is represented in a project-specific ichthyoplankton reference collection at the Bedford NH biology laboratory. Develop this reference collection by removing specimens from PBAPS entrainment samples and store them in vials in a designated area. If available, include several (e.g., 10) specimens per taxon per stage, displaying a variety of sizes. Label the vials with the scientific name, date of capture, capture location, and a reference collection catalog number. The catalog number identifies a card containing more detailed sampling information, identifier, unique sample number or numbers, project number, comments, etc. File the cards alphabetically by family, genus, and species. The specimens added to Normandeau's Bedford Biological Laboratory reference collection from PBAPS entrainment samples will be retained by Normandeau in our "permanent" reference collection.

4.8 Instrument Calibration

Calibrate each ocular micrometer periodically (at least weekly) using a stage micrometer. After calibration of ocular micrometers on zoom microscopes, place a calibration mark on the microscope so that measurement accuracy is maintained. Ocular micrometers on microscopes that have been adjusted or moved must be recalibrated before use. Document the calibrations in a log showing the dates and results of the calibrations.

5.0 Data Processing

5.1 Data Entry Verification and Data Sheet Chain-of-Custody

Provide a submittal form with each batch of data sheets submitted to the Technical Data Processing (TDP) department for data entry. Information on the submittal form should include names of sender and recipient, date sent, and dates of entrainment collections included in the batch.

Key all data twice, and resolve all discrepancies between the two versions as they are flagged by the data entry and verification program.

After data entry and verification are complete, transfer custody of the data sheets from TDP to the originators, where they are used in the error checking and quality control tasks, and finally stored in a project file. Document the transfer from TDP back to the originator by one or more submittal sheets containing the same information as those used to transfer custody to TDP. TDP is not required to maintain copies of the data sheets. After Exelon Power accept the data files and final report, the original data sheets and paper copies of them may be discarded.

5.2 Systematic Error Checks

Keyed data are subjected to a series of systematic error checking programs developed specifically for this project. These consist of univariate, bivariate, and multivariate checks specified by project personnel. Univariate range checks identify records for which one or more variables have values outside their valid or expected ranges. Bivariate and multivariate checks compare values of related variables. Additional checks scan the data for duplicate or missing observations. All records flagged by these programs are resolved, and corrections to both the data files and the data sheets are made as necessary. After error checking is complete, data files are subjected to quality control inspection (refer to Section 5.4).

5.3 Data File Format

Error checked data files are assembled into a SAS, Excel, or Microsoft Access database. A record of data is defined as one line of data consisting of one or more entered or recorded values or observations in a data file.

5.4 Quality Control of Data Files

Data files that have completed the systematic error checking process undergo a QC inspection to assure a 1% AOQL (Average Outgoing Quality Limit) according to a lot sampling plan (American Society for Quality Control. 1993. Sampling procedures and tables for inspection by attributes. ANSI/ASQC Z1.4-1993). This procedure insures that ≥99% of the records in a data file agree with the original data sheets. Randomly select the number of records to be checked using the Lot Sampling Plan table below. The number of records that must be within tolerance are also shown in the Lot Sampling Plan table below. All values found to be outside of tolerance are considered failures, and must be corrected

using the available information. If more records than the acceptable number of failures are found, then the data set must be inspected 100%.

Lot Sampling Plan for QC Inspection at Less Than 1% AOQL.

		Number of Failures	
Lot Size	**Sample Size**	**Accept If ≤**	**Reject If ≥**
1-32	ALL	0	1
33-500	32	0	1
501-3,200	125	1	2
3,201-10,000	200	2	3
10,001-35,000	315	3	4
35,001-150,000	500	5	6
150,001-500,000	800	7	8
500,001 and over	1,250	10	11

6.0 Training

In order to assure the standardization of field, laboratory, and data processing procedures, a two level system for training technicians is followed: the first level being documented standard operating procedures; the second level being a training program for all new project personnel. At a minimum, this training program consists of the following steps:

- A complete reading and explanation of the project SOP and HASP. This is documented by a sign-off sheet which is filed in the program file.
- Observation by the Program Manager, Field Site Supervisor or Laboratory Manager of the first two or more times a new procedure is performed. This is documented with a signed checklist.
- Direct supervision by an experienced technician of personnel assigned to unfamiliar tasks for their first two or more attempts.
- 100% quality control checks for at least the first five samples analyzed.
- On tasks requiring identification of fish and shellfish at various lifestages, the Program Manager will have final approval as to who is qualified to make these identifications. In some cases special training will be required to participate in tasks, as set forth by the Program Manager.

7.0 Quality Assurance

7.1 Nonconformance Reports and Corrective Action

Documentation of problems or unusual events occurring during a program will be accomplished using Extraordinary Event/Nonconformity (EENC) forms. The EENC form (Appendix 1) is designed to dispense information to the Program Manager and Quality Assurance department and to obtain necessary action on items that are critical to technical operations and management of programs. The report results from observations such as these:

- deviations from standard operating procedures
- losing a sample
- finding an endangered species in a sample
- noting samples that are grossly different from expected (content, preservation, labels)
- noting a phenomenon that may deserve continued monitoring in the interest of the client and therefore may require a change in the scope of work
- quality control samples that exceed acceptable limits
- unusually high entrainment counts.

Items, samples, data, or information not in conformity with specifications or which do not meet preconditions for the next step in processing or use, are set aside until the problem is resolved and documented via the EENC report procedure.

The EENC report is designed for use by any person who identifies a problem or discovers information that is germane to a program scope of work or the improvement or change of contract performance. The originator describes the problem and may make recommendations for its resolution. Two temporary copies are made, and the original is sent to the Program Manager. One of the copies is kept by the originator in a file for "open" EENC reports (corrective action in progress), and the other is sent to the Quality Assurance Supervisor, who periodically checks on the progress of corrective action.

The Program Manager confers with appropriate parties and decides what corrective action will be required. Instructions to the Action Addressee (the person responsible for carrying out the corrective action) are written on the original EENC report. The Program Manger retains the original and sends a copy to the Action Addressee.

The Action Addressee resolves the problem as directed and then signs the EENC copy and returns it to the Program Manager to signify that the corrective action has been completed.

The Program Manager files the signed copy from each Action Addressee (there may be more than one), and when all corrective action is complete signs the original EENC report, keeps a temporary copy, and forwards the original to the QA Supervisor.

The QA Supervisor reviews the EENC report, and signifies acceptance of the resolution by signing and dating the report to "close" it. A copy of the closed EENC report is retained in

QA files, the temporary copy received earlier from the originator is discarded, and the original is returned to the Program Manager.

The Program Manager discards the temporary copy and keeps the original on file. A copy of the closed EENC report is sent to the originator, and additional copies are sent to any other affected parties. The originator discards the temporary copy in the file of open EENC reports and files the copy of the closed EENC report.

7.2 QA Audits

It is the responsibility of the Quality Assurance organization to verify the achievement of quality through all phases of the project. Once the proposal, program design, and work development phases are complete, these responsibilities will be accomplished primarily by audits, tests, and surveys which will provide objective evidence that the quality control program and technical requirements, methods, and procedures as outlined in the study QA manual are being implemented. All field, laboratory, and data processing tasks will be subject to at least one audit. These audits will be conducted by an audit team of technically qualified personnel familiar with, but independent of and not responsible for, the work or activities under evaluation. The audit team will review the operations, specifications, QC systems, plans, and project objectives and examine the acquisition and transfer of data from field to report.

Observations of nonconformities and program deficiencies will be classified into three categories:

A. Deficiencies that affect the data adversely;

B. Deficiencies that might affect the data adversely; and

C. Deficiencies or procedural changes that cannot affect the data adversely.

Class A deficiencies will be resolved before that portion of the program can proceed. Class B deficiencies must have a determination as to whether they should be changed to Class A or C deficiencies and whether or not corrective action is necessary. If corrective action is necessary, it will be performed within a reasonable time frame agreed to by the program management, the Quality Assurance Department, and Exelon. Operations with Class A or B deficiencies will be subject to re-audit to determine the effectiveness of corrective action. Class C deficiencies must have corrective action accomplished before the next scheduled audit or end of the project, whichever comes first.

Audit results will be presented orally to the appropriate project or facility management by the audit team after the audit has been completed. At this time, specific findings will be presented and recommended courses of corrective action developed. Subsequently, the audit results will be documented in a written audit report and reviewed by management having responsibility in the areas audited. These reports will include a summary of audit results, observations made with a listing of non-conformities, recommendations and corrective action taken.

The quality assurance director will maintain a file of all project and facility audits. This file will include copies of the audit checklists, audit reports, written replies, the record of

completion of corrective action and follow-up action. A summary report of audit results, and follow-up corrective action will also be made available for Exelon's review.

APPENDIX 1

Data Sheets and Forms

Peach Bottom Station 2016, Proj.# 23754.001

Entrainment Field Data Sheet

S 1

Sample

Year 1 6

Date & Time

	Month	Day	Year	Hour	Min
Start					
End					

Diel

1 = 0900-1500
2 = 1500-2100
3 = 2100-0300
4 = 0300-0900

Week number of year

Monday	Number
01/04/16	1
01/11/16	2
01/18/16	3
01/25/16	4
02/01/16	5
02/08/16	6
02/15/16	7
02/22/16	8
02/29/16	9
03/07/16	10
03/14/16	11
03/21/16	12
03/28/16	13
04/04/16	14
04/11/16	15
04/18/16	16
04/25/16	17
05/02/16	18
05/09/16	19
05/16/16	20
05/23/16	21
05/30/16	22
06/06/16	23
06/13/16	24
06/20/16	25
06/27/16	26
07/04/16	27
07/11/16	28
07/18/16	29
07/25/16	30
08/01/16	31
08/08/16	32
08/15/16	33
08/22/16	34
08/29/16	35
09/05/16	36
09/12/16	37
09/19/16	38
09/26/16	39
10/03/16	40
10/10/16	41
10/17/16	42
10/24/16	43
10/31/16	44
11/07/16	45
11/14/16	46
11/21/16	47
11/28/16	48
12/05/16	49
12/12/16	50
12/19/16	51
12/26/16	52

Week Number

Location

12 = outer intake, Unit 2
13 = outer intake, Unit 3
2 = circulating water discharge outfall for Units 2&3
3 = discharge canal outfall

Use code

1 = valid sample
2 = sampling problems
5 = void, no sample

Sam_Nar

1=Sync OK
2=Out of Sync

Comments

1 = yes
blank = no

Employee Number

Flowmeter Number

NET RINSE (Record time)

	Hour	Min
1		
2		
3		
4		
5		
6		

VOLUME

	Gallons
End	
Start	
Difference	

Q 1

FLOWMETER CALIBRATION

Tank volume (gal)	
Flowmeter gauge (gpm)	
Time to fill tank (sec)	
Gpm to fill tank	
Percent error	
Pass/Fail	

1 = pass
2 = fail

WATER QUALITY

Time	
Temperature (°C)	
Dissolved Oxygen (mg/l)	
Conductivity(µS/cm)	
pH	

COMMENTS: _____

_____

_____

PeachBottom/PBEntField.ai 4/2016

L 1

Peach Bottom Station 2016, Proj.# 23754.000

Entrainment Count Data Sheet

Page ___ of ___

Analyzed By: _____ Analyzed Date: _____

SAMPLE	YEAR	LOCATION	WEEK	Catch_cd	COMMENT
	1 6				

1 = yes
blank = no

SPECIES NAME	TAXON	SPL_FACT	EGGS (1)	YSL (2)	PYSL (3)	YOY (4)	YROL (5)	UNID (0)

PeachBottom\PBIchLabL1.ai Mar 2016

Peach Bottom Station 2016, Proj.# 23754.000

L 2

Entrainment Measurement Data Sheet

Page ___ of ____

SAMPLE	YEAR	CONVERSION FACTOR	COMMENT
	1 6		

1 = yes
blank = no

Stage
0 = Unidentified (not measured)
1 = egg
2 = yolk-sac-larvae
3 = post yolk-sac-larvae
4 = young of the year
5 = yearling or older

	Taxon	Stage	Scale	TL (total length)	BD (body depth)	BW (body width)	HD (head depth)	HW (head width)	Eggs (diameter) Min	Eggs (diameter) Max
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										
17										
18										
19										
20										
21										
22										
23										
24										
25										

COMMENTS: _____

PeachBottom\PBIchLabL2.ai Mar 2016

EXTRAORDINARY EVENT/NONCONFORMITY REPORT

EE/NC Report Number: Date:_____ From:_____

Respond by (date): _____ Project No.: _____ Title:_____

Date closed: _____

ADDRESSEES:
QA: __√__ Project Mgr.: _____ Field Mgr.: _____ Lab Mgr.: _____ Technical Mgr.: _____ Others: _____

PROBLEM DEFINITION (e.g.. Sample ID, Activity, Data, Standard, etc. Not in Conformity) :

RECOMMENDATIONS FOR or CORRECTIVE ACTION TAKEN:

Signed:

ACTION ADDRESSEE RESPONSE:

CORRECTIVE ACTION COMPLETED: Date: _____ Signed:_____

Distribution: ORIGINAL:QA, COPIES OF ORIGINAL: Originator, Addressees
RESPONSES: QA (responses are to be made on copies)

APPENDIX 2

YSI Professional Plus User Manual

YSI®

Professional *Plus*

USER MANUAL

Item # 605596
Rev D
Drawing # A605596
March 2009

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Item # 605596
Rev D
Drawing # A605596
March 2009

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WARRANTY

The YSI Professional Plus Instrument (Pro Plus) is warranted for three (3) years from date of purchase by the end user against defects in materials and workmanship, exclusive of batteries and any damage caused by defective batteries. Pro Plus field cables are warranted for two (2) years from date of purchase by the end user against defects in material and workmanship (6 months for non-field rugged cables*). Pro Plus sensors (pH, ORP, pH/ORP combo, Polarographic DO) are warranted for one (1) year from date of purchase by the end user against defects in material and workmanship (6 months for ammonium**, nitrate**, chloride**, and Galvanic DO). Pro Plus systems (instrument, cables & sensors) are warranted for 90 days from date of purchase by the end user against defects in material and workmanship when purchased by rental agencies for rental purposes. Within the warranty period, YSI will repair or replace, at its sole discretion, free of charge, any product that YSI determines to be covered by this warranty.

To exercise this warranty, call your local YSI representative, or contact YSI Customer Service in Yellow Springs, Ohio at +1 937 767-7241, 800-897-4151 or visit www.YSI.com (Support tab) for a Product Return Form. Send the product and proof of purchase, transportation prepaid, to the Authorized Service Center selected by YSI. Repair or replacement will be made and the product returned, transportation prepaid. Repaired or replaced products are warranted for the balance of the original warranty period, or at least 90 days from date of repair or replacement.

LIMITATION OF WARRANTY

This Warranty does not apply to any YSI product damage or failure caused by:

1. failure to install, operate or use the product in accordance with YSI's written instructions;
2. abuse or misuse of the product;
3. failure to maintain the product in accordance with YSI's written instructions or standard industry procedure;
4. any improper repairs to the product;
5. use by you of defective or improper components or parts in servicing or repairing the product;
6. modification of the product in any way not expressly authorized by YSI.

THIS WARRANTY IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESSED OR IMPLIED, INCLUDING ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE. YSI's LIABILITY UNDER THIS WARRANTY IS LIMITED TO REPAIR OR REPLACEMENT OF THE PRODUCT, AND THIS SHALL BE YOUR SOLE AND EXCLUSIVE REMEDY FOR ANY DEFECTIVE PRODUCT COVERED BY THIS WARRANTY. IN NO EVENT SHALL YSI BE LIABLE FOR ANY SPECIAL, INDIRECT, INCIDENTAL OR CONSEQUENTIAL DAMAGES RESULTING FROM ANY DEFECTIVE PRODUCT COVERED BY THIS WARRANTY.

* The warranty period for the non-field rugged cables (605107, 605177, 605108, 605178, 605109, 605179) is listed as 6 months. However, the true "working life" of these sensors may be 3-9 months depending on storage and usage in solutions other than clean aqueous samples.

** The warranty for the ammonium, nitrate, and chloride sensors (605104, 605105, 605106) is listed as 6 months. However, the true "working life" of these sensors may be 3-9 months depending on storage and usage in solutions other than clean aqueous samples.

INTRODUCTION

Thank you for purchasing the YSI Professional Plus (Pro Plus). The Pro Plus features a waterproof (IP-67) case, backlit display and keypad, user-selectable cable options, USB connectivity, large memory with extensive site list capabilities, and a rugged, rubber over-molded case.

Reading the entire manual before use is recommended for an overall understanding of the instrument's features.

GETTING STARTED

INITIAL INSPECTION

Carefully unpack the instrument and accessories and inspect for damage. Compare received parts with items on the packing list. If any parts or materials are damaged, contact YSI Customer Service at 800-897-4151 (+1 937 767-7241) or the authorized YSI distributor from whom the instrument was purchased.

BATTERY INSTALLATION

The Pro Plus requires (2) alkaline C-cell batteries which are included with the purchase of a new instrument. Battery life depends on parameters and usage. Under normal conditions, battery life is approximately 80 hours for continuous use at room temperature. To install or replace the batteries:

1. Turn the instrument over to view the battery cover on the back.
2. Unscrew the four captive battery cover screws.
3. Remove the battery cover and install the new batteries, ensuring correct polarity alignment on the instrument or the removed cover. (Figure 1)
4. Replace the battery cover on the back of the instrument and tighten the four screws. Do NOT over-tighten.

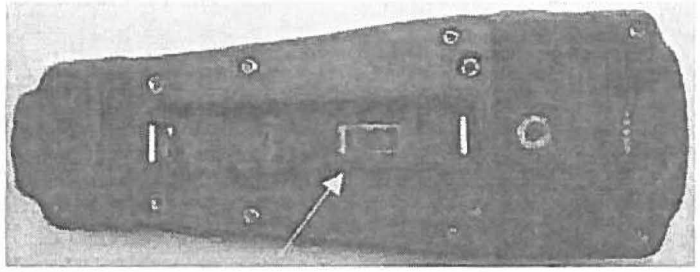


Figure 1. Pro Plus with battery cover removed. Notice battery symbols indicating polarities.

> *Batteries must be installed in the instrument even if powering the unit via the USB connection. This will retain the correct date and time if the PC is turned off. If the USB power is disconnected and there are no batteries in the instrument, the date and time will need to be reset upon subsequent power on.*

NOTE - On subsequent battery changes you will have approximately 2 minutes to change the batteries before the clock resets. If the clock resets, the instrument will automatically bring up the Date/Time menu the next time it is powered on in order to update this information. This is important, especially if you intend to log data!

SETUP

The Pro Plus instrument has several compatible field-rugged cable/sensor options, each with temperature:

Cable:	Available Sensors:
Cable number 60520-x	DO/temp (605780 for lab BOD)
Cable number 60530-x	Conductivity/temp
Cable number 60510-x	ISE*/temp
Cable number 6051010-x	ISE*/ISE*/temp
Cable number 6051020-x	ISE*/DO/temp
Cable number 6051030-x	ISE*/conductivity/temp
Cable number 6052030-x	DO/conductivity/temp
Cable number 605790-x	DO/conductivity/ISE*/ISE*/temp (Quatro**)

*ISE (Ion Selective Electrode) notates a port that can accept pH, ORP, Ammonium, Nitrate, Chloride, and, in some cases, a pH/ORP combination sensor.

**Cable 605790 will be referred to as a Quatro cable throughout this manual.

All cables come in standard lengths of 1, 4, 10, 20, and 30-meters (3.28, 13, 32.8, 65.6, and 98.4-feet) with options for special order lengths up to 100-meters (328-feet) on the 60520-x cables. Contact YSI or your local representative for additional information.

In addition there are several cable options with built in sensors for the measurement of pH and ORP that are not considered field-rugged (non-replaceable sensors, less rugged single-junction sensors). These cables are

recommended for lab use or controlled conditions where a more rugged, field cable is not necessary. These cables include:

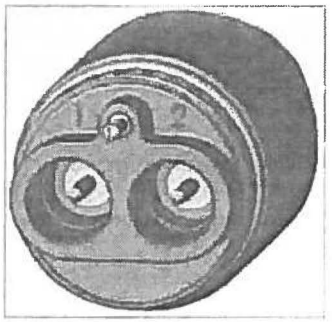
Cable number 605107	1-meter cable; single-junction pH sensor
Cable number 605177	4-meter cable; single-junction pH sensor
Cable number 605108	1-meter cable; single-junction ORP sensor
Cable number 605178	4-meter cable; single-junction ORP sensor
Cable number 605109	1-meter cable; single-junction pH/ORP sensors
Cable number 605179	4-meter cable; single-junction pH/ORP sensors

STANDARD PRO SERIES SENSOR INSTALLATION

Throughout the manual, the term "sensor" refers to the removable portion or electrode sensing portion of the cable assembly. For example, the DO sensor or pH sensor is the part that can be removed from a field cable and replaced with a new sensor. The conductivity sensor is not removable from a non-Quatro cable but still refers to the "sensing" portion and will be referred to as a sensor. This section covers most of the sensor installations on a Professional Series cable bulkhead including the following sensors:

2003 - Polarographic DO (black)	1001 - pH	1003 - pH/ORP	1005 - Chloride
2002 - Galvanic DO (gray)	1002 - ORP	1004 - Ammonium	1006 - Nitrate

See the next section of this manual for installation instructions for the Quatro cable's Conductivity/Temperature sensor.



Dual sensor bulkhead ports are numbered 1 and 2, see figure to the left. Please refer to the following tables to determine correct sensor installation into each port of a two port cable.

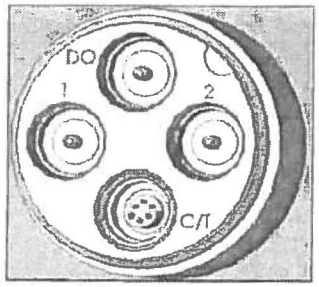
	Port 1 Options	Port 2 Options
1010 dual cable	pH	pH
	ORP	ORP
	pH or pH/ORP*	pH or pH/ORP*
	ammonium	ammonium
	chloride	chloride
	nitrate	nitrate
		none (port plug)

* If using a 6051010 cable, a sensor must be installed in port 1 for correct operation. If you install a pH/ORP combo sensor into a 6051010 cable, ORP will not be measured. It is not recommended to use a pH/ORP combo sensor on a 6051010 cable.

	Port 1 Options	Port 2 Options
1020 dual cable	pH	Polarographic DO
	ORP	Galvanic DO
	pH or pH/ORP	none (port plug)
	ammonium	
	chloride	
	nitrate	
	none (port plug)	

If using a 1020 cable, install a pH, ORP, pH/ORP, Ammonium, Nitrate or Chloride sensor in port 1 and a DO sensor in port 2.

> ⓘ *If using a 605103 pH/ORP combination probe on a 6051020 or 6051030 cable you can report both pH and ORP. However, it is recommended to set ISE1 as pH and ISE2 as ORP in the Sensor Setup menu.*



The Quatro cable bulkheads are labeled 1, 2, DO, and CT, see figure to the left. All sensors except the Conductivity/Temperature sensor can be installed following the Standard Pro Series Sensor Installation instructions. Conductivity/Temperature sensor installation is described in the next section. For ease of installation, YSI recommends that you install a sensor into port 1 first; followed by DO installation, then port 2, and lastly C/T.

	Port 1 Options	Port 2 Options	DO Port Options	CT Port Options
Quatro Cable (pn: 605790)	pH	pH	Polarographic DO	5560 Conductivity/ Temperature sensor only
	ORP	ORP	Galvanic DO	
	pH or pH/ ORP*	pH or pH/ ORP*	none (port plug)	
	ammonium	ammonium		
	chloride	chloride		
	nitrate	nitrate		
		none (port plug)		

* If using a Quatro cable, a sensor must be installed in port 1 for correct operation of port 2. If you install a pH/ORP combo sensor into a Quatro cable, ORP will not be measured. It is not recommended to use a pH/ORP combo sensor on a Quatro cable.

> ⓘ *Before installing either dissolved oxygen sensor, the instrument must be configured for the sensor being installed. See the Setup - Dissolved Oxygen section of this manual for instrument configuration instructions. Failure to do this may result in damage not covered under warranty.*

First, ensure both the sensor connector and sensor port on the cable are clean and dry. To connect the sensor, grasp the sensor with one hand and the sensor connection end of the cable (bulkhead) in the other. Push the sensor into the connector on the cable until it is properly seated and only one o-ring is visible. Failure to properly seat the probe may result in damage. Twist the sensor clockwise to engage threads and finger tighten (Figure 2). Do not use a tool. This connection is waterproof. Please refer to the sensor installation sheet that is included with each sensor for detailed instructions.

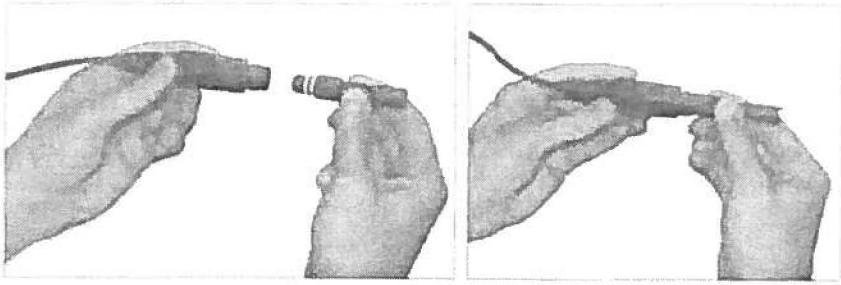


Figure 2. The image on the left shows a clean, dry sensor being aligned with the bulkhead. On the right, the sensor has been pushed into the bulkhead and is being screwed into place.

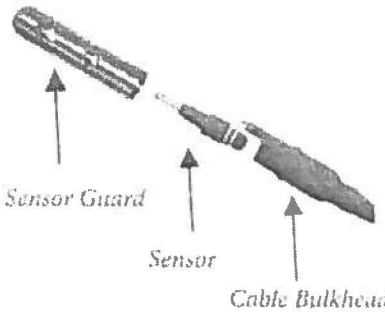


Figure 3. The sensor(s) will install directly in the cable bulkhead. Once installed, the sensor guard will protect the sensor during sampling (DO cap membrane not shown).

CONDUCTIVITY/TEMPERATURE SENSOR INSTALLATION IN A QUATRO CABLE

As mentioned, the installation of the Conductivity/Temperature sensor (model 5560) in a Quatro cable is different from all other Pro Series sensor installations. Follow these instructions when installing a conductivity/temperature sensor in a Quatro cable:

1. Locate the C/T port and, if replacing, remove the old sensor using the installation tool to loosen the stainless steel retaining nut. Once the stainless steel retaining nut has been completely unscrewed from the bulkhead, remove the old sensor from the bulkhead by pulling the sensor straight out of the bulkhead.
2. Apply a thin coat of o-ring lubricant (supplied with the sensor) to the o-rings on the connector side of the new sensor.

> ⓘ *Visually inspect the port for moisture. If moisture is found, it must be completely dried prior to sensor installation.*

3. Align the connectors of the new sensor and the port. With connectors aligned, push the sensor in towards the bulkhead until you feel the sensor seat in its port. You will experience some resistance as you push the sensor inward, this is normal
4. Once you feel the sensor seat into the port, gently rotate the stainless steel sensor nut clockwise with your fingers, Do not use the tool.
5. The nut must be screwed in by hand. If the nut is difficult to turn, STOP, as this may indicate cross threading. If you feel resistance or cross threading at any point, unscrew the nut and try again until you are able to screw the nut down completely without feeling any resistance. Damage to your cable/sensor may occur if you force the parts together.
6. Once completely installed, the nut will seat flat against the bulkhead. At this point, use the tool that was included with the sensor to turn the nut an additional ¼ to ½ turn so it cannot come loose (figure 4). DO NOT over tighten.

> ⓘ *Do not cross thread the sensor nut. Seat nut on face of bulkhead. Do not over tighten.*

Please refer to the sensor installation sheet that is included with the conductivity/temperature sensor for detailed instructions.

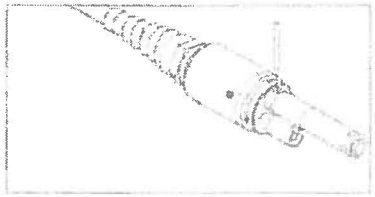


Figure 4. Installation tool used to tighten stainless steel retaining nut of 5560 conductivity/temperature sensor.

INSTALLING PORT PLUGS IN UNUSED PORTS

As necessary, install a port plug into any port that does not have an installed sensor. This will protect the bulkhead from water damage. Port plugs and a tube of o-ring lubricant are included with all Quatro cables. These items can be ordered separately if needed. To install a port plug, apply a thin coat of o-ring lubricant to the two o-rings on the port plug. After application, there should be a thin coat of o-ring lubricant on the o-rings. Remove any excess o-ring lubricant from the o-ring and/or port plug with a lens cleaning tissue. Next, insert the plug into an empty port on the bulkhead and press firmly until seated. Then, turn the plug clockwise to engage the threads and finger-tighten until the plug is installed completely. Do *not* use a tool to tighten the plug.

CONNECTING THE CABLE TO AN INSTRUMENT

To connect a cable, align the keys on the cable connector to the slots on the instrument connector. Push together firmly, then twist the outer ring until it locks into place (figure 5). This connection is water-proof.

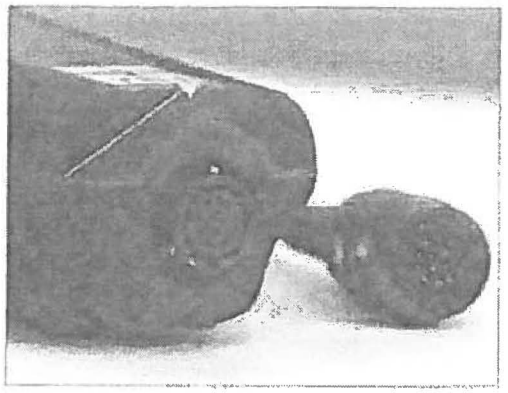


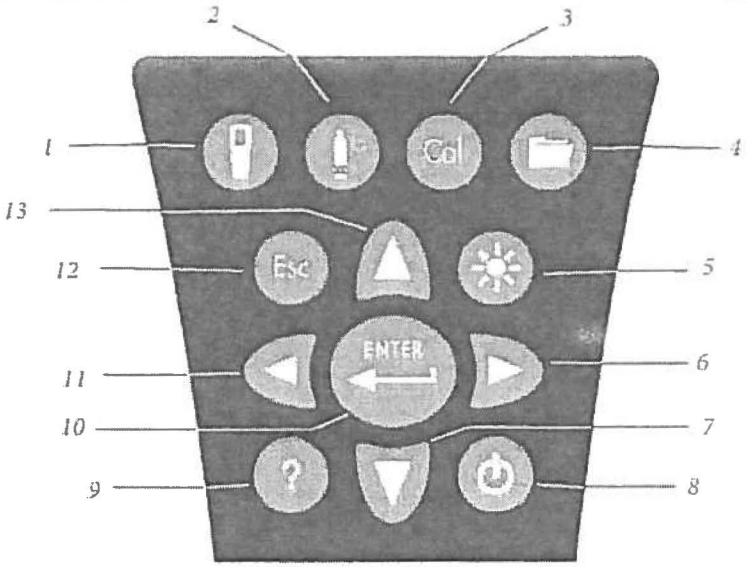
Figure 5. Note the keyed connector. The cable and instrument connectors can only be mated once the keys are properly aligned.

> *When a sensor is not installed, the sensor and cable sensor connectors are NOT water-proof. Do not submerge the cable without a sensor or port plug installed in all available ports.*
>
> *When the cable is disconnected, the cable's instrument connector and the connector on the instrument maintain an IP-67 rating.*

SENSOR STORAGE

The cable assembly is supplied with a storage container, or sleeve, that installs on to the cable. The container is used for short-term storage (less than 30 days). Be sure to keep a small amount of moisture (tap water) in the container during storage. This is done to maintain a 100% saturated air environment which is ideal for short-term sensor storage (see Care, Maintenance, and Storage for more detailed information). Do not submerge the sensors in an aqueous solution. The intent is to create a humid air storage environment.

KEYPAD

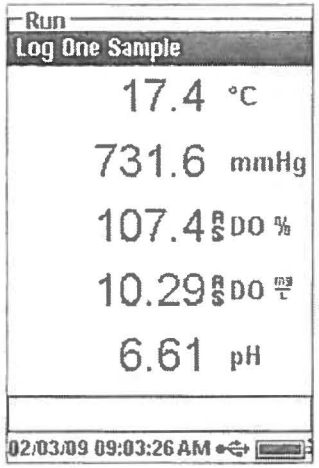


Number	Key	Description
1		**System** Opens System Menu from any screen. Use to adjust system settings.
2		**Sensor** Opens Sensor Menu from any screen. Use to enable sensors and display units.
3	Cal	**Calibrate** Opens Calibrate Menu from any screen. Use to calibrate all parameters except temperature.
4		**File** Opens File Menu from any screen. Use to view data and GLP files, set up site and folder lists, and delete data.
5		**Backlight** Press to turn the instrument backlight on and off and to adjust the display contrast when pressed with the left or right arrow key.

Number	Key	Description
6		**Right Arrow** Use to navigate right in alpha/numeric entry screens. Can be pressed simultaneously with Backlight key to increase display contrast.
7		**Down Arrow** Use to navigate through menus and to navigate down in alpha/numeric entry screens.
8		**Power** Press to turn the instrument on. Press and hold for 3 seconds to turn off.
9		**Help** Press to receive hints & tips during operation.
10		**Enter** Press to confirm selections, including alpha/numeric key selections.
11		**Left Arrow** Use to navigate left in alpha/numeric entry screens. Press to return to previous menu in all screens except alpha/numeric entry. Can be pressed simultaneously with Backlight key to decrease display contrast.
12		**Exit/Escape** Exits back to Run Screen. When in alpha/numeric entry screen, escapes to previous menu.
13		**Up Arrow** Use to navigate through menus and to navigate up in alpha/numeric entry screens.

MAIN DISPLAY

Press the Power key to turn the instrument on. The instrument will briefly display the splash screen with the YSI logo then go directly to the main run screen. The first time the instrument is powered up or if the instrument has had a battery change (with batteries removed for more than 2 minutes), you will need to set the date and time. Follow the instructions under **System Menu | Date/Time.**



The display at the left shows the run mode (main display) with temperature in °C, barometer in mmHg, DO in % and mg/L, and pH as the reported parameters. The date, time and battery level are indicated at the bottom of the screen. The logging preference of Log One Sample at a time is indicated at the top of the screen.

This screen also shows the message line towards the bottom of the display above the date and time. In this case, it doesn't show a message but messages will appear frequently to indicate calibration steps, set date and time, etc.

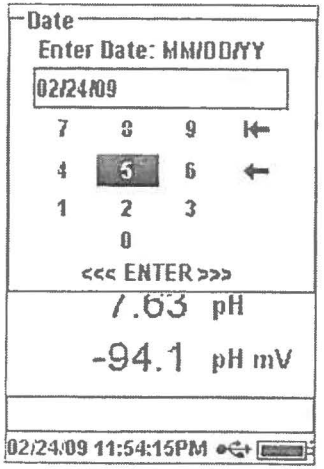
A USB symbol will show up on the bottom of the display when connected to a PC through USB with the communications saddle. The instrument will display full battery power when it is receiving power through the USB connection.

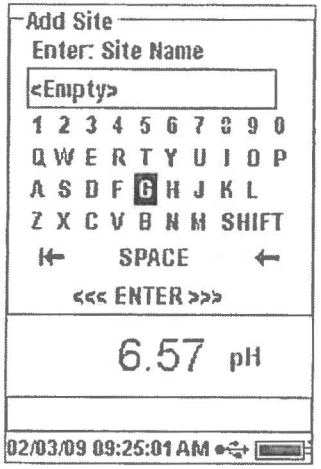
> ⓘ *Contrast – the contrast adjustment can be accomplished by pressing the backlight key and the left or right arrow key at the same time.*

MENU LAYOUT

Press Esc at anytime in the menus to escape back to the Run screen. The left arrow can be used to go back to the previous menu in all screens except alpha/numeric entry screens. You must use Esc to get out of the alpha/numeric screens if you want to exit before finishing or without saving changes. Functions that are enabled appear as a circle with a dot ⊙ or a box with a check mark ☑. Disabled functions appear as a circle only ○ or an empty ☐.

ALPHA/NUMERIC ENTRY





The numeric screens will display numbers only (shown on the left). Alpha/numeric screens will display numbers across the top and letters along the bottom rows (shown on the right). Letters appear as a common keyboard arrangement.

When an alpha or numeric character is required, the screen will show the alpha/numeric entry screen. To select a character, highlight it by using the arrow keys to move the highlight box over the desired selection. Then, press **Enter** on the keypad to confirm the selection. After confirming the selection, it will appear in the line at the top of the display.

For capital letters or lower case entry, highlight "SHIFT" and press **Enter** on the keypad to change the characters from upper to lower case.

To delete the entire line of the current entry, highlight ⇤ and press **Enter** on the keypad. The ← symbol functions as a backspace key in the alpha/numeric entry screens by deleting one character at a time. Use the "SPACE" function to add a space between characters.

When you have finished entering the correct information (16 character max), highlight <<<ENTER>>> at the bottom of the screen and press **Enter** on the keypad to confirm.

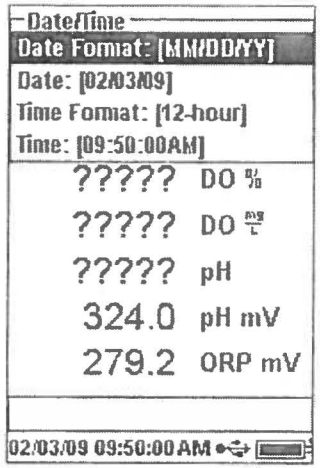
> *The ◀ key cannot be used to escape to the previous menu from an alpha/numeric entry screen. Instead, use the Esc key to go back to the previous menu when in alpha/numeric entry screens.*

SYSTEM MENU

Press System to access any of the following menu items.

The System menu will allow you to access the setup options of the instrument including; **Date/Time, GLP, Language, Radix Point, Logging, Auto-Shutoff, Backlight, SW** (Software) **Version, Serial #,** and **Unit ID.** Any item with [brackets] shows the current setting inside the brackets. For instance, in the example at the left, Radix Point is currently set to [Decimal]. The brackets will also give a quick visual clue as to what items can be changed.

DATE/TIME



Highlight **Date/Time** from the **System** menu. Press enter to select.

Date Format – Highlight and press enter to open a sub menu for selecting the preferred date format: YY/MM/DD, MM/DD/YY, DD/MM/YY, or YY/DD/MM.

Date – Highlight and press enter to use the numeric entry screen to set the correct date.

Time Format – Highlight and press enter to open a submenu to select the preferred time format from 12-hour or 24-hour.

Time – Highlight and press enter to use the numeric entry screen to set the correct time.

> *The date and time will need to be reset if a battery change takes longer than 2 minutes. When this occurs, the Date/Time menu will automatically appear upon power up and require you to set the date and time.*

GLP

The GLP or 'Good Laboratory Practice' file saves detailed information about calibrations. It also includes diagnostic information about the sensors. Calibrations are logged into a file, the GLP, for later review as needed. A single GLP file is utilized to store all calibration records and is capable of storing 500 records. Once the GLP file is full, the instrument will begin to overwrite the oldest record with each new calibration record.

> *In order to keep all of your GLP records, periodically download the GLP to Data Manager and export it to another program. Otherwise, the unit will overwrite the oldest record once the memory is full. Also, since Data Manager saves GLP files under the Unit ID, you must periodically export and rename the GLP file on your PC or it will be overwritten each time you upload the GLP file from the instrument.*

Several calibration parameters are saved for each calibration record including optional ones that can be enabled by the user. Standard parameters include date/time stamp, calibration method, and sensor information. Optional, user selectable parameters include User ID, Probe ID, and User Fields 1 and 2.

The sensor specific information that is saved with each calibration point is different for each sensor. The sensor specific values saved are:

Conductivity
Method (Spec Cond, Cond, Salinity)
Cal Value (value of calibration solution)
Sensor Value (Cell Constant)
Temperature Reference (User selected in Sensor Setup menu)
Temperature Compensation Coefficient %/°C (User selected in Sensor Setup menu)
TDS Constant (User selected in Sensor Setup menu)
Temperature
Cal Cell Constant
Calibrate Status

DO
Method (%, mg/L)
Cal Value
Sensor Value (Sensor Current)
Sensor Type (Polarographic/Galvanic)
Membrane Type (Teflon Black, PE Yellow, PE Blue)
Salinity Mode (user entered value if in Manual Salinity Mode)
Temperature
Barometer
Calibrate Status

pH (up to 6 calibration points)
Buffer Value
Sensor Value (mV)
Temperature
Slope (mV/pH)
Slope (% of ideal)
Calibrate Status

ORP
Cal Solution Value
Sensor Value
Temperature
Calibrate Status

Ammonium
Buffer Value
Sensor Value (mV)
Temperature
Calibrate Status

Chloride
Buffer Value
Sensor Value (mV)
Temperature
Calibrate Status

Nitrate
Buffer Value
Sensor Value (mV)
Temperature
Calibrate Status

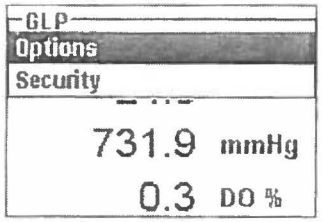
An example of a GLP record

(Operation performed is single point % DO Calibration)

*** Calibrate – DO% ***

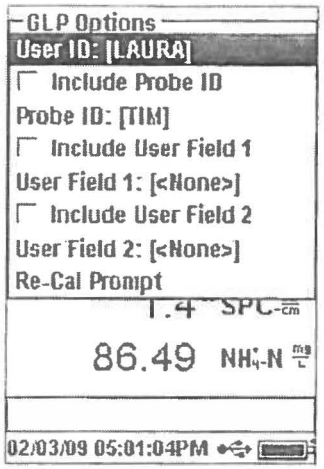
Date	02/03/09 MM/DD/YY
Time	12:14:57PM 12-hour
User ID:	Tech 1
Probe ID	08D
Method	DO Air Calibrate
Cal Value:	100.00%
Sensor Value:	5.175155uA
Sensor Type	Polarographic
Membrane Type	1.25 PE Yellow
Salinity Mode	5.175165 Auto
Temperature	23.9 °C
Barometer	731.4 mmHg
Calibrate Status	Calibrated

GLP SETTINGS



In the System menu, highlight GLP and press enter to view and modify the GLP settings.

Highlight Options and press enter to access **User ID, Probe ID, User Defined Fields,** and **Re-Cal Prompt.**

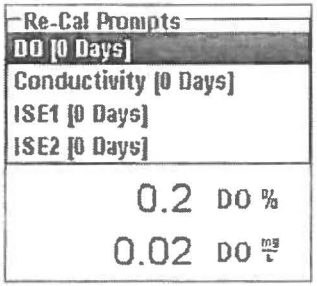


User ID may be used to identify the person calibrating the instrument. Highlight **User ID** and press enter to select, edit, or delete a User ID from a list of previously entered IDs. Or, highlight **Add New** and press enter to create a new User ID using the alpha/numeric entry screen. The User ID may also be changed in the **Calibration** menu during the calibration process. The selected User ID will be stored in the GLP file with each calibration record. A User ID could be a person's initials or badge number. The character limit is 16 characters.

Probe ID is stored with the calibration record and may be used to distinguish one cable/probe

assembly from another, typically by serial number. Highlight **Include Probe ID** and press enter to turn this function on (☑) and off (☐). Highlight **Probe ID** and press enter to add, view, edit, delete, or select a Probe ID. The Probe ID may also be changed in the **Calibration** menu during the calibration process. The character limit is 16 characters.

User Fields 1 and 2 are stored with the calibration record and may be used to enter other parameters pertinent to the user, such as weather conditions, elevation, etc. Highlight **Include User Field 1** or **Include User Field 2** and press enter to turn this function on and off. Highlight **User Field 1** or **User Field 2** and press enter to add, delete, view, edit, or select a User Field. The character limit is 16 characters. When enabled, a prompt for selecting a User Defined Field will appear during the calibration process.



Re-Cal Prompt may be used to remind the user to perform a calibration. To set a time interval, highlight the parameter you wish to be reminded about and press enter to access the numeric entry screen. Enter a value in days and press enter to confirm the reminder time. To turn off the Re-cal prompt, set the reminder to zero (0) days (this is the default).

The **Security** section of the GLP menu is a password protected area. This area includes options to set a new password and to lock access to the calibration menu. When first viewing the security menu, you will be required to enter a password. Use the "shift" on the alpha/numeric screen to switch to lower case if necessary and enter "ysi123". This is the default password.

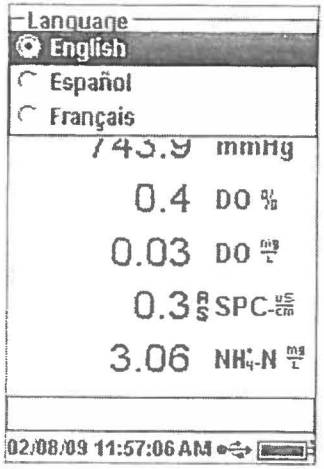
Protect Cal can be enabled (☑) or disabled (☐). When enabled, the user must know and enter the instrument's password to enter the calibration menu option. Highlight **Protect Cal** and press enter to enable or disable this feature.

Set Password allows a user to set the security password. Highlight **Set Password,** press enter, and use the alpha/numeric entry screen to set the new password. The password can have up to 16 characters.

Contact YSI Technical Support at environmental@ysi.com or +1 937 767-7241 if you forget or misplace your password.

> ⓘ *Once a password is set, and the GLP security screen exited, a password must be entered to make changes under GLP security. Keep passwords in a safe place.*

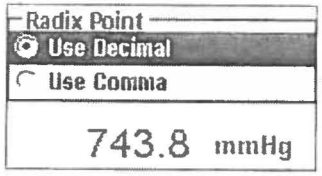
LANGUAGE



The Pro Plus can be configured to display all text in English, Spanish, French, German, Portuguese, Italian, Norwegian, Simplified Chinese, Traditional Chinese, or Japanese. From the factory, the instrument includes English, Spanish, and French language options. The other language options can be downloaded from www.ysi.com/support.

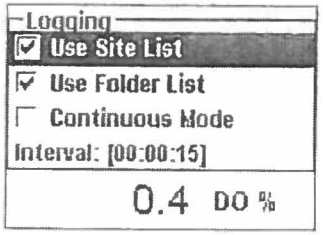
Once the appropriate language file is in the instrument, press System, highlight **Language**, and press enter. Highlight the desired language and press enter to confirm.

RADIX POINT



Radix Point allows the user the option to choose between a comma or a decimal in numeric displays. For example, 1.00 becomes 1,00 when **Use Comma** is selected. Highlight **Use Decimal** or **Use Comma** and press enter to make your selection.

LOGGING



From the System menu, highlight **Logging** and press enter to view or change the logging options. Logging options include **Use Site List**, **Use Folder List**, **Continuous Mode**, and **Interval**.

Use Site List and **Use Folder List** are optional ways of filing or 'tagging' your logged data points. If these settings are enabled, you will be prompted to select a Site and/or Folder to 'tag' to the logged data point. See the **File and Site Lists** section of this manual for information on creating Site and Folder Lists.

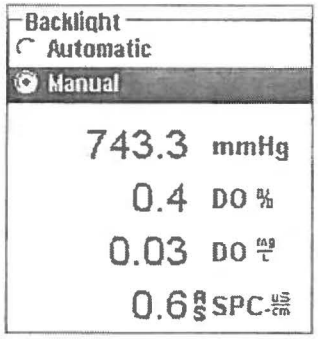
Check the box for **Continuous Mode** if you want to log samples continuously at a specific time interval. To set the length of time between logged samples, highlight **Interval** and press enter. Enter the interval as HH:MM:SS. This interval will display at the top of the screen when you select the **Start Logging** option in run mode.

To log one sample at a time, uncheck **Continuous Mode**. When Continuous Mode is unchecked, **Log One Sample** will appear at the top of the run screen.

AUTO SHUTOFF

Auto Shutoff powers the instrument off after a user specified time period. Highlight **Auto Shutoff** and press enter. Using the alpha/numeric entry screen, enter a value between 0 and 360 minutes. To disable auto shutoff, set the value to 0 (zero).

BACKLIGHT



Backlight can be set to **Automatic** or **Manual**. Automatic turns the backlight on when you turn the instrument on and when you press any key. Manual allows you to turn the backlight on or off with the backlight key. When in Automatic mode, the instrument will turn the backlight off 60 seconds after the last key press. The instrument will "reset" the 60 second time period every time a key is pressed. The lighted keypad will turn off after approximately 20 seconds.

SW VERSION (SOFTWARE VERSION)

SW Version shows the instrument's software version. The instrument's software can be updated via www.ysi.com/support. There you will find the new software files and instructions on how to update the instrument. There is no need to send the instrument back to the factory for upgrades.

SERIAL

Serial # shows the instrument's serial number and allows you to match it with the number engraved on the back of the instrument's case.

UNIT ID

Unit ID is used to identify instruments in the Data Manager software program that was included with your instrument. It is also used to identify GLP files, Site Lists, Configuration files, and Data files transferred from the instrument to the PC. The default Unit ID is the instrument's serial number. To modify the Unit ID, highlight Unit ID, press enter and then use the alpha/numeric entry screen. The character limit is 16 characters.

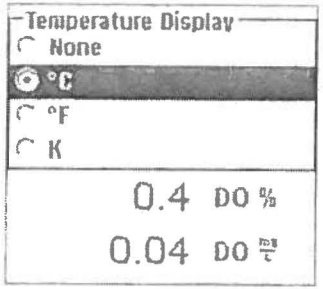
PARAMETERS: SETUP, DISPLAY, AUTO STABLE, AND CALIBRATION

The following section is separated by parameter and will discuss sensor setup, display options, auto stable features, and calibration procedures for each parameter. The sections are separated by parameter due to the versatility of the Pro Plus. You may focus solely on the parameters of your choice.

For the highest accuracy, calibrate or verify each sensor regularly. For your convenience, YSI offers 5580 Confidence Solution* which allows you to check the accuracy of pH, conductivity, and ORP readings to help determine if a sensor calibration is necessary.

If you receive an error message during a calibration that indicates questionable results, you have the option to either accept or decline the calibration. YSI recommends that you decline a questionable calibration since accepting it may result in erroneous data. After declining a questionable calibration, ensure the sensor is clean, the calibration solution is good, the calibration vessel is clean, and that you are entering the correct calibration value if entering manually. Then, try to recalibrate the sensor. If you continue to have problems, see the Troubleshooting section of this manual.

TEMPERATURE



All probe/cable assemblies, except the Quatro, have a built-in temperature sensor. The Quatro cable ships with a Conductivity/Temperature sensor that must be installed on the cable. Temperature calibration is not required nor is it available.

To set the units, press Sensor, highlight **Display** and press enter. Highlight **Temperature** and press enter. Highlight the desired

temperature units of °F, °C, or K and press enter to confirm the selection. Only one temperature unit may be displayed at a time. You may also choose not to display temperature. If you choose not to display temperature, other parameters that require a temperature reading will still be temperature compensated.

DISSOLVED OXYGEN (DO)

DO sensors can be used on 60520-X, 6051020-X, 6052030-X, and Quatro cables.

PREPARING THE DO SENSOR FOR THE FIRST TIME

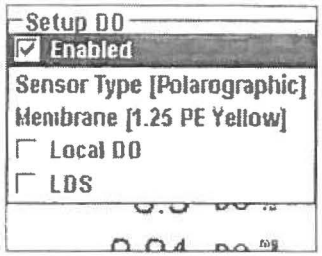
The dissolved oxygen sensor is shipped with a dry, protective red cap that will need to be removed before using. It is very important to put a new membrane with electrolyte solution on the sensor after removing the red cap.

Prepare the membrane solution according to the instructions on the bottle. After mixing, allow the solution to sit for 1 hour. This will help prevent air bubbles from later developing under the membrane. Ensure you are using the correct electrolyte solution for the correct sensor. Galvanic sensors utilize electrolyte with a light blue label and Polarographic sensors utilize electrolyte with a white label. The dissolved oxygen sensor is supplied with cap membranes specific to the sensor type ordered (Polarographic or Galvanic). 5912, 5913, and 5914 membrane kits are for Galvanic sensors and the 5906, 5908, and 5909 membrane kits are for Polarographic sensors. See the **Setup - Dissolved Oxygen** section of this manual for more information on the different types of membranes available from YSI.

Remove the red cap by pulling it straight off the sensor tip. Discard or save for later use during long term storage. Thoroughly rinse the sensor tip with distilled or deionized water. Fill the cap membrane 3/4 full of electrolyte solution, then tap the cap with a finger to release any trapped air. Be careful not to touch the membrane portion of the cap. Thread the membrane cap onto the sensor, moderately tight. Do not use a tool. It's typical for some of the electrolyte solution to spill over. For detailed instructions on changing a membrane cap, see the **Care, Maintenance, and Storage** section of this manual.

SETUP - DISSOLVED OXYGEN

Press Sensor, highlight **Setup** and press enter. Next, highlight **DO** and press enter.



Enabled allows you to enable or disable the Dissolved Oxygen function. Highlight **Enabled** and press enter to activate(☑) or deactivate(☐) dissolved oxygen. Disable dissolved oxygen if you do not have a dissolved oxygen sensor connected to the instrument.

> *If a sensor is Enabled that isn't connected to the instrument, the display will show an unstable, false reading, ?????, or ----- next to the units.*

Sensor Type sets the type of oxygen sensor being used: either Polarographic (black) or Galvanic (grey). Highlight **Sensor Type** and press enter. Highlight the correct sensor type installed on the cable and press enter to confirm.

If using a ProBOD sensor/cable assembly, the sensor type should be set to polarographic.

The Pro Plus has two compatible sensors for use with a field cable:

Polarographic – This sensor has a black sensor body and is engraved with the model number 2003.

Galvanic – This sensor has a grey sensor body and is engraved with the model number 2002.

In terms of physical configuration, membrane material, and general performance, YSI Professional Series Galvanic dissolved oxygen sensors are exactly like the Professional Series Polarographic sensors. The advantage of using Galvanic sensors is convenience. Galvanic sensors provide for an instant-on sensor without the need for warm-up time but this affects the life of the sensor. Polarographic sensors last longer and have a longer warranty but require a 5-15 minute warm-up time before use or calibration.

> **IMPORTANT** - *The instrument default setting is Galvanic. Please change the **Sensor Type** to match the correct sensor. If you observe readings very close to 0 or extremely high readings (i.e. 600%), your **Sensor Type** setting (Polarographic or Galvanic) may be set incorrectly and you should immediately ensure it matches the sensor installed on your cable.*

Membrane sets the type of membrane used on the dissolved oxygen sensor. Highlight **Membrane** and press enter. Highlight the correct membrane type installed on the sensor and press enter to confirm. The DO sensor is supplied with membranes specific to the sensor type ordered and are color coded as described in the following tables.

Galvanic membrane kits:

Item	*Color*	*Material*	*Description*
5912	Black	1 mil Teflon*	Traditional membrane material
5913	Yellow	1.25 mil polyethylene	Improved response time and less flow dependence than Teflon* Ships standard with the sensor.
5914	Blue	2 mil polyethylene	Less flow dependence than 1.25 mil but somewhat slower response

Polarographic membrane kits:

Item	*Color*	*Material*	*Description*
5906	Black	1 mil Teflon*	Traditional membrane material
5908	Yellow	1.25 mil polyethylene	Improved response time and less flow dependence than Teflon* Ships standard with the sensor.
5909	Blue	2 mil polyethylene	Less flow dependence than 1.25 mil but somewhat slower response

Selecting a Dissolved Oxygen Membrane:

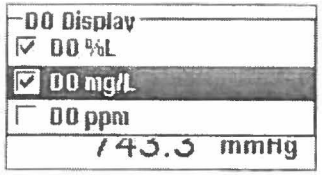
Membrane Type	*Flow Dependence After 4 Minutes*	*Typical Response Time - 95%*
5912, 5906 - Black	60%	18 seconds
5913, 5908 - Yellow	25%	8 seconds
5914, 5909 - Blue	18%	17 seconds

Local DO allows for localized DO% measurements. This sets the calibration value to 100% regardless of the altitude or barometric pressure. Highlight **Local DO** and press enter to enable (☑) or disable (☐) this function. Local DO is a method for the Pro Plus to factor in the barometric pressure on each DO measurement. In essence, if the barometric pressure changes you wouldn't notice the difference in the DO% readings in air-saturated water or water-saturated air. Local DO is ideal for EU compliance. When Local DO is enabled, an L will appear next to DO% on the run screen. DO mg/L readings are unaffected by the selection of DO Local.

LDS (Last Digit Suppression) rounds the DO value to the nearest tenth; i.e. 8.27 mg/L becomes 8.3 mg/L. Highlight **LDS** and press enter to enable (☑) or disable (☐) this function.

DISPLAY - DISSOLVED OXYGEN

Press Sensor, highlight **Display** and press enter. Highlight **DO** and press enter. All DO units can be displayed simultaneously. Highlight the unit(s) and press enter to activate (☑) or deactivate (☐) units from the run screen. Note - You will not be able to display dissolved oxygen unless it is **Enabled** in the Sensor Setup menu first, see previous section.



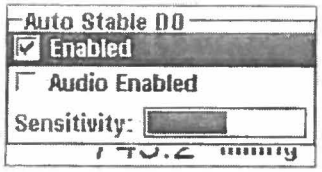
DO % will show DO readings in a percent scale from 0 to 500%.

DO mg/L will show DO readings in milligrams per liter (equivalent to ppm) on a scale from 0 to 50 mg/L.

DO ppm will show DO readings in parts per million (equivalent to mg/L) on a scale from 0 to 50 ppm.

AUTO STABLE - DISSOLVED OXYGEN

Auto Stable indicates when a reading is stable. When Auto Stable is enabled, AS will blink next to the parameter until it is stable. Once the parameter is stable, AS will stop blinking.



To enable Auto Stable, press Sensor, highlight **Auto Stable** and press enter. Highlight **DO** and press enter.

Highlight **Enabled** and/or **Audio Enabled** (instrument will beep when the stability

is achieved) and press enter to confirm. The Auto Stable **Sensitivity** can be decreased or increased. Highlight **Sensitivity** and use the left and right arrow keys to slide the bar. The more sensitive you make it (larger black bar) the harder it is to achieve stability in a changing environment.

The **Auto Stable** system works by examining the previous 5 readings, computing the percent change in the data and comparing that change against a % threshold value. The % threshold value is determined by the **Sensitivity** bar setting. The following chart can be used as a guide when setting the Sensitivity bar.

Sensitivity selected by User	*% Data Variance Threshold*
100 - Most Sensitive, Sensitivity bar is set to the far right	0.05%
75	0.62525%
50	1.275%
25	1.8875%
0 - Least Sensitive, Sensitivity bar is set to the far left	2.5%

Example:

The instrument obtained the following data:

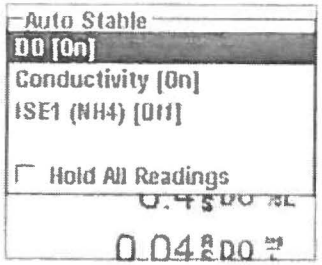
Reading #1 95.5 DO%
Reading #2 95.7 DO%
Reading #3 95.8 DO%
Reading #4 96.1 DO%
Reading #5 95.3 DO%

The instrument is programmed to determine the minimum and maximum data value over the previous 5 samples, and to compute the percent difference between those values. In this example, that gives a percent change of:

% Change = 100 * ((96.1 – 95.3) / 95.3)
% Change = 0.83%

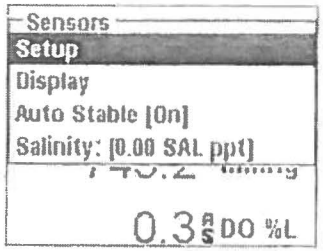
In this example, if the Sensitivity bar is set to the far right, the Auto Stable requirement would not be met and AS would continue to blink. However, if the sensitivity bar is set to the median threshold (1.275%), the Auto Stable requirement would be met and AS would display steadily on the display.

Within the Auto Stable menu, you can also choose to **Hold All Readings** for as many parameters as you set for Auto Stable. For instance, if DO and pH have



Auto Stable and Hold All Readings enabled, then the display will hold the readings once DO and pH have both reached their Auto Stable settings. You must press the Esc key to "release" the held display in order to take subsequent readings **Hold All Readings** must be reactivated after each use!

SALINITY CORRECTION



The last feature in the **Sensor** menu is the Salinity correction value which is used to calculate the dissolved oxygen mg/L and ammonia readings when a conductivity sensor is not in use. Press Sensor, highlight **Salinity**, and press enter. Then, use the numeric entry screen to enter the Salinity value of the water you will be testing from 0 to 70 ppt.

If using a cable with a conductivity sensor, the salinity measured by the conductivity sensor will be used in the DO and ammonia mg/L calculations and 'As Measured' will be displayed next to **Salinity** in the Sensor menu.

As the salinity of water increases, its ability to dissolve oxygen decreases. For example, fully oxygenated 20 °C water at sea level with zero salinity will hold 9.092 mg/L of dissolved oxygen. If that same sample had a salinity value of 9 ppt, then it would hold 8.621 mg/L of dissolved oxygen. Therefore, to obtain accurate mg/L readings, it is important to know the salinity of the water you will be testing and to input that value into the instrument. The salinity of fresh water is typically 0-0.5 ppt and seawater is typically 35 ppt. You will also have the opportunity to enter or modify the Salinity correction value during DO calibration.

CALIBRATION - DISSOLVED OXYGEN

The Pro Plus offers several options for calibrating dissolved oxygen: DO% in water saturated air, DO mg/L and DO ppm in a solution of known dissolved oxygen determined by a Winkler Titration, and a Zero point. If performing a zero point calibration, you must also perform a %, mg/L, or ppm calibration following the zero calibration. For both ease of use and accuracy, YSI recommends performing the following 1-point DO % water saturated air calibration:

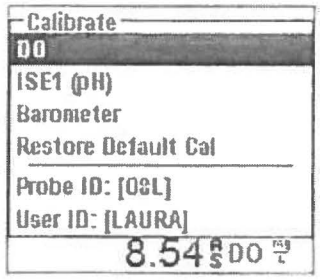
> *It is not necessary to calibrate in both % and mg/L or ppm. Calibrating in % will simultaneously calibrate mg/L and ppm and vice versa.*

Calibrating DO % in Water Saturated Air:
1-Point Calibration

The supplied sensor storage container (a grey sleeve for a single port cable or a screw on plastic cup for the dual-port and Quatro cables) can be used for DO calibration purposes.

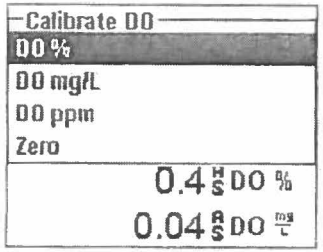
Moisten the sponge in the storage sleeve or plastic cup with a small amount of clean water. The sponge should be clean since bacterial growth may consume oxygen and interfere with the calibration. If using the cup and you no longer have the sponge, place a small amount of clean water (1/8 inch) in the plastic storage cup instead.

Make sure there are no water droplets on the DO membrane or temperature sensor. Then install the storage sleeve or cup over the sensors. The storage sleeve ensures venting to the atmosphere. If using the cup, screw it on the cable and then disengage one or two threads to ensure atmospheric venting. Make sure the DO and temperature sensors are not immersed in water. Turn the instrument on and wait approximately 5 to 15 minutes for the storage container to become completely saturated and to allow the sensors to stabilize.



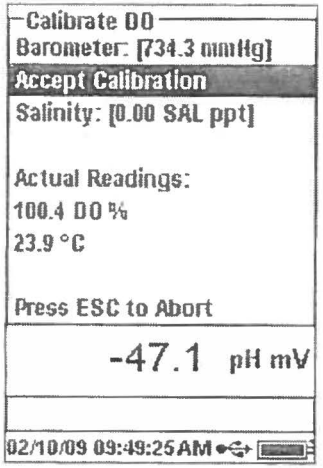
Press Cal. Highlight Probe ID or User ID if you wish to add, select, edit, or delete an ID. Probe ID must be enabled in the System GLP menu to appear in the Calibrate menu. User ID will appear automatically. Select 'None' if you do not want a User ID stored with the calibration. When enabled, these IDs are stored with each calibration record in the GLP file.

After selecting your User ID and/or Probe ID if appropriate, highlight DO and press enter.



Highlight DO % and press enter to confirm.

The instrument will use the internal barometer during calibration and will display this value in brackets at the top of the display. Highlight **Barometer** and press enter to adjust it if needed. If the barometer reading is incorrect, it is recommended that you calibrate the barometer. Note – the barometer should be reading "true" barometric pressure (see Barometer section for more information on "true" barometric pressure). If the value is acceptable, there is no need to change it or perform a barometer calibration.



The Salinity value displayed near the top of the screen is either the salinity correction value entered in the Sensor menu or the Salinity value as measured by the conductivity sensor in use and enabled. If you are not using a conductivity sensor, the Salinity correction value should be the salinity of the water you will be testing. Highlight **Salinity** and press enter to modify this setting if necessary. See the **Salinity Correction** section of this manual for more information.

Wait for the temperature and DO% values under "Actual Readings" to stabilize, then highlight **Accept Calibration** and press enter to calibrate. Or, press Esc to cancel the calibration. If User Field 1 or 2 are enabled in the GLP menu, you will be prompted to select these inputs and then press Cal to complete the calibration. The message line at the bottom of the screen will display "Calibrating Channel..." and then "Saving Configuration...".

Calibrating DO% in Water Saturated Air:
2-Point Calibration with Zero Solution

Place the sensor in a solution of zero DO.

A zero DO solution can be made by dissolving approximately 8 - 10 grams of sodium sulfite (Na_2SO_3) into 500 mL tap water or DI water. Mix the solution thoroughly. It may take the solution 60 minutes to be oxygen-free.

Press Cal. Highlight Probe ID or User ID if you wish to add, select, edit, or delete an ID. Probe ID must be enabled in the System GLP menu to appear in the Calibrate menu. When enabled, these IDs are stored with each calibration record in the GLP file.

After selecting the Probe ID and/or User ID if appropriate, highlight DO and press enter. Highlight **Zero** and press enter. Wait for the temperature and DO% values under "Actual Readings" to stabilize, then press enter to **Accept Calibration**. If User Field 1 or 2 are enabled, you will be prompted to select the fields and then press Cal to complete the calibration. The screen will then prompt for a follow-up second point calibration.

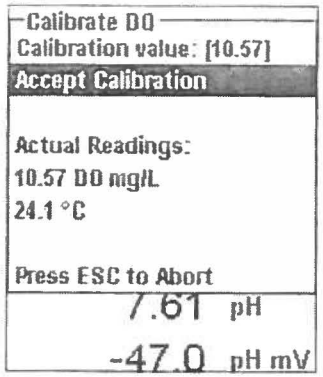
Highlight **DO%** and press enter to continue with the next calibration point. Rinse the sensor of any zero oxygen solution using clean water. Then follow the steps under Calibrating DO % in Water Saturated Air to complete the second point.

Calibrating in mg/L or ppm as a Titration:
1-Point Calibration

Place the sensor into an adequately stirred sample that has been titrated to determine the dissolved oxygen concentration. Allow the sensor to stabilize.

Press Cal. Highlight Probe ID or User ID if you wish to add, select, edit, or delete an ID. Probe ID must be enabled in the System GLP menu to appear in the Calibrate menu. When enabled, these IDs are stored with each calibration record in the GLP file.

After selecting the Probe ID and/or User ID if appropriate, highlight DO and press enter. Highlight **DO mg/L or ppm** and press enter.



Highlight **Calibration value** and press enter to manually input the sample's dissolved oxygen value. Highlight **Accept Calibration** and press enter once the temperature and Dissolved Oxygen readings stabilize. Or, press Esc to cancel the calibration. If User Field 1 or 2 are enabled in the GLP menu, you will be prompted to select the fields after selecting **Accept Calibration**. After making your selection, press Cal to complete the calibration. After completing the calibration, the message line will display "Calibrating Channel..." and then "Saving Configuration...".

Calibrating in mg/L or ppm as a Titration:
2-Point Calibration with Zero Solution

Place the sensor in a solution of zero DO.

A zero DO solution can be made by dissolving approximately 8 - 10 grams of sodium sulfite (Na_2SO_3) into 500 mL tap water. Mix the solution thoroughly. It may take the solution 60 minutes to be oxygen-free.

Press Cal. Highlight Probe ID or User ID if you wish to add, select, edit, or delete an ID. Probe ID must be enabled in the System GLP menu to appear in the Calibrate menu. When enabled, these IDs are stored with each calibration record in the GLP file.

After selecting the Probe ID and/or User ID if appropriate, highlight DO and press enter. Highlight **Zero** and press enter. Wait for the temperature and DO% values under "Actual Readings" to stabilize, then press enter to **Accept Calibration**. If User Field 1 or 2 are enabled, you will be prompted to select the fields and then Press Cal to complete the calibration. The screen will then prompt for a follow-up second point calibration.

Highlight the desired calibration units (mg/L or ppm) and press enter to continue with the next point. Rinse the sensor of any zero oxygen solution using clean water. To complete the second calibration point, follow the steps under Calibrating in mg/L or ppm as a Titration: **1-Point Calibration**.

BAROMETER

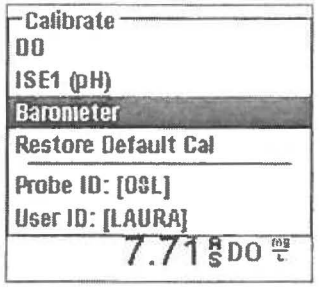
All Professional Plus instruments contain an internal barometer.

DISPLAY - BAROMETER

Press Sensor, highlight **Display** and press enter. Highlight **Barometer** and press enter. The measurement unit options are: mmHg, inHg, mBar, PSI, kPa, or Atm. Only one unit can be displayed at a time. Select **None** if you do not want to display a barometric pressure reading.

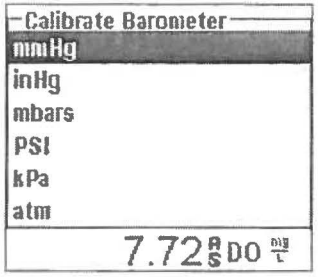
Whether or not you choose to display the barometer reading, the barometric pressure will still be used for calibrating DO% and for compensating for pressure changes if **Local DO** is enabled.

CALIBRATION - BAROMETER

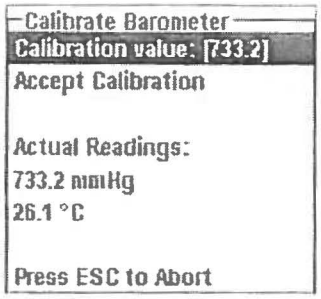


The barometer in the instrument is calibrated at the factory. If the barometer requires calibration, press **Cal**. Highlight Probe ID or User ID if you wish to add, select, edit, or delete an ID. Probe ID must be enabled in the System GLP menu to appear in the Calibrate menu. When enabled, these IDs are stored with each calibration record in the GLP file.

After selecting the Probe ID and/or User ID if appropriate, highlight **Barometer** and press enter.



Highlight the desired unit and press enter.



Highlight **Calibration Value** and press enter to manually enter the correct "true" barometric pressure. Next, highlight **Accept Calibration**, and press enter. If User Field 1 or 2 are enabled, you will be prompted to select the fields and then press Cal to complete the calibration or press Esc to cancel the calibration.

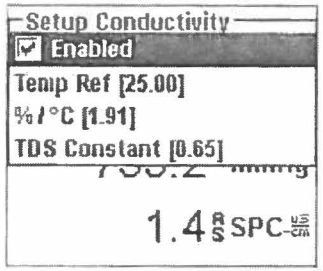
> *Laboratory barometer readings are usually "true" (uncorrected) values of air pressure and can be used "as is" for barometer calibration. Weather service readings are usually not "true", i.e., they are corrected to sea level, and therefore cannot be used until they are "uncorrected". An approximate formula for this "uncorrection" is below:*

True BP = [Corrected BP] – [2.5 * (Local Altitude in ft. above sea level/100)]

CONDUCTIVITY

Conductivity sensors are supplied with 60530-X, 6051030-X, 6052030-X , and Quatro cables. Conductivity sensors are built into the 60530-X, 6051030-X, and 6052030-X cables and are not replaceable. Conductivity/Temperature sensors are shipped with the Quatro cable, must be installed, and are replaceable.

SETUP - CONDUCTIVITY



Press Sensor, highlight **Setup**, and press enter. Highlight **Conductivity**, press enter.

Enabled allows you to enable or disable the conductivity measurement. Highlight **Enabled** and press enter to activate (☑) or deactivate (☐) conductivity. Disable conductivity if you do not have a conductivity sensor connected to the instrument.

> *If a sensor is Enabled that isn't connected to the instrument, the display will show an unstable, false reading next to the units.*

Temp Ref (Temperature Reference) is the reference temperature used for calculating temperature compensated Specific Conductance. This will be the

temperature all Specific Conductance values are compensated to. The default is 25 °C. To change the Reference Temperature, highlight **Temp Ref** and press enter. Use the numeric entry screen to enter a new value between 15.00 and 25.00 °C. Next, highlight <<<ENTER>>> at the bottom of the screen and press enter on the keypad to confirm.

%/°C (Percent per Degree Celsius) is the temperature coefficient used to calculate temperature compensated Specific Conductance. The default is 1.91% which is based on KCl standards. To change the temperature coefficient, highlight %/°C and press enter. Use the numeric entry screen to enter a new value between 0 and 4%. Next, highlight <<<ENTER>>> at the bottom of the screen and press **Enter** on the keypad to confirm.

TDS Constant is a multiplier used to calculate an estimated TDS (Total Dissolved Solids) value from conductivity. The multiplier is used to convert Specific Conductance in mS/cm to TDS in g/L. The default value is 0.65. This multiplier is highly dependent on the nature of the ionic species present in the water sample. To be assured of moderate accuracy for the conversion, you must determine a multiplier for the water at your sampling site. Use the following procedure to determine the multiplier for a specific sample:

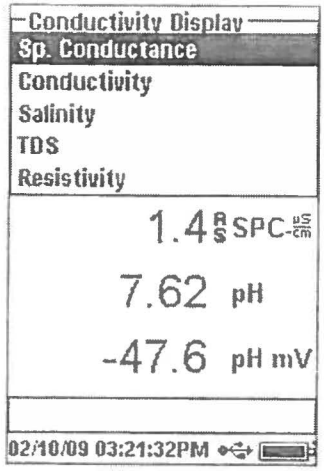
1. Determine the specific conductance of a water sample from the site;
2. Filter a portion of water from the site;
3. Completely evaporate the water from a carefully measured volume of the filtered sample to yield a dry solid;
4. Accurately weigh the remaining solid;
5. Divide the weight of the solid (in grams) by the volume of water used (in liters) to yield the TDS value in g/L for this site; Divide the TDS value in g/L by the specific conductance of the water in mS/cm to yield the conversion multiplier. Be certain to use the correct units.

> *If the nature of the ionic species at the site changes between sampling studies, the TDS values will be in error. TDS cannot be calculated accurately from specific conductance unless the make-up of the chemical species in the water remains constant.*

To change the multiplier, highlight **TDS Constant** and press enter. Use the numeric entry screen to enter a new value between 0 and 0.99. Highlight <<<ENTER>>> at the bottom of the screen and press **Enter** on the keypad to confirm.

DISPLAY - CONDUCTIVITY

Press Sensor 1, highlight **Display** and press enter. Highlight **Conductivity** and press enter. Highlight **Sp. Conductance** (Specific Conductance), **Conductivity**, **Salinity**, **TDS**, or **Resistivity**, and press enter to select the reporting units for each parameter. One reporting unit per parameter may be enabled. To disable a parameter, select **None**. You will not be able to display any of these parameters unless the Conductivity sensor is **Enabled** in the Sensor Setup menu first.



Sp. Conductance can be displayed in us/cm or ms/cm. Specific conductance is temperature compensated conductivity.

Conductivity can be displayed in uS/cm or mS/cm. Conductivity is the measure of a solution's ability to conduct an electrical current. Unlike specific conductance, conductivity is a direct reading without any temperature compensation.

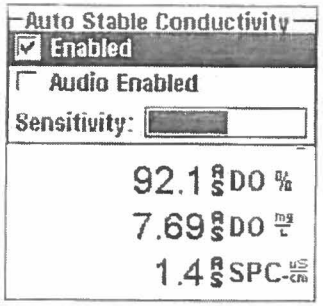
Salinity can be displayed in ppt (parts per thousand) or PSU (practical salinity units). The units are equivalent as both use the Practical Salinity Scale for calculation.

TDS can be displayed in mg/L (milligrams per liter), g/L (grams per liter), or kg/L (kilograms per liter).

Resistivity can be displayed in ohm-cm (ohms per centimeter), kohm-cm (kilo ohms per centimeter), or Mohm-cm (mega ohms per centimeter).

AUTO STABLE - CONDUCTIVITY

Press Sensor 1, highlight **Auto Stable** and press enter. Highlight **Conductivity** and press enter.

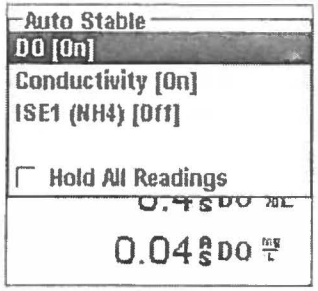


Auto Stable indicates when a reading is stable. Highlight **Enabled** and/or **Audio Enabled** (instrument will beep when the stability is achieved) and press enter enable (☑) or disable (☐). When Auto Stable is enabled, **AS** will blink next to the parameter until it is stable. Once the parameter is stable, **AS** will stop blinking.

The Auto Stable **Sensitivity** can be decreased or increased. Highlight **Sensitivity** and use the left and right arrow keys to slide the bar. The more sensitive you make it (larger black bar) the harder it is to achieve stability in a changing environment.

The **Auto Stable** system works by examining the previous 5 readings, computing the percent change in the data and comparing that change against a % threshold value. The % threshold value is determined by the **Sensitivity** bar setting. The following chart can be used as a guide when setting the Sensitivity bar.

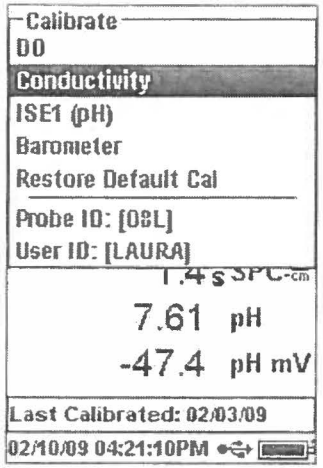
Sensitivity selected by User	*% Data Variance Threshold*
100 - Most Sensitive, Sensitivity bar is set to the far right	0.025%
75	0.39375%
50	0.7625%
25	1.13125%
0 - Least Sensitive, Sensitivity bar is set to the far left	1.5%



Within the Auto Stable menu, you can also choose to **Hold All Readings** for as many parameters as you set for Auto Stable. For instance, if conductivity and DO have Auto Stable and Hold All Readings enabled, then the display will hold the readings once conductivity and DO have both reached their Auto Stable settings. You must press the **Esc** key to "release" the held display in order to take subsequent readings. **Hold All Readings** must be reactivated after each use!

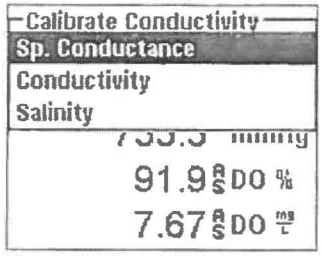
CALIBRATION - CONDUCTIVITY

> *The 6051030 ISE/conductivity cable has a specialized calibration container that resembles a large test tube. This calibration chamber can be used to calibrate the conductivity sensor with an ISE sensor installed. A ring-stand should be used to support this chamber.*



Press Cal. Highlight Probe ID or User ID if you wish to add, select, edit, or delete an ID. Probe ID must be enabled in the System GLP menu to appear in the Calibrate menu. User ID will appear automatically. Select 'None' if you do not want a User ID stored with the calibration. When enabled, these IDs are stored with each calibration record in the GLP file.

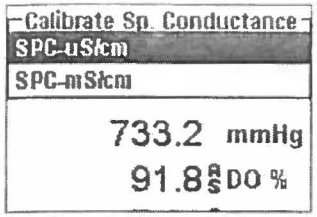
After selecting the User ID and/or Probe ID if appropriate, highlight **Conductivity** and press enter.



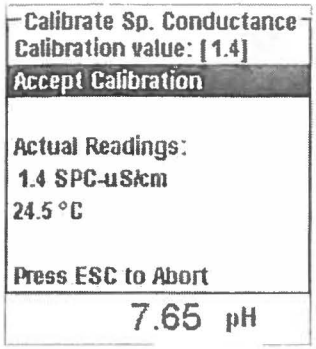
Highlight the desired calibration method; **Sp. Conductance**, **Conductivity**, or **Salinity** and press enter. YSI recommends calibrating in specific conductance for greatest ease.

Calibrating in Specific (Sp.) Conductance or Conductivity

Place the sensor into a fresh, traceable conductivity calibration solution. The solution must cover the holes of the conductivity sensor that are closest to the cable. Ensure the entire conductivity sensor is submerged in the solution or the instrument will read approximately of half the expected value!



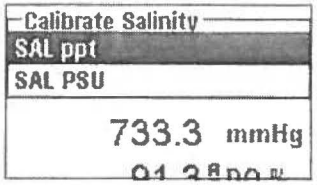
Choose the units in either **SPC-us/cm**, **C-us/cm** or **SPC-ms/cm**, **C-ms/cm** and press enter.



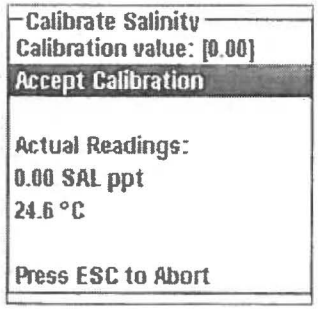
Highlight **Calibration value** and press enter to input the value of the calibration standard. Then, once the temperature and conductivity readings stabilize, highlight **Accept Calibration** and press enter. Or, press Esc to cancel the calibration. If User Field 1 or 2 are enabled in the GLP menu, you will be prompted to select the fields and then press Cal to complete the calibration. After completing the calibration, the message line at the bottom of the screen will display "Calibrating Channel..." and then "Saving Configuration...".

Calibrating in Salinity

Place the sensor into a salinity calibration solution. The solution must cover the holes of the conductivity sensor that are closest to the cable. Ensure the entire conductivity sensor is submerged in the solution or the instrument will read approximately of half the expected value!



Select **SAL ppt** or **SAL PSU** and press enter.



Highlight **Calibration value** and press enter to input the value of the calibration standard. Then, once the temperature and conductivity readings stabilize, highlight **Accept Calibration** and press enter. Or, press Esc to cancel the calibration. If User Field 1 or 2 are enabled, you will be prompted to select the fields and then press Cal to complete the calibration.

pH

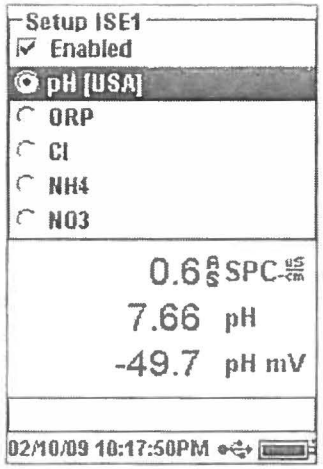
pH sensors can be used on 60510-X, 6051020-X, 6051030-X, 6051010-X, and Quatro cables.

If using a 605103 pH/ORP combination sensor on a 6051020 or 6051030 cable you can report both pH and ORP by configuring ISE1 as pH and ISE2 as ORP in the Sensor Setup menu.

The 605103 pH/ORP combination sensor is not recommended for use on a 6051010 or Quatro cable. If used on one of these cable, only pH will be reported and ORP will not be measured.

SETUP - pH

Press Sensor, highlight **Setup**, press enter. Highlight **ISE1** if using a 60510, 6051020, or 6051030 cable. If using a 6051010 or Quatro cable, highlight **ISE1** if the pH sensor is installed in port 1 or highlight **ISE2** if the pH sensor is installed in port 2(a sensor must be installed in port 1 for port 2 to operate). Press enter.



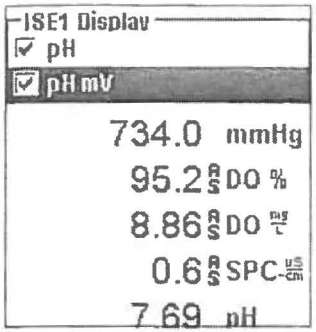
Enabled allows you to enable or disable the ISE function and select which ISE sensor is installed on the cable. Highlight **Enabled** and press enter to enable (☑) or disable (☐) the ISE you selected previously (either ISE1 or ISE2). Disable the ISE function(s) if you do not have a ISE sensor connected to the instrument.

After enabling the ISE function, ensure that it is set to pH as shown in the left screen shot. If necessary, highlight pH and press enter to set the ISE to pH.

Highlighting **pH[USA]** and pressing enter will also allow you to select the values for auto buffer recognition which are used during calibration. The buffer options are **USA** (4, 7, 10), **NIST** (4.01, 6.86, 9.18), and **User-Defined**. The selected option will be displayed in [brackets].

> ⓘ *If a sensor is Enabled that isn't connected to the instrument, the display will show an unstable false reading, ?????, or ----- next to the units.*

DISPLAY - pH



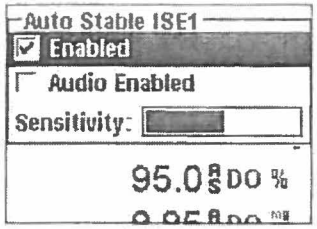
Press Sensor, highlight **Display** and press enter.

Highlight **ISE (pH)** and press enter. You will not be able to **Display** the sensor unless it is **Enabled** in the Sensor Setup menu.

Highlight **pH** and/or **pH mV**, press enter to enable (☑) or disable (☐). Both can be reported at the same time.

AUTO STABLE - pH

Press Sensor, highlight **Auto Stable** and press enter. Highlight **ISE (pH)** and press enter.

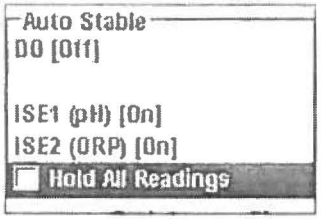


Auto Stable indicates when a reading is stable. Highlight **Enabled** and/or **Audio Enabled** (instrument will beep when the stability is achieved) and press enter enable (☑) or disable (☐). When Auto Stable is enabled, **AS** will blink next to the parameter until it is stable. Once the parameter is stable, **AS** will stop blinking.

The Auto Stable **Sensitivity** can be decreased or increased. Highlight **Sensitivity** and use the left and right arrow keys to slide the bar. The more sensitive you make it (larger black bar) the harder it is to achieve stability in a changing environment.

The **Auto Stable** system works by examining the previous 5 readings, computing the percent change in the data and comparing that change against a % threshold value. The % threshold value is determined by the **Sensitivity** bar setting. The following chart can be used as a guide when setting the Sensitivity bar.

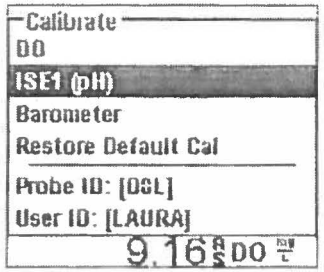
Sensitivity selected by User	*% Data Variance Threshold*
100 - Most Sensitive, Sensitivity bar is set to the far right	0.025%
75	0.39375%
50	1.5%
25	1.13125%
0 - Least Sensitive, Sensitivity bar is set to the far left	0.15%



Within the Auto Stable menu, you can also choose to **Hold All Readings** for as many parameters as you set for Auto Stable. For instance, if ORP and pH have Auto Stable enabled and Hold All Readings is enabled, then the display will hold the readings once ORP and pH have both reached their Auto Stable settings. You must press the Esc key to "release" the held display in order to take subsequent readings. **Hold All Readings** must be reactivated after each use!

CALIBRATION - pH

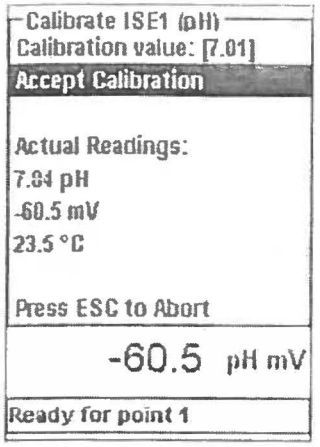
> *Calibration can be accomplished in any buffer order. pH 7 buffer should be used regardless of how many calibration points you use but it does not have to be used first.*



Press Cal . Highlight Probe ID or User ID if you wish to add, select, edit, or delete an ID. Probe ID must be enabled in the System GLP menu to appear in the Calibrate menu. User ID will appear automatically. Select 'None' if you do not want a User ID stored with the calibration. When enabled, these IDs are stored with each calibration record in the GLP file.

After selecting your User ID and/or Probe ID if appropriate, highlight ISE (pH) and press enter. The message line will show the instrument is "Ready for point 1". The pH calibration allows up to six calibration points.

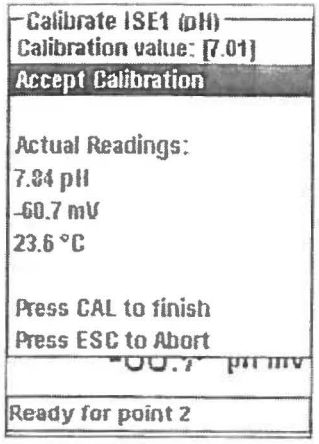
Place the sensor in a traceable pH buffer solution. The instrument should automatically recognize the buffer value and display it at the top of the calibration screen. If the calibration value is incorrect, the auto buffer recognition setting



in the Sensor Setup menu may be incorrect. If necessary, highlight the **Calibration Value** and press enter to input the correct buffer value.

Once the pH and temperature readings stabilize, highlight **Accept Calibration** and press enter to accept the first calibration point. The message line will then display "Ready for point 2".

If you do not wish to perform a second point, press Cal to finalize the calibration. Or, press Esc to cancel the calibration. If User Field 1 or 2 are enabled, you will be prompted to select these fields and then press Cal to finalize the calibration.



To continue with the 2nd point, place the sensor in the second buffer solution. The instrument should automatically recognize the second buffer value and display it at the top of the screen. If necessary, highlight the **Calibration Value** and press enter to input the correct buffer value. Once the pH and temperature readings stabilize, highlight **Accept Calibration** and press enter to confirm the second calibration point. The message line will then display 'Ready for point 3" and you can continue with the 3rd calibration point if desired.

If you do not wish to perform a 3rd calibration point, press Cal to complete the calibration. If User Field 1 or 2 are enabled, you will be prompted to select these fields and then press Cal to finalize the calibration.

Continue in this fashion until the desired number of calibration points is achieved (up to six).

> *Once you've achieved the desired number of cal points you must press Cal to finalize the calibration and to allow the instrument to update the pH offset and slope. The instrument will not take these cal values into account until Cal has been pressed.*

> *The actual readings displayed during the calibration will NOT reflect the updated calibration information. These values will not change until Cal is pressed to finalize the calibration and to update the instrument.*

ORP

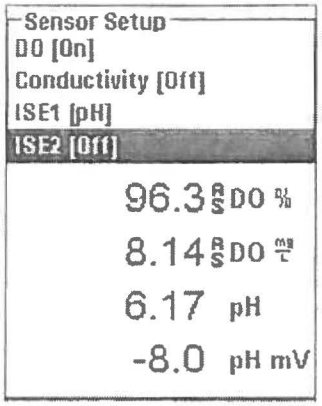
ORP sensors can be used on 60510-X, 6051020-X, 6051030-X, 6051010-X, and Quatro cables.

If using a 605103 pH/ORP combination sensor on a 6051020 or 6051030 cable you can report both pH and ORP by configuring ISE1 as pH and ISE2 as ORP in the Sensor Setup menu.

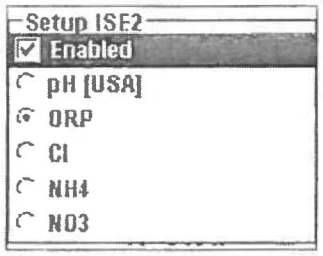
The 605103 pH/ORP combination sensor is not recommended for use on a 6051010 or Quatro cable. If used on one of these cable, only pH will be reported and ORP will not be measured.

SETUP - ORP

Press Sensor, highlight **Setup**, press enter.



Highlight **ISE1** if using a 605102 (ORP sensor) on a 60510, 6051020, or 6051030 cable. Highlight **ISE2** is using a 605103 (pH/ORP sensor) on a 60510, 6051020, or 6051030 cable. If using a 6051010 or Quatro cable, highlight **ISE1** if the ORP sensor is installed in port 1 or highlight **ISE2** if the ORP sensor is installed in port 2 (a sensor must be installed in port 1 for port 2 to operate). Press enter.

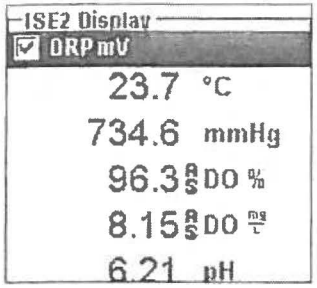


Enabled allows you to enable or disable the ISE function and select which ISE sensor is installed on the cable. Highlight **Enabled** and press enter to enable (☑) or disable (☐) the ISE you selected previously (either ISE1 or ISE2).

After enabling the ISE function, ensure ORP is selected as the ISE sensor as shown in screen shot to the left. If necessary, highlight ORP and press enter to set the selected ISE to ORP.

> *If a sensor is Enabled that isn't connected to the instrument, the display will show an unstable false reading, ?????, or ----- next to the units.*

DISPLAY - ORP

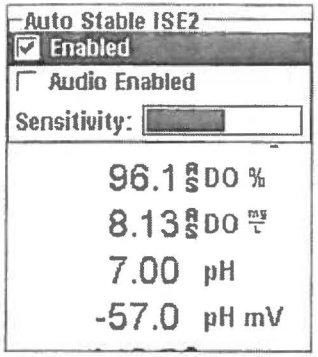


Press Sensor, highlight **Display** and press enter.

Highlight **ISE (ORP)** and press enter. You will not be able to **Display** the sensor unless it is **Enabled** in the Sensor Setup menu.

Press enter to enable (☑) or disable (☐) **ORP mV**.

AUTO STABLE - ORP



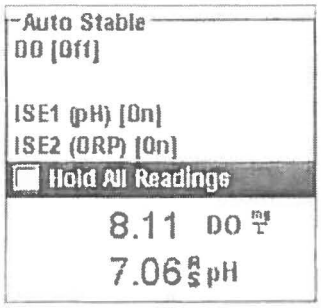
Press Sensor, highlight **Auto Stable** and press enter. Highlight **ISE (ORP)** and press enter.

Auto Stable indicates when a reading is stable. Highlight **Enabled** and/or **Audio Enabled** (instrument will beep when the stability is achieved) and press enter enable (☑) or disable (☐). When Auto Stable is enabled, **AS** will blink next to the parameter until it is stable. Once the parameter is stable, **AS** will stop blinking.

The Auto Stable **Sensitivity** can be decreased or increased. Highlight **Sensitivity** and use the left and right arrow keys to slide the bar. The more sensitive you make it (larger black bar) the harder it is to achieve stability in a changing environment.

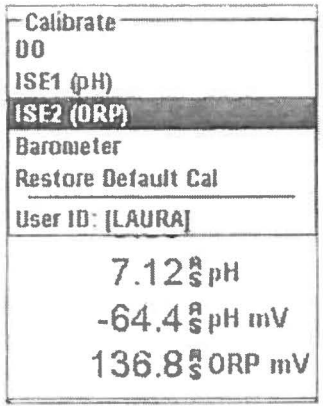
The **Auto Stable** system works by examining the previous 5 readings, computing the percent change in the data and comparing that change against a % threshold value. The % threshold value is determined by the **Sensitivity** bar setting. The following chart can be used as a guide when setting the Sensitivity bar.

Sensitivity selected by User	*% Data Variance Threshold*
100 - Most Sensitive, Sensitivity bar is set to the far right	0.05%
75	0.62525%
50	1.275%
25	1.8875%
0 - Least Sensitive, Sensitivity bar is set to the far left	2.5%



Within the Auto Stable menu, you can also choose to **Hold All Readings** for as many parameters as you set for Auto Stable. For instance, if ORP and pH have Auto Stable enabled and Hold All Readings is enabled, then the display will hold the readings once ORP and pH have both reached their Auto Stable settings. You must press the Esc key to "release" the held display in order to take subsequent readings. **Hold All Readings** must be reactivated after each use!

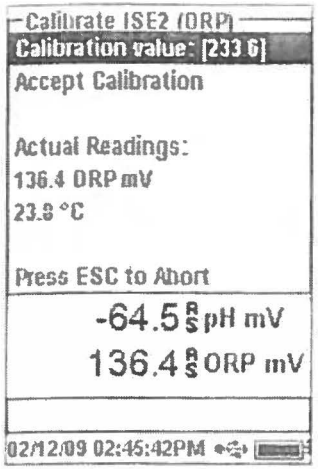
CALIBRATION - ORP



Press Cal. Highlight Probe ID or User ID if you wish to add, select, edit, or delete an ID. Probe ID must be enabled in the System GLP menu to appear in the Calibrate menu. User ID will appear automatically. Select 'None' if you do not want a User ID stored with the calibration. When enabled, these IDs are stored with each calibration record in the GLP file.

After selecting your User ID and/or Probe ID if appropriate, highlight ISE (ORP) and press enter. The message line will show the instrument is "Ready for point".

Place the sensor in a solution of known ORP and wait for the readings to stabilize.



Highlight **Calibration value** and press enter to input the value of the ORP calibration standard. If using the YSI Zobell calibration solution, the Pro Plus will automatically determine the calibration value. However, the calibration value should be verified against the chart on the side of the Zobell bottle. Next, once the temperature and ORP readings stabilize, highlight **Accept Calibration** and press enter to calibrate. Or, press Esc to cancel the calibration. If User Field 1 or 2 are enabled, you will be prompted to select the fields and then press Cal to complete the calibration.

AMMONIUM, NITRATE, CHLORIDE

Ammonium, Nitrate, and Chloride sensors can be used on 60510-X, 6051020-X, 6051030-X, 6051010-X, and Quatro cables. These cables also accommodate pH and ORP sensors so instrument setup is important.

> ⓘ WARNING: *Ammonium, Nitrate, and Chloride sensors should only be used at DEPTHS OF LESS THAN 55 FEET (17 METERS). Use of the sensors at greater depths is likely to permanently damage the sensor membrane.*

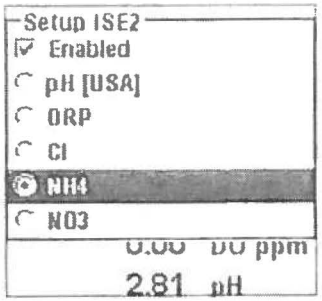
> ⓘ WARNING: *Ammonium, Nitrate, and Chloride sensors should only be used in FRESHWATER.*

SETUP - AMMONIUM, NITRATE, CHLORIDE

Install the Ammonium, Nitrate, or Chloride sensor in Port 2 if using in conjunction with pH or ORP sensor on a 6051010 or Quatro cable. See the **Getting Started Setup** section of this manual for a complete list of cable/sensor configurations.

Press Sensor, highlight Setup, press enter. Highlight ISE1 if using an ammonium, nitrate, or chloride sensor on a 60510, 6051020, or 6051030 cable.

If using a 6051010 or Quatro cable highlight ISE1 if the sensor is installed in Port 1 or highlight ISE2 if the sensor is installed in Port 2. Press enter.



Enabled allows you to enable or disable the ISE function and select which ISE sensor is installed on the cable.

Highlight **Enabled** and press enter to enable (☑) or disable (☐) the ISE you selected previously (either ISE1 or ISE2).

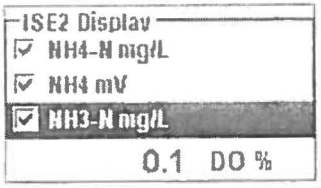
After enabling the ISE function, choose the parameter you want enabled for that ISE. In this example, NH4 is selected.

Cl - Chloride
NH4 - Ammonium
NO3 - Nitrate

> ⓘ *If a sensor is Enabled that isn't connected to the instrument, the display will show an unstable, false reading next to the units.*

DISPLAY - AMMONIUM, NITRATE, CHLORIDE

Press Sensor ❗, highlight **Display**, press enter. Highlight **ISE2(NH4)**, press enter. You will not be able to **Display** the sensor unless it is **Enabled**.



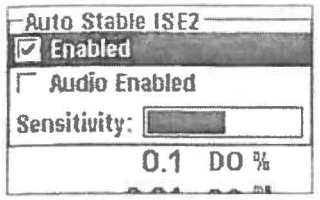
Highlight the value you wish to display and press enter to enable (☑). Ammonium can be displayed as **NH4-N mg/L** (Ammonium), **NH3-N** (Ammonia) and/or **NH4 mV** (sensor signal).

The same steps would be followed to display nitrate or chloride.

Ammonia is calculated from the pH, salinity, and temperature readings. If a pH sensor is not in use, the instrument will assume the sample is neutral (pH 7) for the calculation. If a conductivity sensor (Salinity) is not in use, the instrument will use the salinity correction value entered in the Sensor Menu for the calculation (see Salinity Correction within the Dissolved Oxygen Setup section of this manual for more information).

AUTO STABLE - AMMONIUM, NITRATE, CHLORIDE

Auto Stable indicates when a reading is stable. When Auto Stable is enabled, AS will blink next to the parameter until it is stable. Once the parameter is stable, AS will stop blinking.

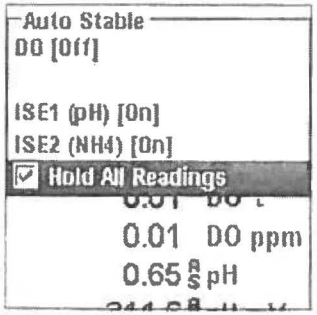


To enable Auto Stable, press Sensor ❗, highlight **Auto Stable** and press enter. Highlight **ISE1** or **ISE2** and press enter.

Highlight **Enabled** and/or **Audio Enabled** (instrument will beep when the stability is achieved) and press enter to confirm. The Auto Stable **Sensitivity** can be decreased or increased. Highlight **Sensitivity** and use the left and right arrow keys to slide the bar. The more sensitive you make it (larger black bar) the harder it is to achieve stability in a changing environment.

The **Auto Stable** system works by examining the previous 5 readings, computing the percent change in the data and comparing that change against a % threshold value. The % threshold value is determined by the **Sensitivity** bar setting. The following chart can be used as a guide when setting the Sensitivity bar.

Sensitivity selected by User	*% Data Variance Threshold*
100 - Most Sensitive, Sensitivity bar is set to the far right	0.05%
75	0.62525%
50	1.275%
25	1.8875%
0 - Least Sensitive, Sensitivity bar is set to the far left	2.5%



Within the Auto Stable menu, you can also choose to **Hold All Readings** for as many parameters as you set for Auto Stable. For instance, if pH and Ammonium have Auto Stable enabled and Hold All Readings is also enabled, then the display will hold the readings once pH and Ammonium have both reached their Auto Stable settings. You must press the Esc key to "release" the held display in order to take subsequent readings. **Hold All Readings** must be reactivated after each use!

CALIBRATION - AMMONIUM, NITRATE, CHLORIDE

The 6051030 ISE/conductivity cable has a specialized calibration container that resembles a large test tube. This calibration chamber can be used to calibrate the ISE sensors with the conductivity sensor. A ring-stand should be used to support this chamber.

> *The ISE sensors can be calibrated at 1, 2, or 3-points.*
> **A 2-point calibration without chilling a third calibration solution is extremely accurate and is the preferred method.**
> *Greatest accuracy is achieved if the actual samples to be measured are within 10 °C of the calibration solutions.*

CALIBRATION TIP: Exposure to the high ionic content of pH buffers can cause a significant, but temporary, drift in the ammonium, nitrate, and chloride ISE sensors. Therefore, when calibrating the pH sensor, YSI recommends that you use one of the following methods to minimize errors in the subsequent readings:

- When calibrating pH, remove ISE sensors from the cable bulkhead and plug the ports. After pH calibration is complete, replace the ISE sensors and proceed with their calibration with no stabilization delay.
- Calibrate pH first, immersing all of the sensors in the pH buffers. After calibrating pH, place the sensors in 100 mg/L nitrate or ammonium standard or 1000 mg/L chloride standard depending on the sensor in use and monitor the reading. Usually, the reading starts low and may take awhile to reach a stable value. When it does, proceed with the calibration. This may take several hours.

Preparing Chloride Standards

The following recipes are provided for preparation of 10 and 1000 mg/L chloride reagents. Nitrate and Ammonium standards can be purchased from YSI or other laboratory supply companies.

It is important to note that some of the chemicals required for these solutions could be hazardous under some conditions. It is the responsibility of the user to obtain and study the MSDS for each chemical and to follow the required instructions with regard to handling and disposal of these chemicals.

You will need: Solid sodium chloride or a certified 1000 mg/L chloride solution from a supplier, magnesium sulfate, high purity water, a good quality analytical

balance, 1000 mL volumetric flask, an accurate 10 mL measuring devices, and 1000 mL glass or plastic storage vessels.

1000 mg/L Standard: Accurately weigh 1.655 grams of anhydrous sodium chloride and transfer into a 1000 mL volumetric flask. Add 0.5 grams of anhydrous magnesium sulfate to the flask. Add 500 mL of water to the flask, swirl to dissolve all of the reagents , and then dilute to the volumetric mark with water. Mix well by repeated inversion and then transfer the 1000 mg/L standard to a storage bottle. Rinse the flask extensively with water prior to its use in the preparation of the 10 mg/L standard. Alternatively, simply add 0.5 grams of magnesium sulfate to a liter of a 1000 mg/L chloride standard from a certified supplier.

10 mg/L Standard: Accurately measure 10 mL of the above 1000 mg/L standard solution into a 1000 mL volumetric flask. Add 0.5 grams of anhydrous magnesium sulfate to the flask. Add 500 mL of water, swirl to dissolve the solid reagents, and then dilute to the volumetric mark with water. Mix well by repeated inversion and then transfer the 10 mg/L standard to a storage bottle.

AMMONIUM (NH4+) , NITRATE (NO3-), AND CHLORIDE CL- 2-POINT

The calibration procedures for ammonium, nitrate, or chloride are similar to pH. The only differences are the calibration solutions. Recommended values for calibration solutions and the order of calibration are as follows:

Sensor	*1st Point*	*2nd Point*
Ammonium-nitrogen (NH4-N)	1 mg/L	100 mg/L
Nitrate-nitrogen (NO3-N)	1 mg/L	100 mg/L
Chloride (Cl-)	10 mg/L	1000 mg/L

Place the proper amount of 1 mg/L standard for Ammonium or Nitrate (10 mg/l for Chloride) into a clean, dry or pre-rinsed calibration cup. Carefully immerse the sensor into the solution. Allow at least 1 minute for temperature equilibration before proceeding.

Press Cal Cal. Highlight Probe ID or User ID if you wish to add, select, edit, or delete an ID. Probe ID must be enabled in the System GLP menu to appear in the Calibrate menu. User ID will appear automatically. Select 'None' if you do not want a User ID stored with the calibration. When enabled, these IDs are stored with each calibration record in the GLP file.

```
Calibrate ISE2 (NH4)
Calibration value: [10.00]
Accept Calibration
Salinity: [0.00 SAL ppt]

Actual Readings:
+++++ NH4-N mg/L
312.3 mV
18.9 °C
```

After selecting your User ID and/or Probe ID if appropriate, highlight **Ammonium, Nitrate,** or **Chloride** to access the appropriate calibration, and press enter. The parameter you want to calibrate may appear under ISE1 or ISE2 depending on your cable type and setup. The message line will show the instrument is ready for the 1st calibration point.

The instrument will display the calibration value at the top of the screen. If necessary, highlight the **Calibration value** and press enter to input the correct value.

Once the readings stabilize, highlight **Accept Calibration** and press enter to accept the first calibration point. The message line will then display "Ready for point 2".

If you do not wish to perform a second point, press Cal to finalize the calibration. If User Field 1 or 2 are enabled, you will be prompted to select these fields and then press Cal to finalize the calibration. Alternatively, you may press Esc to cancel the calibration.

To continue with the 2nd point, rinse the sensor with clean water, then dry it before placing it in the second calibration standard. Allow at least 1 minute for temperature equilibration before proceeding. The instrument will display the second calibration value at the top of the screen. If necessary, highlight the **Calibration value** and press enter to input the correct buffer value. Once the readings stabilize, highlight **Accept Calibration** and press enter to confirm the second calibration point. The message line will then display "Ready for point 3" and you can continue with the 3rd calibration point if desired.

If you do not wish to perform a 3rd calibration point, press Cal to complete the calibration. If User Field 1 or 2 are enabled, you will be prompted to select these fields and then press Cal to finalize the calibration. Alternatively, you may press Esc to cancel the calibration.

AMMONIUM (NH4+) , NITRATE (NO3-), AND CHLORIDE CL- 3-POINT

A 2-point calibration without chilling a third calibration solution is extremely accurate and is the preferred method. If you must perform a 3-point calibration, the following procedure requires one portion of the high concentration calibration solution and two portions of the low concentration calibration solution. The

high concentration solution and one of the low concentration solutions should be at ambient temperature. The other low concentration solution should be chilled to less than 10 °C prior to calibration.

> ⚠ WARNING: *The chilled calibration solution MUST BE CHILLED TO AT LEAST 5 °C COOLER THAN THE 1ST CALIBRATION POINT, otherwise the 1st point will be OVERRIDDEN.*

Follow the procedure for a 2-point cal. After the second calibration point is complete, the message line with state 'Ready for point 3". Place the proper amount of chilled 1 mg/L standard (10 mg/L for the chloride) into a clean, dry or pre-rinsed calibration cup. Carefully immerse the sensor into the solution. Allow for temperature equilibration. If necessary, highlight **Calibration value** and press enter to manually enter the 3rd buffer value. Once the readings are stable, highlight **Accept Calibration** and press enter to confirm. Press Cal to complete the calibration. If User Field 1 or 2 are enabled, you will be prompted to select these fields and then press Cal to finalize the calibration. Alternatively, press Esc to cancel the calibration.

TAKING MEASUREMENTS

To obtain the most accurate readings, be sure the instrument is calibrated before taking measurements.

DISSOLVED OXYGEN

Turn the instrument on and wait 5-15 minutes if using a polarographic sensor. If using a field cable/sensor, install the sensor guard to protect the sensor and membrane. Place the probe in the sample to be measured and give the probe a quick shake to release any air bubbles. Allow the temperature readings to stabilize. Next, stir the probe in the sample to overcome the stirring dependence of the dissolved oxygen sensor. You must provide at least 3 inches per second for 2.0 PE membranes, 6 inches per second for 1.25 PE membranes, and 12 inches per second for Teflon® membranes. Once the values plateau and stabilize, you may record the measurement and/or log the data set. The dissolved oxygen reading will drop over time if stirring is ceased.

If placing the DO sensor into a stream or fast flowing waters it is best to place it perpendicular to the flow and NOT facing into the flow.

If using the DO sensor in an aeration tank/basin, it is helpful to make sure bubbles do not burst on the membrane since this may cause unstable readings. You should be able to prevent this by pointing the sensor upwards so it's facing

the sky and then twist tying, zip tying, or rubber banding the bulkhead to the cable. Making a simple curve to the cable without bending or breaking the cable will allow you to lower the sensor into the aeration tank while the sensor points skyward so the bubbles are no longer bursting on the membrane surface.

CONDUCTIVITY

The conductivity sensor will provide quick readings as long as the entire sensor is submerged and no air bubbles are trapped in the sensor area. Immerse the probe into the sample so the sensors are completely submerged and then shake the probe to release any air bubbles. Occasional cleaning of the sensor may be necessary to maintain accuracy and increase the responsiveness. To clean the sensor, use the conductivity cleaning brush with a mild detergent.

pH/ORP

pH and ORP readings are typically quick and accurate. However, it may take the sensors a little longer to stabilize if they become coated or fouled. To improve the response time of a sensor, follow the cleaning steps in the Maintenance section of this manual.

AMMONIUM, NITRATE, AND CHLORIDE

These sensors may take a little longer to stabilize if the tips are dirty or fouled. If installed with a pH sensor, always maintain a clean pH sensor for a more rapid sensor stabilization.

These sensors can only be used in freshwater.

LOGGING DATA

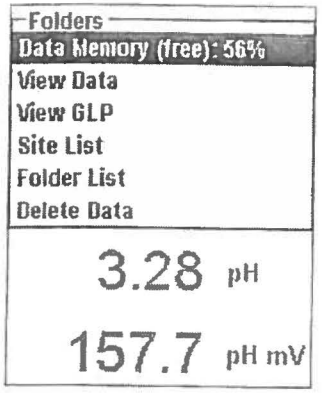
Log One Sample is already highlighted in Run mode. Press enter to open a submenu. If **Use Site List** and or **Use Folder List** are enabled in the Logging Setup menu, you will have to option to select these two items before the data point is logged. If necessary, use the keypad to create a new Site or Folder name. If Site List and Folder List are disabled in the **System** menu, you will not see these options when logging a sample. Once the Site and/or Folder name is selected, highlight **Log Now** and press Enter. The instrument will confirm that the data point was successfully logged.

If you would like to log at a specific interval vs. logging one sample at a time or vice versa, press **System**, then highlight **Logging** and press enter. Select **Continuous Mode** and adjust the time Interval if necessary. On the Run screen, the option to log will change from **Log One Sample** to **Start Logging** based on the time interval entered in the Logging Menu.

During a continuous log, the Start Logging dialog box on the Run screen will change to Stop Logging. Press Enter to stop continuous logging.

FILES AND SITE LISTS

FILE MEMORY

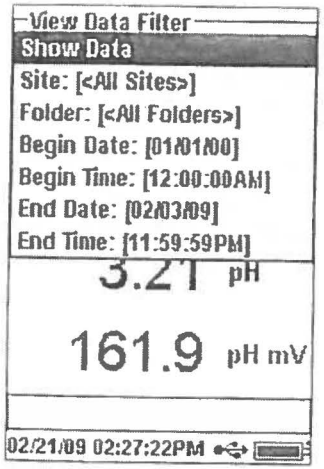


To view the file memory, press **File**.

The **Data Memory** shows a percentage indicating the amount of memory available. If the file memory is near 0%, files should be downloaded to a PC and/or deleted to free up memory.

VIEWING SAVED DATA

Press **File**, highlight **View Data** and press enter.

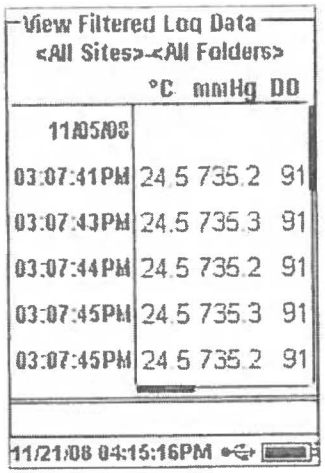


Configuring your data view:

Site: will allow you to view data from one particular site or all sites. Highlight **Site**, press enter, and select the site you wish to view data from or select **All Sites** to view data from all sites.

Folder: will allow you to view data from one particular folder or all folders. Highlight **Folder**, press enter, and select the file you wish to view data from or select **All Folders** to view data from all folders.

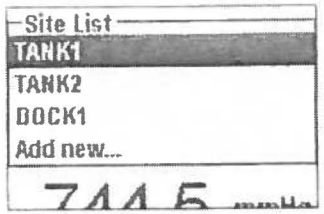
Begin Date, Begin Time, End Date, and **End Time:** will allow you to view data collected between a specific time period. Highlight the



time qualifier you would like to set, press enter, and use the numeric entry screen to select the date/time you wish to view.

After making your selections in the Data Filter, highlight **Show Data** and press enter. The data will have date and time stamps. You will likely have to scroll up and down and side to side using the arrow keys to completely view the data file. No more than 100 data records can be viewed at one time.

SITE LIST



To modify the **Site List**, press **File**, highlight **Site List**, and press enter. Enter new site names or edit existing sites with the alpha/numeric entry screen. Site lists can also be created and edited on your PC with Data Manager and then downloaded to the instrument.

FOLDER

To modify the **Folder List**, press **File**, highlight **Folder List**, and press enter. Enter new Folder names or edit existing folders with the alpha/numeric entry screen.

DELETE DATA

Press **File**, highlight **Delete Data**, and press enter. Enter the criteria for the data you wish to delete in the Delete Data Filter, then highlight **Delete Data** and press enter.

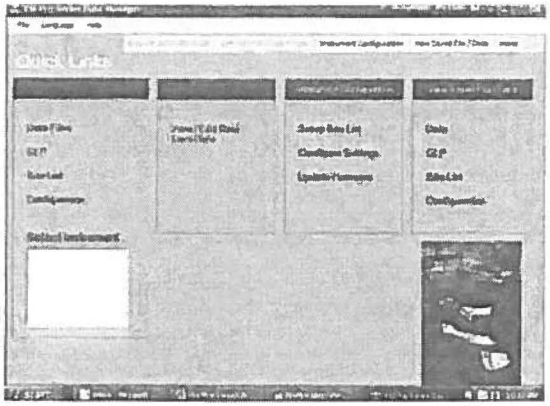
DATA MANAGER DESKTOP SOFTWARE

Data Manager is provided with the purchase of a Pro Plus Instrument. Data Manager is a powerful Windows® based software that will allow you to easily manage logged data, set up instruments, and conduct real time studies.

Minimum PC system requirements for Data Manager are Windows® 2000 with SP4 (minimum) or Windows® XP with SP2 (minimum) Operating System, 300 MHz or higher Pentium®-compatible CPU, 128 MB of RAM or higher, 80 MB or more of free hard-disk space, USB 2.0, and Microsoft® .NET.

Data Manager needs to be installed on a PC before use and before you try to connect a Pro Plus to your PC. First install Data Manger, then connect the communications saddle to the PC and, lastly, connect the saddle to your Pro Plus. Data Manager will identify the connected instruments by their Unit ID.Refer to the Data Manager Readme file for detailed installation instructions. Data Manager will then recognize the attached instruments.

From the 'home' screen of Data Manager, see below, you can select one of the following functions: Retrieve Instrument Data, Real Time Instrument Data, Instrument Configuration, or View Saved File/Data.



USING THE COMMUNICATIONS SADDLE

> ⚠ WARNING: *DO NOT connect the Communications Saddle to your PC before installing Data Manager. The Communication Saddle drivers MUST be installed prior to connecting it to your PC. The drivers will install automatically during the Data Manager installation. The first time the saddle is connected to the PC, you may have to walk through a couple of installation wizards. For detailed instruction, please refer to the Readme file located on the CD that was included with your instrument.*

A PC will recognize the Communications Saddle (saddle) as a YSI water quality instrument with or without the Pro Plus installed in the saddle.

To connect the saddle to a Pro Plus, simply align the saddle to the oval section on top of the instrument and push it down to snap it in place (Figure 6).

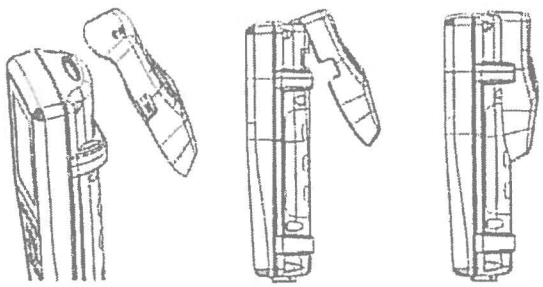


Figure 6. Locate the oval alignment groove at the top of the instrument and inside the saddle. Insert the saddle into this oval groove. Press the saddle towards the back of the instrument until it snaps into place.

Connect the USB cable to the top of the saddle and to a USB port on the PC. Once Data Manager is launched, the program will recognize all saddles with instruments connected to the PC.

The instrument will be powered through the saddle and USB connection when connected to the PC. However, the instrument must still have batteries installed in order to keep the date and time correct when powering the PC off at night. Make sure the instrument is turned off first, then turn off the PC to keep the instrument from running all night on the batteries. If you power it off and power off the PC the instrument will keep the correct date and time if it has batteries installed. If batteries are not installed, the instrument's date and time will not remain correct and will need to be reset each morning.

MANAGE LOGGED DATA

Data that has been logged to the Professional Plus can easily be uploaded to the PC via the provided USB saddle. You can upload sensor data, GLP files, site lists, and instrument configuration files individually or all at once. After connecting the instrument to the PC via the USB saddle and cable and launching Data Manager, click the **Retrieve Instrument Data** tab. Click on the Instrument's Unit ID you would like to retrieve data from, then select the files you would like to retrieve and click Start.

Once the sensor data is uploaded to the PC, you can graph and view tabular data by instrument Unit ID, date/time, site name, and/or folder name. This allows you to configure the report according to your needs. You can choose to view all data from all instruments, or select a certain date/time range for only a few specific instruments, there are multiple ways to view the data. Once the report has been defined, you will be able to print the graph and/or export the table.

Data Manager takes information management one step further and allows you to delete specific points instead of entire files. This allows you to clean up data that is no longer needed or that may have been collected erroneously, for example, when the sensor was out of the water. If you can not delete data due to regulation and compliance purposes, Data Manager has the solution. While viewing logged data or real time data, you have the ability to 'tag' individual data points with comments.

In addition to sensor data, you will be able to view GLP files, site lists, and configuration files that have been uploaded from the instrument. These can be printed and exported as well.

REAL TIME STUDIES

Data Manager allows you to view real time data on the PC.

After selecting your instrument, click the **Real Time Instrument Data** tab. Next, input your sample interval, site/folder name, select the parameters you wish to view and click **OK**. You must click **Start** on the next screen to begin your real time study. Choose to hide the table or graph by unchecking the box next to these options. Click **Stop**, then **Edit Setup** to change the Y-scale min/max of the graph, to select different colors, or to name your graph. Add a comment to a data point by clicking in the comment field of the table next to the data point. You may also **Print** the graph and **Export** the data for viewing in another program.

CONFIGURE INSTRUMENTS

Data Manager allows for easy and quick configuration of single or multiple instruments. Once you have uploaded a site list or configuration file, you can edit it as needed, save it, and download it to other instruments. You no longer need to configure each instrument individually. By using the same configuration file for all instruments, you can rest assured that all instruments will have identical settings.

New site lists and configuration files can be created in Data Manager as well. These lists and files can be downloaded to one or multiple instruments. Save time by creating these files on your PC and downloading them to the instrument as opposed to creating them on the instrument.

CARE, MAINTENANCE, AND STORAGE

This section describes the proper procedures for care, maintenance and storage of the sensors. The goal is to maximize their lifetime and minimize down-time associated with improper sensor usage.

UPDATING INSTRUMENT FIRMWARE

The instrument's firmware can be updated via www.ysi.com. There you will find the new firmware file and instructions on how to update the instrument. There is no need to send the instrument back to the factory for upgrades.

GENERAL MAINTENANCE

GENERAL MAINTENANCE - O-RINGS

The instrument utilizes o-rings as seals to prevent water from entering the battery compartment and sensor ports. Following the recommended procedures will help keep your instrument functioning properly.

If the o-rings and sealing surfaces are not maintained properly, it is possible that water can enter the battery compartment and/or sensor ports of the instrument. If water enters these areas, it can severely damage the battery terminals or sensor ports causing loss of battery power, false readings, and corrosion to the sensors or battery terminals. Therefore, when the battery compartment lid is removed, the o-ring that provides the seal should be carefully inspected for contamination (e.g. debris, grit, etc.) and cleaned if necessary.

The same inspection should be made of the o-rings associated with the sensor connectors when they are removed. If no dirt or damage to the o-rings is evident, then they should be lightly greased without removal from their groove. However, if there is any indication of damage, the o-ring should be replaced with an identical o-ring. At the time of o-ring replacement, the entire o-ring assembly should be cleaned.

To remove the o-rings:
Use a small, flat-bladed screwdriver or similar blunt-tipped tool to remove the o-ring from its groove. Check the o-ring and the groove for any excess grease or contamination. If contamination is evident, clean the o-ring and nearby plastic parts with lens cleaning tissue or equivalent lint-free cloth. Alcohol can be used to clean the plastic parts, but use only water and mild detergent on the o-ring itself. Also, inspect the o-rings for nicks and imperfections.

> ⚠ *Using alcohol on o-rings may cause a loss of elasticity and may promote cracking. Do not use a sharp object to remove the o-rings. Damage to the o-ring or the groove may result.*

Before re-installing the o-rings, make sure to use a clean workspace, clean hands, and avoid contact with anything that may leave fibers on the o-ring or grooves. Even a very small amount of contamination (hair, grit, etc.) may cause a leak.

To re-install the o-rings:
Place a small amount of o-ring grease between your thumb and index finger. (More grease is NOT BETTER!)

Draw the o-ring through the grease while pressing the fingers together to place a very light covering of grease to the o-ring. Place the o-ring into its groove making sure that it does not twist or roll.

Use your grease-coated finger to once again lightly go over the mating surface of the o-ring.

> ⚠ *Do not over-grease the o-rings. The excess grease may collect grit particles that can compromise the seal. Excess grease can also cause the waterproofing capabilities of the o-ring to diminish, potentially causing leaks. If excess grease is present, remove it using a lens cloth or lint-free cloth.*

GENERAL MAINTENANCE - SENSOR PORTS

It is important that the entire sensor connector end be dry when installing, removing or replacing. This will prevent water from entering the port. Once a sensor is removed, examine the connector inside the port. If any moisture is present, use compressed air to completely dry the connector or place directly in front of a steady flow of fresh air. If the connector is corroded, return the cable to your dealer or directly to an YSI Repair Center.

> ⓘ *Remove sensors upside down (facing the ground) to help prevent water from entering the port upon removal.*

SENSOR MAINTENANCE

SENSOR MAINTENANCE - DISSOLVED OXYGEN

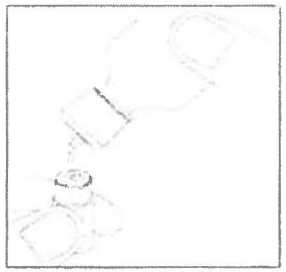
Membrane Cap Installation

The DO sensor (Polarographic and Galvanic) is shipped with a dry, protective red cap that will need to be removed before using. Remove the protective cap or used membrane cap and replace it with a new membrane cap following these instructions:

Remove the sensor guard to access the sensor tip.

Unscrew and remove any old membrane cap by holding the sensor when unscrewing the membrane cap and discard.

Thoroughly rinse the sensor tip with distilled or DI water.



Fill a new membrane cap with O2 sensor electrolyte solution that has been prepared according to the directions on the bottle. Be very careful not to touch the membrane surface. Lightly tap the side of the membrane cap to release bubbles that may be trapped.

Thread the membrane cap onto the sensor. It is normal for a small amount of electrolyte to overflow.

Polarographic Sensors - Model # 605203

The KCl (potassium chloride) solution and the membrane cap should be changed at least once every 30 days during regular use. In addition, the KCl solution and membrane should be changed if (a) bubbles are visible under the membrane; (b) significant deposits of dried electrolyte are visible on the membrane; and (c) if the sensor shows unstable readings or other sensor-related symptoms.

During membrane changes, examine the gold cathode at the tip of the sensor and the silver anode along the shaft of the sensor. If either the silver anode is black in color or the gold cathode is dull, the sensor may need resurfaced using the fine sanding disks included in the membrane kit. Do not sand the electrode every membrane change as this is not routine maintenance. In fact, visually, the anode may appear tarnished and operate just fine. YSI recommends using the 400 grit wet/dry sanding disks to resurface the electrodes if the sensor has difficulty stabilizing or calibrating after a membrane change.

To resurface the sensor using the <u>fine</u> sanding disk, follow the instructions below.

<u>Gold Cathode:</u>

For correct sensor operation, the gold cathode must be textured properly. It can become tarnished or plated with silver after extended use. Never use chemicals or abrasives not recommended or supplied by YSI.

First dry the sensor tip completely with lens cleaning tissue. Wet a sanding disk with a small amount of clean water and place it face up in the palm of your hand. Next, with your free hand, hold the sensor in a vertical position, tip down. Place the sensor tip directly down on the sanding disk and twist it in a circular motion to sand the gold cathode. The goal is to sand off any build-up and to lightly scratch the cathode to provide a larger surface area for the O2 solution under the membrane. Usually, 3 to 4 twists of the sanding disk are sufficient to remove deposits and for the gold to appear to have a matte finish. Rinse thoroughly and wipe the gold cathode with a wet paper towel before putting on a new membrane

cap. If the cathode remains tarnished, contact YSI Technical Support or the Authorized dealer where you purchased the instrument.

Silver Anode

After extended use, a thick layer of Silver Chloride (AgCl) builds up on the silver anode reducing the sensitivity of the sensor. The anode must be cleaned to remove this layer and restore proper performance. The cleaning can be chemical or mechanical:

Chemical cleaning: Remove the membrane cap and rinse the electrodes with deionized or distilled water. Soak the sensing anode section of the sensor in a 14% ammonium hydroxide solution for 2 to 3 minutes or in a 3% ammonia solution overnight for 8-12 hours (most household ammonia cleaners are typically around 3%). Rinse heavily in cool tap water followed by a thorough rinsing with distilled or deionized water. The anode should then be thoroughly wiped with a wet paper towel to remove the residual layer from the anode. You can smell the tip of the sensor to help ensure all the ammonia has been rinsed off. Trapping residual ammonia under the new membrane cap can quickly tarnish the electrode and/or give false readings.

> ⓘ *Chemical cleaning should be performed as infrequently as possible. First attempt a membrane change and recalibrate. If a new membrane does not resolve the problem, then proceed with cleaning.*

Mechanical cleaning: In order to sand the silver anode along the shaft of the sensor, simply hold the sensor in a vertical position. Wet the sanding disk with a small amount of clean water then gently wrap it around the sensor shaft and twist it a few times to lightly sand the anode (the goal is to simply sand off any build-up without scratching or removing layers of the anode itself). Usually, 3 to 4 twists of the sanding disk are sufficient to remove deposits. However, in extreme cases, more sanding may be required to regenerate the original silver surface.

After completing the sanding procedure, repeatedly rinse the electrode with clean water and wipe with lens cleaning tissue to remove any grit left by the sanding disk. Thoroughly rinse the entire tip of the sensor with distilled or deionized water and install a new membrane.

> ⚠ **IMPORTANT:** *Be sure to: (1) Use only the fine sanding disks provided and (2) Sand as mentioned in the above procedures. Not adhering to either of these instructions can damage the electrodes. If this procedure is unsuccessful, as indicated by improper electrode performance, contact YSI Technical Support or the Authorized dealer where you purchased the instrument.*

Galvanic Sensors – Model # 605202

We recommend that the Sodium Chloride (NaCl) solution and the membrane cap be changed at least once every 60 days during regular use. In addition, the NaCl solution and membrane should be changed if (a) bubbles are visible under the membrane; (b) significant deposits of dried electrolyte are visible around the membrane; and (c) if the sensor shows unstable readings or other sensor-related symptoms.

The Galvanic dissolved oxygen sensor is continuously reducing oxygen even when the display of the instrument is not active. This factor allows the sensor to be used with no warm-up period as soon as the instrument is powered on (instant on DO). However, because the sensor is "on" all the time, some solid from the oxidation of the zinc anode will form in the electrolyte within 1-2 weeks of activation. Small amounts of the solid will generally cause no performance problems, but excessive amounts may result in jumpy dissolved oxygen readings. The rate of solid formation is dependent on the type of membrane installed. The formation of solids based on membrane type typically form more rapidly with the 5912 (1 mil Teflon), less rapid with 5913 (1.25 mil PE), and least rapid with 5914 (2 mil PE).

> ⓘ *The Galvanic DO sensor solution will appear milky white after use but will NOT affect the accuracy of the sensor unless there is excessive build up. The color change is acceptable and normal as long as DO readings remain stable.*

At the time the membrane cap is changed, YSI recommends that you rinse the anode (silver shaft of the sensor) with purified water and wipe with a clean paper towel. If white deposits are evident on the anode after cleaning, YSI recommends that you remove this material by sanding the anode with the sandpaper disk enclosed in your membrane kit. Follow the "Mechanical Cleaning" instructions under the Polarographic Silver Anode section.

> ⚠ **IMPORTANT:** *Be sure to: (1) Use only the fine sanding disks provided and (2) Sand as mentioned in the above procedures. Not adhering to either of these instructions can damage the electrodes.*
> **WARNING:** *DO NOT PERFORM THE POLAROGRAPHIC CHEMICAL CLEANING ON A GALVANIC SENSOR. If this procedure is unsuccessful, as indicated by improper electrode performance, contact YSI Technical Support or the Authorized dealer where you purchased the instrument.*

SENSOR MAINTENANCE - CONDUCTIVITY

The openings that allow sample access to the conductivity electrodes should be cleaned regularly. The small cleaning brush included in the Maintenance Kit is ideal for this purpose. Dip the brush in clean water and insert it into each hole 10 to 12 times. In the event that deposits have formed on the electrodes, it may be necessary to use a mild detergent (laboratory grade soap or bathroom foaming tile cleaner) with the brush. Rinse thoroughly with clean water, then check the response and accuracy of the conductivity cell with a calibration standard.

> *If this procedure is unsuccessful, as indicated by improper electrode performance, contact YSI Technical Support or the Authorized dealer where you purchased the instrument.*

SENSOR MAINTENANCE - TEMPERATURE

You must keep the temperature portion of the sensor free of build up. Other than that, the sensor requires no maintenance. The conductivity cleaning brush can be used to scrub the temperature sensor if needed. Alternatively, you can use a toothbrush to clean the sensor.

SENSOR MAINTENANCE - pH, ORP AND COMBINATION pH/ORP

> *Typical working life for pH and ORP sensors is approximately 12-24 months depending on usage, storage, and maintenance. Proper storage and maintenance generally extends the sensor's working life.*

Cleaning is required whenever deposits or contaminants appear on the glass and/or platinum surfaces or when the sensor's response slows. The cleaning can be chemical and/or mechanical.

Removing the sensor from the cable may make cleaning easier. Initially, use clean water and a soft clean cloth, lens cleaning tissue, or cotton swab to remove all foreign material from the glass bulb and/or platinum button. Then use a moistened cotton swab to carefully remove any material that may be blocking the reference electrode junction of the sensor.

> **CAUTION:** *When using a cotton swab, be careful NOT to wedge the swab between the guard and the glass sensor. If necessary, remove cotton from the swab tip, so that the cotton can reach all parts of the sensor tip without stress. You can also use a pipe cleaner for this operation if more convenient.*

If good pH and/or ORP response is not restored, perform the following additional procedure:

1. Soak the sensor for 10-15 minutes in clean water containing a few drops of commercial dishwashing liquid.
2. GENTLY clean the glass bulb and platinum button by rubbing with a cotton swab soaked in the cleaning solution.
3. Rinse the sensor in clean water, wipe with a cotton swab saturated with clean water, and then rerinse with clean water.

If good pH and/or ORP response is still not restored, perform the following additional procedure:

1. Soak the sensor for 30-60 minutes in one molar (1 M) hydrochloric acid (HCl). This reagent can be purchased from most lab supply distributors. Be sure to follow the safety instructions included with the acid.
2. Rinse the sensor in clean water, wipe with a cotton swab saturated with clean water (not DI water), and then rerinse with clean water. To be certain that all traces of the acid are removed from the sensor crevices, soak the sensor in clean water for about an hour with occasional stirring.

If biological contamination of the reference junction is suspected or if good response is not restored by the above procedures, perform the following additional cleaning step:

1. Soak the sensor for approximately 1 hour in a 1:1 dilution of commercially-available chlorine bleach.
2. Rinse the sensor with clean water and then soak for at least 1 hour in clean water with occasional stirring to remove residual bleach from the junction. (If possible, soak the sensor for a period of time longer than 1 hour in order to be certain that all traces of chlorine bleach are removed.) Then rerinse the sensor with clean water and retest.

> *Dry the port and sensor connector with compressed air and apply a very thin coat of o-ring lubricant to all o-rings before reinstallation.*

SENSOR MAINTENANCE - CHLORIDE

> *Typical working life for chloride sensors is approximately 3-6 months depending on usage, storage, and maintenance. Proper storage and maintenance generally extends the sensor's working life.*

The chloride sensor is considered a pellet membrane ISE. As always, when handling sensors, care should be taken to avoid damaging the membrane. This

sensor can be regenerated by washing with alcohol and/or gently polishing with fine emery paper in a circular motion to remove any deposits or discoloration, then thoroughly washing with deionized water to remove any debris. The sensor may require soaking in the high standard chloride calibration solution to recover its performance.

SENSOR MAINTENANCE - AMMONIUM AND NITRATE

> *Typical working life for ammonium and nitrate sensors is approximately 3-6 months depending on usage, storage and maintenance. Proper storage and maintenance generally extends the sensor's working life.*

The ammonium and nitrate sensors are PVC membranes. As always, when handling a sensor, care should be taken to avoid damaging the membrane. After extensive use the membranes may become coated with a deposit or scoured with fine scratches which may cause a slow or reduced response (low slope) or unstable readings. Deposits may be removed with a fine jet of deionized water or rinsing in alcohol followed by soaking in the high standard calibration solution. Gently dab dry with a lint-free tissue before taking measurements.

SENSOR STORAGE

SHORT-TERM STORAGE

The cable assembly is supplied with a sensor storage container, or sleeve, that attaches to the cable. The container is used for short-term storage (less than 30 days). Be sure to keep a small amount of moisture (tap water) in the container during storage. This is done to maintain a 100% saturated air environment which is ideal for short-term sensor storage. The sensors should not be submersed in water. The intent is to create a humid air storage environment.

LONG-TERM STORAGE

Long-term Storage - Temperature

No special storage is required. The temperature sensor can be stored dry or wet as long as solutions in contact with the thermistor are not corrosive (for example, chlorine bleach).

Long-term Storage Temperature: -5 to 70°C (23 to 158°F)

Long-term Storage - Conductivity

No special storage is required. Sensors can be stored dry or wet as long as solutions in contact with conductivity electrodes are not corrosive (for example, chlorine bleach). However, it is recommended that the sensor be cleaned with the provided brush prior to and after long term storage.

Long-term Storage Temperature: -5 to 70°C (23 to 158°F)

Long-term Storage - Dissolved Oxygen

Dissolved oxygen sensors (Polarographic and Galvanic) should be stored in a dry state for long term storage. First, remove the membrane cap and thoroughly rinse the sensor with clean water. Next, either blow it dry with compressed air or allow to air dry completely. Install a clean, dry new membrane cap over the sensor to keep it dry and to protect the electrodes.

After storing the sensor for a long period of time, it is necessary to "condition" the sensor by putting a new membrane with electrolyte solution on the sensor and then turning the instrument on to allow the sensor sufficient time to stabilize.

Long-term Storage Temperature: -5 to 70°C (23 to 158°F)

Long-term Storage - pH

The key to pH sensor storage, short or long-term, is to make certain that the sensor does not dry out. Sensors which have been allowed to dry out due to improper storage procedures may be irreparably damaged by the dehydration and will require replacement. You can try to rehydrate the sensor by soaking it (preferably overnight) in a potassium chloride solution or a pH 4 buffer before attempting to calibrate.

To store the sensor, remove it from the cable and seal the vacant port with a port plug. Fill the original shipping/storage vessel (plastic boot or bottle) with buffer 4 solution and then submerge the sensor into the solution. The sensor should remain submerged in the solution during the storage period; therefore, make certain that the vessel is sealed to prevent evaporation and periodically check the vessel to ensure the sensor does not dry out.

Long-term Storage Temperature: 0 to 30°C (32 to 86°F)

> *It is important not to store the pH sensor in distilled or deionized water as the glass sensor may be damaged by exposure to this medium.*

Long-term Storage - ORP

To store, remove the sensor from the cable and seal the vacant port with the provided plug. Fill the original shipping/storage vessel (plastic boot or bottle) with buffer 4 solution and then submerge the sensor into the solution. The sensor should remain submerged in the solution during the storage period; therefore, make certain that the vessel is sealed to prevent evaporation and periodically check the vessel to ensure the sensor does not dry out.

Long-term Storage Temperature: 0 to 30°C (32 to 86°F)

Long-term Storage - Ammonium, Nitrate, and Chloride

The key to ISE sensor storage, short or long-term, is to make certain that the sensor does not dry out. Sensor junctions that have been allowed to dry out due to improper storage procedures may be irreparably damaged by the dehydration and will require replacement. You can attempt to rehydrate the sensor by soaking it (preferably overnight) in the sensor's high calibration solution before attempting to calibrate.

The recommended storage of these sensors is in moist air. Remove the sensor from the cable and seal the vacant port with the provided plug. Place the sensor in its original shipping storage vessel (plastic boot or bottle) with a small amount of tap water or its high calibration standard. The vessel should remain a saturated air environment. The sensor only needs to be kept in moist air, not submerged. Make certain that the vessel is sealed to prevent evaporation.

Long-term Storage Temperature: 0 to 30°C (32 to 86°F)

TROUBLESHOOTING

Illegal Value may appear during alpha/numeric entry on the message line. This only appears if the values entered do not match the formatting. This will also appear in GLP security area if the password is incorrect.

If you forget the GLP Security Password please contact YSI Tech Support at environmental@ysi.com, 800-897-4151, or +1 937 767-7241.

HELP

During use of the Professional Plus instrument, press **Question** ? from any screen to view help messages directly on the display.

ERROR MESSAGES

If readings for a certain parameter are over range you will see a series of +++++ and if the readings are under range you will see a series of ----- plus the error message along the bottom of the screen. If you see a series of ????? that will indicate that a certain parameter can not be calculated. The following are potential error messages:

Probe Temp over range
Probe Temp under range
Case Temp over range
Case Temp under range
pH over range
pH under range
ORP over range
ORP under range
Cl over range
Cl under range
NH4 over range
NH4 under range
NO3 over range
NO3 under range
DO over range
DO under range
Conductivity over range
Conductivity under range
Barometer over range
Barometer under range

Error messages for the sensors typically indicate a need to properly clean the sensor. First verify the sensor is properly setup in the Sensor menu, then conduct the recommended cleaning and attempt to calibrate the sensor. If this does not work, it may indicate the useful life of the sensor has been reached and may need to be replaced. You may also contact Technical Support to help determine the next step.

DISSOLVED OXYGEN

The dissolved oxygen sensors will use Probe Current (DO uA) and Probe Slope (%/uA) as part of their GLP file records. The following information indicates the acceptable values for each of these readings:

Polarographic DO at 25 °C, 100% saturated air environment at 760 mmHg

- Probe Current
  - 1.25 mil PE membrane
    - Average 6.15 uA (min. 4.31 uA, max. 8.00 uA)
  - 2.0 mil PE membrane
    - Average 3.38 uA (min. 2.37 uA, max. 4.40 uA)
  - 1 mil Teflon* membrane
    - Average 16.29 uA (min. 11.40 uA, max. 21.18 uA)
- Probe Slope
  - 1.25 mil PE membrane
    - Average 16.26 % sat/uA (min. 12.51 uA, max. 23.23 uA)
  - 2.0 mil PE membrane
    - Average 29.56 % sat/uA (min. 22.74 uA, max. 42.23 uA)
  - 1 mil Teflon* membrane
    - Average 6.14 % sat/uA (min. 4.72 uA, max. 8.77 uA)

RESTORE DEFAULT CALIBRATION VALUES

Occasionally, the instrument may need to have the factory calibration default values restored. In order to accomplish this press Calibrate (Cal), highlight **Restore Default Cal** and press enter. Highlight the parameter you wish to restore to default and press enter. Next you will be asked to confirm the operation. Highlight **Yes** and press enter to confirm.

ACCESSORIES / PART NUMBERS

*Cable Part Number**	*Description*
6050000	Professional Plus Instrument
60510-1, -4, -10, -20, or -30	1, 4, 10, 20, or 30-meter cable for ISE/temp
60520-1, -4, -10, -20, or -30**	1, 4, 10, 20, or 30-meter cable for DO/temp
60530-1, 4, -10, -20, or -30	1, 4, 10, 20 or 30-meter cable for Cond/temp
6051010-1, 4, -10, -20, or -30	1, 4, 10, 20, or 30-meter cable for ISE/ISE/temp
6051020-1, -4, -10, -20, or -30	1, 4, 10, 20, or 30-meter cable for ISE/DO/temp
6051030-1, 4, -10, -20, or -30	1, 4, 10, 20, or 30-meter cable for ISE/Cond/temp
6052030-1, -4, -10, -20, or -30	1, 4, 10, 20 or 30-meter cable for DO/Cond/temp
605790-1, -4, -10, -20, or -30	1, 4, 10, 20 or 30-meter Quatro cable for DO/Cond/temp/ISE/ISE
605107	1-meter pH/temp single junction lab-grade combo electrode
605177	4-meter pH/temp single junction lab-grade combo electrode
605108	1-meter ORP/temp single junction lab-grade combo electrode
605178	4-meter ORP/temp single junction lab-grade combo electrode
605109	1-meter pH/ORP/temp single junction lab-grade combo electrode
605179	4-meter pH/ORP/temp single junction lab-grade combo electrode

Sensor Part Number	*Description*
605202	Galvanic DO sensor
605203	Polarographic DO sensor
605101	pH (ISE)
605102	ORP (ISE)
605103***	pH/ORP Combination (ISE)
605104****	Ammonium (ISE)

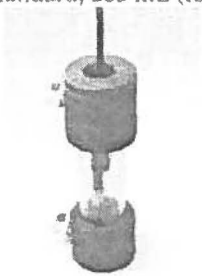
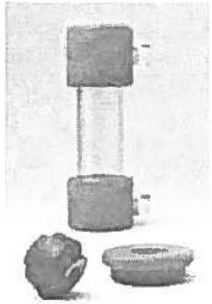
Sensor Part Number	*Description*
605105****	Chloride (ISE)
605106****	Nitrate (ISE)
605780	Self-Stirring BOD sensor
005560	Conductivity/Temperature sensor for Quatro cable

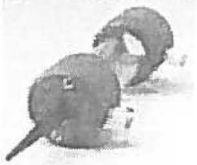
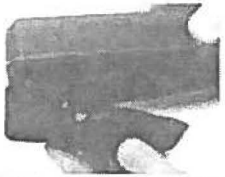
* All cables include temperature.
Cables with conductivity include sensor
(no need to order separate conductivity sensor).

** Special order cables up to 100-meters are available with 60520 cables.

*** Not compatible with 6051010-X or Quatro cables.

**** Freshwater only

Accessory Part Number	*Description*
603059	Flow cell, standard, 203 mL (for two-port sensors) 
603077	Flow cell kit, 1 or 2 port sensor (includes 603059 flow cell for two-port sensors with the 603078 adapter for one-port sensors) 
603078	Flow cell adapter, single port (use with 603059 flow cell to accommodate one-port sensors)

Accessory Part Number	*Description*
605990	Flow cell kit for Quatro cable assemblies.
603056	Flow cell mounting spike 
605604	Communications saddle kit 
605515	Data Manager desktop software
603075	Carrying case, soft-sided
603074	Carrying case, hard-sided
605745	Maintenance kit
038213	Brush, tube cleaner
601205	Grease, o-ring

Accessory Part Number	*Description*
603069	Belt clip
063517	Ultra clamp
063507	Tripod clamp
603062	Cable management kit
605978	Weight, sensor/cable, 4.9 oz.
063019	Weight, sensor/cable, 24 oz., 3"
063020	Weight, sensor/cable, 51 oz., 6"
603070	Shoulder strap

Solutions Part Number	*Description*
3161	1,000 us/cm conductivity solution (quart)
3163	10,000 us/cm conductivity solution (quart)
3169	50,000 us/cm conductivity solution (8 pints)
3682	Zobell ORP solution (125 mL)
3824	pH 4, 7, 10 buffers (2 pints of each)
3841	1 mg/L ammonium solution (500 mL)
3842	10 mg/L ammonium solution (500 mL)
3843	100 mg/L ammonium solution (500 mL)
3885	1 mg/L nitrate solution (500 mL)
3886	10 mg/L nitrate solution (500 mL)
3887	100 mg/L nitrate solution (500 mL)
5580	Confidence Solution (verifies pH, ORP, conductivity sensor performance)

DECLARATION OF CONFORMITY

The undersigned hereby declares on behalf of the named manufacturer under our sole responsibility that the listed product conforms to the requirements for the listed European Council Directive(s) and carries the CE mark accordingly.

Manufacturer:	YSI Incorporated 1725 Brannum Lane Yellow Springs, OH 45387 USA
Product Name:	Professional Plus Water Quality Instrument
Model Numbers	
Instrument/Accessory:	Professional Plus (6050000) / ProComm (605604)
Probe/Cable Assemblies:	605107, 605177, 605108, 605178, 605109, 605179, 605780, 60510, 60520, 60530, 6051010, 6051020, 6051030, 6052030, 605790
Sensors:	605202, 605203, 605780, 605101, 605102, 605103, 605104, 605105, 605106, 005560
Conforms to the following:	
Directives:	EMC 2004/108/EC RoHS 2002/95/EC WEEE 2002/96/EC

Harmonized Standards:	• EN61326-1:2006, Electrical equipment for measurement, control, and laboratory use – EMC requirements – Part 1: General Requirements • EN61326-2-3:2006, Electrical equipment for measurement, control and laboratory use – EMC requirements – Part 2-3: Particular Requirements – Test configuration, operational conditions, and performance criteria for transducers with integrated or remote signal conditioning. • EN61000-3-2:2006, Electromagnetic compatibility (EMC) – Part 3-2: Limits – Limits for harmonic current emissions (equipment input current < 16A per phase). • EN61000-3-3:1995 +A1:2001 +A2:2005. Electromagnetic compatibility (EMC) – Part 3: Limits – Section 3: Limitation of voltage fluctuations and flicker in low-voltage supply systems for equipment with rated current < 16A.
Supplementary Information:	All performance met the continuous unmonitored operation criteria as follows: 1. ESD, EN61000-4-2, Performance Criterion B 2. Radiated Immunity, EN61000-4- 3, Performance Criterion A 3. EFT, EN61000-4-4, (EFT) Performance Criterion B 4. Surge, EN61000-4-5, Performance Criterion B 5. Conducted Immunity, EN61000- -4-6, Performance Criterion A 6. Voltage Interrupts, EN61000-4- 11, Performance Criterion B 7. RF Emissions, EN55011:1998, A1:1999 Class B equipment
Authorized EU Representative	YSI Hydrodata Ltd Unit 8, Business Centre West, Avenue 1 Letchworth, Hertfordshire, SG6 2HB UK

Signed: Lisa M. Abel
Title: Director of Quality

Date: 22 February 2008

The undersigned hereby declares on behalf of the named manufacturer under our sole responsibility that the listed product conforms to the requirements for electrical equipment under US FCC Part 15 and ICES-003 for unintentional radiators.

Manufacturer:	YSI Incorporated 1725 Brannum Lane Yellow Springs, OH 45387 USA
Product Name:	
Model Numbers	
Instrument/Accessory:	Professional Plus (6050000) / ProComm (605604)
Probe/Cable Assemblies:	605107, 605177, 605108, 605178, 605109, 605179, 605780, 60510, 60520, 60530, 6051010, 6051020, 6051030, 6052030, 605790
Sensors:	605202, 605203, 605780, 605101, 605102, 605103, 605104, 605105, 605106, 005560
Conforms to the following:	
Standards:	• FCC 47 CFR Part 15-2008, Subpart B, Class B, Radio Frequency Devices • ICES-003:2004, Digital Apparatus
Supplementary Information:	Tested using ANSI C63.4-2003 (excluding sections 4.1, 5.2, 5.7, 9, and 14)

Signed: Lisa M. Abel
Title: Director of Quality

Date: 22 February 2008

The undersigned hereby declares on behalf of the named manufacturer under our sole responsibility that the listed product conforms with the Australian and New Zealand Electromagnetic Compatibility (EMC) requirements for generic products to be used in residential, commercial, and light industrial environments.

Manufacturer:	YSI Incorporated 1725 Brannum Lane Yellow Springs, OH 45387 USA
Product Name:	Professional Plus Water Quality Instrument
Model Numbers	
Instrument/Accessory:	Professional Plus (6050000) / ProComm (605604)
Probe/Cable Assemblies:	605107, 605177, 605108, 605178, 605109, 605179, 605780, 60510, 60520, 60530, 6051010, 6051020, 6051030, 6052030, 605790
Sensors:	605202, 605203, 605780, 605101, 605102, 605103, 605104, 605105, 605106, 005560
Conforms to the following:	
Standards:	• AS/NZS 4251.1:1999, Electromagnetic Compatibility (EMC) - Generic emission standard – Part 1: Residential, commercial, and light industry.

Signed: Lisa M. Abel Date: 22 February 2008
Title. Director of Quality

RECYCLING

YSI is committed to reducing the environmental footprint in the course of doing business. Even though materials reduction is the ultimate goal, we know there must be a concerted effort to responsibly deal with materials after they've served a long, productive life-cycle. YSI's recycling program ensures that old equipment is processed in an environmentally friendly way, reducing the amount of materials going to landfills.

- Printed Circuit Boards are sent to facilities that process and reclaim as much material for recycling as possible.
- Plastics enter a material recycling process and are not incinerated or sent to landfills.

- Batteries are removed and sent to battery recyclers for dedicated metals.

When the time comes for you to recycle, follow the easy steps outlined at www.ysi.com.

CONTACT INFORMATION

ORDERING AND TECHNICAL SUPPORT

Telephone: 800 897 4151 (US)
+1 937 767 7241 (Globally)
Monday through Friday, 8:00 AM to 5:00 ET

Fax: +1 937 767 9353 (orders)
+1 937 767 1058 (technical support)

Email: environmental@ysi.com or proseries@ysi.com

Mail: YSI Incorporated
1725 Brannum Lane
Yellow Springs, OH 45387 USA

Internet: www.ysi.com

When placing an order please have the following available:
1.) YSI account number (if available)
2.) Name and phone number
3.) Purchase Order or Credit Card
4.) Model Number or brief description
5.) Billing and shipping addresses
6.) Quantity Telephone: 800 897 4151 (US)

SERVICE INFORMATION

YSI has authorized service centers throughout the United States and Internationally. For the nearest service center information, please visit www.ysi.com and click 'Support' or contact YSI Technical Support directly at 800-897-4151.

When returning a product for service, include the Product Return form with cleaning certification. The form must be completely filled out for a YSI Service Center to accept the instrument for service. The form may be downloaded from www.ysi.com by clicking on the 'Support" tab, then the Product Return Form button.

APPENDIX 3

Species Code List

Appendix Table 3-1. Fish Taxon Codes - Master List.

Taxon Code	Family Name	Scientific Name	Common Name
1	Clupeidae	*Alosa pseudoharengus*	Alewife
2	Engraulidae	*Anchoa mitchilli*	Bay anchovy
3	Clupeidae	*Alosa sapidissima*	American shad
4	Pomatomidae	*Pomatomus saltatrix*	Bluefish
5	Centrarchidae	*Lepomis macrochirus*	Bluegill
6	Ictaluridae	*Ameiurus nebulosus*	Brown bullhead
7	Centrarchidae	*Lepomis gibbosus*	Pumpkinseed
8	Centrarchidae	*Pomoxis nigromaculatus*	Black crappie
9	Cyprinidae	*Cyprinus carpio*	Common carp
10	Anguillidae	*Anguilla rostrata*	American eel
11	Cyprinidae	*Carassius auratus*	Goldfish
12	Cyprinidae	*Notemigonus crysoleucas*	Golden shiner
13	Achiridae	*Trinectes maculatus*	Hogchoker
14	Percidae	*Etheostoma olmstedi*	Tessellated darter
15	Fundulidae	*Fundulus diaphanus*	Banded killifish
16	Cyprinidae	*Notropis atherinoides*	Emerald shiner
17	Centrarchidae	*Micropterus salmoides*	Largemouth bass
18	Fundulidae	*Fundulus heteroclitus*	Mummichog
19	Clupeidae	*Brevoortia tyrannus*	Atlantic menhaden
21	Esocidae	*Esox niger*	Chain pickerel
22	Clupeidae	*Alosa aestivalis*	Blueback herring
23	Catostomidae	*Catostomus commersonii*	White sucker
24	Atherinopsidae	*Menidia menidia*	Atlantic silverside
25	Osmeridae	*Osmerus mordax*	Rainbow smelt
26	Centrarchidae	*Micropterus dolomieu*	Smallmouth bass
27	Acipenseridae	*Acipenser brevirostrum*	Shortnose sturgeon
28	Cyprinidae	*Notropis hudsonius*	Spottail shiner
29	Acipenseridae	*Acipenser oxyrinchus*	Atlantic sturgeon
30	Moronidae	*Morone saxatilis*	Striped bass
31	Gasterosteidae	*Apeltes quadracus*	Fourspine stickleback
32	Gadidae	*Microgadus tomcod*	Atlantic tomcod
34	Ictaluridae	*Ameiurus catus*	White catfish
35	Moronidae	*Morone americana*	White perch
36	Percidae	*Perca flavescens*	Yellow perch
37	Cyprinidae	*Cyprinella analostana*	Satinfin shiner
38	Centrarchidae	*Ambloplites rupestris*	Rock bass
39	Syngnathidae	*Syngnathus fuscus*	Northern pipefish
40	Centrarchidae	*Lepomis auritus*	Redbreast sunfish
41	Belonidae	*Strongylura marina*	Atlantic needlefish
42	Carangidae	*Caranx hippos*	Crevalle jack

(continued)

Appendix Table 3-1. (Continued)

Taxon Code	Family Name	Scientific Name	Common Name
43	Cyprinidae	*Hybognathus regius*	Eastern silvery minnow
44	Cyprinidae	*Semotilus corporalis*	Fallfish
45	Sciaenidae	*Cynoscion regalis*	Weakfish
46	Cyprinidae	*Notropis amoenus*	Comely shiner
47	Cyprinidae	*Luxilus cornutus*	Common shiner
48	Cyprinidae	*Notropis volucellus*	Mimic shiner
49	Carangidae	*Selene vomer*	Lookdown
50	Clupeidae	Clupeidae	Herring family
54	Syngnathidae	*Hippocampus erectus*	Lined seahorse
55	Percidae	*Percina caprodes*	Logperch
56	Percopsidae	*Percopsis omiscomaycus*	Trout-perch
57	Catostomidae	*Hypentelium nigricans*	Northern hog sucker
58	Cyprinidae	*Pimephales promelas*	Fathead minnow
59	Cyprinidae	*Cyprinidae*	Carp and minnow family
60	Moronidae	*Morone* sp.	Morone species
61	Esocidae	*Esox americanus americanus*	Redfin pickerel
62	Labridae	*Tautoga onitis*	Tautog
63	Phycidae	*Enchelyopus cimbrius*	Fourbeard rockling
64	Ophidiidae	*Ophidion marginatum*	Striped cusk-eel
66	Sciaenidae	*Menticirrhus saxatilis*	Northern kingfish
67	Sciaenidae	*Leiostomus xanthurus*	Spot
68	Carangidae	*Selene setapinnis*	Atlantic moonfish
69	Gasterosteidae	*Culaea inconstans*	Brook stickleback
70	Acipenseridae	Acipenseridae	Sturgeon family
71	Sparidae	*Stenotomus chrysops*	Scup
72	Pleuronectidae	*Pseudopleuronectes americanus*	Winter flounder
73	Atherinopsidae	*Menidia beryllina*	Inland silverside
74	Petromyzontidae	*Petromyzon marinus*	Sea lamprey
75	Clupeidae	*Dorosoma cepedianum*	Gizzard shad
76	Merlucciidae	*Merluccius bilinearis*	Silver hake
77	Mugilidae	*Mugil cephalus*	Striped mullet
78	Gasterosteidae	*Gasterosteus aculeatus*	Threespine stickleback
79	Salmonidae	*Salmo trutta*	Brown trout
80	Stromateidae	*Peprilus triacanthus*	Butterfish
81	Centrarchidae	*Pomoxis annularis*	White crappie
82	Salmonidae	*Salvelinus fontinalis*	Brook trout
83	Esocidae	*Esox lucius*	Northern pike
84	Centrarchidae	*Lepomis cyanellus*	Green sunfish
85	Sciaenidae	*Bairdiella chrysoura*	Silver perch
86	Tetraodontidae	*Sphoeroides maculatus*	Northern puffer

(continued)

Appendix Table 3-1. (Continued)

Taxon Code	Family Name	Scientific Name	Common Name
87	Cyprinidae	*Rhinichthys atratulus*	Eastern blacknose dace
88	Cyprinidae	*Notropis bifrenatus*	Bridle shiner
90	Cyprinidae	*Exoglossum maxillingua*	Cutlip minnow
96	Centrarchidae	*Centrarchidae*	Sunfish family
97	Cyprinidae	*Cyprinella spiloptera*	Spotfin shiner
98	Phycidae	*Urophycis chuss*	Red hake
100	Umbridae	*Umbra limi*	Central mudminnow
101	Cottidae	*Myoxocephalus aenaeus*	Grubby
102	Umbridae	*Umbra pygmaea*	Eastern mudminnow
103	Moronidae	*Morone chrysops*	White bass
104	Atherinopsidae	*Membras martinica*	Rough silverside
105	Centrarchidae	*Lepomis megalotis*	Longear sunfish
106	Paralichthyidae	*Paralichthys dentatus*	Summer flounder
107	Cyprinidae	*Rhinichthys cataractae*	Longnose dace
108	Cyprinidae	*Semotilus atromaculatus*	Creek chub
109	Ictaluridae	*Ameiurus melas*	Black bullhead
110	Triglidae	*Prionotus evolans*	Striped searobin
111	Triglidae	*Prionotus carolinus*	Northern searobin
113	Sciaenidae	*Micropogonias undulatus*	Atlantic croaker
114	Cottidae	*Myoxocephalus octodecemspinosus*	Longhorn sculpin
115	Clupeidae	*Etrumeus teres*	Round herring
116	Clupeidae	*Alosa mediocris*	Hickory shad
117	Clupeidae	*Clupea harengus*	Atlantic herring
118	Atherinidae	*Hypoatherina harringtonensis*	Reef silverside
119	Engraulidae	*Anchoa hepsetus*	Striped anchovy
120	Congridae	*Conger oceanicus*	Conger eel
121	Fundulidae	*Fundulus majalis*	Striped killifish
122	Centrarchidae	*Lepomis gulosus*	Warmouth
123	Cyprinidae	*Pimephales notatus*	Bluntnose minnow
124	Percidae	*Sander vitreus*	Walleye
125	Mugilidae	*Mugil curema*	White mullet
126	Ictaluridae	*Ameiurus natalis*	Yellow bullhead
127	Ictaluridae	*Ictalurus punctatus*	Channel catfish
128	Gadidae	*Pollachius virens*	Pollock
129	Gobiidae	*Gobiosoma ginsburgi*	Seaboard goby
130	Gobiidae	*Gobiosoma bosc*	Naked goby
131	Pleuronectidae	*Limanda ferruginea*	Yellowtail flounder
132	Scophthalmidae	*Scophthalmus aquosus*	Windowpane
133	Phycidae	*Urophycis regia*	Spotted hake
134	Triglidae	*Prionotus* sp.	Prionotus species

(continued)

Appendix Table 3-1. (Continued)

Taxon Code	Family Name	Scientific Name	Common Name
136	Uranoscopidae	*Astroscopus guttatus*	Northern stargazer
137	Ammodytidae	*Ammodytes americanus*	American sand lance
138	Eleotridae	*Dormitator maculatus*	Fat sleeper
139	Paralichthyidae	*Paralichthys oblongus*	Fourspot flounder
140	Scombridae	*Scomber scombrus*	Atlantic mackerel
141	Serranidae	*Centropristis striata*	Black sea bass
142	Paralichthyidae	*Etropus microstomus*	Smallmouth flounder
143	Pholidae	*Pholis gunnellus*	Rock gunnel
144	Synodontidae	*Synodus foetens*	Inshore lizardfish
145	Umbridae	*Umbra* sp.	Umbra species
146	Petromyzontidae	*Ichthyomyzon unicuspis*	Silver lamprey
147	Salmonidae	*Oncorhynchus mykiss*	Rainbow trout
148	Cyprinidae	*Notropis rubellus*	Rosyface shiner
149	Esocidae	*Esocidae*	Pike family
150	Gobiidae	*Gobiidae*	Goby family
151	Fundulidae	*Fundulus* sp.	Fundulus species
152	Fundulidae	*Fundulidae*	Topminnow family
153	Cottidae	*Myoxocephalus* sp.	Myoxocephalus species
154	Cottidae	Cottidae	Sculpin family
156	Pleuronectidae	Pleuronectidae	Righteye flounder family
157	Atherinopsidae	Atherinopsidae	New World silverside family
158	Atherinopsidae	*Menidia* sp.	Menidia species
159	Paralichthyidae	Paralichthyidae	Sand flounder family
160	Ophichthidae	*Myrophis punctatus*	Speckled worm eel
161	Syngnathidae	Syngnathidae	Pipefish family
162	Carangidae	*Decapterus macarellus*	Mackerel scad
164	Labridae	*Tautogolabrus adspersus*	Cunner
165	Sciaenidae	Sciaenidae	Drum and croaker family
166	Gadidae	Gadidae	Cod family
167	Dactylopteridae	*Dactylopterus volitans*	Flying gurnard
169	Lutjanidae	*Lutjanus griseus*	Gray snapper
170	Gadidae	*Gadus morhua*	Atlantic cod
171	Hemitripteridae	*Hemitripterus americanus*	Sea raven
172	Carangidae	*Selar crumenophthalmus*	Bigeye scad
173	Diodontidae	*Chilomycterus schoepfii*	Striped burrfish
174	Sparidae	*Archosargus probatocephalus*	Sheepshead
175	Percidae	Percidae	Perch family
176	Gerreidae	*Eucinostomus argenteus*	Spotfin mojarra
177	Chaetodontidae	*Chaetodon ocellatus*	Spotfin butterflyfish
178	Gasterosteidae	Gasterosteidae	Stickleback family

(continued)

Appendix Table 3-1. (Continued)

Taxon Code	Family Name	Scientific Name	Common Name
179	Monacanthidae	*Stephanolepis hispidus*	Planehead filefish
180	Trichiuridae	*Trichiurus lepturus*	Atlantic cutlassfish
181	Haemulidae	*Orthopristis chrysoptera*	Pigfish
182	Priacanthidae	*Pristigenys alta*	Short bigeye
183	Sphyraenidae	*Sphyraena guachancho*	Guaguanche
184	Blenniidae	*Hypsoblennius ionthas*	Freckled blenny
185	Tetraodontidae	Tetraodontidae	Puffer family
186	Monacanthidae	*Cantherhines pullus*	Orangespotted filefish
187	Ictaluridae	*Noturus insignis*	Margined madtom
188	Fistulariidae	*Fistularia tabacaria*	Bluespotted cornetfish
189	Sciaenidae	*Pogonias cromis*	Black drum
190	Sphyraenidae	*Sphyraena borealis*	Northern sennet
191	Serranidae	*Mycteroperca phenax*	Scamp
192	Rachycentridae	*Rachycentron canadum*	Cobia
193	Percidae	*Etheostoma microperca*	Least darter
195	Ostraciidae	*Acanthostracion quadricornis*	Scrawled cowfish
196	Exocoetidae	*Cheilopogon furcatus*	Spotfin flyingfish
200	Cyprinidae	*Notropis stramineus*	Sand shiner
201	Cyprinidae	*Notropis procne*	Swallowtail shiner
202	Esocidae	*Esox lucius x e. masquinongy*	Tiger muskellunge
203	Lophiidae	*Lophius americanus*	Goosefish
204	Carangidae	*Trachinotus falcatus*	Permit
205	Sciaenidae	*Aplodinotus grunniens*	Freshwater drum
206	Scombridae	*Scomberomorus cavalla*	King mackerel
207	Lepisosteidae	*Lepisosteus osseus*	Longnose gar
208	Scombridae	*Scomberomorus maculatus*	Spanish mackerel
209	Gobiidae	*Gobionellus oceanicus*	Highfin goby
210	Catostomidae	Catostomidae	Sucker family
211	Labridae	Labridae	Wrasse family
212	Cynoglossidae	*Symphurus plagiusa*	Blackcheek tonguefish
213	Batrachoididae	*Opsanus tau*	Oyster toadfish
214	Blenniidae	*Hypsoblennius hentz*	Feather blenny
215	Monacanthidae	*Aluterus schoepfii*	Orange filefish
216	Rajidae	*Leucoraja erinacea*	Little skate
217	Squalidae	*Squalus acanthias*	Spiny dogfish
218	Liparidae	*Liparis atlanticus*	Atlantic seasnail
219	Paralichthyidae	*Citharichthys arctifrons*	Gulf Stream flounder
220	Mullidae	*Pseudupeneus maculatus*	Spotted goatfish
221	Atherinopsidae	*Labidesthes sicculus*	Brook silverside
222	Stromateidae	*Peprilus paru*	Harvestfish

(continued)

Appendix Table 3-1. (Continued)

Taxon Code	Family Name	Scientific Name	Common Name
223	Sparidae	*Lagodon rhomboides*	Pinfish
224	Pleuronectidae	*Glyptocephalus cynoglossus*	Witch flounder
225	Salmonidae	*Oncorhynchus nerka*	Kokanee
226	Elopidae	*Elops saurus*	Ladyfish
227	Stichaeidae	*Ulvaria subbifurcata*	Radiated shanny
228	Gadidae	*Brosme brosme*	Cusk
229	Phycidae	*Urophycis* sp.	Urophycis species
230	Pleuronectidae	*Hippoglossoides platessoides*	American plaice
231	Cottidae	*Cottus cognatus*	Slimy sculpin
232	Cyprinodontidae	*Cyprinodon variegatus*	Sheepshead minnow
233	Blenniidae	Blenniidae	Combtooth blenny family
234	Rajidae	Rajidae	Skate family
235	Rajidae	*Raja eglanteria*	Clearnose skate
237	Gadidae	*Melanogrammus aeglefinus*	Haddock
238	Cyprinidae	*Scardinius erythrophthalmus*	Rudd
239	Cyprinidae	*Ctenopharyngodon idella*	Grass carp
240	Carangidae	*Caranx crysos*	Blue runner
400	Ostraciidae	*Lactophrys triqueter*	Smooth trunkfish
401	Triakidae	*Mustelus canis*	Smooth dogfish
402	Rajidae	*Leucoraja ocellata*	Winter skate
407	Phycidae	*Urophycis tenuis*	Urophycis tenuis
408	Cyprinodontidae	*Cyprinodon variegatus*	Sheepshead minnow
411	Gasterosteidae	*Pungitius pungitius*	Ninespine stickleback
412	Cottidae	*Myoxocephalus scorpius*	Shorthorn sculpin
413	Agonidae	*Aspidophoroides monopterygius*	Alligatorfish
414	Cyclopteridae	*Cyclopterus lumpus*	Lumpfish
420	Stichaeidae	*Lumpenus lampretaeformis*	Snakeblenny
423	Rajidae	*Amblyraja radiata*	Thorny skate
424	Gasterosteidae	*Gasterosteus wheatlandi*	Blackspotted stickleback
425	Scorpaenidae	*Sebastes fasciatus*	Acadian redfish
426	Liparidae	*Liparis coheni*	Gulf snailfish
427	Liparidae	*Liparis inquilinus*	Inquiline snailfish
428	Zoarcidae	*Zoarces americanus*	Ocean pout
429	Cryptacanthodid	*Cryptacanthodes maculatus*	Wrymouth
430	Anarhichadidae	*Anarhichas lupus*	Atlantic wolffish
431	Pleuronectidae	*Pleuronectes putnami*	Smooth flounder
432		Labridae/Limanda	Cunner/yellowtail flounder
433	Phycidae	*Enchelyopus/Urophycis*	Fourbeard rockling/hake
434	Gadidae	Gadus/Melanogrammus	Atlantic cod/haddock
435		Gadidae/Glyptocephalus	Atlantic cod/haddock/witch

(continued)

Appendix Table 3-1. (Continued)

Taxon Code	Family Name	Scientific Name	Common Name
436	Sternoptychidae	*Maurolicus weitzmani*	Atlantic pearlside
600	Acipenseridae	*Acipenser fulvescens*	Lake sturgeon
601	Percidae	*Etheostoma nigrum*	Johnny darter
603	Cottidae	*Cottus bairdii*	Mottled sculpin
604	Esocidae	*Esox masquinongy*	Muskellunge
605	Catostomidae	*Moxostoma anisurum*	Silver redhorse
606	Catostomidae	*Moxostoma carinatum*	River redhorse
607	Catostomidae	*Moxostoma erythrurum*	Golden redhorse
608	Salmonidae	*Salvelinus namaycush*	Lake trout
609	Gadidae	*Lota lota*	Burbot
610	Percidae	*Etheostoma exile*	Iowa darter
611	Amiidae	*Amia calva*	Bowfin
612	Catostomidae	*Catostomus catostomus*	Longnose sucker
613	Catostomidae	*Moxostoma valenciennesi*	Greater redhorse
614	Ictaluridae	*Noturus gyrinus*	Tadpole madtom
615	Salmonidae	*Salmo salar*	Atlantic salmon
616	Centrarchidae	*Enneacanthus obesus*	Banded sunfish
617	Catostomidae	*Carpiodes cyprinus*	Quillback
618	Ictaluridae	*Noturus flavus*	Stonecat
619	Salmonidae	*Oncorhynchus kisutch*	Coho salmon
620	Salmonidae	*Oncorhynchus tshawytscha*	Chinook salmon
621	Gobiidae	*Neogobius melanostomus*	Round goby
622	Cyprinidae	*Couesius plumbeus*	Lake Chub
623	Cyprinidae	*Phoxinus eos*	Northern redbelly dace
624	Cyprinidae	*Margariscus margarita*	Pearl Dace
625	Cyprinidae	*Notropis heterolepis*	Blacknose shiner
700		Horseshoe crab	Horseshoe crab
710	Penaeidae	*Penaeus aztecus*	Brown shrimp
720	Palaemonidae	*Palaemonetes* sp.	Unidentified grass shrimp
730	Crangonidae	*Crangon* sp.	Sevenspine bay shrimp
740		*Mantis shrimp*	Mantis shrimp
754	Portunidae	*Callinectes sapidus*	Blue crab
755	Xanthidae	*Rithropanopeus harrisii*	Harris mud crab
760	Ocypodidae	*Uca* sp.	Fiddler crab
762		*Carcinus maenus*	Green crab
763		*Ovalipes ocellatus*	Lady crab
764		*Atlantic rock crab*	Atlantic rock crab
765		*Cancer borealis*	Jonah crab
766		*Cancer* sp.	Cancer sp.
770		*Homarus americanus*	American lobster

(continued)

Appendix Table 3-1. (Continued)

Taxon Code	Family Name	Scientific Name	Common Name
798	Cambaridae	Cambarinae	Crayfish
813		*Pagurus longicarpus*	Longwrist hermit
818		*Meganyotiphanes norvegica*	Krill shrimp
821		*Libinia* sp.	Unidentified spider crab
822		*Sesarma* sp.	Unidentified marsh crab
823		*Uca* sp.	Unidentified fiddler crab
824		Xanthidae (zoea)	Unidentified mud crab
825		*Emerita talpoida*	Atlantic sand crab
826		*Panopeus* sp.	Panopeus sp.
829		*Dyspanopeus sayi*	Say mud crab
830		Pinnotheridae	Unidentified pea crab
831		*Pinnotheres maculatus*	Squatter pea crab
832		*Pinnixa sayana*	Pinnixa sayana
835		*Hemigrapsus sanguineus*	Japanese shore crab
846		*Pinnixa chaetopterana*	Tube pea crab
853		*Libinia emarginata*	Portly spider crab
854		*Hyas araneus*	Atlantic lyre crab
855		*Hyas coarctatus*	Arctic lyre crab
856		Unidentified crab	Unidentified crab
858		*Palaemon* sp.	Palaemon sp.

APPENDIX 4

Health and Safety Plan

NORMANDEAU ASSOCIATES, INC.

SITE-SPECIFIC HEALTH AND SAFETY PLAN FOR

EXELON NUCLEAR'S PEACH BOTTOM ATOMIC POWER STATION ENTRAINMENT ABUNDANCE CHARACTERIZATION AND IMPINGEMENT MORTALITY STUDIES

Date: **March 23, 2016**

Normandeau Project No.: **23754.000**

Plan, Preparation, Review, and Approval

Prepared By: **Richard M. Kling, Jr.** **Date: 3/3/2016**
(Health and Safety Coordinator)

Reviewed By: **Bryan Lees** **Date: 3/23/2016**
(Task Manager)

Reviewed By: **Joseph Brozonis** **Date: 3/23/2016**
(Exelon Nuclear - PBAPS)

Approved By: **Mark T. Mattson, Ph.D.** **Date: 3/23/2016**
(Project Manager, Vice President)

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FIGURES

Figure 1 - Site Location

APPENDICES

Appendix 1 – Entrainment Study Sampling Schedule
Appendix 2 – Hazardous Materials Certificate of Registration
Appendix 3 – Impingement Study Sampling Schedule
Appendix 4 - Safety Data Sheets (SDS)
Appendix 5 - Job Safety Analysis
Appendix 6 – Exelon Nuclear Industrial Safety Pocket Guide 2016
Appendix 7 - Statement of Acknowledgement

1.0 SITE DESCRIPTION

Project Name:	Peach Bottom Atomic Power Station (PBAPS) Entrainment Characterization and Impingement Mortality Studies
Site Address (Figure 1):	Exelon Nuclear – PBAPS 1848 Lay Rd Delta, PA 17314
Nearest Intersection:	Lay Road and Paper Mill Road
Township/Municipality:	Delta
County:	York
Type of Facility:	Nuclear Electric Generating Station
Parcel Size:	~ 100 acres
Surrounding Land Uses:	Residential and Agricultural
Media Affected:	Aquatic Biota (fish eggs and larvae, juvenile and adult fish)

2.0 BRIEF DESCRIPTION OF TASKS TO BE PERFORMED

Task 1 - Entrainment Abundance Characterization Study

The objective of the entrainment sampling program to be performed by Normandeau Associates, Inc. (Normandeau) at Peach Bottom Atomic Power Station (PBAPS) during 2016 is to identify the species and abundance of ichthyoplankton (abbreviated IP) in the water that passes through the cooling water system during normal plant operations. Samples will be collected from three locations: (1) the outer intake structure; (2) the circulating water discharge outfall for Units 2 and 3; and (3) the discharge canal outfall. Entrainment abundance sampling at each of the three locations will be performed with a 3-inch electric pump to withdraw cooling water from a vertically mounted pipe deployed at each of the three sampling locations. Entrainment survival studies will not be performed during 2016. Normandeau's field, laboratory, data and quality control/quality assurance (QA/QC) procedures used for this 2016 entrainment characterization study are specified in detail in a project-specific Standard Operating Procedures (SOP), and this document, the site-specific health and safety plan (HASP) is incorporated as Appendix 4 of the entrainment SOP (Normandeau 2016a).

Task 1a - Entrainment Sampling System Installation

Prior to the onset of entrainment abundance sampling at PBAPS, the necessary sampling equipment will be installed at each of the three collection locations (Locations 1, 2 and 3 as described in the previous paragraph). Each location will be fitted with a single electric pump and a custom vertical suction pipe to withdraw samples of cooling water from the location source water body. Appropriate electrical

connections will be supplied by PBAPS staff at each location to power each pump and provide adequate lighting at each location for night work, and Normandeau will install the necessary hoses, piping, sampling tank, and other hardware to operate the installed entrainment sampling system at each location. A Pre-Job Brief will be completed with all field staff prior to all work related to installation of the proposed entrainment sampling system. Project specific contacts are specified in Section 7 below. In addition, daily tasks and objectives will be reviewed in a briefing among all personnel working on the installation prior to the start of each day of work. All Pre-Job Briefs will be conducted using Exelon procedure HU-AA-1211, Pre-Job Briefings and a Job-Specific Pre-Job Briefing checklist using HU-AA-1211-F-01.

Task 1b – Entrainment Field Sampling

Entrainment sampling is scheduled to be performed once day per week from late March 2016 through September 2016 (28 sample events, see schedule in Appendix 1). One 100 m^3 (26,500-28,000 gallons) entrainment sample will be collected by pumping to withdraw cooling water for 2.5 to 3.0 hours at the start of each six-hour interval during each scheduled 24-hour (day) sampling event. It is anticipated that for each scheduled sample at each of the three collection locations there will be two, 12-hour shifts staffed by one (1) field technician per shift/per location (i.e., three staff on site simultaneously for each sampling day). If high debris loading or operational issues prevent entrainment abundance sampling at any of the three locations as proposed, the sampling event will be rescheduled for the next available time before the next event is scheduled to occur.

All entrainment abundance samples have a target volume of 100 m^3 (26,500 – 28,000 gallons) obtained during 2.5 to 3.0 hours of pumping per sample at each of the three locations. A calibrated, in in-line flow meter will be used to quantify the actual volume of each entrainment abundance sample collected. Each entrainment abundance sample will be pumped into a 500 µm mesh net suspended in a barrel sampler (200-300 gallons in capacity) filled with the pumped flow of ambient water to buffer the flow and help concentrate the sample and ensure that ichthyoplankton will be in good condition for identification, targeting an overall percentage of damaged larvae of less than 15%. The timing of the sample collection at each location from outer intake (Location 1) to discharge outfall (Location 2) to discharge canal outfall (Location 3) will be offset to take into consideration the estimated 85-minute transit time of water through the plant. Each sample will be placed in one or more one-liter Nalgene containers, preserved in 6% formalin and Rose Bengal stain, properly labeled with a unique sample number (internal and external label), and transported with chain-of-custody forms to the biological laboratory in Bedford, NH, for processing (sorting, identification and enumeration). Sample shipping from PBAPS to Bedford, NH will follow USDOT Hazardous Materials of Trade requirements (Appendix 2). Safety Data Sheets (SDSs) will be available on site for all chemicals used and safety precautions listed on the SDSs will be reviewed and complied with.

Water quality measurements (water temperature, pH, and dissolved oxygen concentrations) will be obtained with a calibrated YSI Model 85 or YSI Professional Plus meter and a calibrated pH pen for each sample at each of the three collection locations. Water quality measurements will be taken within each sampling tank in the pumped water flowing into and through the sampling tank at each location. Water quality measurements will be taken during the first hour of each 100 m^3 sample collected. Always wear a PFD (U.S. Coast Guard Approved) when working within 10 feet of the water and do not lean over the railing when deploying or retrieving the water quality probe.

A Pre-Job Brief will be developed for field staff that is specific to entrainment sampling. The project specific Pre Job Brief will be performed prior to the start of each day of work. All Pre-Job Briefs will be

conducted using Exelon procedure HU-AA-1211, Pre-Job Briefings and a Job-Specific Pre-Job Briefing checklist using HU-AA-1211-F-01.

Task 2 – Ichthyoplankton Sorting and Identification

All entrainment samples will be shipped to Normandeau's Biological Laboratory (Bedford, NH) processed for fish eggs, fish larvae, and juvenile fish. Samples for entrainment abundance characterization will be received and inventoried in the Biological Laboratory in Bedford, NH. If a large amount of detritus or large numbers of fish eggs and larvae are present in a sample it may be split down to a minimum of 200 specimens. All specimens in each sample will be identified to the lowest practical taxon. A maximum of 20 juveniles and 20 larvae per sample per taxon per lifestage will be measured to the nearest 0.1 mm total length. A maximum of 20 eggs per taxon per sample will be measured to the nearest 0.1 mm along the major and minor axes. Preserved specimens will be retained for one year after the completion of the study and then legally disposed of. Samples will be sorted and identified under magnification to ensure that all organisms are removed. Laboratory processing and identification shall be undertaken only by trained technicians or experienced taxonomists, respectively, operating under a formal Quality Assurance/Quality Control (QA/QC) plan and the project-specific entrainment SOP.

Task 3 – Latent Impingement Mortality Characterization

The objective of this study is to determine latent mortality of fishes that are impinged on the outer intake structure traveling screens (Location 1) at PBAPS. Samples will be collected from the combined fish and debris trough in the outer screenhouse of both Unit 2 and Unit 3. Impingement abundance (i.e., fish impinged per hour or unit volume of cooling water sampled) will not be determined.

A latent impingement assessment study will be conducted at Peach Bottom monthly beginning in 2016 and continuing for 12 consecutive months into 2017. Samples will be collected from the combined fish and debris trough at each end of the outer screenhouse Location 1 (Unit 2 and Unit 3 sluice discharges). One sluice sampler will be fabricated and installed just upstream from the discharge pit near the diversion "Y" for each of the north (Unit 3) and south (Unit 2) screenwash sluices. When collecting impingement survival samples, sluice flow will be diverted into the sampling device until an adequate sample is taken, and then diverted back to the original flow path. A wet table holding facility will be set up along the inner wall in the outer intake structure at a location near the midpoint between the Unit 2 and Unit 3 traveling screens, or at north and south ends of the screen house if insufficient room is available at the midpoint location. Ambient (unchlorinated) source water will be supplied to each wet table (holding facility) by pumping using an electric pool pump to withdraw water through a diamond-plate hatch in the floor of the outer intake structure. Normandeau's field, laboratory, data and quality control/quality assurance (QA/QC) procedures used for this 2016-2017 impingement mortality characterization study will be specified in detail in a project-specific Standard Operating Procedures (SOP), and this document, (the HASP) is incorporated as an Appendix of the impingement mortality SOP (Normandeau 2016b).

A Pre-Job Brief will be developed for field staff that is specific to impingement sampling. The project specific Pre Job Brief will be performed prior to the start of each day of work. All Pre-Job Briefs will be conducted using Exelon procedure HU-AA-1211, Pre-Job Briefings and a Job-Specific Pre-Job Briefing checklist using HU-AA-1211-F-01.

Task 3a - Impingement Mortality Sampling and Fish Holding System

Prior to the onset of impingement mortality sampling at PBAPS, the necessary sampling equipment will be installed at the outer intake structure screen house (Location 1). Appropriate electrical connections will be supplied by PBAPS staff to power the holding facility supply pump(s) and provide adequate lighting for night work, and Normandeau will install the necessary hoses, piping, wet table(s), sluice samplers, and other hardware to operate the installed impingement mortality sampling and fish holding equipment in the outer intake screen house (Location 1). A Pre-Job Brief will be completed with all field staff and the PBAPS point of contact prior to all work related to installation of the proposed entrainment sampling system at each location. Project specific contacts are specified in Section 7 below. In addition, daily tasks and objectives will be reviewed in a briefing among all personnel working on the installation prior to the start of each day of work.

Task 3b - Impingement Mortality Sampling

A sluice sampler will be used to collect the impinged fish from the debris trough near the pit located at the north (unit 2) and south (unit 3) ends of the outer intake screen house. Impingement survival sluice sampling devices will be continuously staffed during survival sampling and monitored so that fish can be removed shortly after they are collected. All fish will be removed and transferred to the wet table holding facility.

Latent mortality for impinged fish will be assessed by placing the fish in the wet tables set up inside the outer screen house. Impingement fish will be monitored at the time of initial collection, and at 12 and 24 hours after placement in the holding facility. Water quality data (temperature, pH, and dissolved oxygen) will be collected at 12 and 24 hour marks in the holding facility. Dead fish will be identified, weighed, and measured as they are removed. All fish live after 24 hours will also be identified, weighed, and measured and released to Conowingo Pond.

Latent mortality sampling is scheduled to occur once per month from January through April, and every other week from mid-June through December 2016 for a total of 20 two-night events. Impingement sampling will likely begin in April 2016 and continue until March 2017 (see schedule in Appendix 3). For each scheduled impingement mortality sampling week, one or two consecutive nighttime sampling events will be completed, depending on the abundance of impinged fish in the collections. It is anticipated that for both sluice samplers in the outer intake structure Location 1 (Unit 2 at the north and Unit 3 at the south) there will be one two person crew present at all times during two, 12-hour shifts with samples collected from both sluice samplers by two (2) field technician per shift. One additional technician per night will also be required to monitor and record latent mortality for the fish held in the wet table facility during the 24 hours of holding time after the last sample was collected for each scheduled sampling event. If high debris loading or operational issues prevent impingement mortality sampling at the outer intake structure as proposed, the sampling event will be rescheduled for the next available time before the next event is scheduled to occur.

Ambient data including water quality (temperature, pH, and dissolved oxygen) and any appropriate weather condition and water condition data that might affect impingement will be recorded from the sluice water flow at each of the north and south sluice sampler locations and from the water supply to each holding facility.

Task 4 – Control/Test Fish Latent Impingement Mortality

Mortality due to impingement on the traveling screens and handling procedures will be assessed once per month on a previously scheduled impingement mortality sampling date by introducing purchased fish (Bluegill and Channel Catfish) obtained from a local hatchery. Test fish will be injected through a pipe placed just in front of a randomly selected traveling screen bay at Unit 2 and Unit 3 and collected in the sluice samplers. Control fish will be injected directly into the screenwash sluice and collected in the sluice samplers for Unit 2 and Unit 3 without passing through the traveling screens or screenwash spray headers.

Latent mortality for test and control fish will be assessed by placing the recovered test or control fish in the wet tables set up inside the outer screen house. Impingement test and control fish will be monitored at the time of initial collection, and at 12 and 24 hours after placement in the holding facility. Water quality data (temperature, pH, and dissolved oxygen) will be collected at 12 and 24 hour marks in the holding facility. Dead fish will be identified, weighed, and measured as they are removed. All fish live after 24 hours will also be identified, weighed, and measured and released to Conowingo Pond.

A Pre-Job Brief will be developed for field staff that is specific to the control/test fish task. The project specific Pre Job Brief will be performed prior to the start of each day of work. All Pre-Job Briefs will be conducted using Exelon procedure HU-AA-1211, Pre-Job Briefings and a Job-Specific Pre-Job Briefing checklist using HU-AA-1211-F-01.

3.0 POTENTIAL HAZARDS

The primary potential chemical hazard which exists is the 6% Formalin solution (saturated solution) that is used to preserve the entrainment samples. The samples will also be stained with Rose Bengal dye. The principal routes of exposure for Formalin are skin contact and inhalation. The Safety Data Sheets for Formalin and Rose Bengal are included in Appendix 4.

Listed below are other potential hazards encountered during implementation of the program. Attached in Appendix 5 is a Job Safety Analysis for detailed descriptions of hazards and their recommended controls:

- Chemical Hazards- 6% Formalin, Rose Bengal dye
- Presence of flammable liquids- None
- Hot and cold weather exposure- Dehydration, heat stroke, and hypothermia
- Drowning hazard- Along facility bulkheads, diversion dolphins, and boat work in the discharge canal
- Driving- Traffic and weather conditions
- Lifting or strain hazard due to physical activity
- Burn and shock hazards from electrical devices
- Slips, trips, and falls- Icy/wet conditions and tripping hazards
- Pinch points- Operating entrainment pumps and valves, pipe installation and removal
- Biological Hazards- spiders, bees, bacteria, etc.
- Cuts- when glass containers or other glass objects are used

4.0 GENERAL SAFETY AND OPERATIONAL GUIDELINES

The purpose of this Site-Specific Health and Safety Plan (SSHASP) is to establish personnel safety/protection standards and mandatory safety operating procedures relative to hazards that may be encountered during day-to-day operation of this project. This Plan has been developed with the intent to meet requirements contained in Normandeau's "Corporate Health and Safety Plan" (CHSP). All information presented in the CHSP that is applicable to this Plan is incorporated herein by reference. Any additional information needed for the project is presented below or in the Job Safety Analysis.

Normandeau has also developed a separate Quality Control Program consisting of procedures for conducting specific field and laboratory work tasks. These procedures are used to train personnel performing activities affecting quality and are provided to our employees to assist in the control of routine activities, which affect quality. Quality control procedures contain, where appropriate, reference to safety precautions and are meant to be a complement to, not a substitute for, Normandeau's CHSP. All project team members are required to receive training on these procedures. Training will be conducted prior to initial assignment in the field and as needed thereafter by the project manager or designee.

The Normandeau project team will also adhere to all client safety requirements, as specified in the Exelon Nuclear Industrial Safety Pocket Guide 2016 (SA-AA-2115, Revision13, expires 1/1/17). The Pocket Guide serves as reference only, detailed requirements are included in the SA procedures referenced within the Guide. A copy of the guide can be found in Appendix 6. In addition, the following general safety procedures will be implemented. If there is a conflict between Exelon's and Normandeau's Safety Programs and/or this document the conflict should be discussed with the Normandeau Task Manager, Exelon POC and the Exelon Site Safety Advisor to determine a resolution.

4.1 Responsibility

The Normandeau Task Manager (TM) assigned to the project will act as the Project Safety Officer. It will be his/her responsibility to ensure all personnel are familiar and comply with this SSHASP.

4.2 General Conduct

It is the responsibility of all personnel working at this facility to maintain a safe work environment and a safe attitude. All personnel must read this SSHASP and sign a Statement of Acknowledgement (Appendix 7) indicating they understand and will comply with the Plan before they may begin work.

4.3 Site Control Measures

All personnel entering Peach Bottom property will check through plant security and assigned points of contact (Exelon POC) prior to each entry. Only those persons who can comply with the requirements of this SSHASP will be allowed into the work area during work activities which may result in exposure to the hazards associated with the specific tasks being performed.

4.4 Employee Training Requirements

For sample collection and maintenance activities, employees will receive On-The-Job Training (OJT) appropriate to the types of hazards expected in the work areas. The OJT will be performed by Normandeau Associates, Inc. Task Manager or designee.

4.5 First Aid

First Aid will be administered by other project technician's working onsite. All medical emergencies MUST be made to the Peach Bottom Control Room (717)-456-3911 or (717)-456-4911. Medical response on the Peach Bottom site is coordinated through the Control Room and any request for offsite assistance must be made by the control room. A First Aid kit must be available in job box or vehicle at all sampling locations. All injuries, however minor, must be reported to Normandeau Task Manager and Exelon POC.

4.6 Housekeeping

All work areas associated with this project will be kept in an orderly condition. The work areas will be cleaned at the end of each shift. Workers will dispose of non-hazardous debris on a daily basis at a location to be specified by the Exelon POC.

4.7 Accidents/Injuries

All accidents/injuries will be reported immediately to the Peach Bottom Control Room (717)-456-3911 or (717)-456-4911 and Exelon POC and the Normandeau project manager, TM, or other Normandeau supervisor. The Normandeau project manager or TM will follow standard Normandeau procedures for handling accidents/injuries. This will include the immediate notification to the Exelon POC. Emergency notification procedures are presented in Section 7 of this HASP. Work will not be allowed to restart until the safety event is fully understood; preventative measures are in place; Exelon required reporting details are completed; and Exelon agrees work can be restarted. Reference Exelon procedure SA-AA-123 for specific information.

As per Normandeau's CHSP, all events surrounding accidents/injuries will be recorded and submitted to Human Resources on Normandeau's Accident/Injury Reporting Form.

4.8 Personal Protective Equipment (PPE)

Personnel performing the sampling on the plant site will wear Level D protection. Hard hats, safety glasses, work boots, work gloves, and hearing protection as needed will be worn as required by Normandeau's CHSP and Exelon safety requirements (SA-AA-116, Rev 018). As per the requirements of Exelon's vendor safety program, hard hats, safety glasses, work gloves, and work shoes meeting ANSI Z-41-1991, ANSI Z-41-1999, ASTM F-2412-2005 or ASTM F-2413-2005 standards must be worn at all times when working on any Exelon property. Additional protective equipment, such as ear plugs, will be worn as applicable to OSHA and Exelon regulations.

In addition to the above required safety equipment, a U.S. Coast Guard approved personal floatation device (PFD) must be worn at all times when working within 10-feet of any shoreline or when collecting water quality measurements. When preserving specimens disposable gloves and safety glasses must always be worn.

4.9 Stand-by Safety Equipment

The following safety equipment will be present at the sampling location at all times:

- fire extinguisher
- first-aid kit (for minor injuries only, all injuries must be reported)
- cell phone
- personal floatation device(s)
- throw ring with 90-ft of line and throw bag
- portable eyewash canister

5.0 SPECIAL SAFETY MEASURES

5.1 Equipment Maintenance

Under normal conditions, there is no major maintenance that can be conducted by one individual to the entrainment or impingement sampling systems; therefore, there is no need to attempt repairs. The Normandeau project manager or TM must be notified immediately if any maintenance is required.

During any system maintenance within 10-feet of the shoreline, as instructed in Section 4.8 above, PFD's must be worn at all times. When working near water a ring buoy with 90 feet of line must be provided for emergency rescue operations. If access to the discharge canal diversion dolphins or boat usage is required, both security and the Exelon POC must be notified and authorization received.

5.2 Boating Safety

The Normandeau CHSP's Section 9.6 – "Boating Safety Program" is designed to help familiarize employees with important information and provide basic training related to boat equipment, operation, water hazards, and emergency rescue techniques to ensure that work is conducted as safely as possible on and around water bodies. This program provides a comprehensive summary of information to assist personnel under most conditions expected in the field. However, it is beyond the scope of this or any other available federal, state, or local programs to cover all boating conditions, equipment, or hazards. For the most part, actual boating "know-how" will be gained only through a thorough understanding of the contents of this program, and real experience. Boating knowledge is not merely composed of boat handling, but it encompasses everything from proper choice of equipment to proper transportation to and from the site of use, as well as being competent to "read the water" to complete activities in as safe a manner as possible. A copy of this safety program is available upon request.

Extreme care and personal safety will take precedence over sample collection and equipment maintenance when working along or "on the water". PFD's (non-inflatable only) will be worn by all personnel whenever working within 10-feet of the shoreline and while working from any work boat or dolphin. Prior to use PFD's should be inspected for defects and discarded if damaged. When working near water a ring buoy with 90 feet of line and a rescue throw bag must be provided for emergency rescue operations.

Boat usage for this project will be limited to installation, removal, and maintenance of the entrainment system intake pipe at the circulating water outfall and will only be authorized through prior approval by site security and the Exelon POC. Only two Normandeau personnel will be on the boat besides the GE operator. The work boat currently moored in the discharge canal is available for project use, but is owned

by GE and will require GE's authorization and oversight. During any boating activity personnel should be located downstream and equipped with a water rescue throw bags.

5.3 Electrical Safety

No work shall be performed on electrically energized equipment at the Peach Bottom Site. All Normandeau employees who are required to operate equipment **which is electrically energized** must have training in accordance with the Normandeau CHSP's Electrical Energy Awareness Program which shall include, but not be limited to, the following topics:

1. The contents of CHSP– Section 9.7 – "Electrical Energy Awareness Program".
2. The contents of CHSP- Section 9.12 – "Control of Hazardous Energy Sources Program".
3. The contents of CHSP- Appendix 9.7-1, "Electrical Hazards Training Program".
4. If applicable, the contents of Normandeau Procedure No. EF4.
5. Methods and means necessary for working safely in the presence of electrical energy.
6. The contents of 29 CFR 1910 Subpart S, and 29 CFR 1926 Subpart K.
7. The contents of 29 CFR 1910.147

All electrically energized equipment (e.g. electric pumps, lighting, etc.) must be equipped with a GFCI at the electrical source. In addition, the starter box on/off switch lever will be left in the down (off) position and locked with a padlock by Normandeau whenever the crew is not on site for entrainment sampling.

5.4 Field Safety

The types of facilities at which Normandeau employees conduct work may vary considerably. In general, field sites are relatively free of serious health and safety hazards, but in some cases the presence of a hazard is difficult to assess. This variety in the degree of health and safety hazards, along with the difficulty of the assessment process presents special safety problems. General safety guidelines are provided in Normandeau's CHSP – Section 9.9 – "Field Safety Awareness Program". This program provides project and task-specific guidelines as needed.

5.5 Hot and Cold Weather Considerations

When work on the project will occur during the summer months, preventative measures to avoid heat stress will be implemented. Measures will include having sufficient drinking water available on the work site, and close monitoring of personnel for symptoms of heat stress such as dizziness, cramps, nausea or headaches. Personnel exhibiting symptoms will immediately discontinue work and be given appropriate first aid. Detailed procedures can be found within Exelon Heat Stress Procedure SA-AA-111- Heat Stress Control.

On cold, windy days improper dress and/or extended exposure could result in frostbite or hypothermia. Minimize exposure of the body to the cold by proper dress, limiting work time and activities directly in the wind, and when practical, moving to a warmer place periodically. Most of all be aware of weather reports and forecasted wind/wind chill factors, and plan field activities accordingly.

5.6 Chemical Hazards

During the process of collecting IP samples, a 6% solution of Formalin will be used to preserve the biological samples. Six percent Formalin, a dilute solution of Formaldehyde, has a Hazardous Materials

Information System (HMIS) Health Rating of 1 (non-flammable) and its primary routes of entry are inhalation, ingestion, and absorption. **Copies of the SDS will be placed in a job packet, maintained on -site, and readily available in the field**. All chemicals will be stored properly. After each use chemicals should be returned immediately to the storage locker or Normandeau vehicle. The storage locker containing chemicals will not be maintained in an Exelon building. All chemicals should be transported back to Normandeau facilities after the completion of a sampling event. No chemicals should be left at the Peach Bottom Site. **Proper spill containment and PPE must be used when handling chemicals.** All field team members using Formalin must read the SDS attached in Appendix 4. In addition, Exelon will provide an ANSI Z538.1-2014 approved portable eyewash canister for Normandeau use. The eyewash canister should be within arms-length when formalin is being used. The eyewash canister will be stored in the outer screenhouse and should be returned after use. Normandeau personnel will be responsible for a weekly inspection of the eyewash canister. The inspection will include a confirmation that the canister has not expired and that the gage is within the green or suitable range. Exelon chemistry personnel should be contacted if the eyewash canister needs to be serviced.

If any other chemicals are brought on-site they must be approved by Exelon and accompanied by the SDS. The SDS should be reviewed and all hazards understood prior to use.

Chemicals will be reviewed with all workers during the Pre-Job Brief to ensure that all are aware of hazards and mitigating actions/PPE to be used to control said hazards.

5.7 Pre-Job Brief

The Pre-Job Brief developed for each task shall be conducted prior to each work shift. It is the responsibility of each Normandeau employee to carefully review the predetermined hazards and major activities for job execution, identify any new hazards and work practices or site conditions that present new or different hazards than the predetermined hazards, and report any unusual circumstances, hazards or conditions to the Normandeau TM or Exelon POC during the Pre-Job Brief. In addition, a 2 Minute Drill shall be completed prior to performing new work tasks.

6.0 EMERGENCY PROCEDURES

All medical emergencies MUST be made to the Peach Bottom Control Room (717)-456-3911 or (717)-456-4911. Medical response on the Peach Bottom site is coordinated through the Control Room and any request for offsite assistance must be made by the control room.

6.1 Personal Injury

The Peach Bottom Control Room (x3911/4911) and Exelon POC shall be notified immediately for any injury above the level of first aid. The Normandeau project manager or TM with support from the Control Room shall evaluate the nature of the injury and, if indicated by the hazards present on site, the injured person shall be decontaminated to the extent possible (if applicable) prior to movement out of the work area.

An individual certified in Standard First Aid and Adult CPR shall initiate the appropriate first aid. Contact shall be made to Station Control Room only for requesting an ambulance and with the designated medical facility, if required (See Section 7). No persons shall resume sampling/maintenance until the

cause of the injury or symptoms is determined and until the risks can be assessed and either removed or minimized.

6.2 Fire/Explosion

The Peach Bottom Control Room (x3911/4911) shall be alerted and all personnel moved to a safe distance from the involved area (See Section 7). The control room shift operator will be responsible for notifying any emergency response units.

6.3 Personal Protective Equipment Failure

If any site worker experiences a failure or alteration of protective equipment that affects the protection factor, then that person shall immediately leave the work area. Re-entry shall not be permitted until the equipment has been repaired or replaced.

6.4 Other Equipment Failure

If any other safety equipment on site fails to operate properly, the Normandeau project manager or TM shall be notified and then determine the effect of this failure on continuing operations. If the failure affects the safety of personnel, all personnel shall leave the work area until the situation is evaluated and appropriate actions are taken. In a situation where an emergency arises at the PBAPS all personnel shall follow instructions/information provided by the facility security or staff.

7.0 EMERGENCY CONTACTS

In the event of an incident or injury during implementation of the project, Normandeau staff will inform the Peach Bottom Control Room (x3911/4911) immediately and then will notify the Exelon POC or other responsible authority who will contact the appropriate response department (e.g., ambulance, fire, police).

7.1 Emergency Information

ON-SITE EMERGENCIES	(Plant phone only)	x3911/4911
	(Cell phone)	(717) 456-3911/4911

LOCAL HOSPITAL(S) NAME AND ADDRESS:

York Hospital
1001 South George Street,
York, PA 17403-3676 (717) 851-2345

ROUTE(S):

To York Hospital:

1. Head northwest on main road from PBAPS onto Lay Rd. for 1.2 miles.

2. Turn right at top of hill onto Paper Mill Rd/State Route 2024 for 3.4 miles to PA-74 N/Delta Rd.
3. Continue on PA-74 N for 18.0 miles and turn right onto N Main St.
4. Go 0.2 miles and take the 3rd left onto W High St for 0.4 miles.
5. Take slight right onto Springwood Rd and continue 1.0 miles to E George St.
6. Travel 0.5 miles on E George St then continue onto Springwood Rd/State Route 2002 for 3.5 miles.
7. Turn left onto Donna Lane for 0.3 miles and take the 1st right onto PA-74 N/S Queen St.
8. Go 1.4 miles and turn left onto Rathton Rd for 0.5 miles, then turn left onto S George St.
9. Go 390 feet and York Hospital will be on the left.

Approximately 31.3 miles total drive distance.

NEAREST TELEPHONE:

Field Samplers Cell Phone: TBD

KEY NORMANDEAU CONTACTS:

Normandeau Associates, Inc. Offices

Stowe Office
400 Old Reading Pike
Building A, Suite 101
Stowe, PA 19464 (610) 705-5733

Drumore Office
1921 River Road,
P.O. Box 10
Drumore, PA 17518 (717) 548-2121

Normandeau Contacts

Name: Mark Mattson
Title: Project Manager
Direct Phone: (603) 319-5307
Cell Phone: (603) 345-0071

Name: Michael Ricci
Title: Field Supervisor
Direct Phone: (603) 637-1148
Cell Phone: (845) 721-8288

Name: Bryan Lees
Title: Task Manager
Direct Phone: (484) 945-2578
Cell Phone: (484) 374-5916

Name: Doug Royer
Title: Senior Manager
Direct Phone: (717) 207-8852
Cell Phone: (717) 823-1253

CLIENT REPRESENTATIVES/POC:

Company: Exelon Nuclear – Peach Bottom Atomic Power Station

Name(s): Joseph Brozonis (POC) (717) 456-3795 (Office)
(484) 467-7524 (Cell)

Operations Work Execution Supervisor (717) 456-4423 (Office)

7.2 Agency Contacts

In the event of a release of a reportable quantity (RQ) of an extremely hazardous substance or CERCLA Hazardous Substance which results in exposure to persons outside the site boundaries, call the Peach Bottom Control Room and the Exelon POC immediately prior to making any agency notifications on behalf of the station. The Peach Bottom Control Room or Exelon POC will be responsible for contacting the following agencies:

Pennsylvania Department of Environmental Protection (PA DEP)
Southcentral Office
909 Elmerton Avenue
Harrisburg, PA 17110 (877) 333-1904

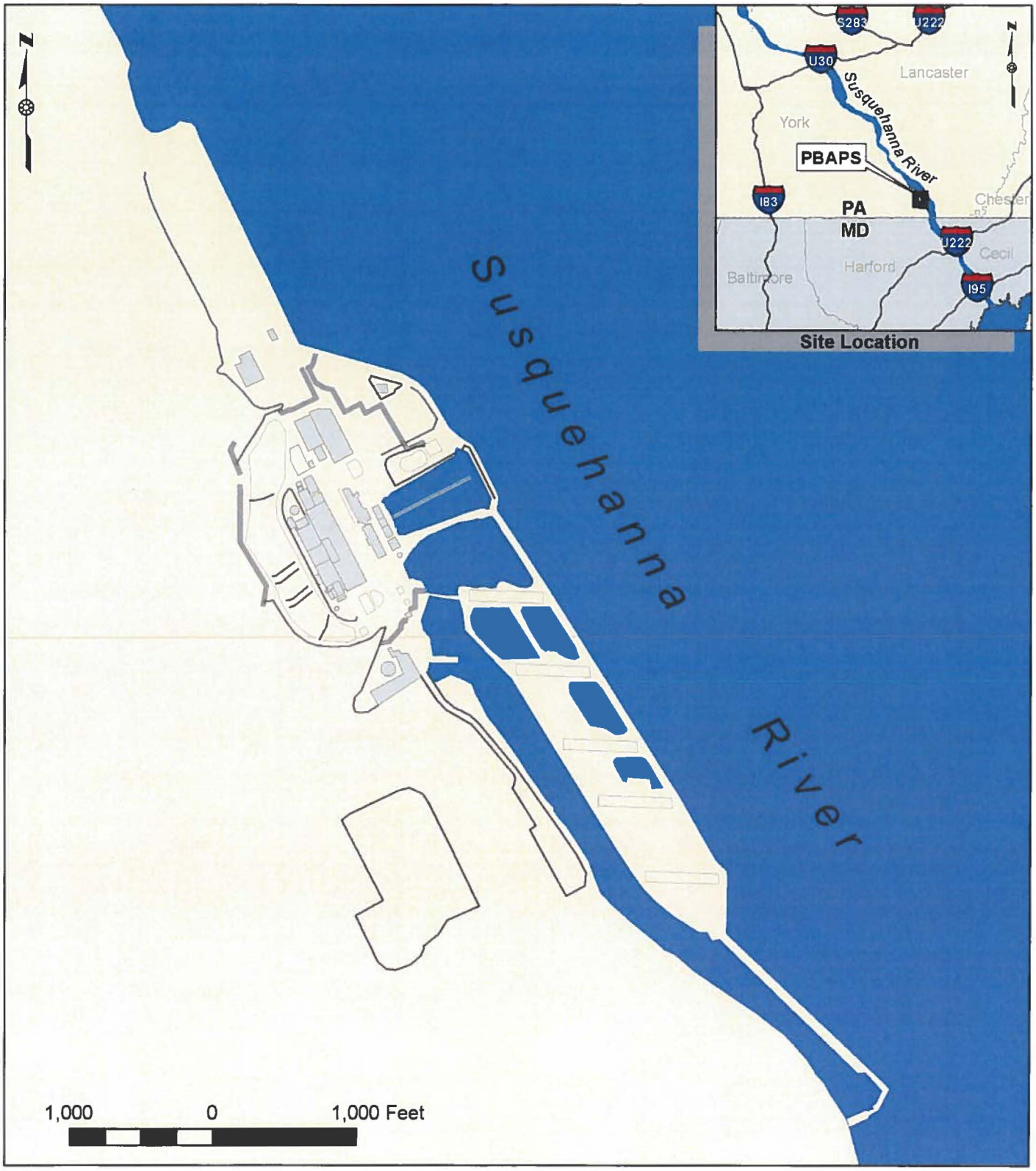
US EPA, Region 3: The Mid-Atlantic Region
1650 Arch Street
Philadelphia, PA 19103-2029 (800) 438-2474

National Response Center (800) 424-8802

Poison Control Center (800) 682-9211

FIGURE

Figure 1.
Peach Bottom Atomic Power Station



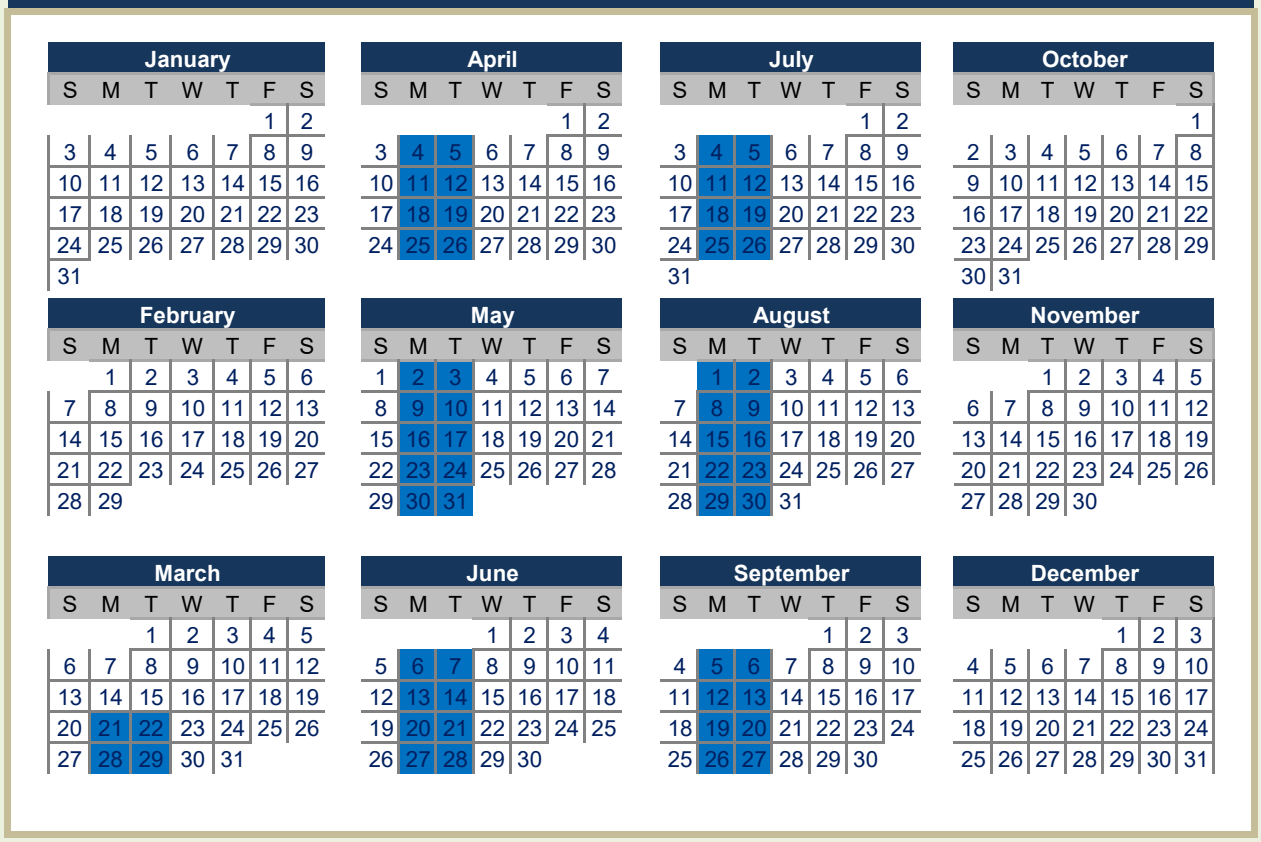
Peach Bottom Atomic Power Station (PBAPS)
1848 Lay Rd
Delta, PA 17314

APPENDIX 1

Entrainment Study Sampling Schedule

Proposed sampling schedule for entrainment characterization study at PBAPS March 2016 through September 2016.

2016



Each Scheduled Entrainment Sampling Event at Outer Intake Structure, Condenser Discharge, and end of the Discharge Canal:

Time Start	Time End	Daily Schedule
9:00	9:00	Entrainment sampling at Outer Intake Structure
9:25	9:25	Entrainment sampling at Condenser Discharge
10:25	10:25	Entrainment sampling at end of Discharge Canal

Notes:

1. Entrainment abundance samples will be collected weekly at each location
2. Each sampling event will occur over a single 24-hr period
3. During each weekly sampling event, four samples representing four 6-hour diel periods will be collected
4. Sampling will start on Monday morning and end on Tuesday morning
5. A total of 28 weeks of sampling between March 2016 and September 2016

APPENDIX 2

Hazardous Certificate of Registration

UNITED STATES OF AMERICA
DEPARTMENT OF TRANSPORTATION
PIPELINE AND HAZARDOUS MATERIALS SAFETY ADMINISTRATION

HAZARDOUS MATERIALS CERTIFICATE OF REGISTRATION FOR REGISTRATION YEAR(S) 2014-2017

Registrant: NORMANDEAU ASSOCIATES INC
Attn: ROBERT C HASEVLAT
25 NASHUA RD
BEDFORD, NH 03110-5527

This certifies that the registrant is registered with the U.S. Department of Transportation as required by 49 CFR Part 107, Subpart G.

This certificate is issued under the authority of 49 U.S.C. 5108. It is unlawful to alter or falsify this document.

Reg. No: 063014 554 070WY **Issued: 06/30/2014** **Expires: 06/30/2017**

HM Company ID: 051527

Record Keeping Requirements for the Registration Program

The following must be maintained at the principal place of business for a period of three years from the date of issuance of this Certificate of Registration:

(1) A copy of the registration statement filed with PHMSA; and
(2) This Certificate of Registration

Each person subject to the registration requirement must furnish that person's Certificate of Registration (or a copy) and all other records and information pertaining to the information contained in the registration statement to an authorized representative or special agent of the U. S. Department of Transportation upon request.

Each motor carrier (private or for-hire) and each vessel operator subject to the registration requirement must keep a copy of the current Certificate of Registration or another document bearing the registration number identified as the "U.S. DOT Hazmat Reg. No." in each truck and truck tractor or vessel (trailers and semi-trailers not included) used to transport hazardous materials subject to the registration requirement. The Certificate of Registration or document bearing the registration number must be made available, upon request, to enforcement personnel.

For information, contact the Hazardous Materials Registration Manager, PHH-52, Pipeline and Hazardous Materials Safety Administration, U.S. Department of Transportation, 1200 New Jersey Avenue, SE, Washington, DC 20590, telephone (202) 366-4109.

APPENDIX 3

Impingement Study Sampling Schedule

Proposed sampling schedule for impingement mortality sampling at PBAPS April 2016 through December 2016.

2016

January						
S	M	T	W	T	F	S
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30
31						

February						
S	M	T	W	T	F	S
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29					

March						
S	M	T	W	T	F	S
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

April						
S	M	T	W	T	F	S
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30

May						
S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

June						
S	M	T	W	T	F	S
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30		

July						
S	M	T	W	T	F	S
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30
31						

August						
S	M	T	W	T	F	S
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

September						
S	M	T	W	T	F	S
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	

October						
S	M	T	W	T	F	S
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31					

November						
S	M	T	W	T	F	S
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30			

December						
S	M	T	W	T	F	S
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

Each Scheduled Impingement Mortality Sampling Event at Outer Intake Structure:
Latent Survival Observations only for fish in holding facility at outer intake structure:
Scheduled refueling outtage, no sampling to occur

Time Start	End	Daily Schedule
15:00	16:00	Day #1 Prewash each operational traveling screen one complete revolution
16:00	4:00	Day #1 Continuous wash all operatonal screens during mortality sampling
15:00	16:00	Day #2 Prewash each operational traveling screen one complete revolution
16:00	4:00	Day #2 Continuous wash all operatonal screens during mortality sampling
16:00	4:00	Day #3 Terminate survival observations after 24 hours no screenwash needed

Notes:
1. Each sampling event requires pre-washing each operational traveling screen one complete revolution to discard old dead fish and debris
2. Each sampling event requires 12 hours of continuous screen operation to collect freshly impinged fish
3. Sampling to be conducted during primarily nighttime conditions
4. Sampling events will be two consecutive days in each scheduled week, one or two weeks per month for 12 consecutive months
5. A total of 21 weeks of sampling between April 2016 and March 2017
6. Impinged fish are collected continuously at time = 0 and held in tanks to determine their survival status at time = 24 (24 hours after collection)

Proposed sampling schedule for impingement mortality sampling at PBAPS January 2017 through March 2017.

2017

January						
S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

February						
S	M	T	W	T	F	S
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28				

March						
S	M	T	W	T	F	S
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

April						
S	M	T	W	T	F	S
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30						

May						
S	M	T	W	T	F	S
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

June						
S	M	T	W	T	F	S
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	

July						
S	M	T	W	T	F	S
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31					

August						
S	M	T	W	T	F	S
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

September						
S	M	T	W	T	F	S
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30

October						
S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

November						
S	M	T	W	T	F	S
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30		

December						
S	M	T	W	T	F	S
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30
31						

Each Scheduled Impingement Mortality Sampling Event at Outer Intake Structure:

Latent Survival Observations only for fish in holding facility at outer intake structure:

Time Start	Time End	Daily Schedule
15:00	16:00	Day #1 Prewash each operational traveling screen one complete revolution
16:00	4:00	Day #1 Continuous wash all operatonal screens during mortality sampling
15:00	16:00	Day #2 Prewash each operational traveling screen one complete revolution
16:00	4:00	Day #2 Continuous wash all operatonal screens during mortality sampling
16:00	4:00	Day #3 Terminate survival observations after 24 hours no screenwash needed

Notes:
1. Each sampling event requires pre-washing each operational traveling screen one complete revolution to discard old dead fish and debris
2. Each sampling event requires 12 hours of continuous screen operation to collect freshly impinged fish
3. Sampling to be conducted during primarily nighttime conditions
4. Sampling events will be two consecutive days in each scheduled week, one or two weeks per month for 12 consecutive months
5. A total of 21 weeks of sampling between April 2016 and March 2017
6. Impinged fish are collected continuously at time = 0 and held in tanks to determine their survival status at time = 24 (24 hours after collection)

APPENDIX 4

Safety Data Sheets (SDS)

Fisher Scientific

Part of Thermo Fisher Scientific

SAFETY DATA SHEET

Creation Date 26-Sep-2009 **Revision Date** 11-Mar-2015 **Revision Number** 3

1. Identification

Product Name **Formalin, Buffered, 10%**

Cat No. : **SF99-4**

Synonyms Formaldehyde solution, buffered

Recommended Use Laboratory chemicals.

Uses advised against No Information available

Details of the supplier of the safety data sheet

Emergency Telephone Number
Chemtrec US: (800) 424-9300
Chemtrec EU: 001 (202) 483-7616

2. Hazard(s) identification

Classification
This chemical is considered hazardous by the 2012 OSHA Hazard Communication Standard (29 CFR 1910.1200)

Flammable liquids	Category 4
Skin Corrosion/irritation	Category 2
Serious Eye Damage/Eye Irritation	Category 2
Skin Sensitization	Category 1
Germ Cell Mutagenicity	Category 2
Carcinogenicity	Category 1A
Specific target organ toxicity (single exposure)	Category 1
Target Organs - Respiratory system, Central nervous system (CNS).	
Specific target organ toxicity - (repeated exposure)	Category 2
Target Organs - Kidney, Liver, Blood.	

Label Elements

Signal Word
Danger

Hazard Statements
Combustible liquid
Causes skin irritation
Causes serious eye irritation
May cause an allergic skin reaction
May cause respiratory irritation
May cause drowsiness or dizziness
Suspected of causing genetic defects
May cause cancer
Causes damage to organs

May cause damage to organs through prolonged or repeated exposure

Precautionary Statements
Prevention
Obtain special instructions before use
Do not handle until all safety precautions have been read and understood
Use personal protective equipment as required
Wash face, hands and any exposed skin thoroughly after handling
Contaminated work clothing should not be allowed out of the workplace
Wear protective gloves
Do not breathe dust/fume/gas/mist/vapors/spray
Do not eat, drink or smoke when using this product
Use only outdoors or in a well-ventilated area
Keep away from heat/sparks/open flames/hot surfaces. - No smoking
Keep cool
Response
IF exposed: Call a POISON CENTER or doctor/physician
Inhalation
IF INHALED: Remove victim to fresh air and keep at rest in a position comfortable for breathing
Call a POISON CENTER or doctor/physician if you feel unwell
Skin
IF ON SKIN: Wash with plenty of soap and water
Take off contaminated clothing and wash before reuse
If skin irritation or rash occurs: Get medical advice/attention
Eyes
IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing
Immediately call a POISON CENTER or doctor/physician
Fire
In case of fire: Use CO_2, dry chemical, or foam for extinction
Storage
Store locked up
Store in a well-ventilated place. Keep container tightly closed
Disposal
Dispose of contents/container to an approved waste disposal plant
Hazards not otherwise classified (HNOC)

Other hazards
WARNING! This product contains a chemical known in the State of California to cause birth defects or other reproductive harm.
Unknown Acute Toxicity
.? % of the mixture consists of ingredients of unknown toxicity.

3. Composition / information on ingredients

Component	CAS-No	Weight %
Water	7732-18-5	82 - 82.9
Formaldehyde	50-00-0	3.9 - 4.0
Sodium acetate	127-09-3	1.2 - 2.0
Methyl alcohol	67-56-1	2

4. First-aid measures

General Advice Show this safety data sheet to the doctor in attendance. Immediate medical attention is required.

Eye Contact Rinse immediately with plenty of water, also under the eyelids, for at least 15 minutes. If eye irritation persists, consult a specialist.

Skin Contact Wash off immediately with plenty of water for at least 15 minutes. If skin irritation persists, call a physician.

Inhalation Move to fresh air. If breathing is difficult, give oxygen. Do not use mouth-to-mouth resuscitation if victim ingested or inhaled the substance; induce artificial respiration with a respiratory medical device. Immediate medical attention is required.

Ingestion Do not induce vomiting. Call a physician or Poison Control Center immediately.

Most important symptoms/effects Breathing difficulties. May cause allergic skin reaction. . Irritating to eyes. Irritating to skin. Symptoms of overexposure may be headache, dizziness, tiredness, nausea and vomiting: Symptoms of allergic reaction may include rash, itching, swelling, trouble breathing, tingling of the hands and feet, dizziness, lightheadedness, chest pain, muscle pain or flushing

Notes to Physician Treat symptomatically

5. Fire-fighting measures

Suitable Extinguishing Media Use water spray, alcohol-resistant foam, dry chemical or carbon dioxide. Cool closed containers exposed to fire with water spray.

Unsuitable Extinguishing Media No information available

Flash Point 90 °C / 194 °F
Method - No information available

Autoignition Temperature No information available
Explosion Limits
Upper No data available
Lower No data available
Sensitivity to Mechanical Impact No information available
Sensitivity to Static Discharge No information available

Specific Hazards Arising from the Chemical
Combustible material. Risk of ignition. Containers may explode when heated. Keep product and empty container away from heat and sources of ignition.

Hazardous Combustion Products
Carbon monoxide (CO) Carbon dioxide (CO_2)
Protective Equipment and Precautions for Firefighters
As in any fire, wear self-contained breathing apparatus pressure-demand, MSHA/NIOSH (approved or equivalent) and full protective gear. Thermal decomposition can lead to release of irritating gases and vapors.

NFPA

Health	Flammability	Instability	Physical hazards
3	2	0	N/A

6. Accidental release measures

Personal Precautions Use personal protective equipment. Evacuate personnel to safe areas. Keep people away from and upwind of spill/leak. Ensure adequate ventilation. Remove all sources of ignition. Take precautionary measures against static discharges.

Environmental Precautions Should not be released into the environment. Do not flush into surface water or sanitary sewer system. See Section 12 for additional ecological information.

Methods for Containment and Clean Soak up with inert absorbent material. Keep in suitable, closed containers for disposal.

Up Remove all sources of ignition.

7. Handling and storage

Handling Use only under a chemical fume hood. Do not get in eyes, on skin, or on clothing. Do not breathe vapors or spray mist. Wear personal protective equipment. Do not ingest. Keep away from open flames, hot surfaces and sources of ignition.

Storage Keep containers tightly closed in a dry, cool and well-ventilated place. Keep away from heat and sources of ignition.

8. Exposure controls / personal protection

Exposure Guidelines

Component	ACGIH TLV	OSHA PEL	NIOSH IDLH
Formaldehyde	Ceiling: 0.3 ppm	(Vacated) TWA: 3 ppm (Vacated) STEL: 10 ppm (Vacated) Ceiling: 5 ppm TWA: 0.75 ppm STEL: 2 ppm	IDLH: 20 ppm TWA: 0.016 ppm Ceiling: 0.1 ppm
Methyl alcohol	TWA: 200 ppm STEL: 250 ppm Skin	(Vacated) TWA: 200 ppm (Vacated) TWA: 260 mg/m^3 (Vacated) STEL: 250 ppm (Vacated) STEL: 325 mg/m^3 Skin TWA: 200 ppm TWA: 260 mg/m^3	IDLH: 6000 ppm TWA: 200 ppm TWA: 260 mg/m^3 STEL: 250 ppm STEL: 325 mg/m^3

Component	Quebec	Mexico OEL (TWA)	Ontario TWAEV
Formaldehyde	Ceiling: 2 ppm Ceiling: 3 mg/m^3	Ceiling: 2 ppm Ceiling: 3 mg/m^3	STEL: 1.0 ppm CEV: 1.5 ppm
Methyl alcohol	TWA: 200 ppm TWA: 262 mg/m^3 STEL: 250 ppm STEL: 328 mg/m^3 Skin	TWA: 200 ppm TWA: 260 mg/m^3 STEL: 250 ppm STEL: 310 mg/m^3	TWA: 200 ppm STEL: 250 ppm Skin

Legend

ACGIH - American Conference of Governmental Industrial Hygienists
OSHA - Occupational Safety and Health Administration
NIOSH IDLH: The National Institute for Occupational Safety and Health Immediately Dangerous to Life or Health

Engineering Measures Use only under a chemical fume hood. Ensure that eyewash stations and safety showers are close to the workstation location. Ensure adequate ventilation, especially in confined areas.

Personal Protective Equipment

Eye/face Protection Tightly fitting safety goggles.

Skin and body protection Long sleeved clothing.

Respiratory Protection Follow the OSHA respirator regulations found in 29 CFR 1910.134 or European Standard EN 149. Use a NIOSH/MSHA or European Standard EN 149 approved respirator if exposure limits are exceeded or if irritation or other symptoms are experienced.

Hygiene Measures Handle in accordance with good industrial hygiene and safety practice.

9. Physical and chemical properties

Physical State Liquid
Appearance Clear

Odor	pungent
Odor Threshold	No information available
pH	7
Melting Point/Range	0 °C / 32 °F
Boiling Point/Range	No information available - 100 °C / - 212 °F
Flash Point	90 °C / 194 °F
Evaporation Rate	> 1.0
Flammability (solid,gas)	Not applicable
Flammability or explosive limits	
Upper	No data available
Lower	No data available
Vapor Pressure	No information available
Vapor Density	1.0
Relative Density	1.10
Solubility	miscible
Partition coefficient; n-octanol/water	No data available
Autoignition Temperature	No information available
Decomposition Temperature	No information available
Viscosity	No information available

10. Stability and reactivity

Reactive Hazard None known, based on information available

Stability Stable under normal conditions.

Conditions to Avoid Incompatible products. Excess heat. Keep away from open flames, hot surfaces and sources of ignition.

Incompatible Materials Strong oxidizing agents

Hazardous Decomposition Products Carbon monoxide (CO), Carbon dioxide (CO_2)

Hazardous Polymerization Hazardous polymerization does not occur.

Hazardous Reactions None under normal processing.

11. Toxicological information

Acute Toxicity

Product Information No acute toxicity information is available for this product
Oral LD50 Based on ATE data, the classification criteria are not met. ATE > 2000 mg/kg.
Dermal LD50 Based on ATE data, the classification criteria are not met. ATE > 2000 mg/kg.
Vapor LC50 Based on ATE data, the classification criteria are not met. ATE > 20 mg/l.
Component Information

Component	LD50 Oral	LD50 Dermal	LC50 Inhalation
Formaldehyde	500 mg/kg (Rat)	270 mg/kg (Rabbit)	0.578 mg/L (Rat) 4 h
Sodium acetate	3530 mg/kg (Rat)	10 g/kg (Rabbit)	30 g/m³ (Rat) 1 h
Methyl alcohol	6200 mg/kg (Rat)	15800 mg/kg (Rabbit)	64000 ppm (Rat) 4 h 83.2 mg/L (Rat) 4 h

Toxicologically Synergistic Products No information available

Delayed and immediate effects as well as chronic effects from short and long-term exposure

Irritation Irritating to eyes, respiratory system and skin

Sensitization No information available

Carcinogenicity The table below indicates whether each agency has listed any ingredient as a carcinogen.

Component	CAS-No	IARC	NTP	ACGIH	OSHA	Mexico
Water	7732-18-5	Not listed	Not listed	Not listed	Not listed	Not listed
Formaldehyde	50-00-0	Group 1	Known	A2	X	A2
Sodium acetate	127-09-3	Not listed	Not listed	Not listed	Not listed	Not listed
Methyl alcohol	67-56-1	Not listed	Not listed	Not listed	Not listed	Not listed

IARC: (International Agency for Research on Cancer)

NTP: (National Toxicity Program)

ACGIH: (American Conference of Governmental Industrial Hygienists)

Mexico - Occupational Exposure Limits - Carcinogens

IARC: (International Agency for Research on Cancer)
Group 1 - Carcinogenic to Humans
Group 2A - Probably Carcinogenic to Humans
Group 2B - Possibly Carcinogenic to Humans
NTP: (National Toxicity Program)
Known - Known Carcinogen
Reasonably Anticipated - Reasonably Anticipated to be a Human Carcinogen
A1 - Known Human Carcinogen
A2 - Suspected Human Carcinogen
A3 - Animal Carcinogen
ACGIH: (American Conference of Governmental Industrial Hygienists)
Mexico - Occupational Exposure Limits - Carcinogens
A1 - Confirmed Human Carcinogen
A2 - Suspected Human Carcinogen
A3 - Confirmed Animal Carcinogen
A4 - Not Classifiable as a Human Carcinogen
A5 - Not Suspected as a Human Carcinogen

Mutagenic Effects No information available

Reproductive Effects Experiments have shown reproductive toxicity effects on laboratory animals.

Developmental Effects Developmental effects have occurred in experimental animals.

Teratogenicity Teratogenic effects have occurred in experimental animals.

STOT - single exposure Respiratory system Central nervous system (CNS)
STOT - repeated exposure Kidney Liver Blood

Aspiration hazard No information available

Symptoms / effects,both acute and delayed Symptoms of overexposure may be headache, dizziness, tiredness, nausea and vomiting: Symptoms of allergic reaction may include rash, itching, swelling, trouble breathing, tingling of the hands and feet, dizziness, lightheadedness, chest pain, muscle pain or flushing

Endocrine Disruptor Information No information available

Other Adverse Effects Tumorigenic effects have been reported in experimental animals. See actual entry in RTECS for complete information.

12. Ecological information

Ecotoxicity

Toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment. The product contains following substances which are hazardous for the environment. Contains a substance which is:. Toxic to aquatic organisms.

Component	Freshwater Algae	Freshwater Fish	Microtox	Water Flea
Formaldehyde	Not listed	Leuciscus idus: LC50 = 15 mg/L 96h	Not listed	EC50 = 20 mg/L 96h EC50 = 2 mg/L 48h
Sodium acetate	-	5000 mg/L LC50 24 h	= 7200 mg/L EC50 Pseudomonas putida 18 h	1000 mg/L EC50 > 48 h
Methyl alcohol	Not listed	Pimephales promelas: LC50 > 10000 mg/L 96h	EC50 = 39000 mg/L 25 min EC50 = 40000 mg/L 15 min EC50 = 43000 mg/L 5 min	EC50 > 10000 mg/L 24h

Persistence and Degradability Miscible with water Persistence is unlikely based on information available.
Bioaccumulation/ Accumulation No information available.

Mobility . Will likely be mobile in the environment due to its water solubility.

Component	log Pow
Formaldehyde	-0.35
Sodium acetate	-4.22
Methyl alcohol	-0.74

13. Disposal considerations

Waste Disposal Methods Chemical waste generators must determine whether a discarded chemical is classified as a hazardous waste. Chemical waste generators must also consult local, regional, and national hazardous waste regulations to ensure complete and accurate classification.

Component	RCRA - U Series Wastes	RCRA - P Series Wastes
Formaldehyde - 50-00-0	U122	-
Methyl alcohol - 67-56-1	U154	-

14. Transport information

DOT Not regulated
- **UN-No** UN3334
- **Proper Shipping Name** AVIATION REGULATED LIQUID, N.O.S.
- **Proper technical name** (10% FORMALIN)
- **Hazard Class** 9

TDG Not regulated

IATA Not regulated
- **UN-No** UN3334
- **Proper Shipping Name** AVIATION REGULATED LIQUID, N.O.S.
- **Hazard Class** 9

IMDG/IMO Not regulated
- **UN-No** FS0002
- **Proper Shipping Name** NOT REGULATED BY IMDG/IMO
- **Hazard Class** NONE

15. Regulatory information

All of the components in the product are on the following Inventory lists: X = listed

International Inventories

Component	TSCA	DSL	NDSL	EINECS	ELINCS	NLP	PICCS	ENCS	AICS	IECSC	KECL
Water	X	X	-	231-791-2	-		X	-	X	X	X
Formaldehyde	X	X	-	200-001-8	-		X	X	X	X	X
Sodium acetate	X	X	-	204-823-8	-		X	X	X	X	X
Methyl alcohol	X	X	-	200-659-6	-		X	X	X	X	X

Legend:
X - Listed
E - Indicates a substance that is the subject of a Section 5(e) Consent order under TSCA.
F - Indicates a substance that is the subject of a Section 5(f) Rule under TSCA.
N - Indicates a polymeric substance containing no free-radical initiator in its inventory name but is considered to cover the designated polymer made with any free-radical initiator regardless of the amount used.
P - Indicates a commenced PMN substance
R - Indicates a substance that is the subject of a Section 6 risk management rule under TSCA.
S - Indicates a substance that is identified in a proposed or final Significant New Use Rule
T - Indicates a substance that is the subject of a Section 4 test rule under TSCA.
XU - Indicates a substance exempt from reporting under the Inventory Update Rule, i.e. Partial Updating of the TSCA Inventory Data Base Production and Site Reports (40 CFR 710(B).
Y1 - Indicates an exempt polymer that has a number-average molecular weight of 1,000 or greater.
Y2 - Indicates an exempt polymer that is a polyester and is made only from reactants included in a specified list of low concern reactants that comprises one of the eligibility criteria for the exemption rule.

U.S. Federal Regulations

TSCA 12(b) Not applicable

SARA 313

Component	CAS-No	Weight %	SARA 313 - Threshold Values %
Formaldehyde	50-00-0	3.9 - 4.0	0.1
Methyl alcohol	67-56-1	2	1.0

SARA 311/312 Hazardous Categorization

Acute Health Hazard	Yes
Chronic Health Hazard	Yes
Fire Hazard	Yes
Sudden Release of Pressure Hazard	No
Reactive Hazard	No

Clean Water Act

Component	CWA - Hazardous Substances	CWA - Reportable Quantities	CWA - Toxic Pollutants	CWA - Priority Pollutants
Formaldehyde	X	100 lb	-	-

Clean Air Act

Component	HAPS Data	Class 1 Ozone Depletors	Class 2 Ozone Depletors
Formaldehyde	X		-
Methyl alcohol	X		-

OSHA Occupational Safety and Health Administration
Not applicable

Component	Specifically Regulated Chemicals	Highly Hazardous Chemicals
Formaldehyde	2 ppm STEL 0.5 ppm Action Level 0.75 ppm TWA	TQ: 1000 lb

CERCLA
This material, as supplied, contains one or more substances regulated as a hazardous substance under the Comprehensive Environmental Response Compensation and Liability Act (CERCLA) (40 CFR 302)

Component	Hazardous Substances RQs	CERCLA EHS RQs
Formaldehyde	100 lb	100 lb
Methyl alcohol	5000 lb	-

California Proposition 65 This product contains the following Proposition 65 chemicals:

Component	CAS-No	California Prop. 65	Prop 65 NSRL	Category
Formaldehyde	50-00-0	Carcinogen	40 µg/day	Carcinogen
Methyl alcohol	67-56-1	Developmental	-	Developmental

State Right-to-Know

Component	Massachusetts	New Jersey	Pennsylvania	Illinois	Rhode Island
Water	-	-	X	-	-
Formaldehyde	X	X	X	X	X
Methyl alcohol	X	X	X	X	X

U.S. Department of Transportation

Reportable Quantity (RQ):	Y
DOT Marine Pollutant	N
DOT Severe Marine Pollutant	N

U.S. Department of Homeland Security
This product contains the following DHS chemicals:

Component	DHS Chemical Facility Anti-Terrorism Standard
Formaldehyde	11250 lb STQ (solution)

Other International Regulations

Mexico - Grade Slight risk, Grade 1

Canada
This product has been classified in accordance with the hazard criteria of the Controlled Products Regulations (CPR) and the MSDS contains all the information required by the CPR

WHMIS Hazard Class
B3 Combustible liquid
E Corrosive material
D2A Very toxic materials

16. Other information

Prepared By
Regulatory Affairs
Thermo Fisher Scientific
Email: EMSDS.RA@thermofisher.com

Creation Date 26-Sep-2009
Revision Date 11-Mar-2015
Print Date 11-Mar-2015
Revision Summary This document has been updated to comply with the US OSHA HazCom 2012 Standard replacing the current legislation under 29 CFR 1910.1200 to align with the Globally Harmonized System of Classification and Labeling of Chemicals (GHS)

Disclaimer
The information provided on this Safety Data Sheet is correct to the best of our knowledge, information and belief at the date of its publication. The information given is designed only as a guide for safe handling, use, processing, storage, transportation, disposal and release and is not to be considered as a warranty or quality specification. The information relates only to the specific material designated and may not be valid for such material used in combination with any other material or in any process, unless specified in the text.

End of SDS

Fisher Scientific

Part of Thermo Fisher Scientific

SAFETY DATA SHEET

Revision Date 11-Mar-2015 **Revision Number** 1

1. Identification

Product Name **Rose Bengal Disodium Salt**

Cat No. : **R323-25**

Synonyms 2,4,5,7-Tetraiodo-3`,4`.5`,6`-Tetrachlorofluorescein, CI 45440; Rose Bengal Sodium

Recommended Use Laboratory chemicals.

Uses advised against No Information available

Details of the supplier of the safety data sheet

Company
Fisher Scientific
One Reagent Lane
Fair Lawn, NJ 07410
Tel: (201) 796-7100

Emergency Telephone Number
CHEMTREC®, Inside the USA: 800-424-9300
CHEMTREC®, Outside the USA: 001-703-527-3887

2. Hazard(s) identification

Classification
This chemical is considered hazardous by the 2012 OSHA Hazard Communication Standard (29 CFR 1910.1200)

Serious Eye Damage/Eye Irritation	Category 2

Label Elements

Signal Word
Warning

Hazard Statements
Causes serious eye irritation

Precautionary Statements
Prevention
Wash face, hands and any exposed skin thoroughly after handling
Wear eye/face protection
Eyes

IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing
If eye irritation persists: Get medical advice/attention

Hazards not otherwise classified (HNOC)

None identified

3. Composition / information on ingredients

Component	CAS-No	Weight %
Spiro[isobenzofuran-1(3H),9'-[9H]xanthen]-3-one, 4,5,6,7-tetrachloro-3',6'-dihydroxy-2',4',5',7'-tetraiodo-, disodium salt	632-69-9	~ 100

4. First-aid measures

Eye Contact Rinse immediately with plenty of water, also under the eyelids, for at least 15 minutes.

Skin Contact Wash off immediately with plenty of water for at least 15 minutes.

Inhalation Move to fresh air.

Ingestion Do not induce vomiting.

Most important symptoms/effects No information available.
Notes to Physician Treat symptomatically

5. Fire-fighting measures

Unsuitable Extinguishing Media No information available

Flash Point
Method - No information available

Autoignition Temperature No information available
Explosion Limits
Upper No data available
Lower No data available
Sensitivity to Mechanical Impact No information available
Sensitivity to Static Discharge No information available

Specific Hazards Arising from the Chemical
Keep product and empty container away from heat and sources of ignition.

Hazardous Combustion Products
None known
Protective Equipment and Precautions for Firefighters
As in any fire, wear self-contained breathing apparatus pressure-demand, MSHA/NIOSH (approved or equivalent) and full protective gear.

NFPA

Health	Flammability	Instability	Physical hazards
2	0	0	N/A

6. Accidental release measures

Personal Precautions Ensure adequate ventilation. Use personal protective equipment.
Environmental Precautions See Section 12 for additional ecological information.

Methods for Containment and Clean Up No information available.

7. Handling and storage

Handling Ensure adequate ventilation.

Storage Keep containers tightly closed in a dry, cool and well-ventilated place.

8. Exposure controls / personal protection

Exposure Guidelines This product does not contain any hazardous materials with occupational exposure limits established by the region specific regulatory bodies.

Engineering Measures Ensure adequate ventilation, especially in confined areas.

Personal Protective Equipment

Eye/face Protection Wear appropriate protective eyeglasses or chemical safety goggles as described by OSHA's eye and face protection regulations in 29 CFR 1910.133 or European Standard EN166.

Skin and body protection Wear appropriate protective gloves and clothing to prevent skin exposure.

Respiratory Protection Follow the OSHA respirator regulations found in 29 CFR 1910.134 or European Standard EN 149. Use a NIOSH/MSHA or European Standard EN 149 approved respirator if exposure limits are exceeded or if irritation or other symptoms are experienced.

Hygiene Measures Handle in accordance with good industrial hygiene and safety practice.

9. Physical and chemical properties

Physical State	Solid
Appearance	Light red
Odor	Odorless
Odor Threshold	No information available
pH	
Melting Point/Range	No data available
Boiling Point/Range	
Flash Point	
Evaporation Rate	negligible
Flammability (solid,gas)	No information available
Flammability or explosive limits	
Upper	No data available
Lower	No data available
Vapor Pressure	negligible
Vapor Density	No information available
Relative Density	No information available
Solubility	Soluble in water
Partition coefficient; n-octanol/water	No data available
Autoignition Temperature	No information available
Decomposition Temperature	No information available
Viscosity	No information available
Molecular Formula	C20H4Cl4I4O5.2Na
Molecular Weight	1019.4346

10. Stability and reactivity

Reactive Hazard None known, based on information available

Stability Stable under normal conditions.

Conditions to Avoid Incompatible products.

Incompatible Materials Strong oxidizing agents

Hazardous Decomposition Products None under normal use conditions

Hazardous Polymerization Hazardous polymerization does not occur.

Hazardous Reactions None under normal processing.

11. Toxicological information

Acute Toxicity

Component Information
Toxicologically Synergistic Products No information available

Delayed and immediate effects as well as chronic effects from short and long-term exposure

Irritation No information available

Sensitization No information available

Carcinogenicity The table below indicates whether each agency has listed any ingredient as a carcinogen.

Component	CAS-No	IARC	NTP	ACGIH	OSHA	Mexico
Spiro[isobenzofuran-1(3H),9'-[9H]xanthen]-3-one, 4,5,6,7-tetrachloro-3',6'-dihydroxy-2',4',5',7'-tetraiodo-, disodium salt	632-69-9	Not listed	Not listed	Not listed	Not listed	Not listed

Mutagenic Effects No information available

Reproductive Effects No information available.

Developmental Effects No information available.

Teratogenicity No information available.

STOT - single exposure None known
STOT - repeated exposure None known

Aspiration hazard No information available

Symptoms / effects,both acute and delayed No information available
Endocrine Disruptor Information No information available

Other Adverse Effects The toxicological properties have not been fully investigated.

12. Ecological information

Ecotoxicity
Do not empty into drains.

Persistence and Degradability No information available
Bioaccumulation/ Accumulation No information available.

Mobility No information available.

13. Disposal considerations

Waste Disposal Methods Chemical waste generators must determine whether a discarded chemical is classified as a hazardous waste. Chemical waste generators must also consult local, regional, and national hazardous waste regulations to ensure complete and accurate classification.

14. Transport information

DOT Not regulated
TDG Not regulated
IATA Not regulated
IMDG/IMO Not regulated

15. Regulatory information

International Inventories

Component	TSCA	DSL	NDSL	EINECS	ELINCS	NLP	PICCS	ENCS	AICS	IECSC	KECL
Spiro[isobenzofuran-1(3H),9'-[9H]xanthen]-3-one, 4,5,6,7-tetrachloro-3',6'-dihydroxy-2',4',5',7'-tetraiodo-, disodium salt	X	X	-	211-183-3	-		X	X	X	X	X

Legend:
X - Listed
E - Indicates a substance that is the subject of a Section 5(e) Consent order under TSCA.
F - Indicates a substance that is the subject of a Section 5(f) Rule under TSCA.
N - Indicates a polymeric substance containing no free-radical initiator in its inventory name but is considered to cover the designated polymer made with any free-radical initiator regardless of the amount used.
P - Indicates a commenced PMN substance
R - Indicates a substance that is the subject of a Section 6 risk management rule under TSCA.
S - Indicates a substance that is identified in a proposed or final Significant New Use Rule
T - Indicates a substance that is the subject of a Section 4 test rule under TSCA.
XU - Indicates a substance exempt from reporting under the Inventory Update Rule, i.e. Partial Updating of the TSCA Inventory Data Base Production and Site Reports (40 CFR 710(B).
Y1 - Indicates an exempt polymer that has a number-average molecular weight of 1,000 or greater.
Y2 - Indicates an exempt polymer that is a polyester and is made only from reactants included in a specified list of low concern reactants that comprises one of the eligibility criteria for the exemption rule.

U.S. Federal Regulations

TSCA 12(b) Not applicable

SARA 313 Not applicable

SARA 311/312 Hazardous Categorization

Acute Health Hazard	Yes
Chronic Health Hazard	No
Fire Hazard	No
Sudden Release of Pressure Hazard	No
Reactive Hazard	No

Clean Water Act Not applicable

Clean Air Act Not applicable

OSHA Occupational Safety and Health Administration
Not applicable

CERCLA
Not applicable

California Proposition 65 This product does not contain any Proposition 65 chemicals

State Right-to-Know Not applicable

U.S. Department of Transportation

Reportable Quantity (RQ):	N
DOT Marine Pollutant	N
DOT Severe Marine Pollutant	N

U.S. Department of Homeland Security
This product does not contain any DHS chemicals.

Other International Regulations

Mexico - Grade No information available

Canada
This product has been classified in accordance with the hazard criteria of the Controlled Products Regulations (CPR) and the MSDS contains all the information required by the CPR

WHMIS Hazard Class D2B Toxic materials

16. Other information

Prepared By
Regulatory Affairs
Thermo Fisher Scientific
Email: EMSDS.RA@thermofisher.com

Revision Date 11-Mar-2015
Print Date 11-Mar-2015
Revision Summary This document has been updated to comply with the US OSHA HazCom 2012 Standard replacing the current legislation under 29 CFR 1910.1200 to align with the Globally Harmonized System of Classification and Labeling of Chemicals (GHS)

Disclaimer
The information provided on this Safety Data Sheet is correct to the best of our knowledge, information and belief at the date of its publication. The information given is designed only as a guide for safe handling, use, processing, storage, transportation, disposal and release and is not to be considered as a warranty or quality specification. The information relates only to the specific material designated and may not be valid for such material used in combination with any other material or in any process, unless specified in the text.

End of SDS

APPENDIX 5

Job Hazard Analysis

Appendix 2

ACTIVITY HAZARD ANALYSIS

ACTIVITY: **EXELON NUCLEAR'S PEACH BOTTOM ATOMIC POWER STATION**
Entrainment Characterization and Impingement Mortality Studies

ANALYZED BY/DATE: **Richard M. Kling** ***21 March 2016***

PRINCIPAL STEPS	POTENTIAL SAFETY/HEALTH HAZARDS	RECOMMENDED CONTROLS
Boating	Discharge Pond	Turbulent environment as such while working in discharge pond the motor will be used to maintain position (no anchoring) for work activities. No more than three people (including captain Bob Scott) to be onboard GE boat, no inflatable PFDs.
	Capsizing	Stay with boat; climb in if possible; use air horn to signal for help in deep water; walk to shore and call for help if shallow water (<5-ft deep).
	Communications	There is only one designated boat captain/operator. The boat captain is responsible for the safety of all on-board personnel. Always have at least one, preferably two or more means of communications on-board at all times (radios, cell phones, walkie talkies).
	Fire onboard	No lighted materials (cigarettes, candles, etc.) are allowed on board, but should a fire start, use fire extinguisher and head immediately to shore; call for assistance from home office. If captain orders, abandon ship.
	First Aid- Injured or Sick Crew Member	At least one crew member should be First Aid and CPR certified. Assist injured or sick crew member to shore. If necessary, immediately notify control room (x3911/4911).
	Flammables	Store fuel in proper cans; ensure all caps and hoses are in proper working order; use pouring spout or funnel on fuel can to minimize gas spillage; and (if applicable) use proper fuel/oil mixture rated for unit. When refueling gas cans, remove from vehicle and keep fueling nozzle in contact with can.
	Lifting and Strain	Use proper lifting technique when launching and loading boat. Get assistance to move heavy items.
	Man Over-board	Maintain safe operating speed; stay seated while boat is in motion; wear PFDs at all times; if all else fails- Yell "Man Over-board", throw out safety line and flotation cushion; and retrieve crew member. One person on shore will be dedicated to throwable device. Immediately call for assistance from home office or emergency rescue service, whichever is applicable.
	Motor Breakdown/Adrift	Throw out anchor; ascertain problem; repair if possible; if not, use oars/paddles to return to shore. Call for assistance from home office.

	Sinking	Always maintain safe speed; if all else fails- Head immediately to shore; activate bilge pump; try to plug hole; call for assistance from home office.

	Standing in boat	While working from the boat, standing may be necessary, but the captain will ensure that all crew members are sitting in a safe position when underway. Extreme care must be taken at all times while working along the sides of the boat. Sitting on gunnels while boat is in full operation is prohibited.
	Loading/Embarking/ Disembarking	Watch for pinch points. Ensure that all boat lights are functioning properly. Make sure boat is thoroughly secured to docking area before loading or climbing aboard.
Entrainment and Impingement Sample Collection	Biological	Keep work areas clean. Open any doors or containers slowly to check for bees/hives. If bees are present, back away and retrieve bee killer spray. Spray away from face and downwind (if possible). Wash face and hands after any sampling. Do not drink water from hoses.
	Chemical	Read SDS for Formalin and Rose Bengal dye before using. The primary routes of exposure for Formalin and Rose Bengal dye are skin contact and inhalation. Proper PPE including gloves and eye protection should be worn during use of these chemicals. Both chemicals should be used in a well ventilated area, preferably outside.
	Electrical Safety	Make sure that your hands and equipment are dry and that you are electrically "safe" before working with any electric (refer to CHSP Electrical Training Program). No Normandeau employee shall perform work on electrically energized equipment.
	Fall Hazard	Before climbing stairs or fixed ladders to sample, ensure that all steps, rungs, and railings are in safe working condition. No jumping on/from or horseplay while working from the platforms. In the event that a stair, rung, or railing breaks, report damage to Normandeau PM or TM immediately. A life vest or USCG-approved flotation coat must be worn within 10-feet of any shoreline, bulkhead, or bridge.
	First Aid- Injured or Sick Crew Member	Immediately notify control room (x3911/4911) if on-site or if off-site EMS (911) and if necessary wait for them to arrive and remove the sick or injured person
	Flammables	Store all flammable liquids in proper cans/receptacle; ensure all caps and spouts are in proper working order; and use pouring spout or funnel to minimize spillage. When refilling containers or cans, remove from vehicle and always use secondary containment. Keep a fire extinguisher available at all times

	Flying Objects and Overhead Obstructions	Hard hats, safety glasses, and work gloves are required at all times while working on-site. Be aware of where you are and what you are doing (attention to detail) at all times.
	Lifting and Strain	Use proper lifting technique when carrying and installing equipment; carrying sample containers; etc. Get assistance to move heavy items.
	Loud Noise Areas	Use proper hearing protection when entering designated/required areas. Obey all posted facility safety signs.
	Pinch Points	When installing or repairing equipment, working with valves, etc. be aware of moving parts and any pinch points that may be involved.
	Slips, Trips, and Falls	Be aware of wet/icy conditions and physical hazards when working on boat decks and climbing stairs or sample platforms. Wear appropriate footwear (work boats) for working conditions.
Driving	Flammables	When refueling vehicle, keep fueling nozzle in contact with fill vent. No smoking and turn off engine. Transport all flammables and chemicals in secure exterior containers.
	Traffic	Operator must have a valid Driver's License; obey all traffic laws and regulations; and maintain posted speed at all times. Seat belts must be worn when operating vehicle. In the event of a motor vehicle accident, notify local law enforcement agency; fill out company traffic accident form; and call home office for assistance (if necessary).
	Weather conditions	In the event of severe weather conditions, ascertain whether or not it is safe to drive. Listen to radio for weather and traffic conditions. Use appropriate vehicle for conditions, i.e. 4-wheel drive.
System Installation/Maintenance	Chemical	Read safety precautions and/or SDS for any insecticides, degreasers, plumbing glues and cleaners, etc. before using.
	Fall Hazard	Before climbing stairs or fixed ladders to sample stations, ensure that all steps, rungs, and railings are in safe working condition. No jumping on/from or horseplay while working on the platforms. In the event that a stair, rung, or railing breaks, report damage to PM immediately. A life vest or USCG-approved flotation coat must be worn within 10-feet of any shoreline, bulkhead, or bridge.
	Electrical Safety	No Normandeau employee shall perform work on electrically energized equipment.

	Flammables	Store fuel in proper cans; ensure all caps and spouts are in proper working order; use pouring spout or funnel on fuel can to minimize gas spillage. When refueling gas cans, remove from vehicle and keep fueling nozzle in contact with can. Always use secondary containment.
	Flying Objects and Overhead Obstructions	Hard hats, safety glasses, and work gloves are required at all times while working on-site. Be aware of where you are and what you are doing (attention to detail) at all times.
	Lifting and Strain	Use proper lifting technique when lifting equipment, and samples, etc. If necessary get assistance to move heavier items.
	Loud Noise Areas	Use proper hearing protection when working in designated/required areas. Obey all posted facility safety signs.
	Slips, Trips, and Falls	Be aware of wet/icy conditions and physical hazards when working on-site.
	Small Hand Tool Use	Be aware of pinch points and electrical wires. Know which tools to use for each task. Wear safety glasses and work gloves at all times. Ensure that all electric cords are in proper operating condition with intact ground plug and no frayed wires. Do not use electrical tools in wet/moist conditions without a ground fault interrupter.
	Welding and Burning	No welding or burning is authorized.
IP Sorting and ID	Chemicals	Follow all project safety requirements and Corporate Health and Safety Plan's "Biological Laboratory Safety Program".
EQUIPMENT TO BE USED	**INSPECTION REQUIREMENTS**	**TRAINING REQUIREMENTS**
Water Pump	Turn on pump breaker; check all pump and pipe seals for leaks before each use.	Qualified Mechanic (major repairs)
Flow Meters	Inspect before each use. Replace batteries as necessary	OJT
Cell Phone	Activate and ensure unit is working properly. Recharge as necessary.	OJT
Vehicles	Yearly Inspection and preventative maintenance	Qualified Mechanic

APPENDIX 6

Exelon Nuclear Industrial Safety Pocket Guide 2016

Invalid as of 1/1/2017 - **REDACTED**

APPENDIX 7

Statement of Acknowledgement

NORMANDEAU ASSOCIATES, INC.

SITE-SPECIFIC HEALTH AND SAFETY PLAN
FOR

EXELON'S
PEACH BOTTOM ATOMIC POWER STATION
ENTRAINMENT CHARACTERIZATION AND IMPINGEMENT MORTALITY STUDIES
March 21, 2016

STATEMENT OF ACKNOWLEDGEMENT

If you understand all aspects of this document please sign your full name and date below and return this page to the Project Manager.

Plan Prepared By: Richard M. Kling, Jr._____

_____ _____

Employee's Signature/Date Health and Safety Coordinator or Project Manager/Date

ENCLOSURE 05

AECOM. 2019. 40 CFR 122.21(r)(10) NPDES Application Requirements for Facilities with Cooling Water Intake Structures, Exelon Generation Company LLC, Peach Bottom Atomic Power Station, Delta PA. January 2019. 155 p.

40 CFR § 122.21(r)(10) NPDES APPLICATION REQUIREMENTS FOR FACILITIES WITH COOLING WATER INTAKE STRUCTURES

Exelon Generation Company, LLC

Peach Bottom Atomic Power Station

Delta, PA

Prepared By:

AECOM Conshohocken
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January 2019

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Appendices

Appendix A Conceptual Layout Figures

Appendix B Social Costs of Purchasing and Installing Entrainment Reduction Technologies: Peach Bottom Atomic Power Station

Appendix C Bathymetry Data

Appendix D Potential Alternative Cooling Water Sources

§ 122.21(r)(10) COMPREHENSIVE TECHNICAL FEASIBILITY AND COST EVALUATION STUDY

The Rule at § 122.21(r)(10) requires that Exelon Generation Company, LLC (Exelon) provides the results of a comprehensive technical feasibility and cost evaluation study for Peach Bottom Atomic Power Station (PBAPS). The specific regulatory requirements for this information are:

(10) Comprehensive Technical Feasibility and Cost Evaluation Study. The owner or operator of an existing facility that withdraws greater than 125 mgd AIF must develop for submission to the Director an engineering study of the technical feasibility and incremental costs of candidate entrainment control technologies. In addition, the study must include the following:

> *(i) Technical Feasibility. An evaluation of the technical feasibility of closed-cycle recirculating systems as defined at 40 CFR 125.92(c), fine mesh screens with a mesh size of 2 millimeters or smaller, and water reuse or alternate sources of cooling water. In addition, this study must include:*
>
> > *(A) A description of all technologies and operational measures considered (including alternative designs of closed-cycle recirculating systems such as natural draft cooling towers, mechanical draft cooling towers, hybrid designs, and compact or multi-cell arrangements;*
> >
> > *(B) A discussion of land availability, including an evaluation of adjacent land and acres potentially available due to generating unit retirement, and potential for repurposing of areas devoted to ponds, coal piles, rail yards, transmission yards, and parking lots;*
> >
> > *(C) A discussion of available sources of process water, grey water, waste water, reclaimed water, or other waters of appropriate quantity and quality for use as some or all of the cooling water needs of the facility; and*
> >
> > *(D) Documentation of factors other than cost that may make a candidate technology impractical or infeasible for further evaluation.*
>
> *(ii) Other entrainment control technologies. An evaluation of additional technologies for reducing entrainment may be required by the Director.*
>
> *(iii) Cost evaluations. The study must include engineering cost estimates of all technologies considered in paragraphs (r)(10)(i) and (ii) of this section. Facility costs must also be adjusted to estimate social costs. All costs must be presented as the net present value (NPV) and the corresponding annual value. Costs must be clearly labeled as compliance costs or social costs. The applicant must separately discuss facility level compliance costs and social costs, and provide documentation as follows:*
>
> > *(A) Compliance costs are calculated as after-tax, while social costs are calculated as pre-tax. Compliance costs include the facility's administrative costs, including costs of permit application, while the social cost adjustment includes the Director's administrative costs. Any outages, downtime, or other impacts to facility net revenue, are included in compliance costs, while only that portion of lost net revenue that does not accrue to other producers can be included in social costs. Social costs must also be discounted using social discount rates of 3 percent and 7 percent. Assumptions regarding depreciation schedules, tax rates, interest rates, discount rates and related assumptions must be identified;*

(B) Costs and explanation of any additional facility modifications necessary to support construction and operation of technologies considered in paragraphs (r)(10)(i) and (ii) of this section, including but not limited to relocation of existing buildings or equipment, reinforcement or upgrading of existing equipment, and additional construction and operating permits. Assumptions regarding depreciation schedules, interest rates, discount rates, useful life of the technology considered, and any related assumptions must be identified; and

(C) Costs and explanation for addressing any non-water quality environmental and other impacts identified in paragraph (r)(12) of this section. The cost evaluation must include a discussion of all reasonable attempts to mitigate each of these impacts.

This report provides information required at § 122.21(r)(10) regarding an engineering study of the technical feasibility and incremental costs of candidate entrainment control technologies, including a closed-cycle recirculating system (CCRS) and installation of fine-mesh screens with a mesh size of 2 millimeters (mm) or smaller to reduce entrainment. The report also provides a discussion on available sources of process water, grey water, wastewater, reclaimed water, or other waters for cooling at PBAPS. The alternatives evaluated may also result in an overall reduction in impingement mortality, which is discussed. An engineering Class 4 evaluation and cost estimate is provided for this assessment of the applicable technologies. According to American Society of Testing and Materials (ASTM) Standard E-2516-06, Class 4 includes a project design of approximately 1 to 15% for a 'Concept Study or Feasibility,' which is typically completed to evaluate overall feasibility and produce costs with an expected accuracy range of (-15% to -30%) Low and (+20% to +50%) High (ASTM 2006).

Candidate entrainment control technologies were selected based on station-specific information, operating data, and previous studies and reports. This and other information were used as the basis to develop conceptual design for the construction and operation of selected technologies at PBAPS, and the conceptual design, in turn, was used to establish costs to implement the technologies. Technologies to reduce impingement mortality and entrainment at PBAPS were previously evaluated by Alden Research Laboratory, Inc. (Alden) and the Electric Power Research Institute (EPRI) in 2003, and by URS Corporation in 2008 (URS Corporation 2008a). The results of that evaluation were incorporated into this assessment, and updated based on the 2014 Existing Facility Rule requirements and updated facility conditions. This study includes an evaluation of site constraints, operability, and interferences, along with potential permitting issues and requirements. The study provides a range of cost estimates to retrofit PBAPS with each respective candidate technology, including an evaluation of the effects on plant efficiency and capacity, if closed-cycle cooling were implemented.

The report organization follows the evaluation methodology for each entrainment reduction alternative and includes the following:

- Description of existing plant configuration, site characteristics, and existing cooling system
- Closed-cycle cooling evaluation, including:
    - Summary of potential technologies evaluated and rationale for design selection of mechanical-draft wet cooling towers
    - Conceptual design of mechanical-draft cooling towers
    - Discussion of land availability and tie-in to existing cooling system
    - Description of other factors affecting feasibility of retrofit
    - Evaluation of plant efficiency, capacity, and energy losses
    - Engineering costs

    - Potential implementation schedule
    - Summary and conclusions regarding the closed-cycle cooling alternative
- Fine-mesh alternative evaluation, including:
    - Initial screening of potential candidate entrainment mortality reduction technologies, and rationale for design selection of 2 mm wedgewire screens and fine-mesh baskets / panels and a fish return
    - Discussion on engineering cost methodology
    - Description of technology
    - Discussion of technology studies and use
    - Conceptual design of each technology
    - Engineering costs
    - Potential implementation schedule
    - Summary and conclusions regarding the fine-mesh alternative
- Discussion of potential alternative cooling water sources
- References cited in the report

1.0 STATION BACKGROUND

PBAPS is a two-unit nuclear-fueled power generation facility that produces approximately 2,600 megawatts-electric (MWe). The station is located in southeastern Pennsylvania, approximately 50 miles southeast of Harrisburg in Peach Bottom Township, York County, Pennsylvania, and is situated on the west bank of the Conowingo Reservoir which is fed by the Susquehanna River. A detailed description of the Conowingo Reservoir hydrology and biology are described in the § 122.21(r)(2) and (r)(4) reports, respectively. The site is bounded by forest and agricultural land to the north, south, and west. To the east of the property is the Conowingo Reservoir. **Figure 1-1** shows an aerial view of the site, its surroundings, and the approximate plant boundary (Google Earth 2017a).

Figure 1-1: PBAPS Plant Boundary and Surrounding Area

PBAPS consists of two power generating units that supply electricity to the electrical grid system and one closed power generating unit. Units 2 and 3 began commercial operation in June 1974 and December 1974, respectively. Unit 1 was a 40 MWe experimental high temperature helium-cooled and graphite-moderated reactor (HTGR) and operated for eight years (1967-1974). This report evaluates the technical feasibility and costs for entrainment reduction technologies for non-contact cooling water used for Units 2 and 3.

Information on existing unit type, gross generating capacity, and year on-line is provided in **Table 1-1.**

Table 1-1: PBAPS's Units' Description

Unit	Type	Approximate Gross Capacity, MWe[1]	Year-on-line
2	Steam Cycle	1,300	1974
3	Steam Cycle	1,300	1974

Both units are steam-cycle units operating with once-through cooling. They have a total gross generating capacity of approximately 2,600 MWe (PSEG 2016, Exelon 2015). Unit capacity factors for both units in recent years are shown in **Table 1-2** (Exelon 2017a).

Table 1-2: Unit Capacity Factors

Unit	Unit Capacity Factor					
	2012	2013	2014	2015	2016	2012-2016 Average
2	85.8%	98.5%	84.8%	95.8%	91.9%	91.4%
3	99.0%	85.3%	99.1%	89.6%	99.8%	94.6%

1.1 SITE CHARACTERISTICS

The meteorology and water characteristics within the Conowingo Reservoir in the area of PBAPS are important factors in the design of the overall performance of the cooling towers. More specifically, the temperature of the Conowingo Reservoir water, ambient dry bulb temperature (air temperature), ambient wet bulb temperature, and wind direction are of interest. The temperature range of inlet water, ambient dry bulb temperatures, and ambient wet bulb temperatures for the facility are provided in **Table 1-3** (WRCC 2017). According to wind data collected from Station No. 14751 – Harrisburg/Capital City Airport, the prevailing wind direction is from the west-northwest direction (WRCC 2017). These data were considered during the design and placement of the towers.

Table 1-3: PBAPS Meteorological and Susquehanna River Data

Parameter	Temperature (°F)		
	Annual Minimum	Annual Maximum	Annual Average
Inlet Water (Conowingo Reservoir)[2]	32.2	89	60.4
Ambient Dry Bulb[3]	24.2	88.9	56.4
Ambient Wet Bulb[4]	20.0	88.6	51.4

1.2 COOLING SYSTEM INFORMATION

Units 2 and 3 currently operate with once-through cooling with water drawn from the Conowingo Reservoir. **Figure 1-2** shows the general arrangement of the intake structure and discharge locations for PBAPS (Google Earth 2017a, Exelon 2014).

The cooling water intake structure (CWIS) provides a continuous supply of water from the Conowingo Reservoir to Units 2 and 3. The outer screenhouse structure is approximately 480 feet (ft.) long and 32 ft.

[1] Per Exelon (2017). Actual generation for 2016 is provided in **Figure 1-5** and **Figure 1-6**.
[2] Minimum, maximum, and annual average inlet water temperatures are based on hourly temperature readings for the period of January 1, 2016 through December 31, 2016.
[3] Dry bulb minimum, maximum and average temperatures are based on monthly average temperatures for 2016.
[4] Ambient wet bulb temperatures were calculated from 2016 meteorological data using the monthly averages for relative humidity (WRRC 2017). (The maximum wet bulb temperature observed in 2016 is notably higher than the statistical 1% wet bulb temperature, which is expected to be reached or exceeded 1% of the time or 87.6 hours per year.)

high. The outer CWIS is a structural configuration that results in velocity reductions and avoids fish entrapment, and was implemented for the purpose of reducing IM. The outer CWIS was designed to minimize fish impingement during construction of the station. The original intake (in 1967), consisting of only an inner set of vertical traveling screens, three per unit (a total of six), is located at the end of the intake canal. The original standard vertical traveling screens in the inner intake circulating water bays were replaced with 3/8-inch mesh dual-flow traveling screens in the late 1990s (NAI 2005). The relatively high velocity resulting from this configuration and the absence of lateral escape routes would entrap most fish in the intake canal where they would eventually become impinged. Consequently, extensive swim speed studies of resident and anadromous fishes (over 580 tests) were initiated in June 1967 to determine the most sensitive species and the critical maximum velocity that would minimize entrapment and impingement. Based on data from these studies and experience from other facilities at that time, the outer CWIS was designed and installed with an approach velocity of 0.75 fps; the maximum velocity tolerated by most sensitive species (i.e., young white crappie).

The outer screenhouse structure occupies the water column from the surface down to the bottom of the trash racks, at an elevation of 84'-0" (Conowingo Datum). The operating floor level of the screenhouse is at elevation 116'-0" (Conowingo Datum) and is enclosed with walls and a roof. To prevent large debris and ice chunks from entering the intake, there are 29 active trash racks with ¼-inch wide by 3-inch deep steel bars spaced 3½ inches on center on the face of the outer intake structure. Divers manually clean the trash racks periodically when needed and collected debris is disposed off-site. Structures for a previous automatic raking system with a manual collection system are still in place. Twenty-four traveling water screens (12 per unit) are approximately 44 ft. inboard of the trash racks. Each screen is 10 ft. wide with a ⅜-inch square opening mesh. Debris, including fish, is removed from the screens by a high-pressure spray wash system on the ascending side of the screens to sluiceways (one per unit). The debris from the screens is collected in dumpsters at both ends of the CWIS and disposed off-site. No fish are returned from the outer screenhouse structure to the Conowingo Reservoir (URS Corporation 2008b).

Water flows through the screens of the outer intake structure, through two, three-acre intake basins (one serving each unit), and then through an inner intake structure/pump house. Within the 'inner' intake structure, there are three sets of traveling screens per unit that protect the three inner pump – circulating water pump - intakes, three in the south basin for Unit 2 and three in the north basin for Unit 3. These components supply water for once-through cooling of the main condensers and for plant services (process/equipment needs) (URS Corporation 2008a). Following the combined discharge of once-through cooling water from Units 2 and 3, heated water enters a common discharge basin prior to being discharged back to the Conowingo Reservoir through a discharge canal. Three 'helper' cooling tower blocks exist at the facility, each with dimensions of 515 ft. L x 71 ft. W x 53 ft. H, to provide cooling to the once-through cooling water that enters the discharge basin. These cooling towers are only used during warm weather months to provide a limited amount of cooling to assist the facility in complying with permit limits for discharge temperature. The facility discharge permit requires operation of the helper cooling towers during specific times and conditions:

- One cooling tower must be placed into operation on June 15 and must operate continuously through August 31, unless otherwise approved by the Regulatory Authority;
- A second cooling tower must be placed into operation within 48 hours of an average intake water temperature greater than 83°F. Once operation of the second tower commences, it must be maintained through August 31, unless permission to terminate the second tower operation is requested and approved by the Regulatory Authority; and
- A third cooling tower must be placed in operation within 48 hours of an average intake water temperature equal to or greater than 86°F. The third tower must remain in continuous operation for a minimum of seven days.

The variation in the inlet cooling water temperatures in 2016 is shown in **Figure 1-3** (Exelon 2017b). The data represent hourly temperature measurements at the Unit 2 and Unit 3 intakes for the period of January 1, 2016 through December 31, 2016.

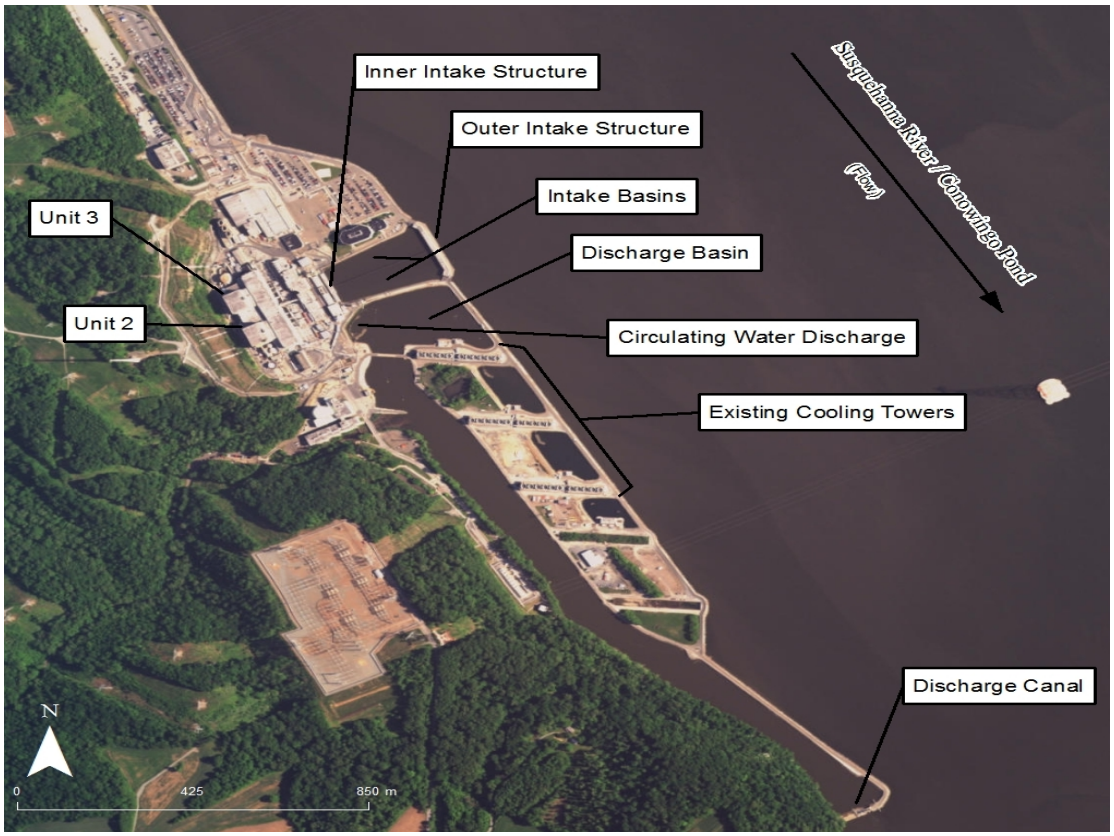


Figure 1-2: Location of Intake and Discharge Areas

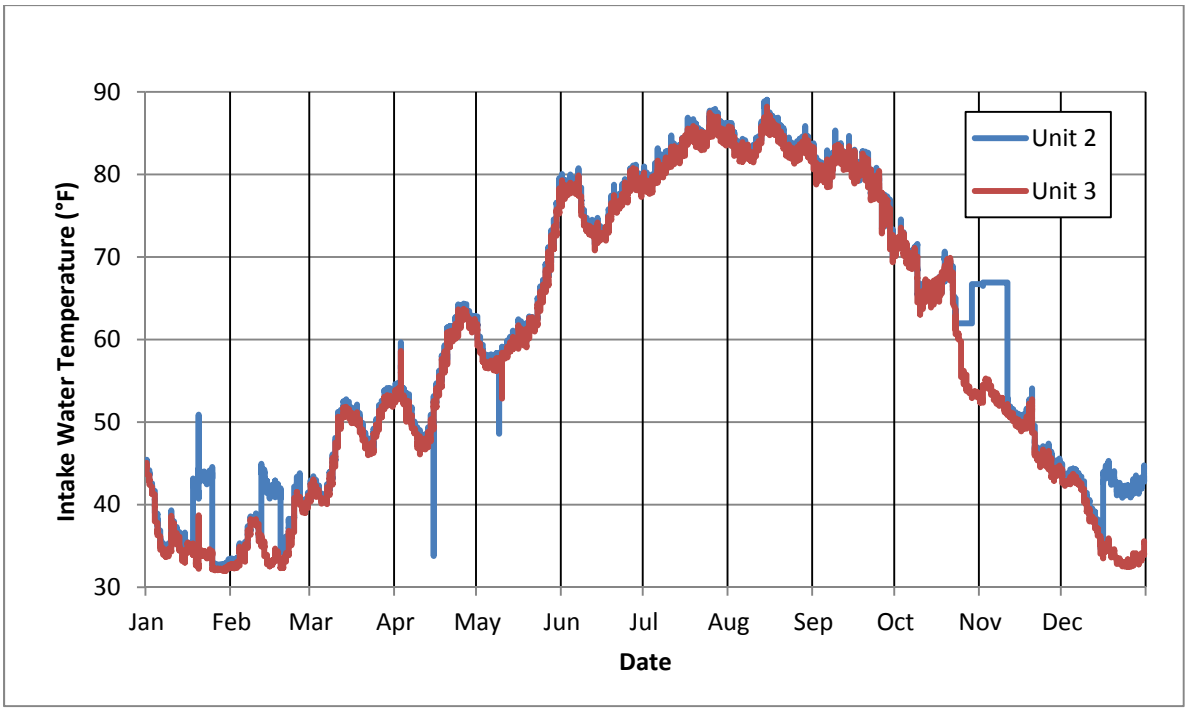


Figure 1-3: Daily Cooling Water Intake Temperatures for Units 2 and 3 in 2016

The pumps that withdraw water from the intake structure and their design flow rates are shown in **Table 1-4** (URS Corporation 2008a). Only the circulating water pumps that provide condenser cooling were included in the evaluation.

Table 1-4: PBAPS Intake Pump Design Capacities

Operation	Number of Installed Pumps	Design Flow (gpm)[5]
Condenser Cooling	6 (3 per unit)	250,000 each
Service Water	6 (2 and 1 spare per unit)	14,000 each
High Pressure Service Water	8 (4 per unit)	4,700 each
Emergency Service Water	2 (common to both units)	8, 000 each
Outer Screen Wash	3 (1 per unit and 1 common to both units)	4,400 each[6]
Inner Service Water Screen Wash	2 (1 per unit)	475 each
Fire Protection	2 (1 electric and 1 diesel driven)	2,500 each

Plant and cooling system design specifications for Units 2 and 3 are provided in **Table 1-5** (Exelon 2017b). The inlet and discharge temperatures of the condenser were used to set the design temperature range of the hypothetical cooling towers. The values in the "Cooling Water Flow" column represent the condenser cooling water design flow. The cooling tower for the retrofit evaluation was sized for the total condenser cooling water flow required for the facility.

[5] These flow capacities are based on the pump manufacturer's ratings and do not account for multiple-pump operation, head loss, pipe capacity, and other "as-built" conditions.
[6] These pumps withdraw water from the condenser discharge (not the intake).

Table 1-5: PBAPS Existing Cooling System Design Values

Unit	Gross Output (MWe)	Cooling Water Flow (gpm)	Condenser Steam Flow (lb/hr)	Condenser Heat Load (BTU/hr)	Turbine Exhaust Pressure (inHga)	Temperature (°F)			
						Inlet Water	Discharge Water	Steam Condensing Temperature	TTD
2	1,300	750,000	9,089,676	9.21E09	5.1[7]	90	114.6	134.6	20.0
3	1,300	750,000	9,089,676	9.21E09	5.1[6]	90	114.6	133.8	19.2

Notes: MWe – megawatt-electric; gpm – gallons per minute; lb/hr – pounds per hour; BTU – British thermal units; inHga – inches of mercury absolute; TTD – terminal temperature difference: saturation temperature of the extraction steam minus the 'hot' cooling water outlet temperature

1.3 PLANT OPERATING DATA

Actual operating data were evaluated and are summarized below. Unit operating data were approximated from data provided by the plant, with the inlet and discharge cooling water temperatures at hourly intervals throughout 2016. The following assumptions were made:

- Unit cooling water flow is constant at the design value (from **Table 1-5**); and
- The gross MWe output as provided by the station (Exelon 2017b).

Upon exiting the Unit 2 and 3 condensers, the heated cooling water is discharged into a discharge basin. From the discharge basin, the cooling water is either directed to the cooling towers and/or into the discharge canal, which is approximately 4,750 ft. long. The cooling water exits the discharge canal through a discharge structure, which contains one fixed opening and three openings with adjustable gates that control the flow to Conowingo Reservoir. The three gates maintain the velocity of the submerged jet discharge to between 5 and 8 feet per second (fps) to enhance mixing. The discharge structure also has a surface overflow spillway in addition to the jet discharge to the Conowingo Reservoir (Exelon 2017b). Cooling water discharge temperatures are graphically displayed in **Figure 1-4**. Discharge temperature data represent hourly temperature measurements at the Unit 2 and Unit 3 circulating water discharge in the discharge canal downstream of the helper towers for the period of January 1, 2016 through December 31, 2016.

The National Pollutant Discharge Elimination System (NPDES) Permit Number PA0009733 for PBAPS sets discharge water temperature limitations. The maximum instantaneous discharge temperature limitation is 110°F at the NPDES discharge compliance point (discharge gates) (PADEP 2014).

Condenser cooling water that is discharged from Units 2 and 3 to the discharge basin can be withdrawn directly from the discharge basin for cooling in an existing helper cooling tower ('Helper' Cooling Tower A). Further cooling of the water present in the discharge basin can be provided, as necessary, via two additional cooling towers: 'Helper' Cooling Towers B and C. 'Helper' Cooling Tower A is supplied directly by the discharge basin, while 'Helper' Cooling Towers B and C are supplied by separate 'hot' water ponds (one for each cooling tower) that are connected to the discharge basin through a series of culverts and/or pipes. Distribution of water among the hot water basins and discharge canal occurs via a series of culverts and/or pipes depending on basin level and whether the cooling tower pumps in each basin are in operation (Exelon 2014).

While the use of closed-cycle cooling would greatly reduce the volume of water and, subsequently, the total heat load discharged to the Conowingo Reservoir, this study did not model the discharge to determine if the current permitted temperature requirements would be met. It is anticipated that a CCRS would improve thermal discharges by reducing the discharge flow.

[7] The main condenser produces a maximum back pressure of 5.12 in Hga when operating at Rated Core Thermal Power with 90°F design value for circulating water inlet temperature and 65% clean tubes DBD P-S-21 Section 2.4.1.2.7. (This is a design value of the main condenser and does not represent typical operating conditions.)

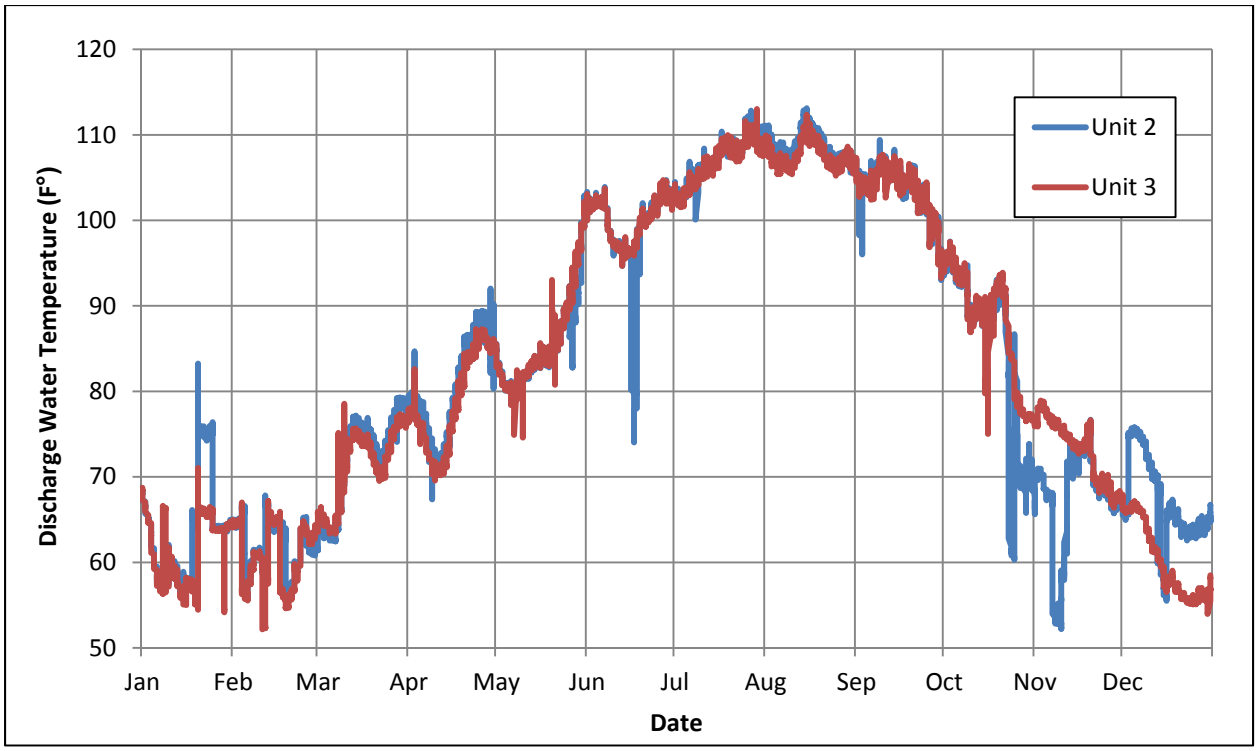


Figure 1-4: 2016 Daily Cooling Water Discharge Temperatures for Units 2 and 3

The power generation of each unit at PBAPS is dependent on the successful operation of the cooling system discussed above. The gross power output values for 2016 for Units 2 and 3 are presented in **Figure 1-5** and **Figure 1-6,** respectively (Exelon 2017b).

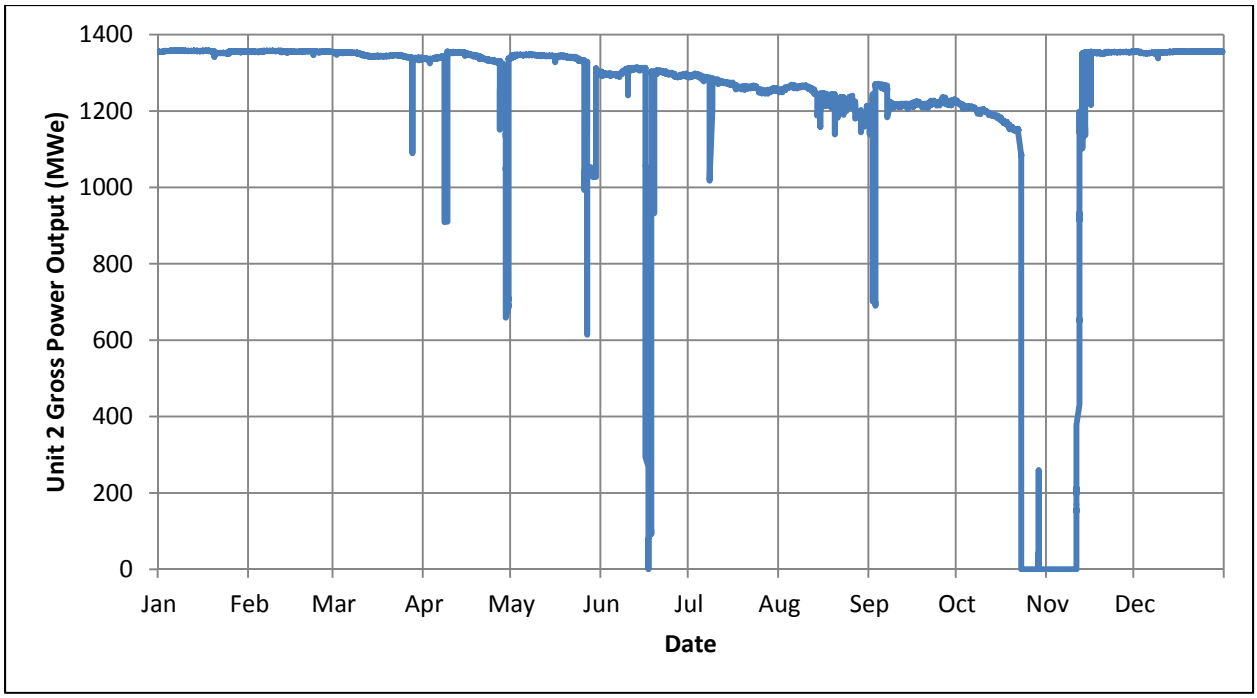


Figure 1-5: Hourly Gross Power Output for Unit 2 for 2016[8]

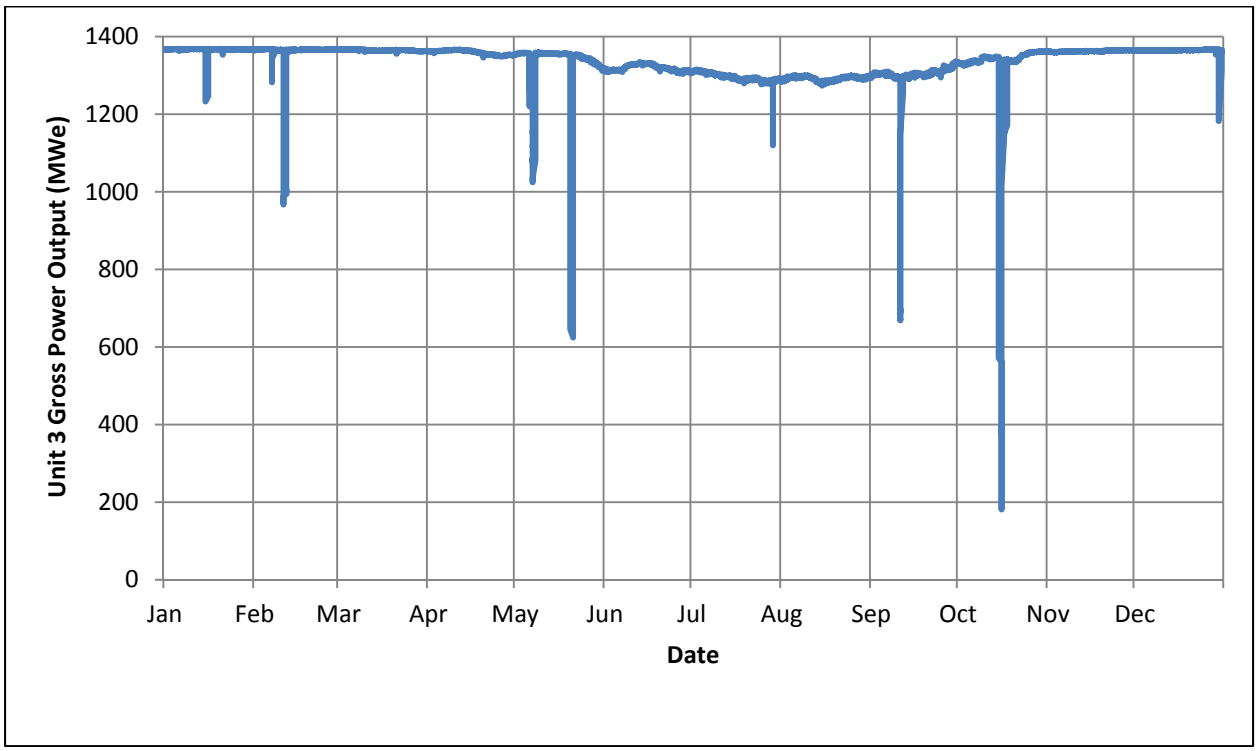


Figure 1-6: Hourly Gross Power Output for Unit 3 for 2016[9]

[8] Figure 1-5 reflects actual hourly gross power output for Unit 2 for 2016 (post-EPU)
[9] Figure 1-6 reflects actual hourly gross power output for Unit 3 for 2016 (post-EPU)

The existing condenser design and plant operating data were used to assess the overall feasibility and costs for a CCRS retrofit at PBAPS. Additional detail on the conceptual design for the closed-cycle cooling system retrofit assessment is provided in the following sections of the report.

2.0 INITIAL SCREENING OF CANDIDATE ENTRAINMENT MORTALITY REDUCTION TECHNOLOGIES

An initial screening of available entrainment mortality reduction technologies was completed to identify potential candidates that could be implemented at PBAPS. This screening started with the list of fish protection technologies evaluated by the United States Environmental Protection Agency (USEPA; 2014a) in its *Technical Development Document for the Final Section 316(b) Existing Facilities Rule* and included a CCRS retrofit option, as required at § 122.21(r)(10). Various types of CCRS were screened (**Section 2.1**), as well as three major categories of fish protection alternatives: screening technologies, offshore intakes, and 'other' technologies and operational measures (**Section 2.2**). Additionally, water reuse and alternative sources of cooling water were evaluated (**Section 5.0**).

2.1 CCRS

As noted in the Introduction, the Clean Water Act (CWA) Section 316(b) Existing Facilities Rule requires that facilities evaluate the use of a CCRS, specifically:

- Natural-draft cooling towers;
- Mechanical-draft cooling towers;
- Hybrid designs; and
- Compact or multi-cell arrangements.

A CCRS is defined at § 125.92(c) as:

> *Closed-cycle recirculating system means a system designed and properly operated using minimized make-up and blowdown flows withdrawn from a water of the United States to support contact or non-contact cooling uses within a facility, or a system designed to include certain impoundments. A closed-cycle recirculating system passes cooling water through the condenser and other components of the cooling system and reuses the water for cooling multiple times.*

and at § 125.92(c)(1):

> *Closed-cycle recirculating system includes a facility with wet, dry, or hybrid cooling towers, a system of impoundments that are not waters of the United States, or any combination thereof. A properly operated and maintained closed-cycle recirculating system withdraws new source water (make-up water) only to replenish losses that have occurred due to blowdown, drift, and evaporation. If waters of the United States are withdrawn for purposes of replenishing losses to a closed-cycle recirculating system other than those due to blowdown, drift, and evaporation from the cooling system, the Director may determine a cooling system is a closed-cycle recirculating system if the facility demonstrates to the satisfaction of the Director that make-up water withdrawals attributed specifically to the cooling portion of the cooling system have been minimized.*

This assessment of a CCRS at PBAPS is intended to evaluate whether replacing the open-cycle cooling system, which is currently used as a means of dissipating the heat rejected during the production of energy, is available and feasible to minimize makeup and blowdown flows from and to the source waterbody.

Four types of CCRS were screened for PBAPS. Based on this screening, only one of these technologies (mechanical-draft cooling towers) was identified as a potential candidate for a CCRS retrofit at PBAPS and included in the comprehensive technical feasibility and cost evaluation. The other three (natural draft cooling towers; hybrid designs; and compact or multi-cell arrangements) were dismissed from further evaluation.

The following sections of the report provide background on key closed-cycle cooling system principles and terminology, and assumptions for a hypothetical CCRS retrofit at PBAPS.

2.1.1 Closed-Cycle Cooling System and Cooling Tower Operating Principles

According to the *second law of thermodynamics*, only a portion of the heat released by nuclear fission is converted to work (production of energy), and the rest must be rejected to an energy sink at a lower temperature (Elliott et al. 1998). For once-through cooling systems, waste heat is transferred to the circulating water system through non-contact cooling in the shell-and-tube condenser and is ultimately discharged back to the source waterbody.

In a closed-cycle cooling system retrofit, a cooling tower is typically the primary heat-dissipating component used to reject waste heat. There are three primary means of rejecting waste heat in a closed-cycle retrofit system:

a. Latent heat transfer, which is associated with a phase change, such as evaporation;
b. Sensible heat transfer, which is associated with an incremental change in temperature of the air or water medium; or
c. A combination of both latent and sensible heat transfer.

For systems designed for latent heat transfer, the ambient wet-bulb temperature is the primary environmental performance-limiting factor, whereas, for systems designed for sensible heat transfer, the ambient dry-bulb temperature is the environmental performance-limiting factor (EPRI 2011c, SPX 2009). Wet bulb temperature is measured by causing air to move across a thermometer with a wet wick or "sock" on the bulb; as the moisture in the sock evaporates, the end of the bulb cools to an end point or equilibrium point. Dry bulb temperature is a measure of ambient "air" temperature using a regular thermometer. Ambient wet bulb temperature and dry bulb temperature are related according to the relative humidity, in that the wet bulb temperature will equal the dry bulb temperature when the relative humidity is 100%. More efficient evaporation can take place in areas with lower relative humidity, because the air has more capacity to take in moisture. In general, areas with higher wet bulb temperatures require larger cooling towers to achieve the same cooling as lower wet-bulb regions.

2.1.2 Cooling Tower Terminology

Many of the following key terms are unique to cooling tower design and assessment, and are used throughout this report (SPX 2009):

Ambient Wet-Bulb Temperature: The *wet-bulb temperature* of the air encompassing a cooling tower, not including any temperature contribution by the tower itself.

Approach: The difference between the cold-water temperature exiting the cooling tower and the wet-bulb temperature entering the cooling tower. (Unit: °F).

Blowdown: The water discharged from the system to control concentrations of salts and other impurities in the circulating water. (Unit: % of circulating water rate, or gpm).

Capacity: The amount of water that a cooling tower will cool through a specified *range*, at a specified *approach* and *wet-bulb temperature*. (Unit: gpm).

Cell: This is the smallest cooling tower subdivision that can function as an independent unit with regard to air and water flow. A cell is bounded with either exterior walls or partition walls.

Cold Water Temperature: The temperature of the water leaving the collection basin, exclusive of any temperature effects incurred by the addition of makeup water and/or the removal of blowdown. (Unit: °F).

Collection Basin: Vessel fabricated below or integral to the tower where water is transiently collected and directed to the sump or pump suction lines for the cooling towers.

Cycles of Concentration: This represents the number of times that total dissolved solids are concentrated in the circulating water system due to evaporation of water in the cooling towers. As pure water evaporates in the cooling towers, total dissolved solids are left behind in the closed-cycle circulating water system and increase over time. The number of times that the dissolved solids are concentrated is relative to the closed-cycle cooling system is relative to the total dissolved solids in the makeup water.

Drift: Circulating water lost from the tower as liquid droplets entrained in the exhaust air stream. (Units: % of circulating water rate or gpm).

Dry Bulb Temperature: The temperature of the entering or ambient air adjacent to the cooling tower as measured with a dry-bulb thermometer. (Unit: °F).

Evaporation: Water loss from the circulating water flow to the surrounding air stream in the cooling process. (Units: % of circulating water rate or gpm).

Fill: Sometimes referred to as 'packing,' this is the portion of the cooling tower that constitutes the primary heat transfer surface.

Fogging: This refers to the visibility and path of the effluent air stream after it exits the cooling tower. If visible and close to the ground, it is referred to as 'fog'; if elevated, it is referred to as a 'plume.'

Heat Load: The total heat to be removed from the circulating water by the cooling tower per, unit time. This is the product of the mass flow rate of the water entering the cooling tower and the cooling tower range. (Units: BTU per minute or BTU per hour).

Hot Water Temperature: The temperature of the circulating water leaving the condenser and entering the cooling tower distribution system. (Unit: °F).

Makeup: Water added to the circulating water system to replace water lost by *evaporation, drift, blowdown*, and miscellaneous minor losses (i.e., due to leakage, etc.). (Units: % of circulating water rate or gpm).

Particulate Matter (PM): Term for a mixture of solid particles and liquid droplets found in the air. Particulate matter can include PM_{10}, inhalable particles, with diameters generally 10 micrometers and smaller; and $PM_{2.5}$, which are fine inhalable particles with diameters that are generally 2.5 micrometers or smaller.

Plume Recirculation: A condition in which a portion of the tower's discharge plume re-enters the air inlets to the cooling tower along with fresh air. The effect of recirculation is that the average entering wet-bulb temperature is higher than ambient.

Range: Temperature difference between the hot water entering the cooling tower and the cold water exiting the cooling tower. (Unit: °F).

Wet Bulb Temperature: The temperature of the entering or ambient air adjacent to the cooling tower as measured with a wet-bulb thermometer, which is a thermometer whose bulb is encased within a wetted wick. (Unit: °F).

2.1.3 TYPES OF COOLING TOWERS AND COOLING SYSTEMS

In the context of this study, the CCRS categories under consideration and screening at PBAPS are defined as:

- **Mechanical-Draft Cooling Towers:** All-wet cooling systems in which the cooling towers are operated in a closed, recirculating loop with a shell-and-tube steam condenser. All of the heat rejection to the environment takes place in the wet cooling tower, primarily by evaporation. Air flow is forced through the tower by 'mechanical' means with a fan and is used to cool the water. Further detail is provided in **Section 2.1.3.1** below.
- **Natural Draft Cooling Towers:** All-wet cooling systems in which the cooling towers are operated in a closed, recirculating loop with a shell-and-tube steam condenser. All of the heat rejection to the environment takes place in the wet cooling tower, primarily by evaporation. Airflow is produced with tall towers which create a "chimney effect" and a buoyancy-driven flow. Natural draft cooling towers rely on natural convection to circulate air through the tower. Further detail is provided in **Section 2.1.3.2** below.
- **Hybrid Systems**: Wet/dry cooling systems in which direct dry cooling using a mechanical-draft air-cooled condenser (ACC) operates in parallel with a wet cooling system using a wet, mechanical-draft cooling tower and a shell-and-tube steam surface condenser. The portion of heat rejected to the environment from each of the two cooling loops depends on the site weather conditions at the time and will vary with atmospheric temperature and humidity as well as plant operating requirements. Further detail is provided in **Section 2.1.3.3** below.
- **Compact or multi-cell arrangements**: Wet/dry cooling systems in which the wet and dry elements are arranged in a single structure. The dry elements are normally indirect dry cooling using air-cooled heat exchangers (ACHE) rather than ACCs. Both series and parallel configurations are possible. Further detail is provided in **Section 2.1.3.4** below.

Based on site-specific considerations for PBAPS, only one of these technologies (mechanical-draft cooling towers) was identified as a potential candidate for a CCRS retrofit and included in the comprehensive technical feasibility and cost evaluation. The other three (natural draft cooling towers, hybrid designs, and compact or multi-cell arrangements) were dismissed from further evaluation.

2.1.3.1 Mechanical-Draft Wet Cooling Tower

Closed-cycle wet cooling systems with mechanical-draft cooling towers operate by inducing an air flow through the tower to cool the water. These are frequently counterflow systems, meaning the air and water flow in opposite directions[10]. Hot water from the steam condensers is pumped to the top deck of the cooling tower where the water is released to flow downward through the tower's fill material via gravity. As the water flows downward, an axial-flow fan runs at the top of the tower to induce outside ambient air to flow through the sides of the tower near the bottom, upwards through the fill material, and out of the top of the tower, all in a counterflow manner with respect to the water. The water cools as it flows through the fill material, and the cold water is collected in a basin beneath the tower before being pumped to the condenser for re-use. A schematic of a closed-cycle wet cooling system with a cooling tower is shown in **Figure 2-1**, and a photograph of a wet mechanical-draft cooling tower is shown in **Figure 2-2** (Cenk Endustri 2010)**.** Service water pumps are not included in the closed-cycle cooling system design for PBAPS and therefore are not included in the schematic below.

[10] If a CCRS were to be selected for implementation, other types of mechanical-draft cooling tower systems (including cross-flow system) may be evaluated further.

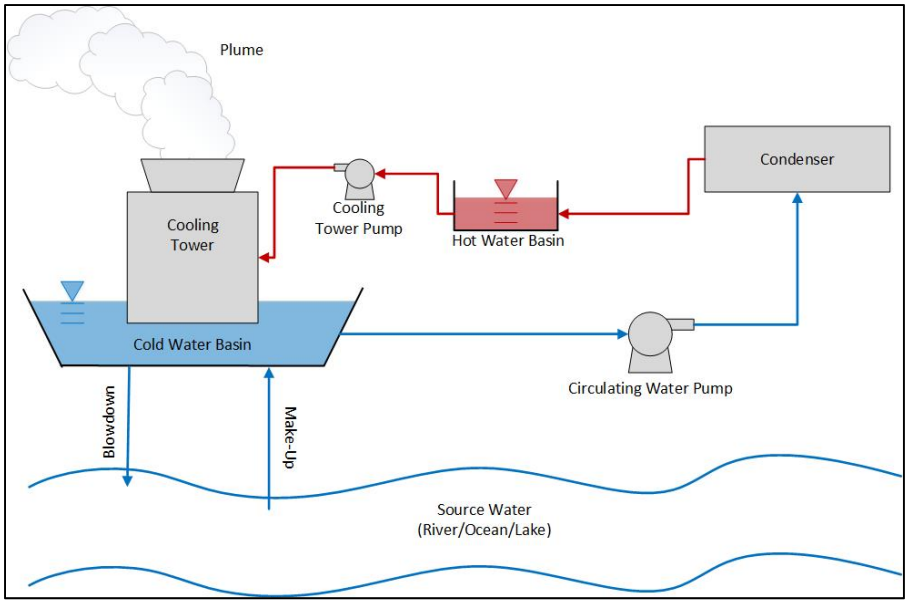


Figure 2-1: Schematic of a Closed-Cycle Wet Cooling System

Figure 2-2: Photograph of a Mechanical-Draft, Counterflow Cooling Tower

Figure 2-3 shows a photograph of one of the helper towers at PBAPS (Exelon 2003). These towers are mechanical-draft cross-flow cooling towers and are currently operated at the plant to provide additional once-through cooling, in accordance with the NPDES permit requirements.

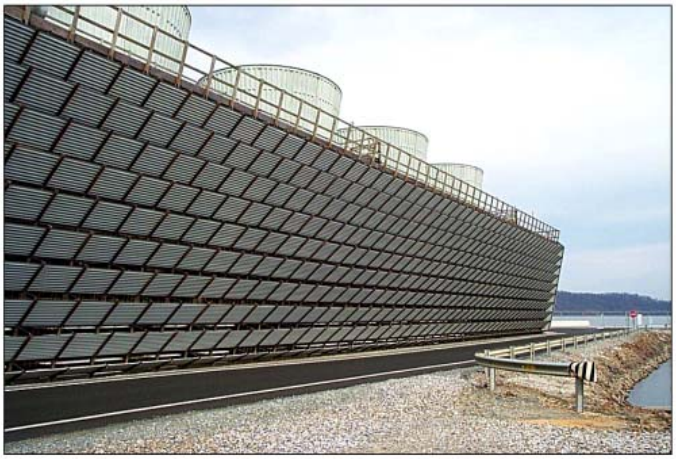


Figure 2-3 Photograph of Mechanical-Draft Cross-Flow Cooling Towers at the PBAPS

2.1.3.2 Natural Draft Wet Cooling tower

Closed-cycle wet cooling systems with natural-draft cooling towers operate in a similar way as mechanical-draft cooling towers as described in the previous section. The major difference between natural draft and mechanical-draft towers is that the airflow in natural draft towers is produced with tall towers which create a "chimney effect" and a buoyancy-driven flow. Natural draft cooling towers rely on natural convection to circulate air through the tower. Airflow through the tower is produced by the density differential that exists between the entering heated (less dense) air inside the tower and the cooler (more dense) air outside the tower. A photograph and schematic of a wet natural-draft cooling tower are shown in **Figure 2-4** (Reckmann 2007) and **Figure 2-5**.

Figure 2-4: Photograph of a Natural-Draft, Counterflow Cooling Tower

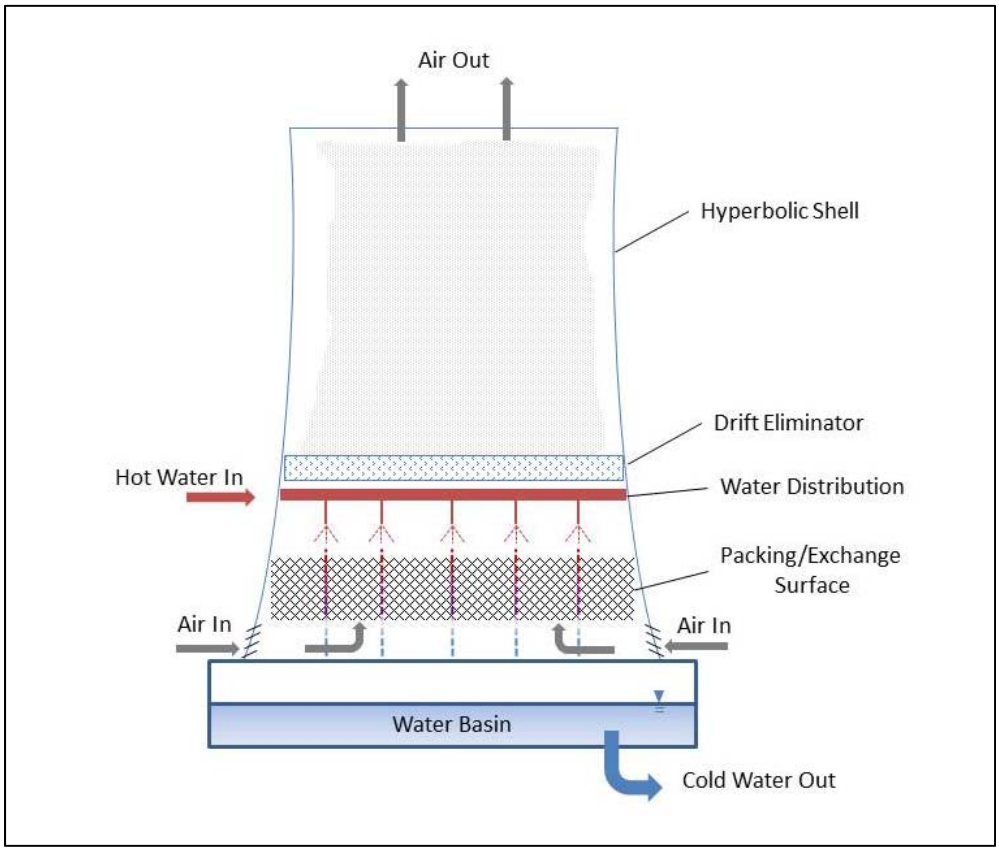


Figure 2-5: Schematic of a Wet Natural-Draft Cooling Tower

Due to the buoyancy-driven airflow in natural draft towers, a large tower height is required to facilitate its operation. A large tower height, in turn, requires a large base for support. Due to the massive size of these towers as compared to smaller mechanical-draft towers, natural draft towers are typically used for plants with large units with a long remaining life, high output (at least 250 MWe), and high capacity factors. This is because the larger towers have higher capital costs, sometimes two to three times higher, compared to mechanical-draft towers, and the longer lifetime and higher output of the larger units allows a facility to recover the costs through reduced operating costs.

Units 2 and 3 are currently licensed to operate until 2033 and 2034, respectively; however, Exelon submitted a license renewal application to the United States Nuclear Regulatory Commission (NRC) in July 2018 for a 20-year operating license extension for each of Units 2 and 3, anticipating that the process will take several years (Exelon 2018). While natural draft towers may be an option for PBAPS due to the high unit generating capacity (approximately 1,300 MWe gross for each unit) and high average capacity factors (91.4% for Unit 2 and 94.6% for Unit 3), mechanical-draft towers provide greater operational flexibility, lower installation cost, less construction time, and less area for construction. In some cases, there may be increased noise effects from mechanical-draft towers over natural draft towers. However, PBAPS currently operates mechanical-draft helper cooling towers during certain periods of the year in accordance with their NPDES permit, and, although the hypothetical system would be required to operate continuously year-round, there are currently no concerns over noise effects from the towers. Lower noise effects from natural draft towers are not expected to offer an advantage at PBAPS. Additionally, the presence of a massive natural-draft tower may raise concerns based on aesthetic grounds. Based on these factors, mechanical-draft towers are considered to be a more viable option for PBAPS and natural-draft towers are not considered further in this study.

2.1.3.3 Hybrid Systems

A hybrid cooling system consists of components of both wet and dry cooling systems. In this type of system, the wet mechanical-draft cooling tower is operated in parallel with a dry ACC. The wet and dry components for a hybrid system do not have to be located in a single structure like the compact/multi-cell arrangements discussed in the next section. Steam from the condenser/turbine is cooled using either the wet or dry cooling components, with the cooled and condensed steam from each part collected, combined, and sent back to the condenser for re-use. Detailed descriptions of hybrid systems are provided by Electric Power Research Institute (EPRI 2011b). A schematic and photograph of a hybrid system are shown in **Figure 2-6** (USDOE [Undated]) and **Figure 2-7** (EPRI 2011b), respectively.

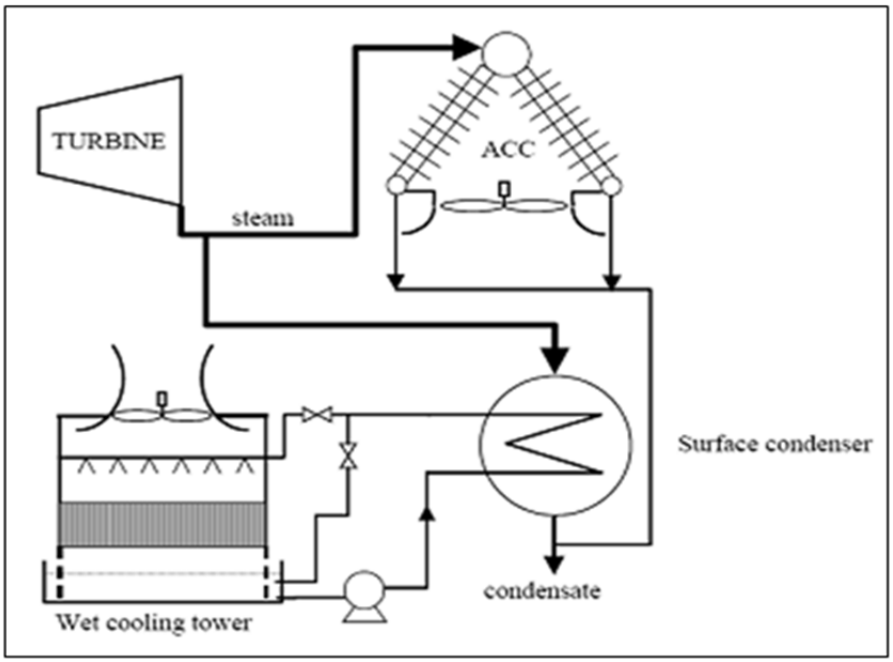


Figure 2-6: Schematic of a Hybrid Cooling System

Figure 2-7: Photograph of a Hybrid Cooling System

Hybrid systems are often considered in situations where the amount of cooling water available is not enough to completely meet the requirements of the cooling system. The following benefits are available for a hybrid system as compared to all-wet and all-dry cooling systems:

- Reduced water consumption compared to all-wet systems;
- Increased efficiency during the hotter days of the year compared to all-dry systems;
- Conventional steam turbines can typically be used, rather than extended backpressure turbines associated with all-dry systems in hot areas; and
- Costs for hybrid systems are significantly lower than all-dry systems, but higher than all wet systems (costs typically fall in between those of all-wet and all-dry systems, and depend on the amount of water that can be used in the system which affects the size of each of the system components (wet and dry).

Even with these benefits, a hybrid cooling system is not considered a feasible option at PBAPS for several reasons:

- Based on available 2016 meteorological data for PBAPS, the dry-bulb temperature was above 90°F for about 115 hours and above 85°F for about 383 hours. During these hotter hours of the year, a reasonably sized ACC would not be expected to contribute to the cooling at the existing system design turbine exhaust pressure. Therefore, the wet portion of the hybrid system would have to be sized to carry the full cooling load on the hottest days.
- The conceptual wet cooling system (with mechanical-draft cooling towers) provides a reduction of approximately 96.9% of the condenser water flow from a once-through cooling system, which satisfies the requirements of the Existing Facilities Rule. Although the use of a hybrid system would potentially reduce the intake water flow further, typical hybrid systems use approximately 50% of the water required by an all-wet system. This would only provide an incremental increase in the overall intake flow reduction from a once-through cooling system, from 96.9% with mechanical-draft cooling towers to approximately 98.4% of the condenser flow with the hybrid system.
- While hybrid systems are less expensive compared to all-dry systems, hybrid systems typically cost 2 to 5 times that of an all-wet system with a mechanical-draft cooling tower (EPRI 2011b, EPRI 2011c). In addition, hybrid systems require approximately 1 to 3 times the footprint of a mechanical draft cooling tower, thus requiring more site space. The higher costs do not provide much return on investment, with no improvement in plant performance on hotter days and only a marginal increase in the reduction of intake flows.

Based on this review of the benefits and drawbacks of this type of system, the hybrid system was considered not feasible for PBAPS and is not discussed further in the study.

2.1.3.4 Compact / Multi-Cell Arrangements

A compact/multi-cell arrangement cooling system is similar in operation to the hybrid system discussed in the previous section, in that it contains components of both all-wet and all-dry cooling systems. However, while the hybrid system operated with the wet and dry components in parallel and separated, this system has all components integrated into a single enclosure. This system also utilizes an Air Cooled Heat Exchanger (ACHE) instead of an ACC which is used in the hybrid system. EPRI provides a discussion on implementations of this type of system. A schematic and photograph of one of these systems are shown in **Figure 2-8** and **Figure 2-9** (EPRI 2011b).

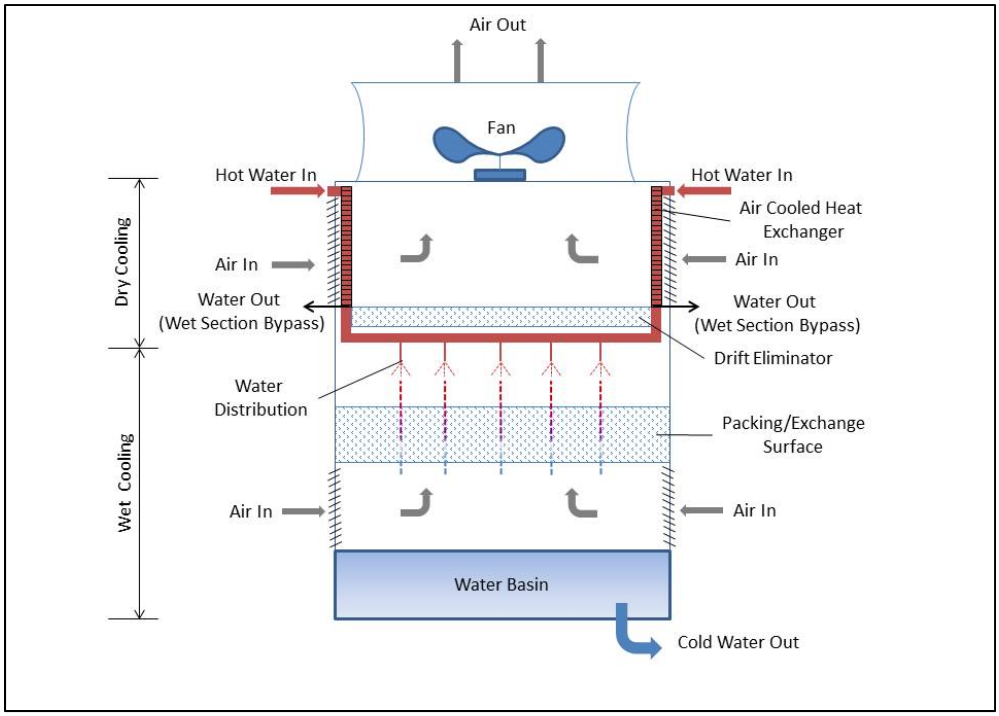


Figure 2-8: Schematic of Integrated Wet/ Dry Tower

Figure 2-9: Photograph of a Wet/Dry Combination Cooling Tower

The conclusions reached for the hybrid systems at PBAPS are similar to those for the compact/multi-cell arrangement cooling system. In particular, major drawbacks of this type of system are the larger size required and only a minor water use reduction compared to an all-wet system. The only such system in the United States, to our knowledge, was the wet/dry tower on Unit 3 at the San Juan Generating Station in Farmington, New Mexico. However, Unit 3 was closed in December of 2017, so this type of cooling system is no longer in operation at the station. To demonstrate the comparison in size, **Figure 2-10** shows an aerial view of Units 3 and 4 of the San Juan Generating Station in New Mexico (Google Earth 2017b). This figure is provided to illustrate the difference in size for the two types of towers, since Unit 3 is no longer in operation. As is evident in the photograph, although the generating capacity for the units was similar (496 MW for Unit 3 and 507 MW for Unit 4) (PNM 2018), the all-wet towers for Unit 4 had a smaller footprint than the compact/multi-cell arrangement towers for Unit 3.

Based on these considerations, compact or multi-cell arrangements are not feasible for PBAPS and are not discussed further in the study.

Figure 2-10: Comparison of Cooling System Sizes at the San Juan Generating Station

Table 2-1 shows the comparison of the potential closed-cycle cooling tower systems mentioned above, assuming that the selected option (mechanical-draft wet towers) is the 'base' option and identifies the technologies that have been retained for further evaluation and those that have been dismissed.

Table 2-1: Comparison of Potential Closed-Cycle Recirculating Cooling Tower Systems

Item	Mechanical Draft[11]	Natural Draft	Hybrid	Compact or Multi-Cell
Capital Cost	Base	Minimum of 2.5 x Base	2 to 5 x Base	2 to 5 x Base
Land	Base	Slightly More	Much More	Slightly More
Water Use	Base	Slightly Less	Less	Less
Construction Time	Base	Much Longer	Longer	Longer
Pumping / Piping	Base	Higher	Lower	Lower
Plume	Yes; Near-Field	Less Near-Field, Higher Far-Field	Controlled	Controlled
Ground Fog	Yes	Less	Controlled to None	Controlled to None
Water Treatment	Base	Base	Base	Base
Consumptive Water Use	Base	Slightly Lower	Lower	Lower
Retain for Further Evaluation?	**Yes**	No (Dismissed)	No (Dismissed)	No (Dismissed)

Thus, natural draft cooling towers, hybrid, and compact or multi-cell arrangements have been dismissed from further evaluation and mechanical-draft wet cooling towers were used for the conceptual cooling tower retrofit design.

2.2 OTHER CANDIDATE TECHNOLOGIES

In addition to a CCRS, a number of other entrainment mortality reduction alternatives were screened, as well as water reuse and alternative sources of cooling water. **Section 5.0** provides a summary of the assessment of water reuse and alternative sources of cooling water.

This section describes the screening of additional entrainment mortality reduction alternatives. A technology was selected for further evaluation if considered potentially feasible based on the following criteria:

1. The technology has proven biological efficacy for reducing entrainment mortality of one or more species similar to those present at PBAPS.
2. The technology is commercially proven, that is, the technology is available for a large-scale generating facility such as PBAPS, and does not require extensive engineering development as demonstrated by its successful operation at another site or pilot-scale data that is sufficiently detailed to develop a conceptual design.
3. The technology has engineering and/or biological advantages over the other technologies evaluated.
4. The technology has a potential for application at PBAPS.

The biological efficacy for reducing entrainment mortality was determined using USEPA's (2014a) technology performance evaluation of three categories of fish protection alternatives: screening technologies, offshore intakes, and 'other' technologies and operational measures. Screening technologies have been used for many years at power plants to prevent debris and aquatic organisms from entering the condensers, and include conventional and modified coarse-mesh traveling screens; Geiger, Hydrolox, and Beaudrey W Intake Protection (WIP) screens; wide-slot cylindrical wedgewire; drum screens; fine-mesh alternatives; barrier nets, and aquatic filter barriers. Of the screening technologies, only fine-mesh (or

[11] For the purpose of this study, 'Linear' or 'Rectilinear' mechanical-draft cooling towers were included in the comprehensive technical feasibility and cost evaluation at PBAPS, since these units can be constructed in a cellular fashion.

narrow-slot) screens and aquatic filter barriers have the potential to reduce entrainment mortality. Offshore intakes can reduce entrainment by withdrawing water from areas of reduced biological productivity. An offshore intake can be coupled with a velocity cap to reduce impingement mortality. Other fish protection technologies and measures include physical design changes to the intake, reduced intake velocity, substratum intakes, louvers, and behavioral technologies. Of these alternatives, only substratum intakes have the potential to reduce entrainment (USEPA 2014a). Therefore, the following alternatives have proven biological efficacy for reducing entrainment mortality:

- Fine-mesh traveling screens
- Narrow-slot (called "fine mesh" by USEPA [2014a]) wedgewire screens
- Aquatic filter barriers
- Offshore intakes
- Substratum intakes

Fine-mesh barrier nets, Filtrex Filter Systems, and modular inclined screens (MIS) with fine slots were not identified by USEPA (2014a) to reduce entrainment. However, EPRI (2013) discusses these alternatives as entrainment reduction technologies and therefore, these alternatives were included in the next screening step.

In addition, two flow reduction measures not addressed with cooling towers were screened:

- Install and operate variable frequency drives on the circulating water pumps to reduce entrainment by reducing flow during selected periods of high entrainment, and;
- Seasonal circulating water pump shutdown during selected periods of high entrainment.

One operational measure, timing of the outage period, was also included as a candidate technology.

The 11 technologies identified as potentially effective for reducing entrainment during the first screening step were further evaluated to determine if they are commercially proven by reviewing USEPA (2014a) and EPRI (2013) technology evaluations and publically available literature. The results of the screening are summarized in **Table 2-2**.

Table 2-2: Selection of Final Candidate Technologies for Comprehensive Technical Feasibility & Cost Evaluation Study

Candidate Technology	Biological efficacy for reducing entrainment mortality of one or more species similar to those present at PBAPS	Commercially proven, and available for a large-scale generating facility	Engineering and/or biological advantages over the other technologies evaluated	Potential for application at PBAPS
Fine-mesh traveling screens	Yes	Yes	Yes	Yes
Narrow-slot wedgewire screens	Yes	Yes	Yes	Yes
Aquatic filter barriers	Yes, experimental deployment	No	No	No, experimental, high level of maintenance and debris concerns, very large footprint
Offshore intakes	Yes, dependent on lower densities of entrainable organisms offshore	Yes	No	No, no significant difference in near shore vs offshore densities likely.
Substratum intakes	Unknown	No (USEPA 2014a)	No experimental short term pilot deployment only	No
Fine-mesh barrier nets	Yes, experimental deployment	No, only experimental deployment identified (EPRI 2013)	No	No, experimental, high level of maintenance and debris concerns
Filtrex Filter System	Unknown, pilot tested in marine environment only	No, only experimental deployment identified (EPRI 2013)	No	No, experimental performance unknown
Modular inclined screens (MIS) with fine slots	Unknown, lab and prototype testing for impingement reduction only	No, no full-scale MIS installations have been identified at power stations (Alden et al. 2011)	No	No, experimental performance unknown
Variable frequency drives on the circulating water pumps	Yes, reducing flow during periods of higher entrainment would reduce entrainment mortality	Yes	No, limited by discharge temperature limits	No, temperature discharge limits diminish EM reduction
Seasonal circulating water pump shutdown	Yes, reducing flow during periods of higher entrainment would reduce entrainment mortality	Yes	No, prohibited by discharge temperature limits	No, temperature discharge limits
Timing of outage period	Yes, moving outage to a higher entrainment month would reduce entrainment mortality, limited to low electric demand month	Yes	Yes, April outage may reduce annual entrainment by 0.5 to 4.7% during outage years[12]	No, insufficient benefit and negative impacts on Operations

[12] Based on entrainment sampling in 2012 and 2016.

Although variable frequency drives were considered due to the potential biological efficacy for reducing entrainment mortality of one or more species similar to those present at PBAPS (i.e., reducing flow during periods of higher entrainment would reduce entrainment mortality), and the technology is commercially proven for a large-scale generating facility, variable frequency drives were not considered to have any Engineering and/or biological advantages over the other technologies evaluated due to the site-specific discharge temperature limits and considerations at PBAPS. This technology was not considered to have potential for application at PBAPS, since most spawning occurs May through July and the temperature discharge limitations would diminish the amount of flow reduction achievable during these months.

Based on the screening of candidate technologies, two alternatives (modified traveling screens with fine-mesh panels or overlays and narrow-slot wedgewire screens) were selected for the comprehensive technical feasibility and cost evaluation.

In order to further analyze the differences in costs and benefits between the two selected technologies, a preliminary design was developed for each of these technologies. Feasibility, construction, operation and maintenance (O&M), biological efficacy, engineering costs and schedule, and permitting were taken into consideration when developing these designs.

3.0 COMPREHENSIVE EVALUATION – MECHANICAL-DRAFT WET COOLING TOWER

3.1 CONCEPTUAL DESIGN

Based on the initial screening described in the previous sections**,** the preferred CCRS alternative at PBAPS would be an all-wet system with a mechanical-draft cooling tower. EPRI provides a document to develop cost estimates for CCRS retrofits (EPRI 2011a). This EPRI document is used as the basis for the USEPA in its assessment of closed-cycle cooling system retrofits, and the USEPA has even cited the EPRI document in its Technical Development Document that was issued as part of the CWA Section 316(b) Existing Facilities Rule; therefore, the EPRI approach was used as part of this study.

This section describes the conceptual design of a hypothetical retrofit. The conceptual design of mechanical-draft wet cooling towers for PBAPS assumes that the circulating water flow rate and the condenser of the existing once-through cooling system for each unit would be retained. A basis of design for the mechanical-draft cooling towers was developed in order to properly size the towers and evaluate their performance. The following key design assumptions were made for sizing the towers:

- Total Circulating Water Flow: 750,000 gpm per Unit;
- Design Ambient Wet-Bulb Temperature (1% annual exceedance): 77.0°F[13] (temperature reached or exceeded for approximately 87.6 hours per year)
- Cooling tower approach temperature: 10°F[14]
- Cooling Tower Range: 25°F[15]

Additional design considerations are provided in the following sections.

[13] Summer wet bulb temperature at 1% exceedance from Delta Cooling Towers, Inc. (Delta 2013). Note that use of the 1% exceedance level provides a margin for recirculation/interference since the peak wet bulb temperature occurs in periods of short duration and rarely occurs in consecutive hours.
[14] Assumed; chosen to account for potential plume recirculation in the towers.
[15] Cooling tower range was selected as the maximum difference between the condenser cooling water outlet temperature and the cooling water inlet temperature (Exelon 2017b).

3.1.1 COOLING TOWER DESIGN BASIS

The key conceptual design values for the cooling tower are provided in **Table 3-1**. These values were based on conservative estimates of ambient conditions, the existing condenser specifications, and actual operating conditions.

Based on the cooling tower design values in **Table 3-1**, the turbine exhaust pressure is expected to be maintained below approximately 5 inHga at CCRS design conditions.

Table 3-1: Cooling Tower Design Characteristics

Unit	Gross Output (MWe)	Temperature (°F)						P_b (inHga)
		Condenser TTD	Design Wet Bulb	Cooling Tower Approach	Cold Water	Hot Water	Steam Condensing Temperature	
2	1,300	20	77.0	10.0	87.0	112	132	5
3	1,300	20[16]				112	132	5

Note: P_b = Turbine Backpressure

Additional assumptions regarding the cooling tower design include:

- Tower material of construction: fiber-reinforced plastic (FRP);
- Makeup water source: freshwater source (Conowingo Reservoir) with total dissolved solids concentrations of approximately 200 milligrams per liter (mg/L);
- Operating cycles of concentration: n = 5[17];
- Plume abatement is not required; and
- The existing helper towers would be decommissioned and demolished as discussed in **Section 3.1.7**. The areas now occupied by these towers would be utilized as a part of the new tower implementation.

As discussed further in **Section 3.4**, no regulations on plumes were identified in the Peach Bottom Township Zoning Ordinance (2016). PBAPS currently operates helper cooling towers that are not designed with plume abatement. Therefore, there does not appear to be a need for plume abated cooling towers. A back-to-back cooling tower arrangement has therefore been assumed to reduce the overall area or footprint of the towers and to simplify the piping configuration. If this alternative is selected for implementation, further evaluation of the plume may be required to evaluate winter driving hazards, fogging, and icing.

3.1.2 COOLING TOWER SIZING

Based on the design values in **Table 3-1**, the required number of cells per unit for the towers was calculated for a back-to-back arrangement. The total number of required cells in a back-to-back

[16] The conceptual cooling tower design assumes that the condenser cooling water supply and discharge would be comingled; therefore, the cooling towers design basis assumes the higher (Unit 2) TTD.

[17] For the purpose of this evaluation, 5 cycles of concentration were assumed for the cooling towers. This was selected for the conceptual CCRS retrofit at PBAPS as a mid-range value to balance minimized makeup water flows with reduced increases in air-borne particulate matter (i.e., higher cycles of concentration would reduce makeup water flows but would increase air-borne particulate matter and also concentrations of dissolved solids in the blowdown water.) Another Exelon facility on the Susquehanna River (Three Mile Island) uses approximately 3 to 4 cycles of concentration in their natural draft cooling towers. If this alternative were to be selected for implementation, site-specific water quality would be assessed further to identify the optimal cycles of concentration. Additionally, water quality of the cooling tower blowdown (i.e., discharge metals concentrations) was not evaluated. Water quality would be addressed as part of the permitting activities described in **Section 3.4** of the report.

arrangement is shown in **Table 3-2** for a range of cell sizes at an assumed water loading of 6 gallons per minute per square foot (gpm/ft^2). To accommodate site space limitations, a cell size of 50 ft. x 50 ft. was selected for a total cooling tower requirement of 50 cells per unit for Units 2 and 3, for a total of 100 cells for both units.

Table 3-2: Cooling Tower Cells Required

Cell Size (L/W) (ft.)	Area Per Cell (ft^2)	Number of Cells Required at 6 gpm/ft^2	
		Unit 2	Unit 3
50/50*	2,500*	50*	50*
56/56	3,136	40	40
60/60	3,600	36	36
66/66	4,356	30	30

Notes: *chosen sizing
L/W - Length/width; the number of cells for each cell size are rounded up so that the required flow can be processed by the towers.

3.1.3 COOLING TOWER ARRANGEMENT AND CONCEPTUAL LAYOUT

Based on the selected size of the towers, an ASTM Level 4 conceptual layout and siting of the towers, along with all of the necessary piping, pumps, and basins, was completed. This conceptual layout was prepared under the assumption that existing helper cooling tower units could not be reused within the available footprint of area.

In order to use the existing available cooling tower footprint as much as possible, five sets of 20-cell tower blocks were assumed for the entire combined plant condenser flow. Each of the cooling tower blocks would consist of 20 back-to-back 50 ft. x 50 ft. cells. The total area for each 20-cell tower block is approximately 508 ft. x 108 ft. (basin dimensions). The basin extends 4 ft. beyond the cells on all sides. The hypothetical cooling tower blocks are shown superimposed on the site aerial photo in **Figure 3-1** (Google Earth 2017a). A larger view of the cooling tower layout, along with the other system details including piping and basins, is provided as a Conceptual Cooling Tower Layout in **Appendix A.**

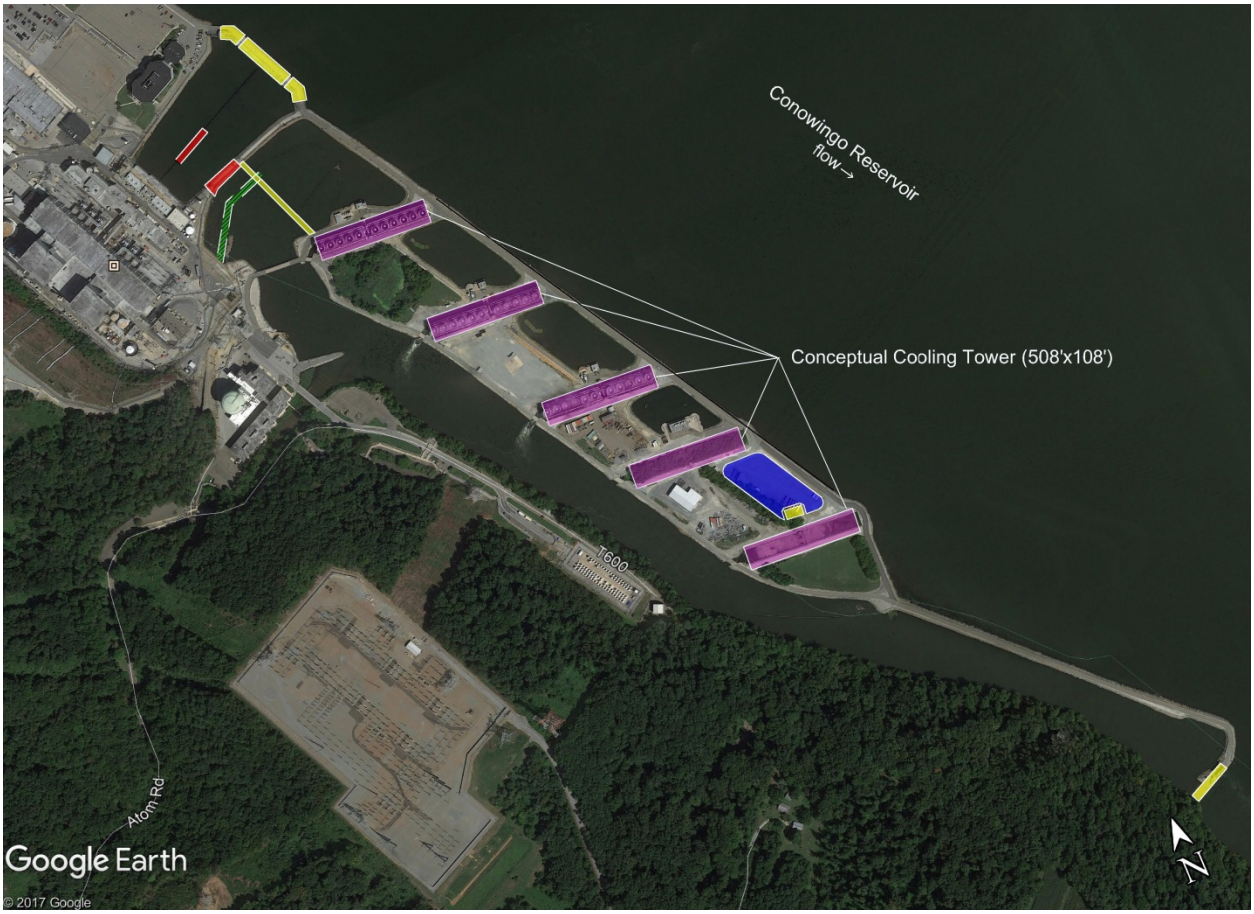


Figure 3-1: Possible Tower Location at PBAPS

Based on a preliminary review of available land and existing site features, an acceptable location for the towers appears to be available. As shown in **Figure 3-1**, there is an existing open area along the Conowingo Reservoir that is currently occupied by three helper cooling tower blocks. The hypothetical towers for the CCRS would be aligned with the prevailing winds. The tower blocks would be aligned in a west-southwest to east-northeast direction and separated by an adequate distance (one-tower length) to minimize potential recirculation of the plumes. Additionally, the cooling tower approach temperature was selected to account for some recirculation. The magnitude of the impact of recirculation on tower performance is not known. Finally, as discussed in **Section 3.4.1**, depending on the wind direction, the drift produced by the towers could cause potential issues with the switchyard, transmission lines, and the plant's roadways due to the location of the towers. If this alternative is selected for implementation, further evaluation of the plume may be required to address icing in the winter, fogging, and solids deposition in the area of the cooling towers.

The hypothetical location for the cooling towers was selected to take advantage of the existing helper tower footprint and infrastructure, where possible. Additionally, the discharge canal would be extended into the existing intake basin to the north, and the hot water discharge line from Units 2 and 3 would be extended into the reduced-size discharge basin. Further, the existing separation wall within the intake basin would be completely or partially removed to allow for cold water to equalize within the entire intake basin and the discharge canal. With these modifications, the facility could eliminate the need for pumps and piping to return cool water from the discharge canal to the intake basin and condenser inlet. The location of the towers was selected to be as close as possible to both the existing cooling water intake and discharge given the existing infrastructure and site constraints.

The hypothetical cooling tower arrangement would utilize as much of the existing infrastructure with the exception of the existing helper towers. Since the entire available footprint would be needed for the retrofit, the existing helper towers would be demolished and replaced with the new cooling tower arrangement, as discussed in **Section 3.1.7**. Additionally, the existing discharge canal and discharge structure would be retained for the cooling tower blowdown to minimize permitting issues for the blowdown discharge. However, the discharge structure would be modified to allow for a reduced discharge flow. The existing structure includes three adjustable gates; one or more of these gates may be completely closed, and the remaining gate would be adjusted to reduce the discharge flowrate based on the required blowdown flows. A surface overflow spillway would remain in operation. The conceptual cooling tower layout with all system components is shown in **Appendix A**.

The existing outer intake structure would be blocked on the makeup water side, and a sluice gate(s) would be installed behind the existing through-flow traveling water screens to restrict flow from Conowingo Reservoir. The required makeup water for the closed-cycle cooling system and service water pumps would be supplied from the Conowingo Reservoir by opening the sluice gate. This setup would allow for continued use of the intake basins for cool condenser inlet water. Additional CWA Section 316(b) intake requirements for the service water and makeup water flow through the new sluice gates have not been evaluated in more detail as part of this conceptual closed-cycle cooling retrofit evaluation. These additional requirements would be evaluated as part of the final design process if the CCRS retrofit is selected for implementation.

While the existing intake structure, intake basin, pumps, condenser piping, discharge basin, discharge canal, and discharge structure would be utilized, new infrastructure would be installed and existing infrastructure would be modified to allow for the operation of the cooling towers and to return cooled water to the intake basins. The existing discharge basin would be reduced in size and would be blocked from the discharge canal to 'close' the cooling water system. The 'hot' water exiting the condenser would be transferred through an extended discharge channel and collected in the discharge basin. 'Hot' water would be equalized, through a series of underground tunnels/pipelines, across five hot water basins, each of which feeds an individual cooling tower block. 'Hot' water would then be pumped to the top of the respective cooling tower hot water distribution deck. The treated 'cold' cooling water would be collected in inter-connected basins beneath the towers. The treated cooling water would then discharge via gravity to the existing discharge canal, which would be directly connected to the intake basin. Therefore, 'cold' cooling water would equalize back to the existing intake basins. New piping would not expected to be required for the 'cold' water, as modifications to existing infrastructure would allow for the discharge canal to be connected to the intake basin. However, new 'hot' water pumps and piping would be required to feed the cooling towers. Cooling tower blowdown would be discharged from the discharge canal through the existing outfall structure, which would require modification (partially blocked) for the smaller blowdown flow.

The hypothetical closed-cycle cooling system layout described here is a conceptual level layout required to develop costs and evaluate the overall feasibility of retrofitting the existing system with a cooling tower. Not enough information is currently available to perform an in-depth evaluation of the constructability of the system retrofit. In addition, the siting of the towers and all system components would need to be confirmed after discussions with plant personnel and regulatory agencies, and after an evaluation of the existing site features/characteristics such as buildings, underground utilities, and soil conditions.

It is important to note that the radioactive waste (rad-waste) currently discharges into the discharge canal and is mixed with the once-through condenser cooling water prior to being discharged with the rest of the heated condenser water to the environment. For the hypothetical retrofit, the rad-waste discharges would be partitioned off (piped) to prevent comingling with the 'cold' cooling tower flows that are redirected back through the condenser. Rad-waste discharges would only be mixed with the cooling tower blowdown prior to discharge to the Conowingo Reservoir. If the closed-cycle cooling retrofit is selected

for implementation, the rad-waste discharges would also be evaluated further to confirm that adequate dilution flow is available after the retrofit. Additional review and approval by the NRC would also be likely for the conversion to closed-cycle cooling at PBAPS, as discussed further in **Sections 3.2** and **3.4.10**.

3.1.4 COOLING TOWER AIRFLOW AND FAN SIZING

With the tower size and arrangement selected, the airflow was then determined. **Table 3-3** shows the airflow required per cell for a range of liquid/gas (L/G) ratios. An L/G = 1.2 was selected, which permits the use of typically sized (fan diameter: 30 to 34 ft.; motor power: ~ 250 horsepower [HP]) fan/motor assemblies per cell, delivering approximately 1.45 x 10^6 actual cubic feet per minute (acfm) of air to each cell.

Table 3-3: Fan Size/Airflow Required per Cell

Unit	Cells Required	Actual Cooling Water Flow per Cell (gpm)	Airflow per Cell (acfm)				
			L/G Ratio				
			0.8	1.0	1.2	1.4	1.6
2	50	15,000	2.2E+06	1.8E+06	1.5E+06*	1.3E+06	1.1E+06
3	50	15,000	2.2E+06	1.8E+06	1.5E+06*	1.3E+06	1.1E+06

* chosen ratio

3.1.5 COOLING TOWER WATER REQUIREMENTS

Based on the conceptual design selected for PBAPS, the consumptive water use of the closed-cycle cooling system with cooling towers was calculated. This included calculations of evaporation, blowdown, drift, and total withdrawal (makeup). The values for each of these components are shown in **Table 3-4**. A comparison of the total water withdrawal required for once-through condenser cooling (1,500,000 gpm) with the withdrawals required for closed-cycle cooling tabulated in **Table 3-4** (46,888 gpm) shows that retrofitting to closed-cycle cooling would result in a reduction in condenser water withdrawal of approximately 96.9%.

Table 3-4: Cooling Tower Water Requirements

Unit		Water Balance			
	Cycles of Concentration[18]	Evaporation Rate[19] (gpm)	Blowdown (gpm)	Approx. Drift (gpm)	Total Makeup (gpm)
2	5	18,750	4,690	4	23,444
3	5	18,750	4,690	4	23,444
Total		37,500	9,380	8	46,888

[18] For the purpose of this evaluation, 5 cycles of concentration were assumed for the cooling towers. This was selected for the conceptual CCRS retrofit at PBAPS as a mid-range value to balance minimized makeup water flows with reduced increases in air-borne particulate matter (i.e., higher cycles of concentration would reduce makeup water flows but would increase air-borne particulate matter and also concentrations of dissolved solids in the blowdown water.) Another Exelon facility on the Susquehanna River (Three Mile Island) uses approximately 3 to 4 cycles of concentration in their natural draft cooling towers. If this alternative is selected for implementation, site-specific water quality would be assessed further to identify the optimal cycles of concentration.

[19] Cooling tower evaporation is dependent on the flow rate to the tower and the temperature difference across the tower (Green and Perry 2008). Drift loss has been assumed with drift eliminator efficiency of 0.0005%.

3.1.6 *Cooling Tower Effects on Turbine Backpressure*

PBAPS provided 2016 backpressure data for Units 2 and 3, which are plotted in **Figure 3-2** and **Figure 3-3**, respectively. Three backpressures are measured for each unit, as shown in the figures. According to these data, the condenser backpressure typically ranges from approximately 0.9 inHga to 1.7 inHga when the units are generating at full capacity during the cooler winter months, and up to 2.5 to 5.1 inHga when the units are generating at full capacity during the hotter summer months (Exelon 2017b).

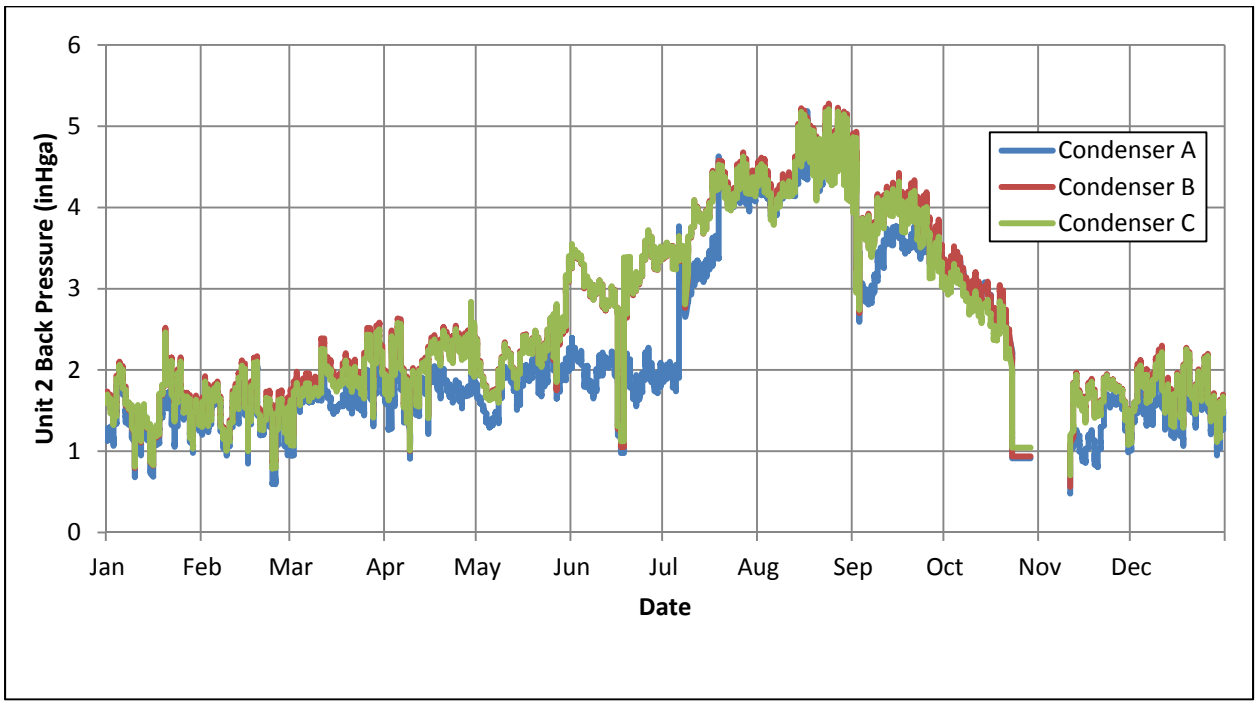


Figure 3-2: PBAPS Unit 2 Backpressures for 2016

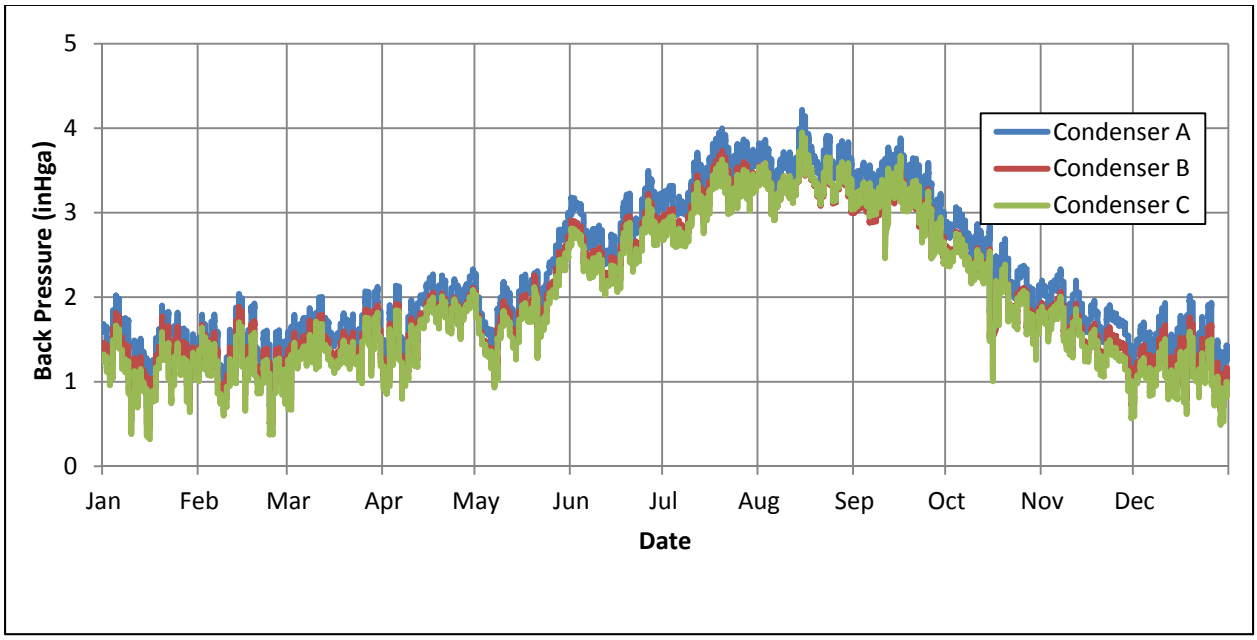


Figure 3-3: PBAPS Unit 3 Backpressures for 2016

After a hypothetical CCRS retrofit, the turbine backpressure would be expected to be similar to the current back pressure during the hotter summer months, based on available ambient temperature data. This is based on condenser design data that indicate that the steam condensing temperature can be as high as 134.6°F with a cooling water inlet temperature of 90°F (and condenser 'hot' water discharge temperature of 114.6°F).

Available data from 2016 indicate that the cooling water intake temperature was as high as 89°F, which is very close to this design value. According to available statistical information on wet bulb temperatures near PBAPS, the wet bulb temperature at 1% exceedance is approximately 77°F. This is the wet bulb temperature that is expected to be reached or exceeded for approximately 87.6 hours per year. Assuming a cooling tower approach of 10°F, which establishes a maximum cold water temperature of 87°F, the maximum condenser cooling water inlet temperature would therefore be very similar after the retrofit at the design conditions. In reality, the instantaneous wet bulb may exceed the design 1% exceedance temperature on the hottest summer days.

CCRS retrofits typically result in an overall increase in temperature on an annual basis and, consequently, an overall increase in turbine backpressure on an annual basis. As discussed further in **Section 3.4.9**, a higher turbine backpressure would result in lower turbine efficiency and reduced electrical energy output.

3.1.7 Alternative Mechanical-Draft Wet Cooling Tower Retrofit

The mechanical-draft wet cooling tower arrangement and conceptual design detailed above was based on the assumption that existing cooling tower infrastructure would have to be replaced at the facility. However, the facility currently operates and maintains three existing helper tower blocks, each of which has an 11-cell in-line arrangement with dimensions of 515 ft. L x 71 ft. W x 53 ft. H. In order to more fully evaluate conceptual cooling tower installations at PBAPS, it is necessary to assess the possibility for a retrofit option to include long-term operation of the existing helper cooling towers.

The three PBAPS helper cooling tower blocks were originally designed to treat approximately 57% (876,000 gpm) of the circulating water flow (Exelon 2014) and currently operate on a seasonal basis to meet thermal discharge criteria in the NPDES permit. Each cooling tower block has a heat rejection capacity of 2,015 x 10^6 BTU/hr at 78°F wet bulb (Sargent & Lundy 2010), for a total heat rejection for the facility of 6,045 x 10^6 BTU/hr. In order for the facility to operate with a CCRS, and taking into consideration the post-Extended Power Uprate increase in temperature range, the hypothetical cooling tower system is designed for a total facility heat rejection capacity of approximately 18,730 x 10^6 BTU/hr.

The existing cooling tower blocks therefore only satisfy approximately 33% of the cooling required for a retrofit, although they take up approximately 66% of the most favorable available footprint for a CCRS. Under the retrofit, approximately 154,000 additional square feet of cooling tower cells would be required beyond the current helper tower configuration. The existing available footprint does not support additional new tower installation without construction in "Waters of the State" (Conowingo Reservoir) or the existing hot water basins. Additionally, the existing helper towers are currently only required to run up to two-and-one-half months of the year. Therefore, a comprehensive assessment of the condition of the towers would be required to confirm that they are capable of continuous operation for the expected life of the facility, and whether operation during the colder winter months may require additional modifications such as a de-icing system. Based on these factors (limited land availability to expand the cooling tower 'footprint' and unknown condition and capability of the existing helper towers to operate year-round for the life of the facility), the CCRS retrofit assumes that the existing helper towers would be demolished and new cooling towers would be installed as described above.

3.2 Establishment of Degree of Difficulty

In order to estimate the cost of a CCRS retrofit using EPRI (2011a) methods, a rating must be assigned to PBAPS based upon a judgment as to the "degree of difficulty" of a retrofit. This judgment is based on an

analysis of a set of characteristics of the plant, the plant's property, and the surrounding area. The following set of eleven characteristics was established for the analysis:

1. The availability of a suitable location for a tower on-site;
2. The separation distance between the existing turbine/condenser location and the selected location for the new cooling tower;
3. Site geological conditions which may result in unusually high site preparation or system installation costs;
4. The presence of known, existing underground infrastructure which may present significant interferences to the installation of circulating water lines;
5. The possible requirement for reinforcement of existing condenser and water tunnels;
6. The possible need for plume abatement;
7. The presence of on- or off-site drift deposition constraints;
8. The possible need for noise reduction measures;
9. The need to bring in alternate sources of makeup water;
10. Any requirements for related modifications to the balance of plant equipment, particularly the auxiliary cooling systems, that may be necessitated by the retrofit; and
11. The need for re-optimization of the cooling water system or extensive modification or reinforcement of the existing condenser and circulating water tunnels to avoid the heat rate penalty.

Three additional factors, while not tied to the capital cost of the retrofit, directly influence the duration and complexity of the retrofit. These factors can significantly increase the overall retrofit costs:

1. Outage time required to complete the retrofit;
2. Costs related to permitting procedures which might be required for the installation of a cooling tower at the site; and
3. For nuclear facilities, specific requirements such as NRC review and approval of design, and operating safety considerations such as maintaining adequate cooled water supply for the ultimate heat sink and security issues.

The conceptual design of the closed-cycle cooling system retrofit assumes that the existing helper towers would not be re-used and would have to be demolished in order to construct the new system. Additionally, the condenser discharge structure would have to be modified in order to discharge into the hot water basin created by partitioning off the existing discharge channel and extending the existing condenser discharge structure. The partition is intended to allow for the treated 'cold' water from the towers to be directed back to the intake canal. Additionally, since the existing helper tower operation is required per the NPDES permit during certain periods of the year, construction activities would have to be sequenced to allow for operation of the helper towers during the construction period where the units are still generating. This would complicate the construction activities and could increase the overall construction schedule. Construction activities would have taken into consideration safety-related systems and keep these operable during construction.

Additional review and approval by the NRC would also be likely for the conversion to closed-cycle cooling at PBAPS. All nuclear plant modifications must comply with NRC regulations and guidelines regarding safety and security. Unproven technologies may require additional NRC review. NRC requirements are addressed in the station design change process and evaluated under the 10 CFR 50.59 review procedure. In addition, if an alternative was not previously reviewed by the NRC during the initial

construction and operating stage licensing process or during the license renewal process (NUREG-1437, Supplement 22), the alternative may be considered an Unreviewed Environmental Impact. In this case, the NRC would be required to undertake a full National Environmental Policy Act review, including the need for an environmental assessment or environmental impact statement. The NRC authorization to proceed with construction and operation of the PBAPS units was based on once-through cooling. Installation of cooling towers would represent an Unreviewed Environmental Impact.

Based on the substantial construction activities required to reconfigure the discharge channel and demolish the existing helper towers, the potential impacts due to the modifications of the condenser discharge structure, review and compliance with 10 CFR § 50, Appendix I design objectives, and approval from the NRC, and the complexity of the construction sequencing anticipated to minimize the generation downtime, the closed-cycle cooling system retrofit at PBAPS is considered to be in the "more difficult" category. The following sections provide a review of site-specific characteristics for PBAPS that was used to assess the overall degree of difficulty and establish costs for the closed-cycle cooling system retrofit.

3.3 Discussion of Land Availability

As described in **Section 3.1**, a suitable location for the towers appears to be available, assuming that the existing helper towers would be demolished and the new tower blocks would be installed near their existing footprints. However, the existing discharge basin would have to be modified to allow for the return of 'cold' water back to the intake channels, and to extend the existing condenser discharge structure to the new partitioned 'hot' water basin. Installation of cooling towers would therefore require substantial construction, which would have to be routed around existing infrastructure, piping and underground utilities. Additionally, for the hypothetical retrofit, the rad-waste discharges would be partitioned off (piped) to prevent comingling with the 'cold' cooling tower flows that are redirected back through the condenser. Rad-waste discharges would only be mixed with the cooling tower blowdown prior to discharge to the Conowingo Reservoir. The hypothetical closed-cycle cooling system layout described in this report has been developed at an ASTM Level 4 conceptual level in order to develop costs and evaluate overall feasibility of retrofitting the existing system with cooling towers. Further evaluation of the new structures and piping layout would need to be confirmed after a careful examination of the existing geological features, underground utilities/infrastructure, and other site features.

3.4 Other Factors Affecting Practicality or Feasibility

In addition to factors discussed previously (most applicable CCRS type, land availability, and tower location), other factors identified in **Section 3.2** must be assessed to establish the degree of difficulty and practicality/feasibility of the retrofit at PBAPS. These additional factors include issues and limitations regarding the environment, noise, height, aesthetics, site's hydrogeology, plant performance (parasitic energy loads, heat rate penalties, and capacity limits), and plant security.

A retrofit to closed-cycle cooling may introduce some environmental, zoning, and plant performance issues. The regulations set forth in the Peach Bottom Township Zoning Ordinance govern the plant property; however, since the plant is located on the border of Lancaster and York counties, the regulations in these counties must be considered. An initial regulatory review was performed as part of the conceptual study; however, a more detailed regulatory review, including possible discussions with both federal and state (Pennsylvania) regulators, is recommended before detailed design and construction of the cooling towers occurs.

3.4.1 Drift

The drift produced by the hypothetical cooling towers could create environmental and maintenance issues for the plant and surrounding areas. It is assumed that any new cooling tower installed would be equipped with drift eliminators rated to control drift to 0.0005% of circulating water flow. The use of drift

eliminators on the towers would not affect the capital cost of the retrofit. **Table 3-5** estimates expected emissions from a hypothetical cooling tower.

Table 3-5: PBAPS Drift Estimates

Unit	Cooling Water Flow	Drift[1]		Average 2012-2016 Unit Capacity Factor	PM_{10} Emissions[2,4]	$PM_{2.5}$ Emissions[2,4]	Total PM Emissions[2,3]
	gpm	gpm	lb/hr	%	ton/yr	ton/yr	ton/yr
2	750,000	3.75	1,878	91.4	6.28	2.80	7.52
3	750,000	3.75	1,878	94.6	6.50	2.90	7.78

Note: [1] – Based on a drift rate of 0.0005%; [2] - Based on 2012-2016 average capacity factors; [3] – Emission factors and equations derived from USEPA (1995); [4] – Emission factors and equations derived from Reisman and Frisbie (2002) with drift eliminator mass distribution and drift particle size similar to a SPX Cooling Technologies Marley TU12 Xcel Drift Eliminator

Drift deposition both on-site and off-site has the potential to impact nearby facilities. Depending on the wind direction, solids deposition may occur on the switchyard, transmission lines, local roadways, and plant buildings and roadways. This could have a deleterious effect to the station, and potentially affect nearby property values. Since the switchyard and transmission lines are located 1,000 to 2,500 ft. west southwest of the hypothetical cooling tower locations, they are at a high risk and could require increased maintenance. Although not performed here, plume and drift modeling is addressed in the § 122.21(r)(12) report, and should be taken into consideration before a final location is set for the towers.

3.4.2 PLUME

Operation of wet cooling towers would result in a 'visible plume' under some atmospheric conditions, as the warm water droplets exiting the tower come in contact with the colder ambient air. Although a cooling tower plume is harmless in most cases, a plume could create issues with corrosion and ice formation (**Section 3.4.1**) on nearby equipment and may create safety issues for nearby roads, railways, or airports. There could also be safety and security, regulatory, and aesthetic (**Section 3.4.6**) issues caused by the plume. In these cases, plume abatement technology might be required.

Plume abatement could be provided by a hybrid cooling system as described in **Section 2.1.3.3** above, in which warm, dry air is mixed with the wet air to drop the saturation point and reduce the visible plume. Another alternative is a system such as the SPX ClearSky™ technology that uses heat exchanger modules to condense the moisture before it leaves the tower. This technology minimizes the potential for a plume through the removal of the moisture and the slight cooling of the wet air that normally would leave the tower. Plume abatement technologies have a higher capital cost, require a larger footprint, and require more power (potentially 25% more power) to operate. Additionally, according to available vendor information, plume abatement technologies such as the SPX ClearSky™ have not been used at a facility with more than 120,000 gpm of flow (SPX 2017b).

In regards to potential restrictions or regulatory limitations, the Peach Bottom Township Zoning Ordinance does not currently include a regulation in place for the emission of a plume. The ordinance states that "the discharge of any substance into the atmosphere shall be in strict compliance with the provisions of the Federal Clean Air Act and the Pennsylvania Air Pollution Control Act and the regulations adopted pursuant thereto, all of which regulations are incorporated herein by reference." 25 Pa. Code §123.41 limits visible air contaminants to 20% opacity for a period or periods aggregating more than 3 minutes in any one hour and 60% at any time. Per 25 Pa. Code §123.42, visible emission limits in 25 Pa. Code §123.41 do not apply to emissions of uncombined water from an emissions unit.

In addition to the regulatory issues a plume might cause, a plume from the cooling towers could cause visibility problems at the facility and on nearby roads. A plume from a low-profile mechanical-draft

cooling tower could be acceptable if it is rising into the air; however, during certain climatic conditions the plume may put the entire surrounding area in fog. This could create potential security concerns at the station. As stated in **Section 3.4.1**, plume modeling is addressed in the § 122.21(r)(12) report.

For this CCRS retrofit study, it was assumed that plume abated towers were not needed. If a CCRS retrofit was chosen for implementation and it is determined that plume abatement is required, the conceptual design would have to be revisited if in-line arrangements are required because plume abatement capabilities are not as readily available for back-to-back configurations. Switching to an in-line arrangement would create siting issues for the tower in the current hypothetical locations. In addition, plume abatement technology would increase the cost of the retrofit.

3.4.3 AIR CONSIDERATIONS

3.4.3.1 Air Permitting

PBAPS is currently permitted under State Only Permit (SOP) No. 67-05020 issued by the Pennsylvania Department of Environmental Protection (PADEP). The installation of the hypothetical cooling towers would require a Plan Approval per 25 Pa. Code §127.11. Facility emissions, including those from the hypothetical cooling towers, would remain below the Title V permitting threshold and the station would continue to operate under an SOP after the Plan Approval was incorporated.

3.4.3.2 National Ambient Air Quality Standards (NAAQS)

Attainment status designations are found in 40 CFR Part 81. As shown in **Table 3-6**, York County is considered in attainment (better than national standards or unclassifiable/attainment) for all criteria pollutants. York County is a maintenance area for the annual and 24-hour $PM_{2.5}$ (2006) standards as well as the 1997 8-hour ozone (O_3) standard. However, since Pennsylvania is within the Ozone Transport Region, the entire commonwealth is classified as Moderate Non-Attainment for ozone.

Table 3-6: Attainment Status Designations

Pollutant	York County, PA
Sulfur Dioxide (SO_2)	Better than National Standards (Attainment)
PM_{10}	Unclassifiable/Attainment
$PM_{2.5}$ (Annual NAAQS)	Attainment (12/8/14)
$PM_{2.5}$ (24-hour NAAQS)	Attainment (12/8/14)
Nitrogen Dioxide (NO_2)	Unclassifiable/Attainment
Carbon Monoxide (CO)	Unclassifiable/Attainment
1997 8-hour O_3	Attainment (2/13/08)
2008 8-hour O_3	County is Unclassifiable/Attainment, but classified as Moderate Nonattainment due to Ozone Transport Region
Lead	Unclassifiable/Attainment

PM – particulate matter; PM_{10} - PM with diameters of 10 microns and less; $PM_{2.5}$ - PM with diameters of 2.5 microns and less

3.4.3.3 Federal Air Regulations

Emissions from PBAPS are currently and would remain below the Prevention of Significant Deterioration (PSD) major source thresholds. As such, PSD permitting would not be required for this CCRS retrofit option.

York County is in attainment for all criteria pollutants. Therefore, Nonattainment New Source Review (NNSR) does not apply to this conceptual CCRS retrofit.

There are no New Source Performance Standards (NSPS) or National Emission Standards for Hazardous Air Pollutants (NESHAP) applicable to the hypothetical cooling towers.

3.4.3.4 State Air Regulations

Per 25 Pa. Code §123.13(c), particulate emissions for process emission units are limited to 0.04 grain per dry standard cubic foot, when the effluent gas volume is less than 150,000 dry standard cubic foot per minute (dscfm) and 0.02 grain per dry standard cubic foot when the effluent gas volume is greater than 300,000 dscfm. For effluent gas volumes in between 150,000 and 300,000 dscfm, the allowable emissions are determined using the equation $A = 6000*E^{-1}$, where E is the effluent gas volume in dscfm. Expected emissions from these sources are expected to remain well below this limit

As stated above, permitting of the hypothetical cooling towers would need to be performed in accordance with Pa. Code Chapter 127.

3.4.4 NOISE

Section 200.3 of the Peach Bottom Township Zoning Ordinance (2016) states that "…*in no case is a use permitted which by reason of noise, dust, odor appearance, or other objectionable factor creates a nuisance, hazard, or other substantial adverse effect upon the property value or reasonable enjoyment of the surrounding property, Every reasonable effect must be made to prevent this effect through*…". In addition, Section 201.4.3.I of the Drumore Township Zoning Ordinance (2016) requires all water structures designed for the intake or discharge of water from the Susquehanna River to not "*emit any deleterious dust, electromagnetic, interference, glare, heat, liter, noise, odor, radiation, smoke, vibration, or other objectionable impact beyond the area in the Township permitted for the facility*…". However, exceptions to the rule apply during construction, maintenance, replacement or demolition of the facility. Based on an initial review of these requirements, it appears that the plant is required to minimize noise effects with operating the cooling towers according to the Peach Bottom and Drumore Township Ordinances.

Based on an initial review, there are no local or state ordinances that apply specifically to electricity generating facilities or to general industrial facilities. While this study assumed no noise dampening would be required, further noise evaluation is addressed in the §122.21(r)(12) report. Noise modeling would be used to evaluate whether measures are needed to reduce noise levels at the property boundary, such as sound barrier walls around the perimeter of the towers or a barrier on the fan deck. Any additional measures that would be required would increase the overall cost of the retrofit.

3.4.5 HEIGHT

The Peach Bottom Township Zoning Ordinance (2016) Section 202.6 limits building heights to 50 ft., with an exception for agricultural building with no height limitations. Section 214 of the ordinance also provides height exceptions for water tanks and other mechanical appurtenances, provided they do not cover more than 25% of the roof on which they are located. 34 Pa. Code §403.42 makes height exceptions for water tanks that carry less than 5,000 gallons of water and the height-to-diameter ratio does not exceed 2 to 1. Even though Section 202.11 of the Drumore Township Zoning Ordinance limits the height of principal structures to 35 ft., no height requirements exist for cooling towers. No other height limitations were identified for Peach Bottom Township or surrounding townships and counties.

3.4.6 AESTHETICS

No aesthetic requirements for the presence of cooling towers are incorporated within the zoning ordinances for Peach Bottom Township, Fulton and Drumore Townships, Lancaster County, York County and the state of Pennsylvania. The absence of regulations would need to be confirmed before detailed design and construction. Renderings of the visible plumes could be developed to further evaluate the

aesthetic impact of the cooling tower operation during the detailed design, if this alternative is selected for further evaluation.

3.4.7 SITING, SEISMIC, GEOLOGIC, AND HYDROLOGICAL IMPACTS

PBAPS operates four on-site wells for the supply of non-potable water to remote facilities. PBAPS has three closed groundwater wells (filled with concrete) and four wells providing non-potable water on demand to remote facilities. The well at the Salt Storage Facility near the North Substation, which is of unknown depth, supplies approximately 41.6 L/min (11 gpm) of water solely to an outdoor pressure washer and hose bib, which are used primarily for washing company vehicles. The well at the North Substation is 76.2 m (250 ft) deep and supplies water for a toilet and sink at the unmanned substation control house. While the pumping capacity is unknown, the North Substation well's use is like that of the well at the South Substation, which suggests a pumping capacity of no more than 19 L/m (5 gpm). The well in the Hazardous Materials Yard, occasionally used for washing hands or rinsing equipment, is 61 m (200 ft) deep and provides 22.7 L/min (6 gpm). The well in the South Substation, is 91 m (300 ft) deep and provides 3.8 L/min (1 gpm) to a toilet at the substation control house (Conestoga-Rovers & Associates 2006).

The locations of the cooling tower and associated piping in **Figure 3-1** and **Appendix A** do not conflict with the existing wells or any known major subsurface structures. No other siting, seismic, geologic, or hydrological issues have been identified during this preliminary evaluation, but these items would have to be comprehensively assessed during the detailed engineering design if this alternative was selected for implementation.

3.4.8 PARASITIC POWER LOADS

A retrofitted CCRS would have a deleterious effect on the plant's net heat rate. Considering only the wet mechanical-draft cooling tower system, the power requirements would be higher than the current pumping power requirements for the once-through system. This power would be used for the additional circulating pumps and for the cooling tower fans, and it represents power generated by the plant that would be used instead of sold (parasitic power load). These potential additional power requirements are estimated in the following sections.

3.4.8.1 Pumping Power

The existing circulating water system would continue to discharge water from the condensers into the existing cooling water discharge basin. However, this discharge line would be extended into the smaller discharge basin, as a result of the discharge canal being extended to the north. New pumps would be required to convey the 'hot' water to the top of the cooling tower hot water distribution deck. The additional head increase for pumping the water is estimated to be approximately 51 ft. to account for the lift out of the respective discharge basin(s), the elevation change (rise) to the 'hot' water distribution deck on the top of the towers, and the head loss through the pipes to the towers. Velocity through the new piping has been assumed to be 9 fps. A pump efficiency of 85% and a motor efficiency of 90% were assumed. Each of these factors would be refined in a detailed analysis, but these are considered adequate to reasonably estimate the effect of additional operating power on the plant. The pumping power required for the 'hot' water pumps at PBAPS is provided in **Table 3-7**.

Table 3-7: PBAPS Units: Retrofit Additional Pumping Power for "Hot" Water Pumps

Unit	Cooling Water Flow (gpm)	Approx. Head (ft.)	Pump Efficiency (%)	Motor Efficiency (%)	Additional Pump Power (MWe)
2	750,000	50.8	85	90	9.4
3	750,000	50.8	85	90	9.4

Due to the hypothetical closed-cycle cooling system arrangement that includes an extended discharge canal to be directly connected to the intake basin, 'cold' water pumps would not be required. Cooled water discharged from the cooling towers would equalize by gravity with water in the intake basin, rather than being pumped.

Although PBAPS currently operates existing helper towers, this operation is limited to up to two-and-one-half months according to the requirements included in the existing NPDES permit. During operation, up to approximately 58% of the condenser discharge flow may be directed through the helper towers. The total additional pumping power for the CCRS retrofit is approximately 18.8 MWe. If the operation of the helper towers is taken into consideration (assuming 58% of the condenser flow is directed to the helper towers), incremental increased pumping power is limited to approximately 7.9 MWe for a two-and-one-half month period during the year, and remains at 18.8 MWe during the other nine-and-one half months of the year. Due to the variability (and uncertainty) of the existing helper tower operation, this study assumes that additional pumping power would be required for the hypothetical cooling towers for the entire condenser circulating water flow.

3.4.8.2 Fan Power

The power required by the cooling tower's fans can be approximated similarly to the pumping power. The number of cells was specified in **Table 3-2**, and the fan horsepower was approximated as 250 HP per fan based on the typically utilized fan with a diameter of 30 to 34 ft. The motor/motor drive efficiency was assumed to be 90%. The fan power for the PBAPS units is given in **Table 3-8**.

Table 3-8: PBAPS Units: Retrofit Fan Power

Unit	Cells per Cooling Tower	Air Flow per Cell (acfm)	Drive/Motor Efficiency (%)	Fan Power (MWe)
2	50	1.45E+06	90	10.4
3	50	1.45E+06	90	10.4

Although PBAPS currently operates existing helper towers, this operation is limited to a two-and-one-half month period according to the requirements included in the existing NPDES permit. During operation, up to 33 existing cooling tower cells (each equipped with a fan) could be in operation. The total fan power for the CCRS retrofit would be about 20.8 MWe. If the operation of the helper towers is taken into consideration (assuming up to 33 existing fans are operated continuously), incremental increased fan power is limited to approximately 13.9 MWe for up to a two-and-one-half month period during the year, and remains at 20.8 MWe during the other nine-and-one half months of the year. Due to the variability (and uncertainty) of the helper tower operation, this study assumes that additional fan power would be required for all of the cooling towers in the hypothetical CCRS.

When added together, the pump and fan loads together represent a combined, full-load operating power requirement of approximately 39.6 MWe or approximately 1.5% of the gross plant power rating of 2,600 MWe. The actual annual power loss would depend on the capacity factor, the number of hours on-line, and whether some fans are turned off when operating at partial load. Since the closed-cycle cooling system was sized for full load at acceptable backpressures at the so-called "1%" ambient conditions, it would be oversized for nearly the entire year and reductions in fan power would be available. If closed-cycle cooling is selected for implementation at PBAPS, variable speed fans may be evaluated to reduce operating power requirements.

3.4.9 Heat Rate Penalty and Capacity Limits

Heat rate penalty is associated with the use of a CCRS, since closed-cycle cooling results in an overall annual average increase in cooling water temperatures used in the condenser, which increases the turbine exhaust pressure and, consequently, lowers turbine efficiency and reduces electrical energy output.

Overall, the turbine performance improves with cooler water exiting the condenser. Based on assumptions included in USEPA's (2014a) Technical Development Document, retrofit with a closed-cycle cooling system with wet cooling towers would result in an estimated 2.5% reduction in output at full capacity (equal to 65 MWe of power total from Units 2 and 3). This heat rate penalty of 2.5% has been assumed for costing purposes described in **Section 3.5.2.**

3.4.10 Safety and Security Considerations

Any significant change in the cooling water system design and operation would be subject to NRC review and approval. All nuclear plant modifications must comply with NRC regulations and guidelines regarding safety and security.

This CCRS retrofit analysis assumes that the service water pumps would not be included in the closed-cycle cooling system design and would continue to operate in their current configuration. Security issues with the towers would also have to be reviewed and might require additional monitoring equipment, fencing, and increased security staffing.

As discussed in **Section 3.1.3**, the rad-waste discharges would have to be evaluated further if the closed-cycle retrofit is selected for implementation. The rad-waste discharges would be partitioned off (piped) from the 'cold' cooling tower discharge flows that are returned to the condenser intake and recycled. Rad-waste discharges would only be mixed with the cooling tower blowdown prior to discharge to Conowingo Reservoir. If the closed-cycle cooling retrofit is selected for implementation, the rad-waste discharges would be evaluated to confirm that adequate dilution flow is available after the retrofit, and would likely require review and compliance with 10 CFR § 50, Appendix I design objectives; and approval from the NRC.

3.4.11 Additional Considerations

Two final factors in terms of costs must be considered as part of the CCRS retrofit: outage time of the plant during construction of the closed-cycle system, and costs of permitting. Concerns include:

1. During the outage period while the hypothetical cooling towers are constructed, Exelon would have to provide replacement power to the grid. For this conceptual level design, there is no basis available to determine the required outage time with any precision. The average outage time for nuclear plants has been identified as 6 months, but studies have shown estimated outage times in the range of 4 to 22 months (EPRI 2011a).
2. Potential permitting needs have been identified concerning drift, plume, noise, and aesthetics, NRC review and approval, although further evaluation would be required to evaluate the costs associated with obtaining the permits, if applicable. Additional environmental permitting costs may be incurred to address items such as water quality related to the cooling tower blowdown, and the increased consumptive water use at the facility.

3.4.12 Evaluation of Overall Degree of Difficulty of Retrofit

Of the key factors identified in **Section 3.2**, the most significant appears to be:

- Demolition of existing helper towers;
- Modification and extension of the existing condenser discharge structure in order to construct the CCRS;
- Partitioning off (piping) the rad-waste discharges to prevent comingling with the 'cold' cooling tower flows that are redirected back through the condenser, and
- Construction sequencing required to allow for use of the existing helper towers as much as possible to meet NPDES permit requirements and minimize facility downtime.

Additionally, there are potential concerns with routing the condenser discharge piping under the new 'cool water' basin to the hot basin (including potential geological conditions along the new alignment). Additional permitting modifications would be required to address the replacement of the helper tower operation, water quality associated with the cooling tower blowdown, and the increased consumptive water use at the facility.

Based on the substantial construction required to reconfigure the discharge channel and demolish the existing helper towers, and the potential impacts due to the modifications of the condenser discharge structure, the closed-cycle cooling system retrofit at PBAPS is considered to be in the "more difficult" category. Assuming the demolition of the existing helper cooling towers and use of their existing footprint, there does appear to be an acceptable on-site location for the towers. The existing intake and circulating water pumps would be re-used but may have an increased discharge pressure due to the extension of the existing condenser discharge to the new partitioned area of the discharge channel. Plume abatement would not be expected to be required. Off-site drift deposition would not be expected to present a significant problem. Noise reduction would not be expected to be required. An existing water source is available, so an alternate source of makeup water would not be expected to be required. Re-optimization of the cooling water system does not appear to be required at this time, although this would have to be evaluated further if this alternative is chosen for implementation. Outage time (approximately 6 months), permitting, and safety issues are expected to be typical for a nuclear facility retrofit.

Based on a review of all these site-specific factors, the "degree of difficulty" for a closed-cycle cooling system retrofit is assumed to be "more difficult" for PBAPS than for other nuclear facilities. Costs for the closed-cycle cooling system retrofit are provided in the following section and are based on the EPRI methodology assuming "more difficult" nuclear retrofit cost factors.

3.5 ENGINEERING COST ESTIMATES

The estimated capital and operating costs of a CCRS retrofit using a wet mechanical-draft cooling tower at PBAPS were determined using EPRI (2002, 2011c) analyses. Cost information for each unit is given separately. Since the correlations used in the EPRI studies are linear with circulating water flow rate, the costs for the two units calculated separately are identical to what would be calculated for a single tower for the total flow rate. While it is likely that there would be some cost savings associated with a "combined" approach, no data are available to evaluate any "economy of scale" that might be realized.

3.5.1 EPRI ESTIMATES – CAPITAL COSTS

The EPRI (2011c) report presents a detailed description of the development of cost estimates for the once-through cooled plants in the United States. A set of correlating equations was developed based on cost information from over 80 plants (EPRI 2011a). The costs were correlated against circulating water flows and then divided into four natural groupings associated with differing degrees of difficulty of a closed-cycle retrofit at a given plant. **Table 3-9** gives the cost coefficients for degrees of difficulty for "Less Difficult" and "More Difficult". The coefficients are in units of U.S. dollars per gallons per minute ($/gpm) which, when multiplied by the circulating water flow for the existing once-through cooling system, gives the estimated cost of a closed-cycle retrofit as of 2010. As indicated in above, the CCRS retrofit at PBAPS is considered to be in the "More Difficult" category.

Table 3-9: EPRI Cost Correlating Coefficient Estimates Based on Degree of Difficulty

	Degree of Difficulty for Retrofit	
	Less Difficult	**More Difficult**
Cost Correlating Coefficient ($/gpm)	274	644

Table 3-10 lists the estimated capital costs resulting from the application of these factors to the two units at PBAPS. These costs have been escalated from the values in the 2011 EPRI report from 2010 to 2016 values using the Engineering News-Record's factors (ENR 2016).

Table 3-10: EPRI Estimated Range of Capital Costs (escalated for 2016)

Unit	Cooling Water Flow (gpm)	Cost of Retrofit for Degree of Difficulty	
		Less Difficult	More Difficult
2	750,000	$243,840,000	$573,114,000
3	750,000	$243,840,000	$573,114,000
Total	1,500,000	$487,680,000	$1,146,228,000

3.5.2 *Costs – Operation and Maintenance (O&M) Costs*

To determine the O&M costs for a retrofit to a CCRS, commonly accepted factors were utilized. For maintenance (labor, materials, chemicals, etc.) for wet cooling systems, the costs range from 2-3% of the system equipment costs. For wet systems, the important costs are for water treatment, biofouling control, and keeping the basin clean. The drift produced by the cooling towers would also create the need for rust control, extra painting, etc., and this would increase overall facility O&M costs. Operation costs were estimated using an assumed power cost of $35 per megawatt-hour (MWh), the unit's average 2012 through 2016 capacity factors, and the combined pumping and fan power requirements. According to the USEPA (2014a,b) guidance, costs have been assessed as Net Present Value (NPV) costs and Equivalent Annual Costs (EAC), using discount rates of 3% and 7%, and the USEPA assumption that the useful life of cooling towers is 30 years. The current NRC licenses for Unit 2 and Unit 3 expire at the end of 2033 and 2034, respectively. It is anticipated that Exelon will receive a 20-year extension of their operating licenses for each unit; however, since this is currently the first NRC second license renewal in the United States, the timing and outcome of the license extension is unknown at this time.

The estimated Capital, Operation, Maintenance, Heat Rate Penalty, EAC, and NPV costs for PBAPS are summarized in **Table 3-11** assuming an extended NRC license, a 30-year life of the cooling towers, and a 7% discount rate. Estimated costs assuming an extended NRC license, a 30-year life of the cooling towers and using a discount rate of 3% are summarized in **Table 3-12**.

Table 3-11: EPRI Estimated Capital and O&M Costs (7% Discount Rate)

Unit	Capital Cost (More Difficult)	Operation		Maintenance Cost Per Year	Heat Rate Penalty Cost Per Year	Total Annualized Cost (EAC)[20]	Net Present-Value Cost (NPV)
		Power Required	Cost Per Year				
2	$573,114,000	19.8 MWe	$5,546,200	$1,950,800	$9,103,600	$62,785,800	$779,111,600
3	$573,114,000	19.8 MWe	$5,740,500	$1,950,800	$9,422,500	$63,299,000	$785,479,900
Total	$1,146,228,000	39.6 MWe	$11,286,700	$3,901,600	$18,526,100	$126,084,800	$1,564,591,500

Notes: Operation costs were estimated using an assumed power cost of $35/MWh, the units' 2012-2016 average capacity factors, and the units' gross generating capacities. Heat rate penalty assumes 2.5% reduction in output at full load steam flow.

[20] USEPA Development Document EPA-821-R-14-001, "Economic Analysis for the Final Section 316(b) Existing Facilities Rule", May 2014 establishes useful life of cooling towers (30 years) and discount rate (3%) and (7%).

Table 3-12: EPRI Estimated Capital and O&M Costs (3% Discount Rate)

Unit	Capital Cost (More Difficult)	Operation		Maintenance Cost Per Year	Heat Rate Penalty Cost Per Year	Total Annualized Cost (EAC)[21]	Net Present-Value Cost (NPV)
		Power Required	Cost Per Year				
2	$573,114,000	19.8 MWe	$5,546,200	$1,950,800	$9,103,600	$45,840,500	$898,493,100
3	$573,114,000	19.8 MWe	$5,740,500	$1,950,800	$9,422,500	$46,353,700	$908,552,100
Total	$1,146,228,000	39.6 MWe	$11,286,700	$3,901,600	$18,526,100	$92,194,200	$1,807,045,200

Notes: Operation costs were estimated using an assumed power cost of $35/MWh, the units' 2012-2016 average capacity factors, and the units' gross generating capacities. Heat rate penalty assumes 2.5% reduction in output at full load steam flow.

In addition to the costs outlined in **Table 3-11** and **Table 3-12,** construction of the closed-cycle cooling system would result in up to six months of downtime. Loss of power produced by the facility would have to be made up elsewhere. Assuming the power replacement cost of $35/MWh, the units' average 2012 to 2016 capacity factors, and a 6-month downtime period for construction of the closed-cycle cooling system, the replacement power costs would be approximately $182 million for Unit 2 and $188 million for Unit 3, or a total cost of $370 million for the facility.

3.5.3 Costs – Social Costs

In the preamble to the 2014 Existing Facilities Rule, USEPA defines the social cost of compliance as the total burden imposed on society. That is, total social costs reflect all of the negative effects imposed on the facility, the government, or other members of society. Social costs can be greater than, less than, or similar to engineering cost estimates.

If some social cost elements are not monetized, total social cost will be under-estimated and any associated benefit to cost comparison will overstate the potential net social benefit of a technology. This observation is relied upon to streamline the estimation of social costs. For example, if one component of a technology's social cost (perhaps capital expenditures) exceeds the total social benefit of that technology, the technology is not cost effective. Efforts to monetize additional social cost components for that technology will not change this conclusion and are not required as part of a best technology available (BTA) determination.

The USEPA defines social costs as the "opportunity cost to society of employing scarce resources to prevent the environmental damage otherwise occurring except for the design and operation of compliance technology" (79 Fed. Reg. 158, 48387). Social costs can be further categorized as Real Resource Compliance costs, Government Regulatory Costs and Environmental Externality costs. Real Resource Compliance costs result from the purchasing and installing technologies, Government Regulatory Costs are developed from USEPA's estimates in the national rule (79 Fed. Reg. 158, 48387), and the social costs of environmental externalities are developed from a Power System Capacity Loss and Offsite Emissions study, a Recreation Study and a Property Value study conducted at PBAPS (Veritas Economic Consulting 2018).

First, social costs of installing entrainment reduction technologies are estimated by determining the design construction and installation costs, along with the O&M, permitting and power system costs. The analysis conducted by Veritas Economic Consulting (2018) assumes that all compliance costs at PBAPS would be passed on to the shareholders in the form of lower returns, shown in **Table 3-13** as shareholder dividend decreases.

[21] USEPA Development Document EPA-821-R-14-001, "Economic Analysis for the Final Section 316(b) Existing Facilities Rule", May 2014 establishes useful life of cooling towers (30 years) and discount rate (3%) and (7%).

Following USEPA guidance, annual costs are expressed in real dollars (pre-tax) which are then then adjusted with discount rates of both 3% and 7% to account for society's rate of time preference[22]. The partial social cost estimate is then expressed as a present value and as an annualized value.

Table 3-13 reports the social costs of installing a CCRS retrofit at PBAPS. Social cost elements are generally extracted from **Sections 3.5.1** and **3.5.2** along with the following criteria from the analysis conducted by Veritas Economic Consulting (2018).

- Engineering costs are specified over a 30 year time period for cooling towers.
- Power system costs are specified to occur during construction, based on outage impacts, and during operation, based on efficiency and auxiliary load impacts. Power system costs represent the additional power needed to operate the new technologies and the additional fuel needed from running less efficient units during installation construction outages. The power system costs are developed from evaluating backpressure and auxiliary load effects, capacity losses from each of the technologies with estimated outage times, and electricity consumption associated with each technology.
- Permitting costs include the total costs associated with permitting, monitoring, administering, and enforcing the technology selection and installation. Costs are incurred by the government as the permitting and review process is undertaken. These vary with the type of technology, as certain technologies require substantially more permitting. Those with more significant environmental effects would have higher permitting costs. These costs are initially borne by the government, but ultimately paid by taxpayers.

Table 3-13: Social Costs of a CCRS Retrofit at PBAPS

Discount Rate	Engineering Cost[a]		Social Costs[b]					
	Total Design, Construction &Installation Costs	Annual Maintenance Costs	Shareholder Dividend Decrease	Power System Costs[b]	Externality Costs	Regulatory Permitting Costs[c]	Total Present Value of Social Costs	Annualized Social Costs
3%	$1.1B	$3.9M	$691.5M	$1.2B	$6.9M	$0.2M	$1.3B	$44.2M
7%	$1.1B	$3.9M	$348.2M	$1.2B	$6.9M	$0.2M	$667.6M	$22.3M

[a] The engineering compliance costs presented in the table are undiscounted and in 2016 dollars.
[b] The social costs associated with each technology are discounted at 3 and 7 percent using specifications outlined in Veritas, 2018. Additional details on the Social Cost components (i.e., shareholder dividend decrease, power system costs, etc.) are provided in Appendix B. Social costs are presented in 2019 dollars for the perspective of the Reviewer, assumed to be reading this report in 2019.
[c] Regulatory permitting costs itemized in the Social Costs sections of the table are Government permitting costs that include the total additional government costs associated with permitting, monitoring, administering, and enforcing the technology selection and installation. Costs are incurred by the government as the permitting and review process is undertaken. These costs are initially borne by the government, but ultimately paid by taxpayers. Permitting costs are developed from EPA's estimates in the national rule (79 Fed. Reg. 158, 48300-48439) and are specified to be .02% of direct capital costs. These costs do not include compliance permitting costs that are borne by the Station.

The social costs presented in **Table 3-13** were estimated based on the engineering schedule presented in **Section 3.6.** For additional details on social costs see **Appendix B**.

[22] Discounting reflects the notion that society places more value on a benefit received today than they would the same benefit received in the future. There are two reasons for this. First, inflation diminishes the purchasing power of a dollar over time; economists address this factor by discounting real values (real values are adjusted to remove the effects of inflation). Second, humans tend to prefer receiving a good now rather than in the future. This "rate of time preference" is the motivation behind discounting real values at a rate of 3 to 7%. The resulting present-value is the value today of a stream of social costs or social benefits occurring over time.

3.6 ENGINEERING SCHEDULE

The NRC licenses for Units 2 and 3 at PBAPS expire at the end of 2033 and 2034, respectively. According to the project schedule shown in **Figure 3-4**, it would take at least eight years (2017-2025) to complete the CWA Section 316(b) studies and evaluations, and to design, permit, and construct the cooling tower retrofits. Therefore, eight years would be left for operation under the current license for Unit 2 and nine years would be left for operation under the current license for Unit 3. However, the station is in the process of extending its license for another twenty years. Since this is currently the first NRC second license renewal in the United States, the timing and outcome of the license extension is unknown at this time; therefore, using USEPA's estimated 30-year life will underestimate the total annualized costs.

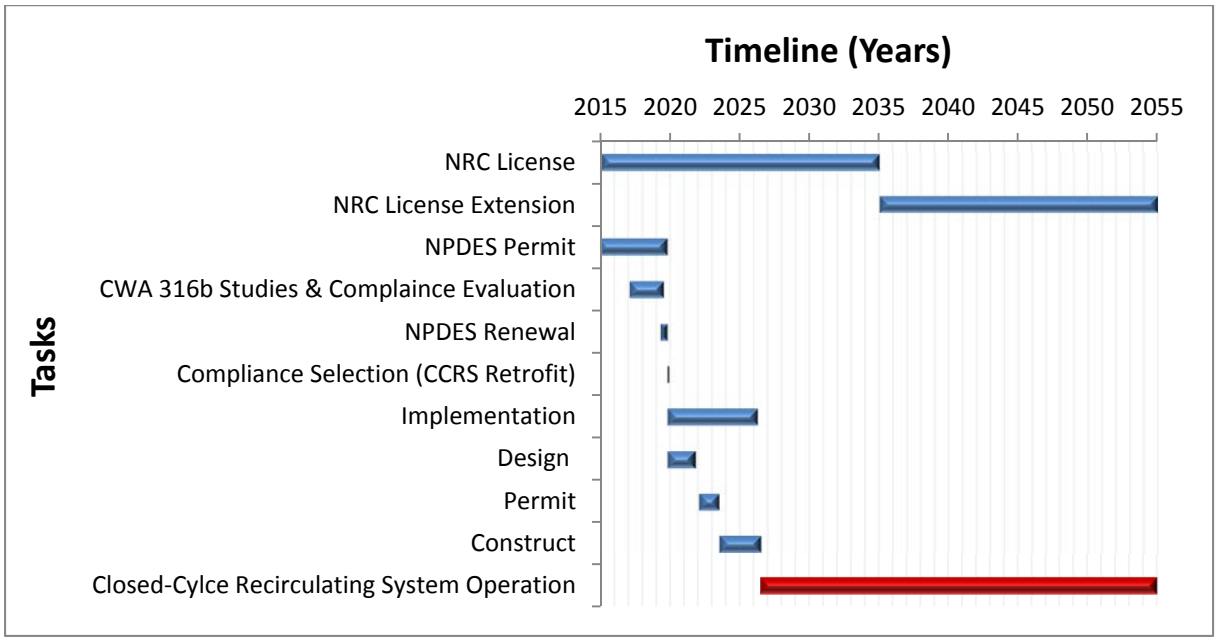


Figure 3-4: Engineering Schedule for PBAPS

4.0 COMPREHENSIVE EVALUATION – FINE MESH SCREENS

As noted in the Introduction, the CWA Section 316(b) Rule requires that facilities evaluate the use of fine-mesh screens with a mesh size of 2 mm or smaller for entrainment mortality reduction. Entrainment mortality includes death resulting from both entrainment through the CWIS as well as that caused by exclusion from the intake by fine-mesh screens (79 FR 48431; August 15, 2014). Therefore, the evaluation of any fine-mesh screening technology must balance the engineering considerations caused by smaller mesh size or slot width (e.g., decreased open area and therefore, the need for a larger surface area to attain a 0.5 fps through-screen velocity) and biological aspects such as increased entrainment mortality produced by more effectively excluding eggs and larvae from entrainment. In laboratory studies, EPRI (2010) found that latent survival of smaller larvae collected off very fine mesh (0.5- to 1.0-mm) screens was poor (approximately 30%). However, latent survival of larger larvae and early juveniles collected on 2 mm screens was significantly higher (approximately 90%). Additionally, EPRI (2010) found that through-mesh survival was species-specific, but was as high as 80%. Based on laboratory, pilot test, and full scale studies, EPRI (2013) found that survival of collected organisms (i.e., previously entrained) decreases significantly with screen mesh size ≤ 2 mm; potentially negating the benefit of reducing entrainment for the very early life stages. This finding was confirmed in an EPRI (2017) study at the East River Generating Station. The results for both eggs and larvae demonstrate that the use of fine-mesh

screen panels on the dual-flow traveling screens would not reduce entrainment mortality because of the high mortality early life stages retained on the screen. The study also concluded that fish eggs survive entrainment (through the condenser) at the East River Generating Station substantially better than they survive exclusion by fine-mesh screens. The through-mesh survival coupled with through-plant entrainment survival may be more protective of early life stages than retaining the organisms on very fine mesh and returning them to the waterbody. Early life stages entrained at PBAPS were numerically dominated by the fragile species alewife/gizzard shad (over 90% during the 2016 study and approximately two-thirds of the 2012 entrainment)thus, early life stage survival on narrow-slot or fine-mesh screens size ≤ 2 mm, for the numerically dominate species would likely be negligible. These species also have high natural mortality and low benefit value as forage. Thus, utilizing finer mesh to retain the numerically dominant species would result in an insignificant increase in benefit.

Mesh/slot sizes smaller than 2 mm would also increase the through-screen velocity and would be more susceptible to fouling, increase the annual O&M and potentially effect plant reliability. For the fine-mesh wedgewire screen application, slot sizes narrower than 2 mm would require more wedgewire screens in order to maintain the 0.5 fps through-screen velocity. For example, 53 1-mm screens are needed rather than 36 2-mm screens to maintain the 0.5 fps through-screen velocity. This would increase the project cost by approximately $26.8 million and increase the construction impacts and annual O&M, while achieving only a small increase in benefits even assuming no impingement-related mortality of early life stages occur with wedgewire screens. The only species that would not be retained by 2 mm screens that occur in substantial numbers (> 400 equivalent adults) are low-value forage species such as gizzard shad, darters, carp/minnow and suckers (see Table 1-18 of the § 122.21(r)(11) Report). Conversely, the 2 mm screens retain species with higher survival probability and higher economic values such as catfish and American eel (over 99%), and greater than 50% of American shad and yellow perch. This mesh size also allows entrainment (through the condenser) of early life stage that, per EPRI research, should have greater survival than retention on the screen. Therefore, a mesh size / slot width of 2 mm was chosen for both fine-mesh technologies evaluated.

Based on the screening of candidate technologies (**Section 2.2**), two alternatives (cylindrical wedgewire screens and modified-Ristroph traveling screens with seasonal fine-mesh baskets / panels) were selected for the comprehensive technical feasibility and cost evaluation.

In order to further analyze the differences in costs and benefits of the selected technologies, a preliminary design was developed for the potential technologies. Feasibility, construction, O&M, biological efficacy, engineering costs and schedule, and permitting were taken into consideration when developing these designs.

4.1 NARROW-SLOT CYLINDRICAL WEDGEWIRE SCREENS

4.1.1 DESCRIPTION OF TECHNOLOGY

Cylindrical wedgewire screens are a type of physical barrier that can reduce both impingement mortality and entrainment mortality, depending on the slot size at the CWIS. Wedgewire screens effectively reduce impingement mortality and entrainment mortality through low through-screen velocities and narrow slot widths, respectively. These screens are designed to function passively, in environments that typically provide cross-current flow in order to promote the transport of organisms with limited motility and debris away from the screens. Wedgewire screens range in slot widths, which affect entrainment reduction potential; smaller widths provide greater levels of exclusion, but also require a larger overall surface area to achieve the maximum through-screen velocity of 0.5 fps to prevent impingement of juvenile and adult fish. In order to maintain low through-screen velocities at narrow slot widths, wedgewire screens are arranged in a system that utilizes the high surface intake area of many screens. Wedgewire screens have wire that is "V" or wedge-shaped in cross-section. The wire is secured to a framing system to form a

slotted screening element. Cylindrical wedgewire screens have the wedge-shaped openings around the perimeter of the screen. A cylindrical wedgewire tee-screen is shown in **Figure 4-1**.

Figure 4-1: Photograph of a Cylindrical Wedgewire Tee-screen (Courtesy: Johnson Screens)

In order for cylindrical wedgewire screens to most effectively reduce impingement mortality and entrainment mortality, the following conditions must exist:

1. Sufficient space and water depth for the layout of screens;
2. Sufficiently small screen slot size to physically block passage of the smallest life stage to be protected (typically 0.5 to 2 mm);
3. Low through-slot velocity (typically ≤ 0.5 fps); and
4. Ambient currents providing a sweeping velocity to provide continuous flushing of debris.

Although entrainment benefits increase with smaller slot widths, screens with narrower openings are more prone to clogging, which can lead to increased capital and O&M costs. To counteract clogging and maintain sufficient operation, screen cleaning systems are required. Most wedgewire screen cleaning systems include air-burst systems or automated brush-cleaning systems. While automated brush-cleaning systems typically have a higher up-front cost, these systems have lower O&M costs, require less space for system components, and do not require as much vertical clearance from the top-of-screen to the water surface. However, brush-cleaning systems are a newer technology, and have not been in use as long as the air-burst cleaning systems. Both cleaning systems are discussed further in the conceptual design described below. According to USEPA (2014a), the service life of wedgewire screens is assumed to be 30 years.

4.1.2 TECHNOLOGY STUDIES AND USE

Narrow-slot cylindrical wedgewire screens are physical barriers that have been successfully used at several power generating facilities, including Cope Generating Station in South Carolina, Logan Generating Station in New Jersey, York Power Station in Pennsylvania and Valley Power Plant in Wisconsin (USEPA 2014a; AECOM 2017). In addition, they have been tested in the laboratory and at several large facilities such as Seminole Generating Station in Florida, Chalk Point Generating Station in Maryland, and Oyster Creek Nuclear Generating Station in New Jersey (USEPA 2014a; EPRI 2013). These screens can be manufactured with slot widths ranging from 0.5 mm to 10.0 mm and installations on

a scale similar to what is needed at PBAPS have been implemented at power facilities using larger slot widths (>6.0 mm) (EPRI 2013).

As discussed above, for cylindrical wedgewire screens with air-burst cleaning systems to function optimally, sweeping or flushing currents and adequate screen submergence are needed. Brush-cleaned cylindrical wedgewire screens have operated successfully at the Valley Power Station in an environment with minimal crossflow. With air-burst cleaning, sweeping current is needed to transport aquatic organisms and debris past the screens and to improve the cleaning efficiency by moving debris removed from the screens during the cleaning cycle away from the screens. Adequate submergence is required to prevent damage to the screens from boats and large floating debris, and, for air burst cleaning systems, to provide adequate water column above the screen.

Wedgewire screens are prone to biofouling. To reduce the potential for biofouling, the screens can be made of a copper-nickel alloy. In northern climates with fresh water applications, the screens are susceptible to frazil ice formation.

Readily-available information on narrow-slot cylindrical wedgewire screens used at facilities with the quantity of cooling water required for PBAPS is limited. An Enercon (2010) desktop evaluation found that installation of cylindrical wedgewire screens at Indian Point Units 2 and 3 would be more beneficial than retrofitting to closed-cycle cooling because they could be implemented sooner, do not produce harmful emissions, and are more likely to receive the necessary permits. However, these screens would be more prone to debris loading and biofouling than the existing wider slot traveling water screens. Testing of narrow-slot wedgewire screens at the Chalk Point Generating Station found that entrainment was reduced, but some biofouling and clogging were observed (USEPA 2014a). If this technology is chosen for installation at PBAPS, a pilot study would be required given that the reliability of service water supply is a NRC safety and reliability concern, and the entire Design Intake Flow (DIF) including service water would be screened with the conceptual wedgewire retrofit system (a conceptual safety-related bypass will be included in the design as noted below). Therefore, these factors would have to be considered in the design of a wedgewire screen.

A narrow-slot cylindrical wedgewire system has been operating at the York Power Plant on the Susquehanna River upstream of PBAPS for over 10 years.

The infrastructure requirements for a wedgewire screen system sized for PBAPS would be substantial. The construction of a new bulkhead, risers, or other in-water structures would disrupt bottom habitat in Conowingo Reservoir and may impact the recreational use of the Reservoir in front of the PBAPS intake structure. This installation would require additional environmental review and permits, and the permanent loss of aquatic habitat may require mitigation.

Cylindrical wedgewire screens with larger slot widths are commercially proven and may result in a reduction in impingement at PBAPS. Narrow-slot wedgewire screen (i.e., 2 mm slot width) have been installed at steam generating stations, but based on public information, the screens have not been installed at a facility the size of PBAPS. The application of narrower slot widths has proven effective experimentally; however, there are significant concerns with performance and reliability under debris loading.

4.1.3 CONCEPT DESIGN

Since wedgewire screens are considered to be commercially proven and an 'off-the-shelf' technology, retrofit of the existing intake structure with wedgewire screens is expected to be feasible for the site from a construction point of view. However, significant infrastructure, intake modifications and construction would be required to install the screens.

An ASTM Level 4 conceptual wedgewire screen design has been developed for PBAPS. This conceptual design is based on the DIF of 2,240.6 MGD, and also includes a conceptual safety-related bypass, since

the service water pump supply would be included in the DIF. Several alternative design configurations are available and were considered for the hypothetical narrow-slot wedgewire screening system at PBAPS. These options included mounting the screens on a bulkhead in front of the existing outer intake structure, on risers, on a separate structure or pier, or on other in-water supports. All options considered in this report were evaluated based on design criteria selected to meet CWA Section 316(b) requirements at PBAPS and site-specific considerations. Though several alternative configurations were considered, the three most viable options, based on feasibility and costs, are discussed in this section. **Option A** is considered the most favorable option and was evaluated further for costs and implementation in the following sections of this report.

Key design considerations are described in more detail below. Detailed layouts and profiles of each option are included in **Appendix A** of the report.

Water Depth

An initial assessment of the bathymetry in front of the existing CWIS was completed to identify water depth limitations. Based on available bathymetry data, two cross-sectional views of the Conowingo Reservoir area in front of the intake were created, as shown in **Figure 4-2, Figure 4-3**, and **Figure 4-4** below. Bathymetry data and a bathymetry map are provided in **Appendix C** of the report.

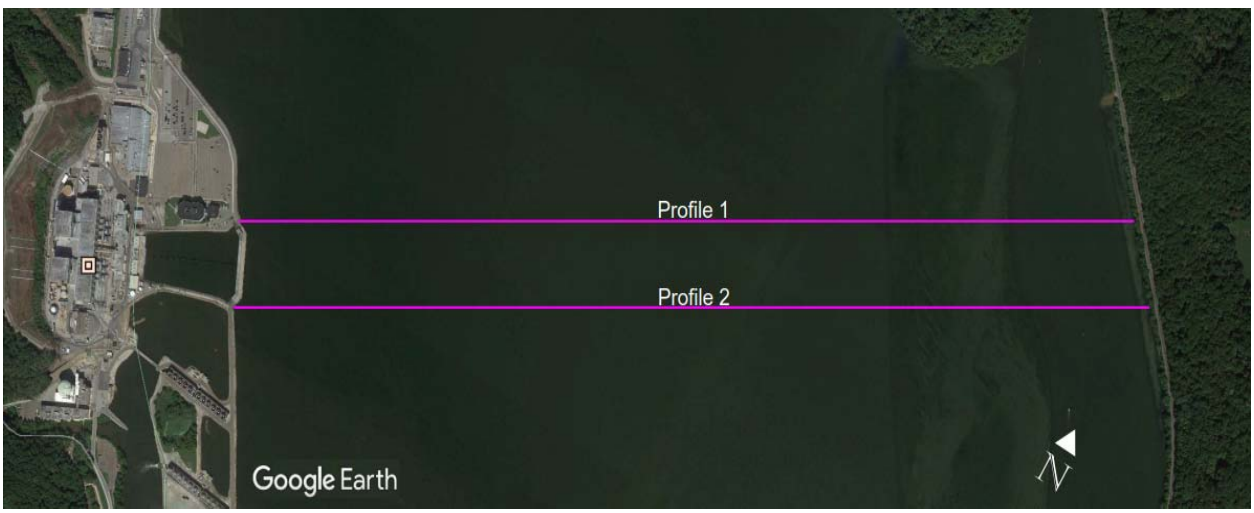


Figure 4-2: Plan View of Conowingo Reservoir with Profile Locations

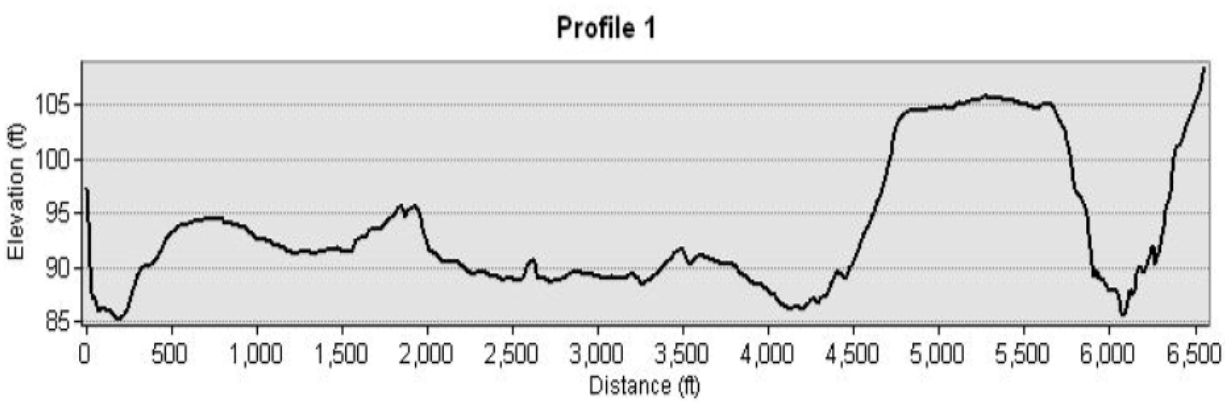


Figure 4-3: Cross-Sectional View of Conowingo Reservoir at Northern End of CWIS

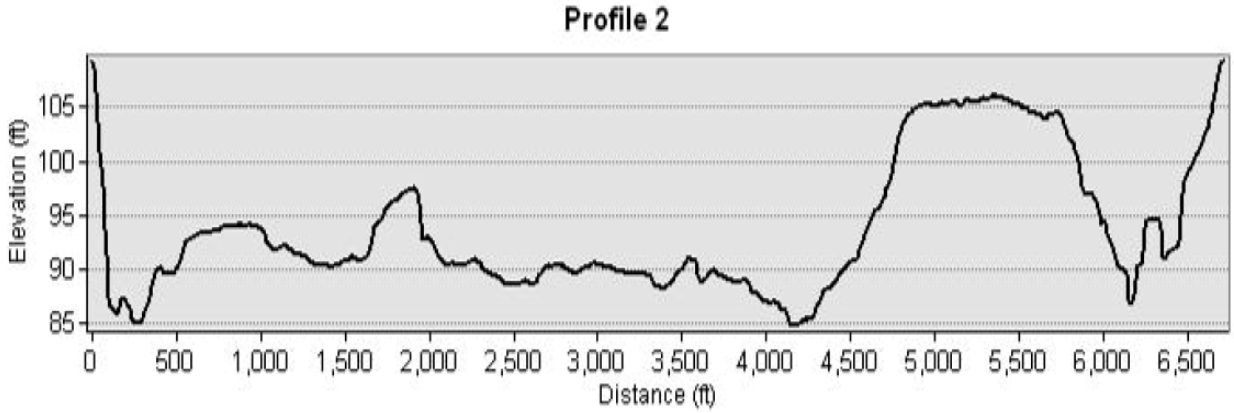


Figure 4-4: Cross-Sectional View of Conowingo Reservoir at Southern End of CWIS

Although the normal water level of the Reservoir at PBAPS is between 104.5 ft. and 108 ft. (Conowingo Datum), the lowest the Reservoir can be without causing shut-down of the Muddy Run Pumped Storage Hydroelectric Facility is 104.0 ft. (SRBC 2006). Based on the bathymetry above, the minimum water depth in front of the existing CWIS is approximately 20 ft. This 20-ft. water depth only extends approximately 250 to 300 ft. in front of the intake.

The minimum water depth has an impact on the selection of the size of the wedgewire screen. Per vendor recommendations for wedgewire screens with a traditional air-burst cleaning system, the minimum water depth for a submerged wedgewire screen should be twice the screen diameter. Additionally, to accommodate shipping and handling requirements, the diameter of the cylindrical screens is often limited to a maximum of 7 ft. Based on the available water depth in front of the existing intake, a 7-ft. diameter screen was selected for PBAPS.

Wedgewire Screen Sizing and Configuration

The wedgewire screen sizing and configuration was selected to achieve a maximum through-screen velocity of 0.5 fps, with a 10% safety factor to allow for some fouling or debris plugging of the screen surface. Furthermore, as indicated above, the screen diameter is limited by the water depth and other construction and installation issues. Each hypothetical system therefore utilizes at least (36) 7-ft. diameter tee-shaped wedgewire screens connected to header pipes that convey the intake water through a new intake structure 'bulkhead' wall constructed in front of the existing CWIS. (One alternative includes 40 tee-shaped screens to achieve a more balanced flow and configuration). The wedgewire screen assemblies are 25 to 28.5 ft. in length based on vendor quotes, and connect to the respective header pipe via 6-ft. diameter outlets (Hendrick Screen Company).

Although available screen slot widths range in size, a 2 mm slot width has been assumed for all the alternatives considered at PBAPS. As slot width size increases, the overall screened area can be decreased to achieve the maximum through-screen velocity of 0.5 fps; the 2 mm width represents the largest screen size considered by the USEPA to provide a benefit to entrainable life stages (USEPA 2014a). For the purpose of this evaluation, smaller screen widths (< 2mm) were not considered due to engineering constraints, including a significantly larger screening area and overall footprint, as well as potential fouling issues associated with finer mesh openings.

The three alternative configurations presented below would all tie into the bulkhead wall via individual 12-foot header pipes; however, the number and configuration of the header pipes (and connecting pipes between the headers and screens) varies among the options. The number and size of header pipes were selected to maintain a maximum velocity of approximately 5-7 fps in the piping system, which, in turn, was selected to limit the head loss through the piping network to 1 ft. (maximum head loss). This would be expected to minimize adverse effects on the existing circulating water pump performance due to

changes in hydraulic conditions. A hydraulic model study would be recommended for the chosen option to confirm flow balancing and to prevent pump performance issues; study costs are included in the project estimate.

In the designs considered, header pipes would convey water from the wedgewire screens to the existing intake canals. The header pipes would penetrate the CWIS via new bulkhead walls that would be constructed in front of the bays that receive header pipes. The bulkhead walls would be three-sided open structures, with the open side facing the intake structure and a bulkhead fitting on the Conowingo Reservoir side, through which the header pipe would enter. To access the inside of the structure for maintenance and repair, a manhole would be placed on the top of the structure. The structures would be made of reinforced concrete and be connected by dowels to the CWIS. A cofferdam would be used around the intake bay in which the bulkhead is being constructed. In the remaining bays, stop logs would be installed after the tie-in of the header pipes to completely seal off intake flow from the Reservoir. All piping for the systems would be supported by driven piles in the Reservoir bed.

The wedgewire screens and conveyance piping materials are assumed to be stainless steel for this conceptual design. If this alternative is selected for implementation, material selection would be further assessed for structural, cost, and operational considerations (such as biofouling). For example, if zebra mussels are considered to be of concern at PBAPS at that time, the screens may be constructed of copper-nickel alloy. Copper-nickel alloy helps prevent the accumulation of biofouling organisms, which would maintain a higher efficiency in the screen, but would increase the capital cost of the screening system. To account for biofouling, debris plugging, and other possible intake issues, the screen configuration includes a 10% 'safety factor' or increase in required screen area for each alternative.

Wedgewire Screen Cleaning System

The average current in the Conowingo Reservoir in the area of the hypothetical wedgewire screens is expected to be low (<0.5 fps) and, therefore, the river flow would provide little aid in the transport of debris and organisms away from the screens. A cleaning system has been included in the design. Two types of cleaning systems were considered for the conceptual designs: 1) an air-burst system and 2) a mechanical brush-cleaning system. Mechanical brush-cleaning systems may provide better reduction of biological growth and debris build up based on vendor data, would require minimal clearance between the screen and water surface, and have been demonstrated to work in low flow environments. These cleaning systems typically have lower O&M costs; however, mechanical brush-cleaning systems have a considerably higher up-front (capital) cost. Air-burst systems, though potentially not as effective as mechanical brush-cleaning systems at removing biofouling and debris, have a lower capital cost per screen. This low cost may be offset by an increased O&M costs associated with the system. Furthermore, use of an air-burst system includes specific waterbody constraints, such as maintaining the recommended minimum screen diameter of water column above the top of the screen, as well as a sweeping current. Air lines are typically limited to less than 1,000 ft., so location of the screens relative to the compressor must be considered. Finally, an air-burst system also requires additional area for the installation of air compressor, air lines, etc. At PBAPS, the hypothetical location for the compressors is within the existing outer intake screenhouse, where the traveling screens would be removed. For both systems, biannual diver inspections would be required to remove any build-up of debris at the base of the screens. Costs for the inspections are factored into the O&M costs.

Each of the potential wedgewire screen alternative designs is described in further detail below.

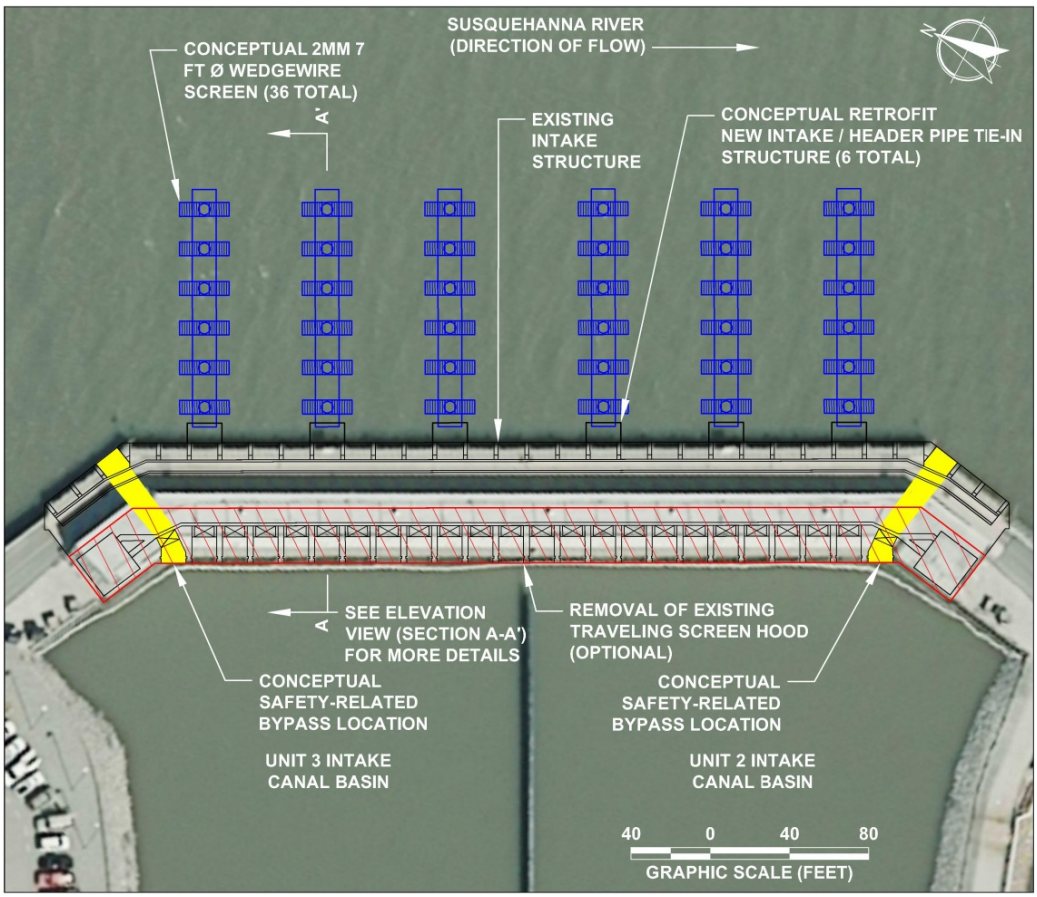
4.1.3.1 Option A

Option A is considered the most favorable option at PBAPS, based on the factors described below. This alternative includes closing off the existing intake structure bar screen bays, except for penetrations for the six header pipes and safety-related bypasses; installation of the bulkhead structures for the header pipes; and installation of 36 tee-shaped wedgewire screens and connector pipe. The safety-related bypass

would be installed to maintain water supply for the service water pumps if the wedgewire screens are completely blocked. This would be expected to consist of a weight/pressure activated gate that would allow water to bypass to the inner intake structure if the differential pressure between Conowingo Reservoir and the intake canals gets too high. If this alternative is selected for implementation, further evaluation of the safety bypass is recommended.

Costs for a cleaning system have been provided, including options for an air-burst cleaning system or a mechanical brush system. The wedgewire screen configuration evenly divides the 36 wedgewire screens among the 6 x 12-ft. diameter header pipes (six screens per header pipe) and each header would extend approximately 120 ft. in front of the CWIS into Conowingo Reservoir. The new header pipes would be partially buried in the Reservoir bed and would be installed via dredging/backfill. The header pipes would be supported by driven piles. The wedgewire screens would be connected to the top of the header pipes via flanged outlet pipes approximately 3.5 ft. in length (one-half screen diameter), and all screens would be aligned transversely. A plan view and profile view of Option A is shown in **Figure 4-5** (background aerial image reference – DCNR PAMAP 2007-2008).

Of all options considered feasible, Option A would have the smallest overall footprint and would include less customized equipment and components. However, the linear configuration of the screens along the header pipes could provide preferential flow pathways since the screens closest to the intake would experience lower head loss than those located further out in the waterbody. If this alternative is selected for implementation, further hydrodynamic studies would be recommended, along with the installation of flow regulating / flow balancing measures such as restricting orifice plates. This alternative would require more dredging than the other options considered.



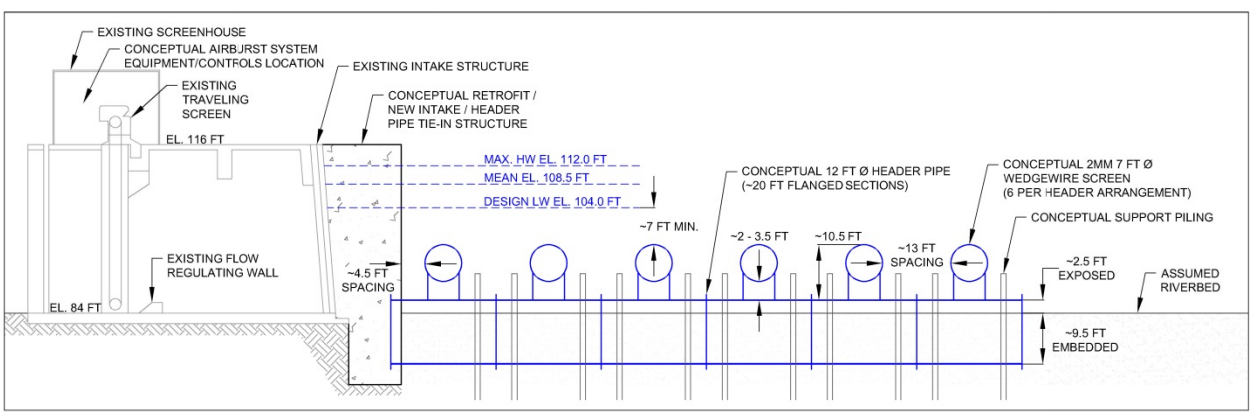


Figure 4-5: Wedgewire Screen Configuration – Option A

4.1.3.2 Option B

Option B is considered the second-most favorable option. This alternative would consist of four 12-ft. diameter header pipes (two per unit) each connected to a separate hexagon manifold that would split to five 10-ft. diameter lateral pipes, all installed as partial burial via dredging/backfilling and all supported by driven piles. The screens in Option B would connect to the top of the 10-ft. diameter pipes via a flanged outlet pipe and extend 3.5 ft. above the header pipe. Two screens would connect to each lateral, each aligned transversely on the lateral pipe, for a total of 10 screens per manifold and 40 screens total. A plan view and profile view of Option B is shown in **Figure 4-6** (background aerial image reference – DCNR PAMAP 2007-2008).

Due to the smaller interconnecting pipe diameters, Option B would only require approximately 7.5 ft. of dredging. Option B would also have a more even distribution of flow compared to Option A. Though increasing the number of screens to 40 increases the screen costs, the additional screens would provide a greater contingency for clogging or damage to the screens. Option B would also require only four header pipes/structures, which reduces the overall length of the large (12-ft. diameter) head pipe. The hexagon manifold assemblies would require custom design and custom welding.

The footprint of Option B would be larger than Option A. Although Option B extends into the Conowingo Reservoir approximately the same distance as Option A (~120 ft.), Option B would have the largest width (630 ft.) in front of the existing intake. The larger footprint is expected to increase permitting and installation costs, along with O&M costs due to difficult access.

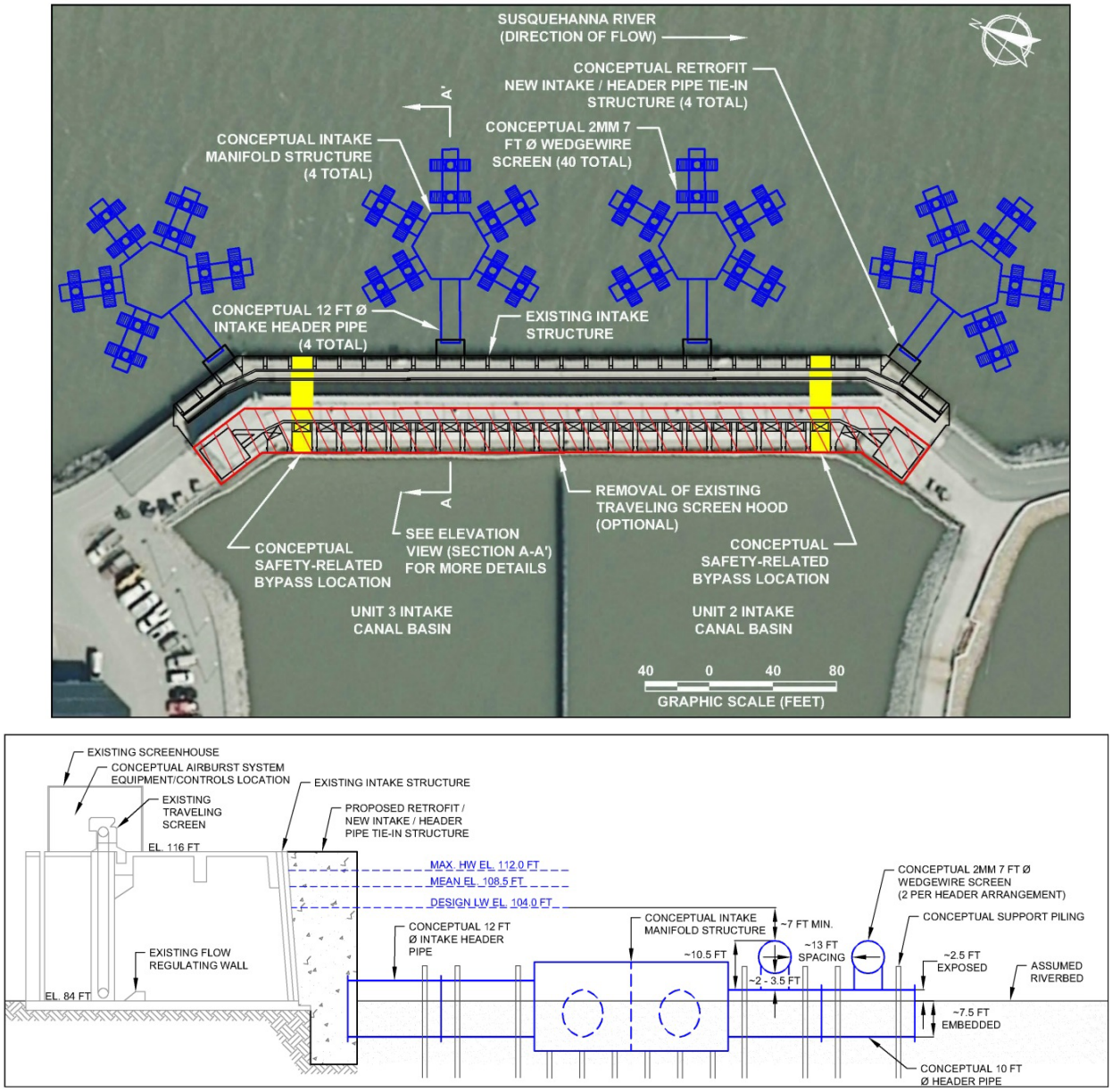
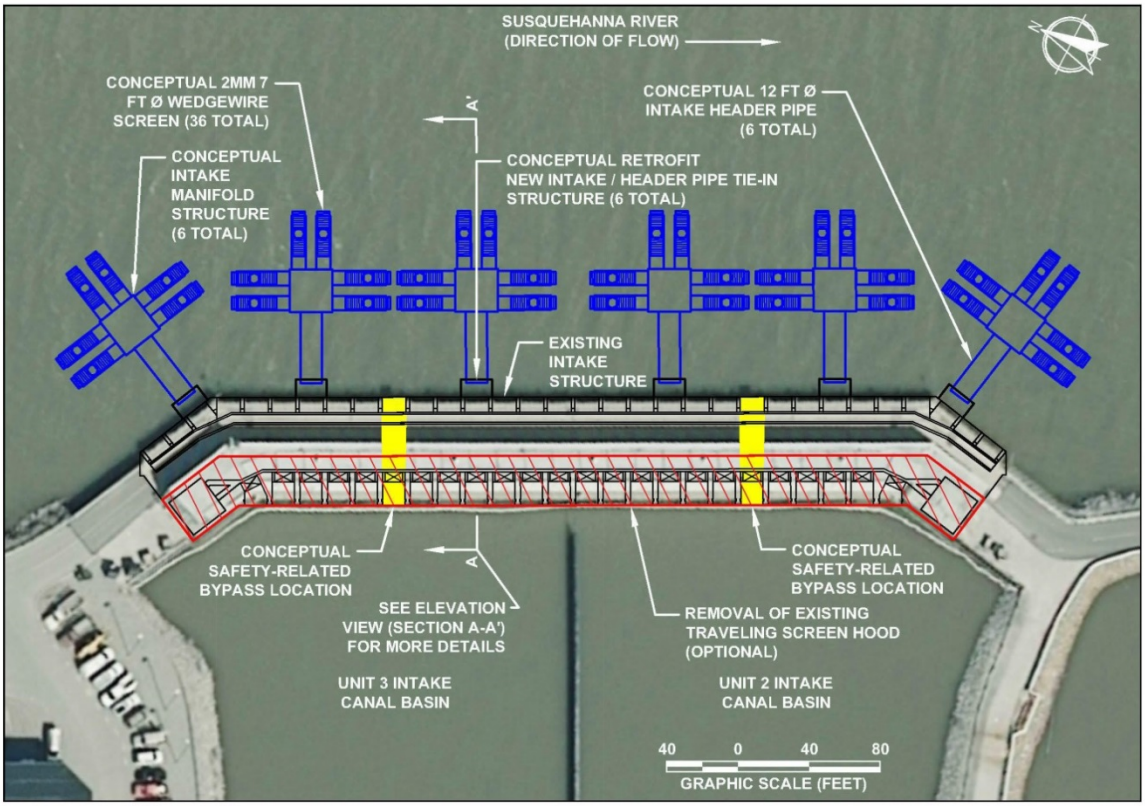


Figure 4-6: Wedgewire Screen Configuration – Option B

4.1.3.3 Option C

Option C is the least favorable option considered in detail for PBAPS. This option is similar to Option B and would use a manifold system to minimize the distance the wedgewire screen system extends into Conowingo Reservoir. Option C would consist of six 12-ft. diameter header pipes (three per unit), each connected to a square manifold. Divided evenly among six manifolds would be 36 8-ft. diameter lateral pipes, each containing one wedgewire screen attached to the top of the lateral pipe and aligned with the pipe's longitudinal axis. All 36 screens would be equidistant from the manifold, which would create an even flow distribution on each manifold. The header pipe for each array would be installed as partial burial via dredging/backfill and would be supported by driven piles as in the other two options. A plan view and profile view of Option C is shown in **Figure 4-7** (background aerial image reference – DCNR PAMAP 2007-2008).

Option C would require the least amount of pipe burial of the three options. The dredging/backfill installation would only require approximately 5.5 ft. of burial, which would decrease the permitting and earthwork costs. Option C would use the smallest size pipe of the three options, including 8-ft. diameter laterals. The size and shape of the manifolds in Option C would also be smaller and easier to construct than those in Option B. However, this option would have the largest overall footprint and higher overall costs.



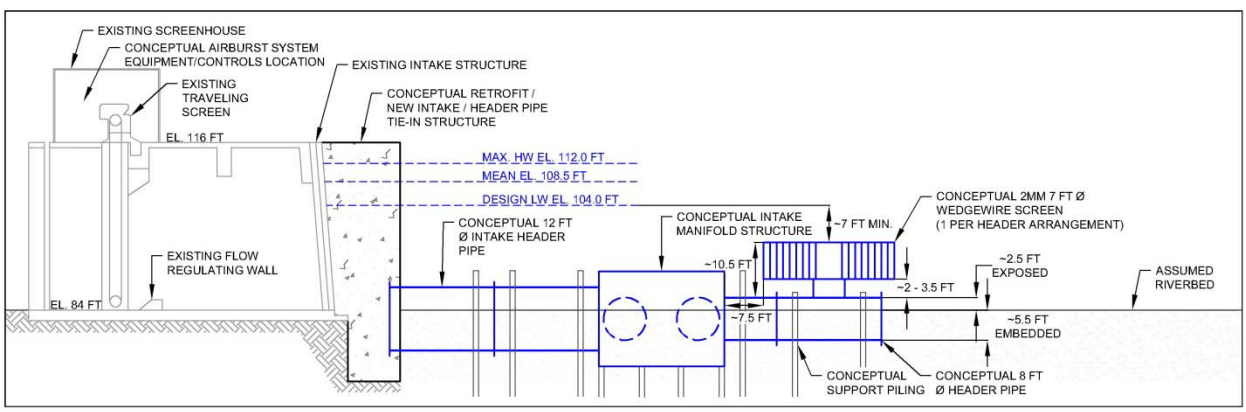


Figure 4-7: Wedgewire Screen Configuration – Option C

4.1.3.4 Other Options Considered

If narrow-slot wedgewire screens are selected for implementation, other configurations may be evaluated further. Other alternative wedgewire screen configurations were initially assessed during this evaluation, such as a vertical alignment of the screens or vertically stacking the screens for a retrievable bulkhead installation; however, these options were eliminated from further evaluation due to space constraints, customized design, and/or higher expected costs than the alternatives described above. The preliminary conceptual designs described above were also selected to provide some flexibility in vendor / technology selection and to minimize sole-sourcing of specific vendors, equipment or components.

For example, one option initially considered included mounting the wedgewire screens on guiderails or tracks on a new bulkhead wall in various arrangements; however, there would not be enough vertical water depth or horizontal space to accommodate the required screen diameter. A bulkhead wall

configuration would also make it difficult to include an emergency bypass. Additional configurations that were considered included stacking two headers vertically and attaching screens to the ends of each, staggering the headers and screens vertically and/or horizontally, mounting three screens on one header, sloping guiderails or tracks into the Reservoir, and mounting 10-ft. long, 9-ft. diameter screens side by side along the length of the bulkhead wall. However, the space required by each of the systems – with a few exceptions for specific vendor options – would exceed or nearly exceed the available water column or available horizontal space when minimum recommended clearances were considered. The most favorable vertically stacked option would provide only 1.5 ft. of water column above the top of the highest screen, which would preclude the use of an air-burst cleaning system and would require the use of a brush cleaning system currently only supplied by one known vendor. Dredging for deeper installation is not considered practical. Without a header pipe separating the screen from the river bed, screen flow would be expected to constantly pull sediment toward the screens, thus requiring regular dredging underneath and around screens if the river bed is lowered. High costs and low feasibility to lift the screens out of the water for regular dredging and for cleaning/maintenance offset the benefits of such options.

Extending the intake further and/or deeper into the source waterbody was another option that was initially considered since it has provided benefits at other plants (e.g., cooler intake water temperatures). This option is not feasible at PBAPS based on existing bathymetry. As seen in **Figure 4-2** and **Figure 4-4** above, bathymetry data show that the deepest sections of the Conowingo Reservoir near PBAPS are approximately 20 ft. deep and are located directly in front of the existing CWIS and approximately 4,000 ft. from the existing intake structure. Extending the intake screening system beyond 250 ft. in front of the CWIS into the Reservoir would provide no benefit.

PBAPS currently operates two intake structures. For the purpose of this evaluation, the inner intake structure and traveling screens would be assumed to remain in operation after the outer intake screens are replaced with the wedgewire screens. If this alternative is selected for implementation, further evaluation of the inner intake structure and traveling water screens may be completed to assess whether they should be removed or remain in operation after the retrofit.

4.1.3.5 Construction

Construction-related outage costs are a significant factor in the overall cost estimate. If wedgewire screens are selected for implementation, construction optimization to limit outage time would be evaluated in detail. The description and possible construction sequence described below is a based on a concept that is expected to minimize interruption to the station operations and outage.

Construction for each unit would be completed separately. The first stage of construction (per individual unit) would be completed during the unit's outage time to minimize unplanned outages. The first stage would consist of the installation of the three bulkhead walls in front of the respective unit. Installation of the bulkhead walls would be completed in a dry environment established with the use of stop logs and cofferdams. Construction would consist of the installation of sheet pile cofferdams around the trash rack bays in which bulkheads are being constructed (three per unit; total of six). Stop log panels would be installed behind all other trash racks for the respective unit. Stop log panels would also be used to divide the flow between the two units within the intake structure (behind the trash racks and in front of the traveling screens). Additionally, stop logs would be installed in all 12 of the respective unit's traveling water screen bays. After the bulkhead walls are installed, the stop logs in the trash racks would be removed and stop logs in the traveling screen bays would be replaced with the traveling water screens to allow flow to resume during the remaining construction. The second stage of construction would consist of installation of the header pipe and screen assembly. These would be installed by dredging down to the required elevation, installing the header pipes and screens (using barge mounted equipment), and then backfilling over the header pipe with water depth/space between the screens and fill. The third phase of construction would include the tie-in of the wedgewire screen system, including the cleaning system. An

allocation for pre-construction studies such as geotechnical investigation has been included in the cost estimate.

Following tie-in of the wedgewire screen system, the final stage of construction would begin. Stop logs would be re-installed in the trash racks without wedgewire screen headers, in order to completely separate the wedgewire intake flow from the river flow and finalize construction activities. After tie-in, the system would be ready to operate. Overall construction would be expected to take approximately 20 months and is expected to be completed in phases. However, if construction sequencing proceeds as anticipated, the outage or downtime would be minimized to four months per unit. Costs for facility outage are included as a stand-alone cost in the **Section 4.1.4.3.** An approximate schedule for this option, including detailed design and engineering, permitting and construction, is provided in **Figure 4-8**.

4.1.3.6 O&M

The O&M efforts at PBAPS would depend on the configuration, and on the type of cleaning system selected. Personnel operation of the automated air-burst cleaning system would be minimal; labor costs of the cleaning system would be expected to be approximately 832 total hours annually. Energy cost estimates were completed assuming a cleaning duration of 3 hours per compressor per cleaning cycle, with 2 cleaning cycles per day (24 hr of combined operation per day)(Hendrick Screen Company 2017; USEPA 2004) and $35/MWhr, and should further be refined in a pilot study if this alternative is selected for implementation. In addition to the cleaning system, divers would inspect the screens twice annually. Each inspection is estimated as a three-man diving crew working approximately 2 hours per screen, from a workboat, for a total of 18 days of cleaning per year. O&M of the outer intake structure's traveling screens would no longer be required, which would partially offset new O&M costs and is factored into the incremental costs. O&M of the automated air-burst system, including a 6% parts replacement cost, would require approximately $1.26 million per year; with the existing system O&M costs at approximately $0.76 million per year, incremental costs are calculated to be approximately $0.5 million per year. As long as the head loss is maintained below 1 ft., maintenance requirements for the existing inner intake traveling water screens and circulating water pumps with the wedgewire screens in place would not be expected to change from the existing requirements.

4.1.3.7 Biological Efficacy

The biological efficacy of cylindrical wedgewire screens to reduce entrainment is dependent upon the narrow slot size to physically exclude organisms and low intake velocities that may allow eggs and larvae to avoid the intake due to hydrodynamic influences of the crossflow. Therefore, the local hydraulic conditions that control the ambient crossflow and the biological composition of the source waterbody will dictate the performance of this technology (79 FR 48334; August 15, 2014). Laboratory studies and modeling performed by Alden Laboratories found that narrow-slot wedgewire screens can reduce entrainment by nearly 90% (USEPA 2014a). These results are supported by entrainment data showing a reduction in entrainment of 90% collected from Logan Generating Station in New Jersey, which withdraws 19 MGD from the Delaware River through a 1-mm wedgewire screen. Testing of 2 mm wedgewire screens in the St. John River for the Seminole Generation Station found a 62% reduction in larval entrainment over conventional (9.5 mm) systems (USEPA 2014a). EPRI (2005) laboratory and field testing also found that entrainment reduction for larger larvae (7 mm and greater) was often >68%, supporting other studies that have shown that slot widths greater than 1 mm can effectively reduce entrainment of larvae greater than 10 mm in length (EPRI 2003; Hanson et al. 1978; Hanson 1981; Heuer and Tomljanovich 1978; Otto et al. 1981). Valley Power Plant on the Menomonee River in Milwaukee, Wisconsin was recently retrofitted with 2 mm bulkhead mounted wedgewire screens, which were found to effectively reduce entrainment impacts by approximately 78%-85% (AECOM 2017).

As explained in **Section 4.0** above, 2 mm mesh size was chosen for evaluation based on EPRI (2013) research that concluded survival of previously entrained organisms decrease significantly with screen mesh size ≤ 2 mm, potentially negating the benefit of reducing entrainment for the very early life stages.

Additionally, an EPRI (2017) study found that fish eggs survive entrainment (through the condenser) at the East River Generating Station substantially better than they survive exclusion by fine-mesh screens. These data, along with the fact that the numerically dominant entrained species were the fragile, low-value alewife/gizzard shad, suggested that using finer mesh size ≤ 2 mm, to retain the numerically dominant species would result in an insignificant increase in benefit.

Using entrainment characterization data collected in 2012 and 2016 at PBAPS, including egg diameter and larval lengths, and fine-mesh screen survival rates from EPRI (2013), the biological benefit of 2 mm narrow-slot cylindrical wedgewire screens on raw entrainment numbers ranged from approximately 1% reduction in entrainment mortality (2016 data) to 4% (2012 data) [see the § 122.21(r)(11) Benefits Valuation Study for details]. However, when the reductions were converted to Age Equivalents, entrainment mortality could be reduced by 37% (2012 data) to 89% (2016 data) with the installation of narrow-slot cylindrical wedgewire screens because most of the organisms excluded by the 2 mm slots were juveniles and age-1.

4.1.4 ENGINEERING COMPLIANCE COST ESTIMATES

4.1.4.1 Engineering Cost Methodology

The engineering costs associated with the potential intake technologies identified for further evaluation at PBAPS are provided to assess the potential financial and compliance costs that would be incurred by Exelon to meet the CWA Section 316(b) requirements using each respective intake technology. The cost estimates include five major cost components:

- Indirect costs – the costs to conduct pre-construction studies, design and permit each technology;
- Direct and 'capital' costs – the one-time costs to construct the technology including equipment costs, distributable costs, overhead and profit, and administrative costs;
- Construction related outage costs – costs for any loss of generation during construction-related downtime or shutdown;
- Annual and periodic costs – annual O&M costs such as increased labor, wear item replacement, and auxiliary energy needed for the continued operation of the technology, as well as periodic cost for major overhauls at the end of each technology's expected service life; and
- Post-installation study costs needed to demonstrate compliance during the first permit cycle.

The costs were estimated using material quantities and labor estimates developed from the conceptual designs. Most of the costing information is based on published materials and labor costs such as RSMeans (2017). Technology-specific costs were based on vendor quotes, where possible. The combined costs allow a valid comparison of the cost difference between alternatives and their associated benefits. As indicated above, these costs estimates have been developed to meet an ASTM Standard E-2516-06 Class 4 assessment, with an expected accuracy range of (-15% to -30%) Low and (+20% to +50%) High (ASTM 2006).

Additionally, the estimated costs are based on the following assumptions:

- Present-day prices and fully contracted labor rates as of 2016.
- 'Standard' business hours for construction activities assumes ten hour work days, five days per week.
- Direct costs for material and labor required for construction of all project features have been included, along with an additional overhead and profit cost estimated at 5% of the materials, labor and equipment costs.

- Contingency (20%) has been applied to the overall cost estimate to account for unforeseeable site conditions and design and construction elements.
- Exelon administration costs of 3% have been applied to the overall cost estimate to account for contract, engineering, and construction management.
- Permitting costs have been estimated as 0.5 % of the direct costs for each alternative plus an additional permitting fee allowance specific to each alternative.
- Miscellaneous indirect costs for pre-construction engineering services inclusive of bathymetric, topographic/structural, and geophysical surveys, geotechnical, biological/ecological, and power availability assessments; and detailed drawings, specifications, and design documents have been estimated based on anticipated size of the alternative and the level of effort required for design.
- Cost to dispose materials that may be encountered during excavation and dredging activities have been included if quantifiable; however, at this level of design, waste classification has not been made and disposal costs assume non-hazardous wastes.
- No additional costs have been added to address security issues, since the outer intake structure traveling water screens are outside of protected area.

Additional information on the assessment of the five major cost components is provided below.

Indirect Costs

For this study, pilot study costs were estimated using vendor input and data from studies developed for other facilities. These studies include additional laboratory or field studies that may be required such as hydraulic model studies (i.e., to balance the flow through a new wedgewire intake), assessment of operation and reliability (potential for fouling), and biological evaluations to assess the biological efficacy of the technology. These are estimated separately from pre-construction engineering services.

Direct Costs

The one-time direct costs required to construct the technology were estimated as described above, using published materials and labor costs, as well as vendor quotes for the conceptual design. Assumptions on the direct costs are included in the bulleted list above.

Construction-Related Outage Costs

During the construction outage for each potential CWA Section 316(b) compliance alternative, PBAPS would not produce any power, and thus other power generation facilities would need to provide replacement power. Construction-related outages could have a significant impact on the feasibility and costs of the selected intake technologies. For this analysis, construction techniques and sequencing were selected to minimize construction-related outages and their impacts. If performed properly, the impacts to plant operation would be minimized. However, some construction-related outage would be expected for the wedgewire compliance technology, and has been included in this analysis.

Annual and Periodic Costs

Each of the selected technologies would involve the installation of equipment that would require ongoing upkeep. The alternative technologies were therefore evaluated to establish the required power, labor, and replacement components/parts needed for O&M. These costs provide the annual O&M costs required for the selected technologies.

Annual power costs represent the power necessary to operate an intake technology. These costs were assumed to be equal to the marginal cost to produce the power. Operation costs were estimated using an assumed power cost of $35/MWh, and the units' average 2012 through 2016 capacity factors (**Table 1-2**). This cost does not include the loss of revenue associated with the power not being available for sale.

Periodic component replacement costs assume that each of the entrainment mortality reduction technologies would require a major overhaul every 20-30 years. In the *Technical Development Document for the Final Section 316(b) Existing Facilities Rule* (USEPA 2014a), USEPA estimated the service life of the technologies selected for PBAPS to range from 20 years for the fine-mesh modified traveling water screens, to 30 years for the narrow-slot cylindrical wedgewire screens. These costs were estimated separately from annual O&M costs.

Energy penalty costs represent the estimated loss in revenue from generation losses associated with generating inefficiencies related to flow or operating restrictions. Some of the selected fine-mesh screening technologies, such as the cylindrical wedgewire screen system, is expected to maintain the current condenser cooling water flows without impact to the circulating water pumps, and, therefore, the energy penalty costs are expected to be zero; however, retrofit of the existing intake with modified-Ristroph screens with fine-mesh overlays could increase head loss through the screens and have an impact on the circulating water pump operation. Each technology has been evaluated to establish the associated energy penalty after implementation.

Post-Installation Costs

Costs associated with post-construction studies necessary to demonstrate compliance with CWA Section 316(b) requirements and/or the impact of the retrofit on plant generating efficiencies have been assessed for each alternative.

Incremental O&M Costs

In order to establish the net change in O&M costs for each alternative technology, costs for the O&M of the existing traveling water screens at PBAPS were calculated based on the same assumptions described above. These costs include labor, energy, and component replacement for the existing traveling screens (**Table 4-1**). The existing O&M costs were then subtracted from the post-retrofit O&M costs to calculate the incremental cost associated with each retrofit option.

Table 4-1: Existing Traveling Screen O&M Costs

Annual and Periodic Costs[1]	
Annual Labor[2]	$400,600
Annual Energy[3] (MWh)	211
Annual Energy[3]	$9,400
Periodic Component Replacement [4]	$347,700
Total Annual O&M Cost	$758,700

1. All costs are adjusted for a nuclear facility (USEPA 2004).
2. Assumes 207 hours/screen for annual labor (USEPA 2004) and a labor rate of $59.29/hr in 2016 dollars (USEPA 2004, RSMeans 2017).
3. Each screen is assumed to rotate twice per shift, 3 shifts per day for 10 minutes for a total of 1 hour per day; spray wash systems operate while screens are rotating.
4. Major overhaul of screens and spray wash system every 20 years (once during remaining plant life); assumed 3% of material costs will need replacing per year (USEPA 2004).

Facility Compliance Costs

Facility (compliance) costs were developed for the fine-mesh Ristroph and narrow-slot wedgewire screen options to include the five cost categories identified above. These costs are presented as the NPV and EAC. NPV is provided to convert all the present and future costs to a base year, assumed to be 2016. This was done to estimate the present cost of each alternative over the remaining life of the facility. EAC is the annual costs of owning, operating and maintaining each option over the life of the technology. This cost can be used as part of a benefits cost analysis by comparing it to the expected annual benefits provided by each alternative. NPV and EAC costs have been estimated using discount rates of 3% and 7% to account for the time value of money. The use of these discount rates is consistent with the social discount rates

required as part of the social cost analysis required by USEPA under the Existing Facility Rule. Taxes were not considered in this analysis.

The costs used for the NPV and EAC analysis are based on incremental changes over current operations. In addition to the assumptions of the USEPA's estimated service life for each technology, the NRC licenses for Units 2 and 3 have been taken into consideration. The current NRC licenses for Unit 2 and Unit 3 expire at the end of 2033 and 2034, respectively. It is anticipated that Exelon will receive a 20-year extension of their operating licenses for each unit. However, since this is currently the first NRC second license renewal in the United States, the timing and outcome of the license extension is unknown at this time.

Social Costs

In the preamble to the 2014 Rule, USEPA defines the social cost of compliance as the total burden imposed on society. That is, total social costs reflect all of the negative effects imposed on the facility, the government, or other members of society. Social costs can be greater than, less than, or similar to engineering cost estimates.

If some social cost elements are not monetized, total social cost will be under-estimated and any associated benefit to cost comparison will overstate the potential net social benefit of a technology. This observation is relied upon to streamline the estimation of social costs. For example, if one component of a technology's social cost (perhaps capital expenditures) exceeds the total social benefit of that technology, the technology is not cost effective. Efforts to monetize additional social cost components for that technology will not change this conclusion and are not required as part of a BTA determination.

The USEPA defines social costs as the "opportunity cost to society of employing scarce resources to prevent the environmental damage otherwise occurring except for the design and operation of compliance technology" (79 Fed. Reg. 158, 48387). Social costs can be further categorized as Real Resource Compliance costs, Government Regulatory Costs and Environmental Externality costs. Real Resource Compliance costs result from the purchasing and installing technologies, Government Regulatory Costs are developed from USEPA's estimates in the national rule (79 Fed. Reg. 158, 48387), and the social costs of environmental externalities are developed from a Power System Capacity Loss and Offsite Emissions study, a Recreation Study and a Property Value study conducted at PBAPS (Veritas Economic Consulting 2018).

Following USEPA guidance, annual costs are expressed in real dollars (pre-tax) which are then then adjusted with discount rates of both 3% and 7% to account for society's rate of time preference[23]. The social cost estimate is then expressed as a present value and as an annualized value.

4.1.4.2 Estimated Cost Summary

The estimated costs for retrofitting the existing traveling water screens with narrow-slot wedgewire screens at PBAPS were evaluated based on the conceptual design and construction sequencing described above. These costs are presented in **Table 4-2**.

[23] Discounting reflects the notion that society places more value on a benefit received today than they would the same benefit received in the future. There are two reasons for this. First, inflation diminishes the purchasing power of a dollar over time; economists address this factor by discounting real values (real values are adjusted to remove the effects of inflation). Second, humans tend to prefer receiving a good now rather than in the future. This "rate of time preference" is the motivation behind discounting real values at a rate of 3 to 7%. The resulting present-value is the value today of a stream of social costs or social benefits occurring over time.

Table 4-2: Wedgewire Screen Costs

Capital Costs	Estimated Cost
Indirect Design and Permitting Costs	
Pre-Design Field Assessments	$ 356,000
Engineering Design	$ 4,126,000
Permitting[24]	$ 307,000
Post-Installation Studies	$ 200,000
Total Indirect Project Costs (2016$)	**$ 4,989,000**
Direct Construction Costs	
General Site Civil (GSC)	$ 21,716,000
Structural	$ 5,316,000
Intake System	$ 14,224,000
Intake Screen Header/Manifold	*$3,487,000*
Intake Screens	*$6,150,000*
Air-Burst System & Air Supply Lines	*$4,587,000*
Construction Management & Record Documentation	$ 665,000
Exelon Administrative (3%)	$ 1,388,000
Direct Construction Costs (2016$)	**$ 43,309,000**
Overhead and Profit (10% Mat/Equip)	$ 2,787,000
Subtotal (Indirect, Direct, & Overhead and Profit)	**$ 51,085,000**
Allowance for Indeterminates/Contingencies (20%)	$ 10,216,000
Total Project Cost (Year 2016$)	**$ 61,301,000**
Construction Impacts	
Estimated Construction Duration (Months)	20
Estimated Outage Per Unit During Construction (Months)	4
Incremental Annual and Periodic Costs[25]	
Annual Incremental Labor Costs[26]	($224,500)
Annual Incremental Energy[27] (MWh)	1,053
Annual Incremental Energy Costs	$46,700
Periodic Component Replacement Costs[28]	$678,000
Annual Incremental O&M Costs	$500,100

[24] These Permitting costs are compliance costs that are estimated to be borne by the Station for the implementation of the proposed technology.
[25] All costs are adjusted for a nuclear facility (USEPA 2004).
[26] Labor costs include annual monitoring and inspection of the screen cleaning system, plus biannual diver inspection(s) (USEPA 2004).
[27] Assumes four air-burst cleaning compressors collectively run for 24 hours/day at 125 HP.
[28] Assumes major overhaul of screens and cleaning system every 30 years; assumes 6% of material costs will need replacing each year (USEPA 2004).

4.1.4.3 Compliance Costs – O&M Costs

Operation costs were estimated using an assumed power cost of $35/MWh, the units' average 2012 through 2016 capacity factors, anticipated maintenance requirements, and the air-burst cleaning system power requirements. O&M labor costs include a nuclear facility factor of 1.36 (USEPA 2004). The wedgewire screen O&M costs are presented in **Table 4-3**.

Based on USEPA (2014a, b) guidance, costs have been assessed as NPV and EAC using discount rates of 3% and 7%, and the USEPA assumption that the useful life of wedgewire screens is 30 years. At PBAPS, operation of the existing traveling water screens incurs O&M costs. These have been subtracted from the wedgewire screen costs in the Annual and Periodic Costs in **Table 4-2** and in the calculations for the NPV and EAC costs presented in **Table 4-3** and **Table 4-4** below.

The current NRC licenses for Unit 2 and Unit 3 expire at the end of 2033 and 2034, respectively. It is anticipated that Exelon will receive a 20-year extension of their operating licenses for each unit; however, since this is currently the first NRC second license renewal in the United States, the timing and outcome of the license extension is unknown at this time.

The estimated Capital, Incremental Operation, Incremental Maintenance, EAC, and NPV costs for PBAPS are summarized in **Table 4-3** assuming an extended NRC license, a 30-year life of the wedgewire screens, and a 7% discount rate. Estimated costs assuming an extended NRC license, a 30-year life of the wedgewire screens and using a discount rate of 3% are summarized in **Table 4-4**.

Table 4-3: Estimated Wedgewire Screen Capital and Incremental O&M Costs[29] (7% Discount Rate)

Unit	Initial Cost[30] ($)	Operation[31]		Incremental Maintenance Cost Per Year ($)	Total Annualized Cost (EAC)[32] ($)	Net Present-Value Cost (NPV) ($)
		Power Required (MWh)	Cost Per Year ($)			
2	30,650,500	526.5	23,000	226,750	2,720,000	33,749,000
3	30,650,500	526.5	23,700	226,750	2,721,000	33,759,000
Total	61,301,000	1,053	46,700	453,500	5,441,000	67,508,000

Table 4-4: Estimated Wedgewire Screen Capital and Incremental O&M Costs (3% Discount Rate)

Unit	Initial Cost ($)	Operation		Incremental Maintenance Cost Per Year ($)	Total Annualized Cost (EAC)[10] ($)	Net Present-Value Cost (NPV) ($)
		Power Required (MWh)	Cost Per Year ($)			
2	30,650,500	526.5	23,000	226,750	1,814,000	35,544,000
3	30,650,500	526.5	23,700	226,750	1,815,000	35,560,000
Total	61,301,000	1,053	46,700	453,500	3,629,000	71,104,000

Based on the hypothetical construction sequencing, the facility outage is expected to be approximately four months (16 weeks) per unit. Assuming the power replacement cost of $35/MWh, the units' average 2012 to 2016 capacity factors, and a 4-month (16 week) outage period for construction of the wedgewire

[29] O&M labor costs are adjusted for a nuclear facility (USEPA 2004).
[30] Initial costs are capital costs and include direct and indirect project costs.
[31] Operation costs were estimated using an assumed power cost of $35/MWh, the units' 2012-2016 average capacity factors, and the units' gross generating capacities.
[32] USEPA Development Document EPA-821-R-14-001, "Economic Analysis for the Final Section 316(b) Existing Facilities Rule", May 2014 establishes useful life of wedgewire screens (30 years) and discount rate (3% and 7%).

screening system, the replacement power costs would be approximately $112 million for Unit 2 and $116 million for Unit 3, or a total cost of $228 million for PBAPS.

4.1.4.4 Costs – Social Costs

Table 4-5 reports the social costs of installing narrow-slot wedgewire screens at PBAPS. Social cost elements are generally extracted from **Section 4.1.4.2** and **Section 4.1.4.3,** along with the following criteria from the analysis conducted by Veritas Economic Consulting (2018).

- Engineering costs are specified over a 30 year time period for wedgewire screens.
- Power system costs are specified to occur during construction, based on outage impacts, and during operation, based on efficiency and auxiliary load impacts. Power system costs represent the additional power needed to operate the new technologies and the additional fuel needed from running less efficient units during installation construction outages. The power system costs are developed from evaluating backpressure and auxiliary load effects, capacity losses from each of the technologies with estimated outage times, and electricity consumption associated with each technology.
- Permitting costs include the total costs associated with permitting, monitoring, administering, and enforcing the technology selection and installation. Costs are incurred by the government as the permitting and review process is undertaken. These vary with the type of technology, as certain technologies require substantially more permitting. Those with more significant environmental effects would have higher permitting costs. These costs are initially borne by the government, but ultimately paid by taxpayers.

Table 4-5: Social Cost of Wedgewire Screens

Discount Rate	Engineering Cost[a]		Social Costs[b]					
	Total Design, Construction &Installation Costs	Annual Maintenance costs	Shareholder Dividend Decrease	Power System Costs[1]	Externality Costs	Regulatory Permitting Costs[c]	Total Present Value of Social Costs	Annualized Social Costs
3%	$61.3M	$0.5M	$41.0M	$139.2M	$0.0M	$0.01M	$117.1M	$3.9M
7%	$61.3M	$0.5M	$20.6M	$139.2M	$0.0M	$0.01M	$59.0M	$2.0M

[a] The engineering compliance costs presented in the table are undiscounted and in 2016 dollars.
[b] The social costs associated with each technology are discounted at 3 and 7 percent using specifications outlined in Veritas, 2018. Additional details on the Social Cost components (i.e., shareholder dividend decrease, power system costs, etc.) are provided in Appendix B. Social costs are presented in 2019 dollars for the perspective of the Reviewer, assumed to be reading this report in 2019.
[c] Regulatory permitting costs itemized in the Social Costs sections of the table are Government permitting costs that include the total additional government costs associated with permitting, monitoring, administering, and enforcing the technology selection and installation. Costs are incurred by the government as the permitting and review process is undertaken. These costs are initially borne by the government, but ultimately paid by taxpayers. Permitting costs are developed from EPA's estimates in the national rule (79 Fed. Reg. 158, 48300-48439) and are specified to be .02% of direct capital costs. These costs do not include compliance permitting costs that are borne by the Station.

The social costs presented in **Table 4-5** were estimated based on the engineering schedule presented in **Section 4.1.5**. For additional details on estimated annual social costs and totals, see **Appendix B**.

4.1.5 ENGINEERING SCHEDULE

The NRC licenses for Units 2 and 3 at PBAPS expire at the end of 2033 and 2034, respectively. The existing NPDES Permit expires on September 30, 2019. The selected technology would then require approximately five years for implementation after the permit is renewed, including approximately three years for engineering and permitting, and 20 months for construction. According to the project schedule

shown in **Figure 4-8,** assuming that implementation begins with the NPDES Permit renewal at the earliest potential date of October 1, 2019, it would therefore take at least seven years from the date of this report (2017-2024) to complete the CWA Section 316(b) studies and evaluations, design, permit, and construct the wedgewire screen retrofits. Therefore, nine years would be left for operation under the current license for Unit 2 and 10 years would be left for operation under the current license for Unit 3. However, the station is in the process of extending its license for another twenty years. Since this is currently the first NRC second license renewal in the United States, the timing and outcome of the license extension is unknown at this time; therefore, using USEPA's estimated 30-year estimated life will underestimate the total annualized costs.

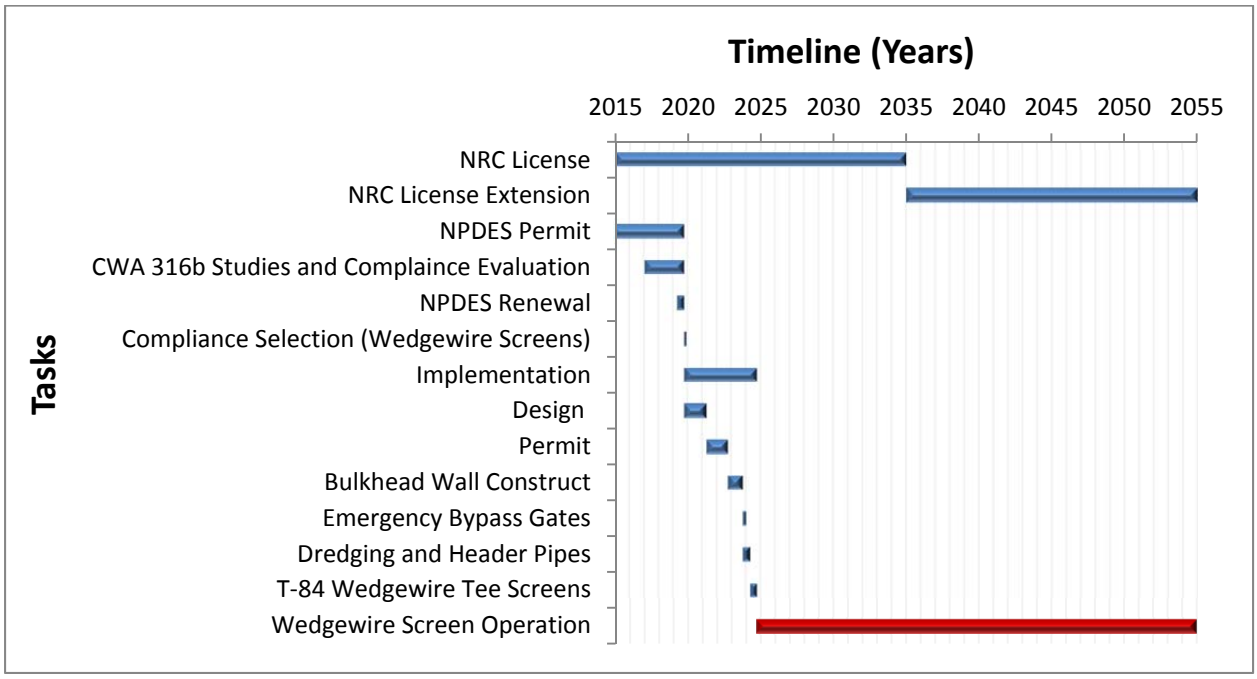


Figure 4-8: Engineering Schedule for Wedgewire Screens at PBAPS

4.2 MODIFIED-RISTROPH TRAVELING SCREENS WITH SEASONAL FINE MESH PANELS AND FISH RETURN

4.2.1 DESCRIPTION OF TECHNOLOGY

This technology involves the use of modified-Ristroph-type traveling screens that incorporate a smooth, woven mesh to minimize abrasion of fish; use of seasonal fine mesh baskets or panels; a low pressure spray wash to remove fish and aquatic organisms; and a Fletcher-type fish bucket that creates a quiescent area to promote the survival of impinged organisms. Each screen consists of a modified traveling screen bucket that, with the continuous rotation of the screens, carries submerged impinged fish up the screen well where a low pressure spray (~20 pounds per square inch [psi]) washes them into a fish return trough. **Figure 4-9** provides a schematic of the typical fish-friendly features of a modified-Ristroph traveling screen with fine-mesh overlays (Evoqua 2017a [patent pending]). At PBAPS, the debris trough would not combine with the fish return trough[33]. Debris would continue to be directed to the existing debris trough, directed to dumpsters inside the screenhouse, and would be disposed off-site. The new fish return flume

[33] The current NPDES permit for PBAPS indicates that "*Debris collected on the intake screens shall be collected and not discharged back to the river...*" (PADEP 2014). This report assumes that debris will continue to be collected and disposed off-site.

would convey the fish back to Conowingo Reservoir, separate from the debris. Fine-mesh screen or basket 'overlays' would be used seasonally during peak entrainment periods. However, reduction in entrainment achieved through smaller screen openings would be offset by an increase in entrainment mortality of smaller life stages caused by impingement on the screens.

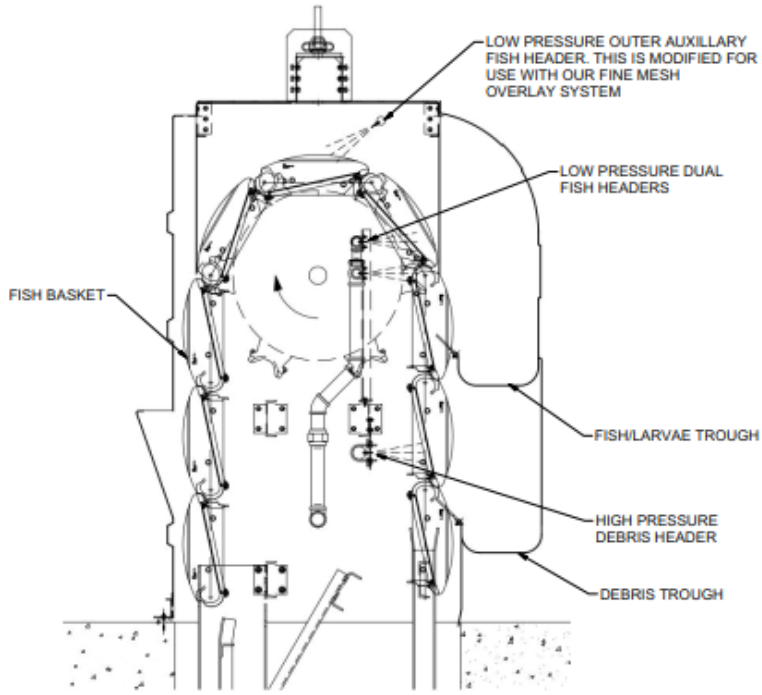


Figure 4-9: Typical Modified Traveling Water Screen with Fine-Mesh Overlays

According to USEPA (2014a) Technical Development Document guidance, the service life of traveling screens is assumed to be 20 years.

4.2.2 TECHNOLOGY STUDIES AND USE

Modified-Ristroph vertical traveling screens have been widely tested and are installed at power generating stations and other facilities including Salem Generating Station and Deepwater Generating Station in New Jersey, and Mohawk Pumping Station and Arthur Kill Generating Station in New York (EPRI 2013). Modified-Ristroph screens are considered to be an "off-the-shelf" technology (USEPA 2004) with a well-established operational history. Efficacy studies have shown species-specific success in reducing impingement mortality. For most species, survival increased with screen speed and rotation interval (USEPA 2004). It would be possible to replace or modify the existing screens at PBAPS to this design.

4.2.3 CONCEPT DESIGN

Since modified-Ristroph screens are considered to be an 'off-the-shelf' technology, complete replacement of the screens is expected to be feasible for the site from a construction point of view. However, significant modifications would be required within the screenhouse to accommodate the two separate fish and debris handling systems.

An ASTM Level 4 conceptual design for the modified-Ristroph screen with seasonal fine mesh baskets / panels and a fish handling and return system has been developed for PBAPS. This conceptual design is based on the DIF of 2,240.6 MGD, since the service water pump supply would be included in the DIF

that is screened by the Outer Intake at PBAPS. As indicated above, the current outer intake configuration includes 24 through-flow traveling water screens with ⅜-inch square mesh (coarse mesh) 14-gauge wire with a high-pressure screen wash system to clean the screens of debris. The existing screens are not equipped with fish buckets and there is no fish handling system to return impinged fish to Conowingo Reservoir. Therefore, this alternative would include the replacement of the existing screens with new modified-Ristroph screens with smooth, woven coarse mesh or slightly finer (¼" x ½") wire screen panels and fish bucket upgrades, along with seasonal fine-mesh screen panel overlays with 2 mm woven mesh and a fish return. The traveling screens would include variable frequency drive (VFD) motors to incorporate multiple screen rotation speeds (i.e., screen rotation speed may be increased during periods of heavy fouling).

The most favorable design option for this alternative, Option A, consists of a new fish handling system that would be installed to collect and convey impinged fish to a discharge location downstream of the intake. The new fish return trough would be mounted above deck level in the screenhouse, would collect spray water and impinged organisms from all 24 screens, and would discharge to a common location in the Conowingo Reservoir away from the outer intake. Debris would be removed after the fish by the high-pressure spray wash, collected in a separate debris trough, and disposed off-site. The slope and resulting space requirements of the fish return system may require a vertical expansion to the facility's outer intake structure screenhouse height. The fish return system would discharge to Conowingo Reservoir at a point that is determined by slope requirements, availability of space, and distance of the discharge from the hydraulic zone of influence of the CWIS (to minimize re-impingement).

The existing debris return systems are located on the front (ascending or Reservoir side) of the screens. The modified-Ristroph design requires separate fish and debris return systems. These are typically located on the back or descending side of the screen, and would need to be installed for this conceptual design. The existing high-pressure spray wash water supply system would be re-used where possible, but modifications would be required to accommodate the new screen wash locations. Additionally, retrofitting a low-pressure spray wash system to the existing high-pressure spray system would be considered, but if unfeasible, new low-pressure spray system components would be installed.

Flow requirements for the combined high-pressure and low-pressure spray wash systems are approximately 484 gallons per minute (gpm) per screen, plus a makeup flow of 192 gpm (for the first screen). This screen wash water supply flow includes approximately 238 gpm of flow for the high-pressure spray wash, plus 176 gpm flow for the low-pressure spray wash, and 70 gpm for the auxiliary fish wash (Evoqua 2017b) per screen. The total screen wash water supply flow for all 24 screens would therefore be approximately 11,808 gpm. However, since it is anticipated that state regulatory requirements would preclude the return of debris to Conowingo Reservoir, the debris wash water would be directed to the existing debris trough, which discharges to the existing dumpsters. Debris would continue to be hauled off-site for disposal and screen washwater would be returned to Conowingo Reservoir (through the existing outfalls).

The low-pressure spray wash and auxiliary fish wash would be directed to a new fish return trough. The flow into the fish return trough includes the 176 gpm flow for the low-pressure spray wash, 70 gpm for the auxiliary fish wash per screen, and the makeup flow of 192 gpm for the first screen. However, based on vendor input, there may be up to 40% loss of the low-pressure spray wash due to spray/splashing. The total flow into the fish return trough from all 24 screens would therefore be approximately 4,406 gpm to 6,096 gpm.

Each unit currently has a debris trough that starts at the center of the CWIS and slopes to the end of the screenhouse. Debris is collected in one of two sumps located at each end of the screenhouse, approximately 430 ft. apart. For the hypothetical retrofit of the system, the existing debris return troughs would be reused, and would be connected to the new debris troughs receiving the high-pressure spray wash on the descending (back) side of each screen. The debris troughs for each traveling screen would be

routed to the existing debris return trough on the ascending (front) side of the screen. The debris return troughs would continue to discharge to the sumps at each end of the screenhouse. One foot above the debris-catching troughs, the conceptual design at PBAPS includes a 2-ft. wide fish return trough that begins at the northern end of the CWIS and slopes along the entire structure to a flume at the southern end of the structure.

Space constraints within the screenhouse would make the installation of separate fish and debris return systems difficult. The screen sprocket spacing (overall height of the screens) would have to be increased by approximately 2 to 4 ft. to accommodate the separate fish and debris troughs and allow for adequate sloping of the fish return trough. A fish return trough slope of 1/8" per foot is recommended, but can be reduced to 1/16" per foot in situations with limited vertical space (Evoqua 2017b). For PBAPS, the fish trough would be sloped at 1/16" per foot over the length of the traveling screens (~390 ft.), and the required vertical space for the fish return trough would be 2'1". The debris-catching troughs would be connected approximately 12" below the fish return trough and routed to the existing debris channel in the screenhouse. Increased sprocket spacing is feasible; however, accessibility to the screens and fish and debris troughs becomes more limited, increasing O&M efforts.

The fish trough would discharge into a 2-ft. diameter, steel or fiberglass return flume at the southern end of the intake structure. The flume would be installed through the southern-most wall of the screenhouse structure, where it would transition to a 24-inch diameter pipe that would be angled down for burial under the access road adjacent to the screenhouse. In the winter, warm water from the discharge may be pumped through the fish return to prevent icing and/or freezing. On the other side of the road (Conowingo Reservoir side of the roadway), the fish return pipe would 'daylight' and transition to a rectangular trough shown in **Figure 4-12**. The trough would be 2 ft. wide x 2 ft. high. The above-ground fish trough would be covered to minimize predation. The fish return trough would convey the fish alongside the existing drive, supported by H-frames, continuing at a downward slope of 1/16-inch per foot, before discharging into Conowingo Reservoir shown in **Figure 4-10**. To minimize re-impingement and entrainment of organisms, the return flume would be designed to discharge back into the Reservoir downstream of the CWIS.

The horizontal length of the fish return would be limited by the vertical space required to maintain the slope of the flume (1/16–inch per foot), and the vertical separation between the existing screenhouse deck and the mean water surface elevation (108.5 ft.). For the buried section outside the existing screenhouse, the fish return pipe invert, assuming 4 ft. of cover, would be at an elevation of 110 ft. The overall length of the fish return flume from this point would be 288 ft. to meet the minimum slope requirements and provide a discharge at 108 ft. (the mean Reservoir water surface elevation). At the discharge location, the fish return trough would be angled down for a submerged discharge even at low Reservoir water elevation to provide a smooth transition to the waterbody and prevent predation.

The fish return and debris return systems have been designed to meet recommendations by EPRI, the American Society of Civil Engineers (ASCE) and federal and state organizations to limit fish harm, and minimize head loss, installation costs, and clogging (EPRI 2015). The fish return flume would be designed as steel or fiberglass since smooth materials, such as metals, are likely to minimize abrasion, head loss, biofouling, and plugging. Bends along the fish return flume would be limited where possible to further protect fish and prevent potential clogging. All turn radii would be 5 ft. or more ($R/D > 2.5$) in order to promote smooth flow and prevent plugging. Plugging would be further reduced by designing the return flume to be above ground to the greatest extent possible. An above-ground design presents a much more accessible fish return, which is favorable for cleaning, maintenance, and installation costs. The hypothetical design also minimizes the need for a subsurface investigation, drive closure, and roadway disturbance.

Return channel geometry design recommendations are used to further limit fish impacts and clogging. EPRI (2015) lists ASCE's guidelines for fish conveyance for fish return recommendations. The fish

return trough would be designed to meet ASCE guidelines, which require a width of at least 18-inches, a water depth of at least 6-inches, and enough freeboard to protect against the jumping capabilities of the strongest fish present (ASCE 1982). Additionally, at full flow and at 40% splash loss, the fish return pipe and above-ground trough have been designed to maintain velocities (ranging from 5 fps to 6 fps) within the EPRI-recommended range (2 fps to 12 fps), which is estimated to be higher than the sustained cruising velocity of the fish and also high enough to reduce sand and silt accumulation in the pipe (EPRI 2010).

Option B, an alternative considered to mitigate vertical space requirements in the screenhouse, includes using two separate return systems. The systems maintain the same design as the single return system, but would use two separate fish return troughs that both begin at the center of the CWIS and flow toward the opposite ends of the structure, thus decreasing both the required horizontal and vertical distance traveled **(Figure 4-11)**. With the same required slopes and clearances, a total of 1'1" between initial trough inverts and the inverts of the return flume would be required. Each would reach its respective fish return flume and discharge into the Conowingo Reservoir as far away from the CWIS as practicable to minimize re-impingement and entrainment. This alternative is not preferred due to the potential for re-impingement of organisms from the upstream discharge location; discharging upstream of the zone of influence could lead to reuptake of returned fish. Installation of two separate return systems also increases installation costs along with O&M costs. However, Option B may be necessary due to the vertical limitations between the screens and the Conowingo Reservoir water surface. The layouts of both Option A and Option B, along with the profile of the outside fish return trough used in both options, are shown in **Appendix A** of the report.

In general, fine-mesh screens have a higher head loss than course-mesh screens due to lower open areas, so using a fine-mesh overlay tends to increase head loss through the intake; however, the constant rotation of the traveling screens works to minimize head loss through continuous screen cleaning. Furthermore, screens would only be operating with overlays during approximately four months out of the year during peak entrainment periods. The 2 mm fine-mesh overlay screen option at PBAPS has an estimated through-screen velocity of 1.64 fps. The existing traveling screens have a calculated maximum through-screen velocity of 1.21 fps (URS Corporation 2008b), thus the velocity will increase by approximately 35.5%.

4.2.3.1 Option A

Option A is considered the most favorable option at PBAPS to reduce biological impacts, as discussed below. A plan view of Option A is shown in **Figure 4-10** (background aerial image reference – DCNR PAMAP 2007-2008).

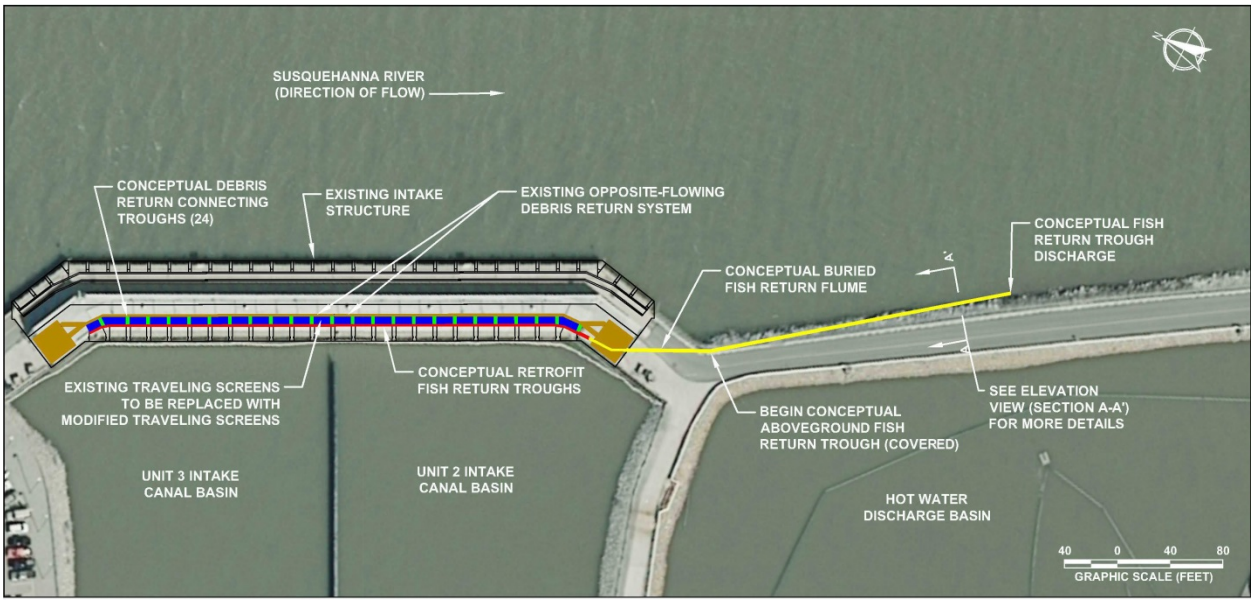


Figure 4-10: Fish Return – Option A

4.2.3.2 Option B

A plan view of Option B is shown in **Figure 4-11** (background aerial image reference – DCNR PAMAP 2007-2008).

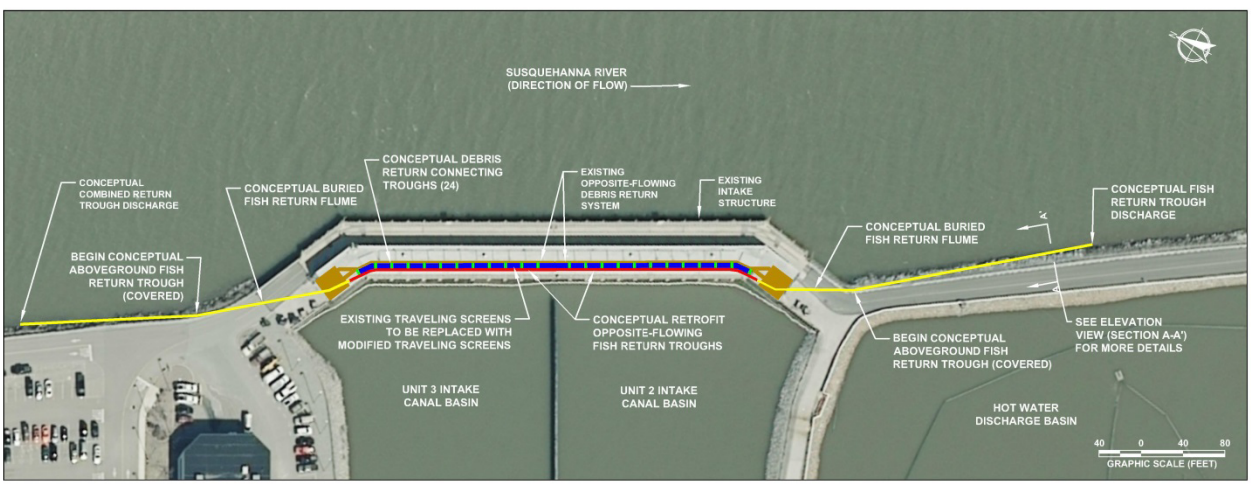


Figure 4-11: Fish Return – Option B

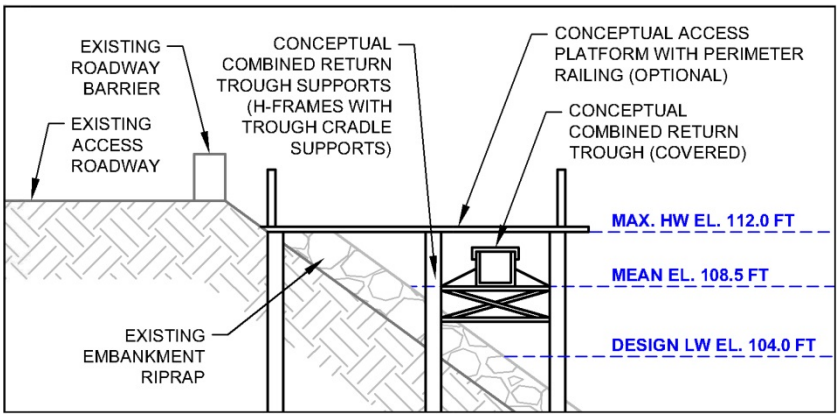


Figure 4-12: Outside Fish return Trough Profile – Option A and Option B

4.2.3.3 Construction

Construction-related outage costs are a significant factor in the overall cost estimate, therefore the following construction sequence was developed to minimize station outage times.

Prior to screen removal/replacement, the fish/debris return systems would be installed. Installation of the system outside of the screenhouse would consist of trenching/backfill of the fish return pipe and installation of the rectangular fish return trough along with its accompanying H-frame structures. Inside of the screenhouse, the two separate fish and debris troughs would be installed on the descending side of the existing traveling water screens and the debris troughs connected to the existing debris return trough. During this time, the new low- and high-pressure systems would also be installed.

Following return system installation and before any existing traveling water screens are removed or replaced, traveling screen bays and traveling screen guide tracks would be inspected and repaired if necessary. Any bays that are damaged would be repaired when their respective screens are removed for replacement. Repairs are estimated at three weeks per damaged screen and are included in the engineering schedule and costs. Replacement of the existing traveling screens with the hypothetical modified traveling screens consists of installing the prefabricated screen into the existing tracks and is estimated at 2 weeks per screen, per vendor input. Screen replacement would begin with the southern-most screen and progress northward, so that each screen could be put into operation immediately after installation. Only one screen would be replaced at a time. Construction would be planned to coincide with routine plant refueling outages and sequenced to minimize adverse impacts on plant performance.

An approximate schedule for this option, including detailed design and engineering, permitting and construction, is provided in **Figure 4-13**.

4.2.3.4 O&M

The O&M efforts at PBAPS would be expected to increase with the installation of modified-Ristroph screens and fine-mesh overlays at the outer intake and the operation of the fish return system. Overall debris handling would be expected to increase with continuous operation of the screens. The modified screens would have additional electrical requirements for continuous operation and increased wear of the screen chains, sprockets and other parts. Additional screen wash water would be required for the return system (total requirements are up to 11,800 gpm based on vendor inputs). The system is estimated to require approximately 414 labor hours per screen per year for cleaning and maintenance, 157.5 labor hours per screen to install/remove fine-mesh overlays once a year, 8,760 annual hours per screen of motor operation, and 392 MWh per screen annually for spray wash operation, totaling approximately $2.26 million in O&M per year, including the 6% parts replacement. With the existing system O&M costs at approximately $0.76 million per year, incremental costs are calculated to be approximately $1.5 million per year. Installation of VFDs on the screen motors could reduce power costs.

4.2.3.5 Biological Efficacy

During the period of the year when the fine-mesh overlays are not installed, a minimal change in the number of organisms entrained or impinged would be expected, since the screen mesh open area would be the same as the existing configuration. However, adding a fish return system would reduce impingement mortality. Additionally, the smooth mesh wire would, in general, reduce fish injuries and increase the likelihood for survival.

Biological efficacy data for 2 mm fine-mesh screens is limited. In laboratory studies of fine-mesh screens, EPRI (2010) found that latent survival for larvae collected off 2 mm screens was >80% for common carp and 92% for bluegill (two species entrained at PBAPS) when the approach velocity was 1.5 fps. As explained in **Section 4.0** above, 2 mm mesh size was chosen for evaluation based on EPRI (2013) research that concluded survival of previously entrained organisms decrease significantly with screen mesh size ≤ 2 mm, potentially negating the benefit of reducing entrainment for the very early life stages. Additionally, an EPRI (2017) study found that fish eggs survive entrainment (through the condenser) at the East River Generating Station substantially better than they survive exclusion by fine-mesh screens. These data, along with the fact that the numerically dominant entrained species were the fragile, low-value alewife/gizzard shad, suggested that using finer mesh size ≤ 2 mm, to retain the numerically dominant species would result in an insignificant increase in benefit.

Using entrainment characterization data, including egg diameter and larval lengths, collected in 2012 and 2016 at PBAPS and fine-mesh screen survival rates from EPRI (2013), the biological benefit of 2 mm fine-mesh overlays on raw entrainment numbers ranged from approximately 1% reduction in entrainment mortality (2016 data) to 3% reduction in entrainment mortality (2012 data) [see the § 122.21(r)(11) Benefits Valuation Study for details]. However, when the reductions were converted to Age Equivalents, entrainment mortality would be reduced by 34% (2012 data) to 85% (2016 data) with the installation of fine-mesh overlays, even considering the additional mortality caused organisms being impinged on the screens.

4.2.4 ENGINEERING COMPLIANCE COST ESTIMATES

4.2.4.1 Engineering Cost Methodology

The engineering cost methodology for used modified-Ristroph traveling screens with fine mesh and a fish return is the same as that described in **Section 4.1.4.1** above for wedgewire screens.

4.2.4.2 Estimated Cost Summary

The estimated costs for retrofitting the existing traveling water screens with modified-Ristroph traveling screens with fine-mesh overlays at PBAPS were evaluated based on the conceptual design and construction sequencing described above. These costs are presented in **Table 4-6**.

Table 4-6: Fine-Mesh Traveling Screen Costs

Capital Costs	Estimated Cost
Indirect Design and Permitting Costs	
Pre-Design Field Assessments	$ 250,000
Engineering Design	$ 2,428,000
Permitting[34]	$ 148,000
Post-Installation Studies	$ 200,000
Total Indirect Project Costs (2016$)	**$ 3,026,000**
Direct Construction Costs	
General Site Civil (GSC)	$ 3,150,000
Intake System	$ 21,130,000
Modified Ristroph Traveling Water Screens	*$20,130,000*
Fish Return System[35]	*$995,000*
Construction Management & Record Documentation	$ 930,000
Exelon Administrative (3%)	$ 820,000
Direct Construction Costs (2016$)	**$ 26,030,000**
Overhead and Profit (10% Mat/Equip)	$ 1,169,000
Subtotal (Indirect, Direct, & Overhead and Profit)	**$ 30,225,000**
Allowance for Indeterminates/Contingencies (20%)	$ 6,042,000
Total Project Cost (Year 2016$)	**$ 36,267,000**
Construction Impacts	
Estimated Construction Duration (Months)	12
Estimated Outage During Construction (Months)	0
Incremental Annual and Periodic Costs[36]	**Duration**
Annual Incremental Labor Costs[37]	$681,000
Annual Incremental Energy[38] (MWh)	9,804
Annual Incremental Energy Costs	$424,300
Periodic Component Replacement Costs[39]	$391,000
Incremental O&M Costs	$1,496,300

4.2.4.3 Compliance Costs – O&M Costs

Operation costs were estimated using an assumed power cost of $35/MWh, the units' average 2012 through 2016 capacity factors, and the combined screen motor and spray wash power requirements. Per USEPA (2014a, b) guidance, costs have been assessed as NPV and EAC, using discount rates of 3% and 7% and the USEPA assumption that the useful life of the traveling screens is 20 years. NPV and EAC are

[34] These Permitting costs are compliance costs that are estimated to be borne by the Station for the implementation of the proposed technology.
[35] Some costs for structural support and installation costs are included in the General Site Civil costs.
[36] All costs are adjusted for a nuclear facility (USEPA 2004).
[37] Labor costs include annual monitoring and inspection of the screen cleaning system (USEPA 2004).
[38] Traveling screens run at 3.5 HP (Evoqua Water Technologies, LLC) continuously throughout year, along with spray wash systems.
[39] Assumes major overhaul of screens and cleaning system every 20 years; assumes 6% of material costs will need replacing each year (USEPA 2004).

calculated using the incremental O&M costs of running the conceptual system in place of the existing system. The current NRC licenses for Unit 2 and Unit 3 expire at the end of 2033 and 2034, respectively. It is anticipated that Exelon will receive 20-year extension of their operating licenses for each unit; however, since this is currently the first NRC second license renewal in the United States, the timing and outcome of the license extension is unknown at this time.

The estimated Capital, Incremental Operation, Incremental Maintenance, EAC, and NPV costs for PBAPS are summarized in **Table 4-7**, assuming an extended NRC license, a 20-year life of the traveling screens, and a 7% discount rate. Estimated costs assuming an extended NRC license, a 20-year life of the traveling screens and using a discount rate of 3% are summarized in **Table 4-8**.

Table 4-7: Estimated Fine Mesh Screens Capital and Incremental O&M Costs[40] (7% Discount Rate)

Unit	Initial Cost[41] ($)	Operation[42]		Incremental Maintenance Cost Per Year ($)	Total Annualized Cost (EAC)[43] ($)	Net Present-Value Cost (NPV) ($)
		Power Required Per Year (MWh)	Cost Per Year ($)			
2	18,133,500	4902	208,500	536,000	2,456,000	26,017,000
3	18,133,500	4902	215,800	536,000	2,464,000	26,094,000
Total	36,267,000	9804	424,300	1,072,000	4,920,000	52,111,000

Table 4-8: Estimated Fine-Mesh Screens Capital and Incremental O&M Costs (3% Discount Rate)

Unit	Initial Costs ($)	Operation		Incremental Maintenance Cost Per Year ($)	Total Annualized Cost (EAC)[44] ($)	Net Present-Value Cost (NPV) ($)
		Power Required (MWh)	Cost Per Year ($)			
2	18,133,500	4902	208,500	536,000	1,963,000	29,204,000
3	18,133,500	4902	215,800	536,000	1,971,000	29,313,000
Total	36,267,000	9804	424,300	1,072,000	3,934,000	58,517,000

Construction of the modified-Ristroph traveling screens and fish return would not be expected to result in any facility outage.

4.2.4.4 Costs – Social Costs

Table 4-9 reports the social costs of installing modified-Ristroph-type traveling screens with fine mesh at PBAPS. Social cost elements are generally extracted from **Section 4.2.4.2** and **Section 4.2.4.3** along with the following criteria from the analysis conducted by Veritas Economic Consulting (2018).

- Engineering costs are specified over a 20 year time period for traveling screens.
- Power system costs are specified to occur during construction, based on outage impacts, and during operation, based on efficiency and auxiliary load impacts. Power system costs represent the additional power needed to operate the new technologies and the additional fuel needed from

[40] O&M labor costs are adjusted for a nuclear facility (USEPA 2004).
[41] Initial Costs are capital costs and include direct and indirect project costs.
[42] Operation costs were estimated using an assumed power cost of $35/MWh, the units' 2012-2016 average capacity factors, and the units' gross generating capacities.
[43] USEPA Development Document EPA-821-R-14-001, "Economic Analysis for the Final Section 316(b) Existing Facilities Rule", May 2014 establishes useful life of traveling screens (20 years) and discount rate (3 and 7%).
[44] USEPA Development Document EPA-821-R-14-001, "Economic Analysis for the Final Section 316(b) Existing Facilities Rule", May 2014 establishes useful life of traveling screens (20 years) and discount rate (3 and 7%).

running less efficient units during installation construction outages. The power system costs are developed from evaluating backpressure and auxiliary load effects, capacity losses from each of the technologies with estimated outage times, and electricity consumption associated with each technology.

- Permitting costs include the total costs associated with permitting, monitoring, administering, and enforcing the technology selection and installation. Costs are incurred by the government as the permitting and review process is undertaken. These vary with the type of technology, as certain technologies require substantially more permitting. Those with more significant environmental effects would have higher permitting costs. These costs are initially borne by the government, but ultimately paid by taxpayers.

Table 4-9: Social Cost of Fine-Mesh Screens

Discount Rate	Engineering Cost[a]		Social Costs[b]					
	Total Design, Construction &Installation Costs	Annual Maintenance costs	Shareholder Dividend Decrease	Power System Costs[1]	Externality Costs	Permitting Costs[c]	Total Present Value of Social Costs	Annualized Social Costs
3%	$36.3M	$1.1M	$35.9M	$1.8M	$0.0M	$0.007M	$37.1M	$1.9M
7%	$36.3M	$1.1M	$20.4M	$1.8M	$0.0M	$0.007M	$21.0M	$1.1M

[a] The engineering compliance costs presented in the table are undiscounted and in 2016 dollars.
[b] The social costs associated with each technology are discounted at 3 and 7 percent using specifications outlined in Veritas, 2018. Additional details on the Social Cost components (i.e., shareholder dividend decrease, power system costs, etc.) are provided in Appendix B. Social costs are presented in 2019 dollars for the perspective of the Reviewer, assumed to be reading this report in 2019.
[c] Regulatory permitting costs itemized in the Social Costs sections of the table are Government permitting costs that include the total additional government costs associated with permitting, monitoring, administering, and enforcing the technology selection and installation. Costs are incurred by the government as the permitting and review process is undertaken. These costs are initially borne by the government, but ultimately paid by taxpayers. Permitting costs are developed from EPA's estimates in the national rule (79 Fed. Reg. 158, 48300-48439) and are specified to be 0.02% of direct capital costs. These costs do not include compliance permitting costs that are borne by the Station.

The social costs presented in **Table 4-9** were estimated based on the engineering schedule presented in **Section 4.2.5**. For additional details on estimated annual social costs and totals, see **Appendix B**.

4.2.5 ENGINEERING SCHEDULE

The NRC licenses for Units 2 and 3 at PBAPS expire at the end of 2033 and 2034, respectively. The existing NPDES Permit expires on September 30, 2019. The selected technology would then require approximately five years for implementation after the permit is renewed, including approximately three years for engineering and permitting, and two years for construction (assuming the phased construction of the screens, with key construction activities scheduled to coincide with the respective unit outage). According to the project schedule shown in **Figure 4-13,** it would take approximately seven years (including five years for implementation after the permit is renewed) (2017-2024) to complete the CWA Section 316(b) studies and evaluations, design, permit, and construct the fine-mesh screens with fish return. Therefore, nine years would be left for operation under the current license for Unit 2 and ten years would be left for operation under the current license for Unit 3. However, the station is in the process of extending its license for another 20 years. Since this is currently the first NRC second license renewal in the United States, the timing and outcome of the license extension is unknown at this time; therefore, using USEPA's estimated 20-year estimated life will underestimate the total annualized costs. In addition, PBAPS may first pilot test a fine mesh screen to confirm the performance and reliability of the cooling water supply prior to full scale implementation. This could involve replacing one screen bay and monitoring over a year period. This would extend the over installation schedule.

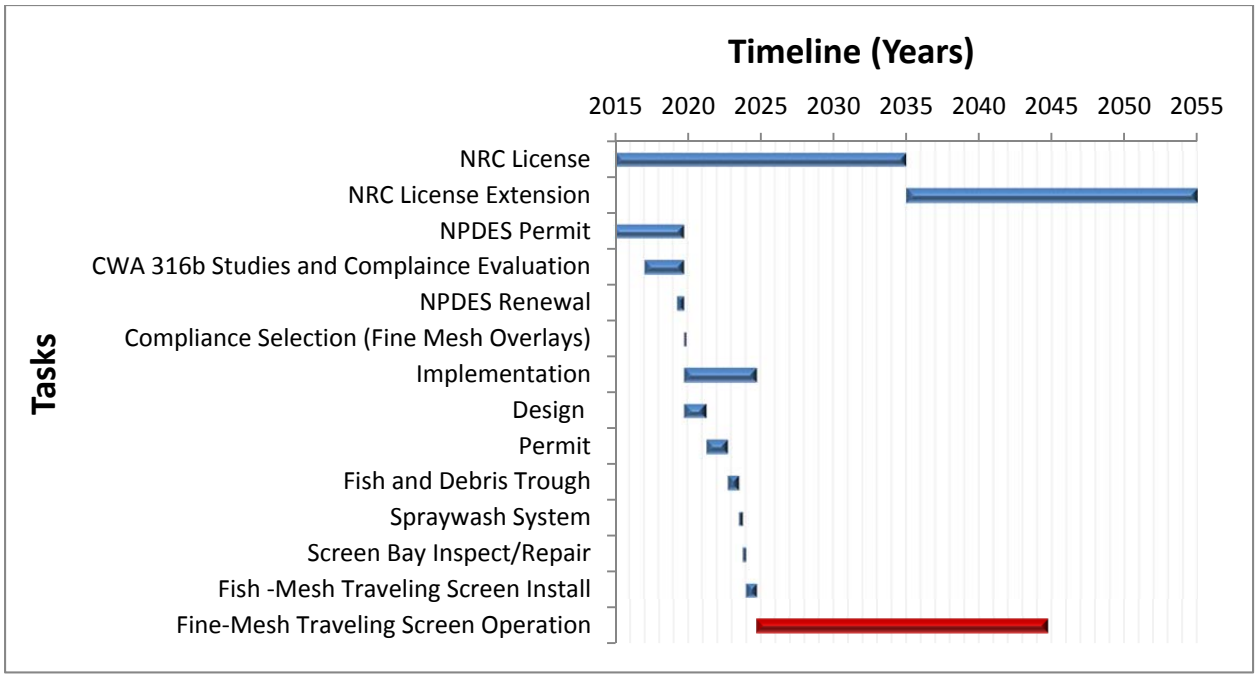


Figure 4-13: Engineering Schedule for Fine-Mesh Screens at PBAPS

5.0 WATER REUSE AND POTENTIAL ALTERNATIVE WATER SOURCE

Regulatory requirement at § 122.21(r)(10)(i)(C): "A discussion of available sources of process water, grey water, waste water, reclaimed water, or other waters of appropriate quantity and quality for use as some or all of the cooling water needs of the facility"

The Rule requires that potential alternative cooling water sources be explored to meet some or all of the cooling water needs at the facility. However, the USEPA (2014a) also recognizes that this may be difficult for a power generating facility:

> *For power plants, water reuse (outside of closed-cycle cooling) is typically not an available option, as there is very little water that is used for purposes other than non-contact cooling; the "credit" would be extremely small.*

PBAPS does not have a source of process water, grey water, or wastewater available from other on-site industrial activities to replace the cooling water needs at the facility. However, alternative sources from the surrounding area were explored in an effort to reduce the cooling water intake flows.

Five potential alternative cooling water sources were investigated, including municipal reclaimed wastewater, groundwater, irrigation drainage water, "produced" water from local industrial activities, and mine water. Potential sources within a 5-mile radius of PBAPS are provided in the figure titled Alternative Cooling Water Sources – Peach Bottom Atomic Power Station included in **Appendix D**. Of the sources within this approximate 5-mile radius of PBAPS, each source, with the exception of the Delta Borough Sewage Treatment Plant (STP), included a septic system and/or well water supply for on-site use. Even by expanding the search for potential sources to within a 15-mile radius of PBAPS, none of the five types of alternative sources were identified that could provide a reliable source of water required for operation of the cooling system at PBAPS in terms of quantity and water quality. The following conclusions have been reached for each alternative:

1. Municipal reclaimed wastewater: The closest municipal wastewater plants identified are located in Delta, Pennsylvania, Perryville, Maryland, and Joppatowne, Maryland. The Delta Borough STP is approximately 4 miles from PBAPS. Both of the plants located in Maryland are over 15

miles from PBAPS. The construction of the infrastructure (i.e., pipelines) to convey the water to the facility, coupled with the possible need for pretreatment of the water before it is used in the cooling system makes this option impractical. In addition, all three of the municipal wastewater treatment plants are relatively small with average daily discharge flows less than 1 million gallons per day (694 gpm). These flow rates are negligible compared to PBAPS circulating water flows, and represent less than 0.5% of the total cooling water flow required at PBAPS.

2. Groundwater: PBAPS operates four on-site wells for the supply of non-potable water to remote facilities. PBAPS has three closed groundwater wells (filled with concrete) and four wells providing non-potable water on demand to remote facilities. The well at the Salt Storage Facility near the North Substation, which is of unknown depth, supplies approximately 41.6 L/min (11 gpm) of water solely to an outdoor pressure washer and hose bib, which are used primarily for washing company vehicles. The well at the North Substation is 76.2 m (250 ft) deep and supplies water for a toilet and sink at the unmanned substation control house. While the pumping capacity is unknown, the North Substation well's use is like that of the well at the South Substation, which suggests a pumping capacity of no more than 19 L/m (5 gpm). The well in the Hazardous Materials Yard, occasionally used for washing hands or rinsing equipment, is 61 m (200 ft) deep and provides 22.7 L/min (6 gpm). The well in the South Substation, is 91 m (300 ft) deep and provides 3.8 L/min (1 gpm) to a toilet at the substation control house (Conestoga-Rovers & Associates 2006). Therefore, due to the uncertainty of production from existing and additional wells and the small yield that the current wells produce, this option is not feasible.
3. Irrigation Drainage Water: With the large amount of agricultural areas in the area of the PBAPS facility, there is a potential for excess irrigation drainage water to be present in the area. There is no certainty on the availability of the water, especially during very hot summer months. Similar to the municipal reclaimed wastewater option, infrastructure would need to be built to convey the water up to a few miles, and pretreatment of the water before use may be required. These issues make this option impractical.
4. "Produced" Water from Local Industrial Activities: There are quarries such as the Funkhouser quarry located in the vicinity of PBAPS that may contain water, but it is uncertain as to whether or not the water is available for use and how much water it will produce. Without a water source consistently feeding the quarry, it is unlikely it would be able to consistently produce water required for cooling water flow. Similar to the municipal reclaimed wastewater option, this water may also need to be pretreated before use. Based on the uncertainty of water quantity and quality, this option is not practical.
5. Mine Water: There do not appear to be any nearby mines available to provide reliable quantities of water at the quality required for the cooling water system at PBAPS. This option presents similar issues as the municipal reclaimed wastewater option in terms of infrastructure to convey the water large distances and possible pretreatment of the water before use; therefore, the option is, not practical.

The increase in both cost and difficulty with using one of the alternative cooling water sources identified, while at the same time potentially only reducing the required intake water flow marginally, makes these alternative sources not practical. None of these sources could provide a reliable source of water at the volume (flow) and water quality required for operation of the cooling water system at PBAPS.

6.0 GENERAL CONCLUSION

An engineering study of the technical feasibility and incremental costs of a CCRS that meets requirements at § 125.92(c)(1) of the Rule and of fine-mesh screens with a mesh size of 2 mm was performed. Potential alternative sources of cooling water and water reuse were also assessed.

CCRS

Based on a consideration of the alternatives, the all-wet CCRS with a mechanical-draft cooling tower is the most feasible cooling tower retrofit option at PBAPS. A review of the likely installation considerations and additional costs to be encountered at PBAPS put the retrofit at this site in the "more difficult" category. A CCRS would require demolition of the existing helper towers, and modification and extension of the existing condenser discharge structure which would require substantial construction and new infrastructure, as well as construction sequencing required to allow for use of the existing helper towers as much as possible to meet NPDES permit requirements and minimize facility downtime, an acceptable location for the towers appears to be available. Additional factors such as drift, plume, noise, aesthetics, air permitting, environmental permitting, siting, safety, security, and NRC review and approval would have to be considered further, but do not appear to be prohibitive for the retrofit. However, the high costs associated with the retrofit appear to be prohibitive.

Using the methodology and results from the EPRI (2011c) document on national retrofit costs, which was used by USEPA in developing the cost/performance basis for the CWA Section 316(b) Rule in the associated Technical Development Document (USEPA 2014a), the project capital costs were estimated to be approximately $1,146 million. The project operation, maintenance, and heat rate penalty costs per year were estimated to be in the range of $11.3 million, $3.9 million, and $18.5 million, respectively. Replacement power during installation could cost an additional $370 million.

Total annualized costs (EAC) (including amortized capital costs), not including replacement costs during installation are estimated at $126 million per year and total present-value life costs (NPV) for the cooling tower retrofit (including annual operation, maintenance, and heat rate penalty costs) are estimated at $1,565 million, assuming the USEPA's useful life of cooling towers of 30 years and a discount rate of 7%.

EAC costs (including amortized capital costs), not including replacement costs during installation are estimated at $92 million per year and NPV costs for the cooling tower retrofit (including annual operation, maintenance, and heat rate penalty costs) are estimated at $1,807 million, a assuming the USEPA's useful life of cooling towers of 30 years and a discount rate of 3%.

Note that Unit 2 and Unit 3 are currently licensed to operate until 2033 and 2034, respectively (Exelon 2017b), so the assumed 30 years of useful life is overestimated, unless the NRC license is extended. It is anticipated that Exelon will apply for a 20 year extension of their operating licenses for each unit, with a decision expected from NRC in 2020 or 2021. Thus the total annualized costs may be underestimated in this analysis, depending on the long-term life of the operating license for each unit.

The social cost of the CCRS option PBAPS has been calculated in pre-tax U.S. Dollars as described above. At a discount rate of 3%, the present value social cost is $1.3 billion which is equivalent to an annualized value of $44.2 million. At a discount rate of 7%, the present value social cost is $667.6 million which is equivalent to an annualized value of $22.3 million.

Wedgewire Screen

Based on a consideration of the alternatives, Option A has been selected as the preferred wedgewire screen retrofit option at PBAPS. This option includes the use of the most commercially-available (least customized) materials or equipment, which lowers construction time and costs, and provides more predictability for cost estimating. Selection of this alternative also satisfies the recommended installation requirements for both types of cleaning systems (mechanical-brush and air-burst cleaning systems), which allows flexibility for the detailed design selection. Additionally, Option A also has the smallest footprint of the three alternatives assessed, which limits the obstruction in Conowingo Reservoir. If this alternative is selected for implementation, a detailed engineering design and assessment may identify a configuration with better hydraulic, cost, and/or operational benefits.

Using the methodology and results described in this report, the project capital costs were estimated to be approximately $61.3 million. The project incremental operation costs and project incremental maintenance costs per year were estimated to be approximately $47,000 and $454,000, respectively. Total annualized costs (EAC) (including amortized capital costs), not including replacement energy costs during installation, are estimated at $5.45 million per year and total present-value life costs (NPV) for the wedgewire retrofit (including annual O&M costs) are estimated at $67.5 million, assuming the USEPA's useful life of wedgewire screens of 30 years and a discount rate of 7%. EAC costs (including amortized capital costs), not including replacement energy costs during installation, are estimated at $3.63 million per year and NPV costs for the wedgewire screen retrofit (including annual O&M costs) are estimated at $71.1 million, assuming the USEPA's useful life of wedgewire screens of 30 years and a discount rate of 3%.

Note that Unit 2 and Unit 3 are currently licensed to operate until 2033 and 2034, respectively (Exelon 2018), so the assumed 30 years of useful life is overestimated, unless the NRC license is extended. In July 2018, Exelon applied to NRC for a 20-year extension of their operating licenses for each unit, anticipating the process to take several years. Thus, the total annualized costs may be underestimated in this analysis, depending on the long-term life of the operating license for each unit. In addition, PBAPS may first pilot test a wedgewire screen to confirm the performance and reliability of the cooling water supply prior to full scale implementation. This could involve a prototype screen and monitoring over a year period. This would extend the over installation schedule.

The social cost of the wedgewire screen retrofit at PBAPS has been calculated in pre-tax U.S. Dollars. At a discount rate of 3%, the present value social cost is $117.1 million which is equivalent to an annualized value of $3.9 million. At a discount rate of 7%, the present value social cost is $59.0 million which is equivalent to an annualized value of $2.0 million.

Modified-Ristroph Traveling Screens with Seasonal Fine-Mesh Baskets / Panels

This option includes upgrading the existing traveling screens with modified-Ristroph screens with seasonal fine mesh baskets / panels, and construction of a fish handling and return system. Based on a consideration of the alternatives, Option A is the preferred fine-mesh traveling screen retrofit option at PBAPS since it is considered to have higher biological benefits due to reduced re-impingement and entrainment of organisms. However, space constraints and/or constructability issues may require further assessment of other fish return configurations during the detailed design, if this alternative is selected for implementation.

Using the methodology and results described in this report, the project capital costs were estimated to be approximately $36.3 million. The project incremental operation costs and project incremental maintenance costs per year were estimated to be approximately $0.42 million and $1.07 million, respectively. Total annualized costs (EAC), not including replacement costs during installation, are estimated at $4.92 million per year and total present-value life costs (NPV) for the fine-mesh traveling screen retrofit (including annual O&M costs) are estimated at $52.1 million, assuming the USEPA's useful life of traveling screens of 20 years and a discount rate of 7%. EAC costs (including amortized capital costs), not including replacement costs during installation, are estimated at $3.93 million per year and NPV costs for the fine-mesh traveling screen retrofit (including annual O&M costs) are estimated at $58.5 million, assuming the USEPA's useful life of traveling screens of 20 years and a discount rate of 3%.

Note that Unit 2 and Unit 3 are currently licensed to operate until 2033 and 2034, respectively (Exelon 2018), so the assumed 30 years of useful life is overestimated, unless the NRC license is extended. In July 2018, Exelon applied to NRC for a 20-year extension of their operating licenses for each unit, anticipating the process to take several years. Thus, the total annualized costs may be underestimated in this analysis, depending on the long-term life of the operating license for each unit.

The social cost of the fine-mesh traveling screen retrofit option at PBAPS has been calculated in pre-tax U.S. Dollars. At a discount rate of 3%, the present value social cost is $37.1 million which is equivalent to an annualized value of $1.9 million. At a discount rate of 7%, the present value social cost is $21.0 million which is equivalent to an annualized value of $1.1 million.

Water Reuse and Potential Alternative Water Source

None of the available alternative water sources could provide a reliable source of water at the volume (flow) and water quality required for operation of the cooling water system at PBAPS. The increase in both cost and difficulty with using one of the potential alternative cooling water sources identified, while at the same time potentially only reducing the required intake water flow marginally, makes these alternative sources not practical.

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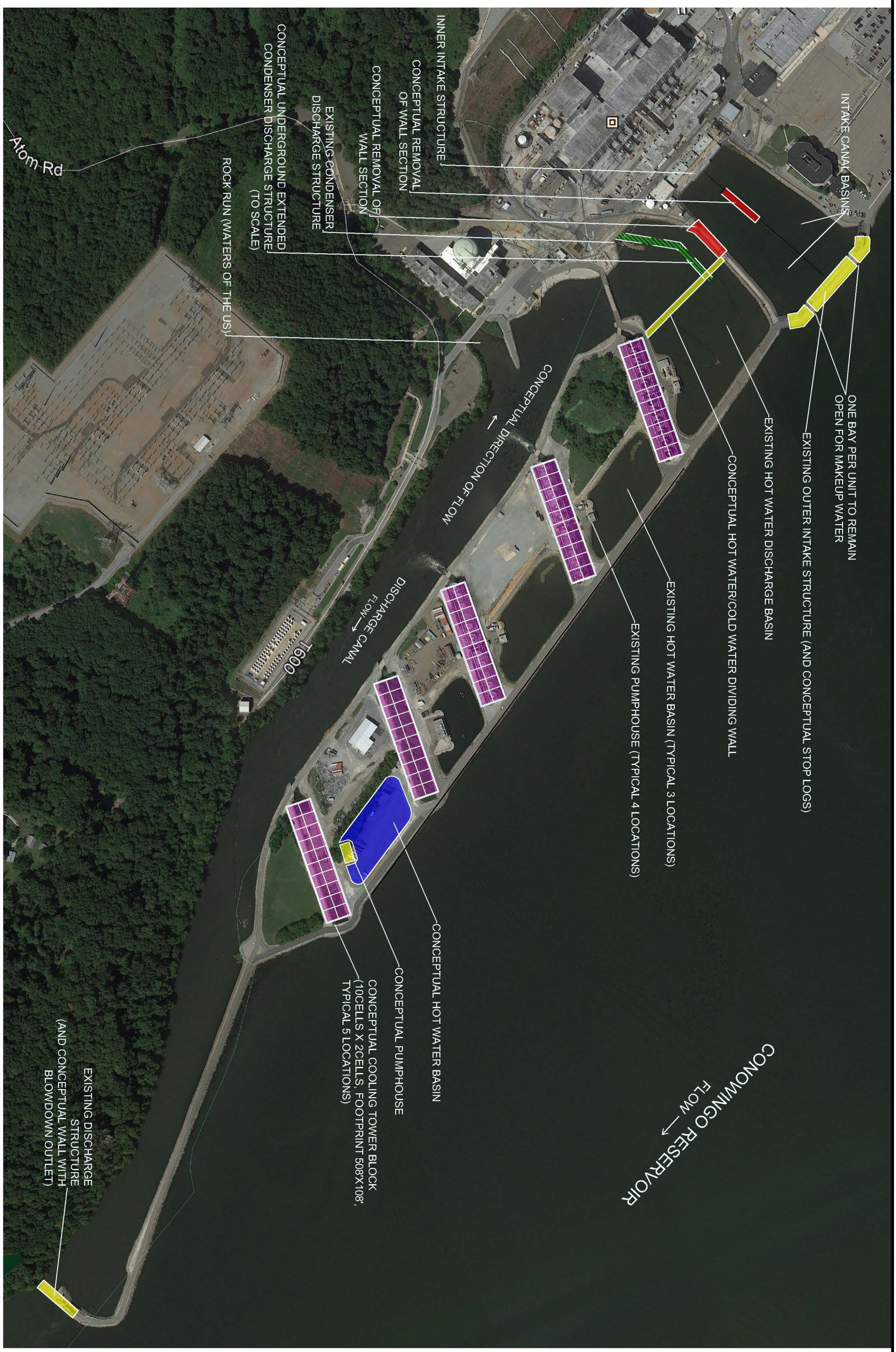
APPENDIX A

CONCEPT LAYOUTS



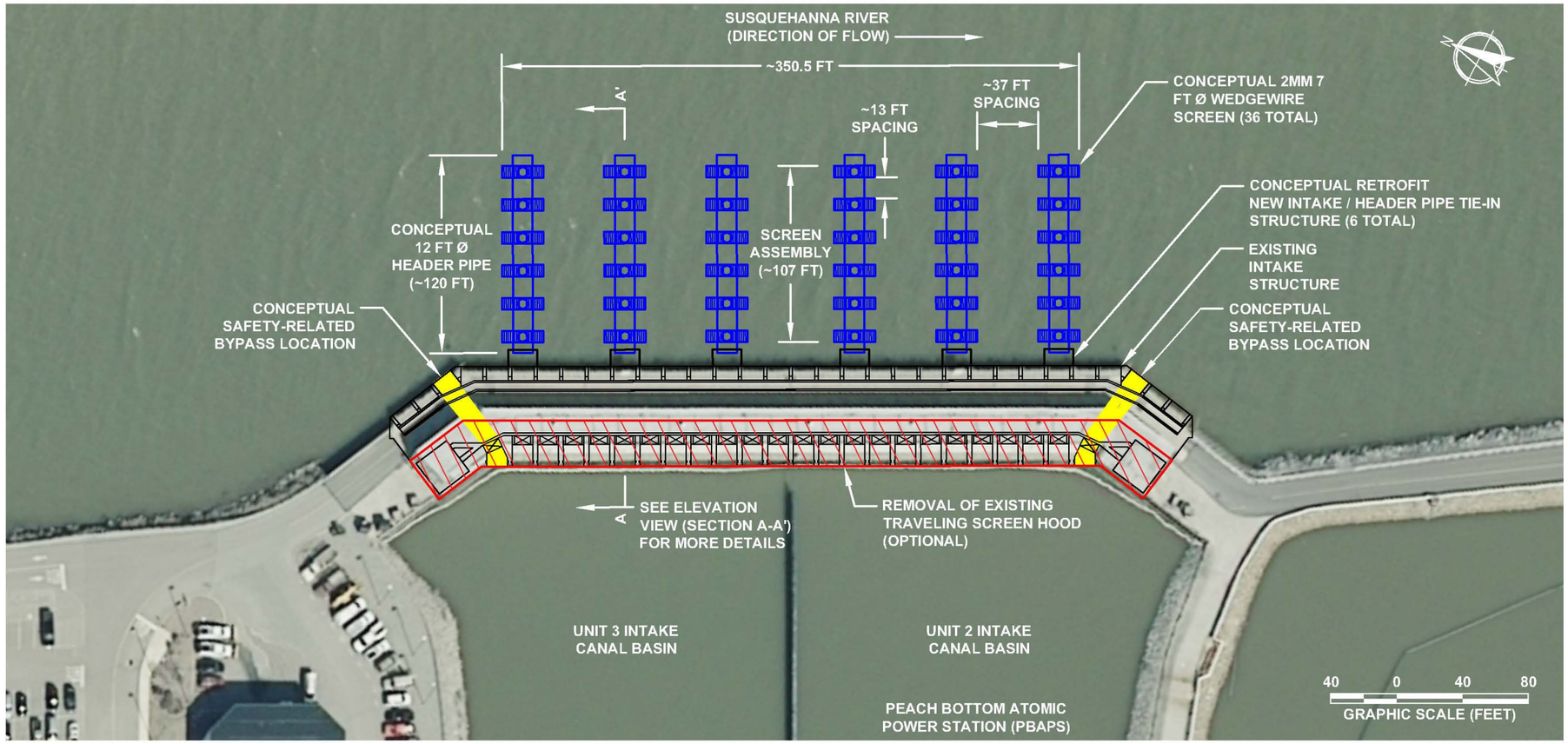
NOTE:
1. AERIAL IMAGERY REFERENCE: 2017 GOOGLE EARTH

EXELON GENERATING COMPANY
PEACH BOTTOM ATOMIC POWER STATION
YORK COUNTY, PENNSYLVANIA
Project No.: 60538796 Date: 2018-08-24

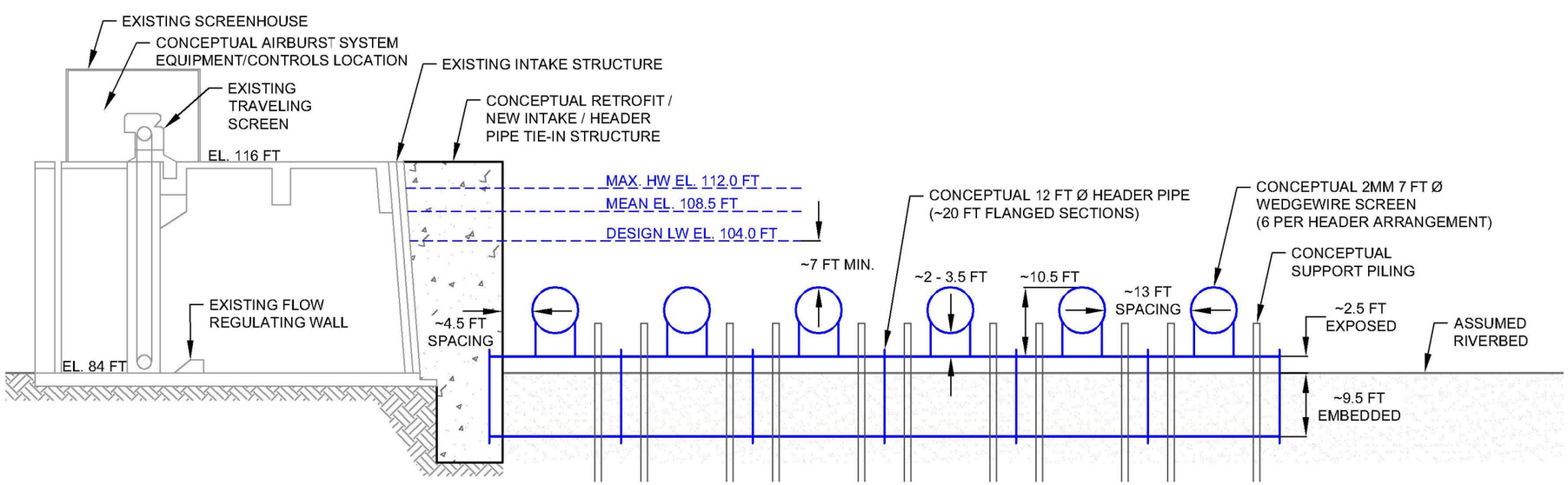
CONCEPTUAL COOLING TOWER LAYOUT
40 CFR §122.21(r)(10) NPDES APPLICATION REQUIREMENT
FOR FACILITIES WITH COOLING WATER INTAKE STRUCTURES

AECOM

Appendix A



CONCEPTUAL INTAKE SCREEN LAYOUT - PLAN VIEW
SCALE: 1 INCH = 80 FEET



CONCEPTUAL INTAKE SCREEN LAYOUT - ELEVATION VIEW (SECTION A-A')
SCALE: 1 INCH = 20 FEET

GENERAL NOTES:

1. THIS FIGURE ILLUSTRATES A CONCEPTUAL INTAKE SCREEN LAYOUT; IT IS NOT INTENDED FOR DESIGN, PERMITTING, OR CONSTRUCTION PURPOSES.
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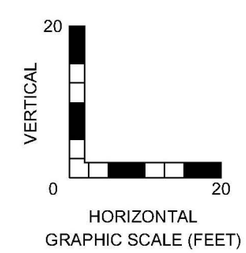
4. AERIAL IMAGERY REFERENCE: PORTIONS OF THE 2007-2008 DCNR PAMAP PROGRAM ORTHOIMAGERY AVAILABLE THROUGH THE PENNSYLVANIA SPATIAL DATA ACCESS (PASDA) WEBSITE.

CONCEPTUAL LAYOUT BASIS:

5. THE MINIMUM SCREEN SUBMERGENCE IS ASSUMED TO BE ONE (1) SCREEN DIAMETER BELOW THE DESIGN LOW WATER ELEVATION (LW EL.) TO ACCOUNT FOR EITHER MECHANICAL BRUSH OR AIRBURST CLEANING SYSTEMS.
6. THE MINIMUM CLEARANCE FROM THE BOTTOM OF THE SCREEN TO THE BOTTOM OF THE WATER SOURCE (RIVERBED) IS HALF (1/2) SCREEN DIAMETER TO ALLOW ROLLING DEBRIS AT THE BOTTOM OF THE SCREEN TO ROLL PAST AND TO MINIMIZE THE FORMATION OF A STANDING EDDY (SUCKING DEBRIS UP TO THE SCREEN SURFACE FROM THE RIVERBED).
7. THE MINIMUM CLEARANCE FROM A WALL OR OTHER STRUCTURE IS ASSUMED TO RANGE BETWEEN 2 FEET OR HALF (1/2) SCREEN DIAMETER DEPENDING UPON THE TYPE OF CLEANING SYSTEM.
8. THE MINIMUM CLEARANCE BETWEEN SCREENS IS ASSUMED TO BE ONE (1) SCREEN DIAMETER.

CONCEPTUAL LAYOUT SUMMARY:

9. SIX (6) TOTAL HEADERS AND THIRTY-SIX (36) TOTAL WEDGEWIRE SCREENS.
10. THE EXISTING INTAKE STRUCTURE WILL BE RETROFITTED WITH SIX (6) CAST-IN-PLACE CONCRETE STRUCTURES AND BULKHEADS OR SIMILAR STRUCTURES.
11. STOP LOGS/GATES OR SIMILAR MEANS WILL BE USED TO ISOLATE AND CLOSE EXISTING TRAVELING SCREEN BAYS.
12. AN ARRANGEMENT OF SUPPORT PILINGS WILL BE CONSTRUCTED TO ANCHOR AND PROTECT THE CONCEPTUAL INTAKE SCREEN LAYOUT.



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Appendix A

CONCEPTUAL INTAKE SCREEN LAYOUT - OPTION A
40 CFR §122.21(r)(10) NPDES APPLICATION REQUIREMENT
FOR FACILITIES WITH COOLING WATER INTAKE STRUCTURES

EXELON GENERATION COMPANY
PEACH BOTTOM ATOMIC POWER STATION
YORK COUNTY, PENNSYLVANIA
Project No.: 60538796 Date: 2018-08-24

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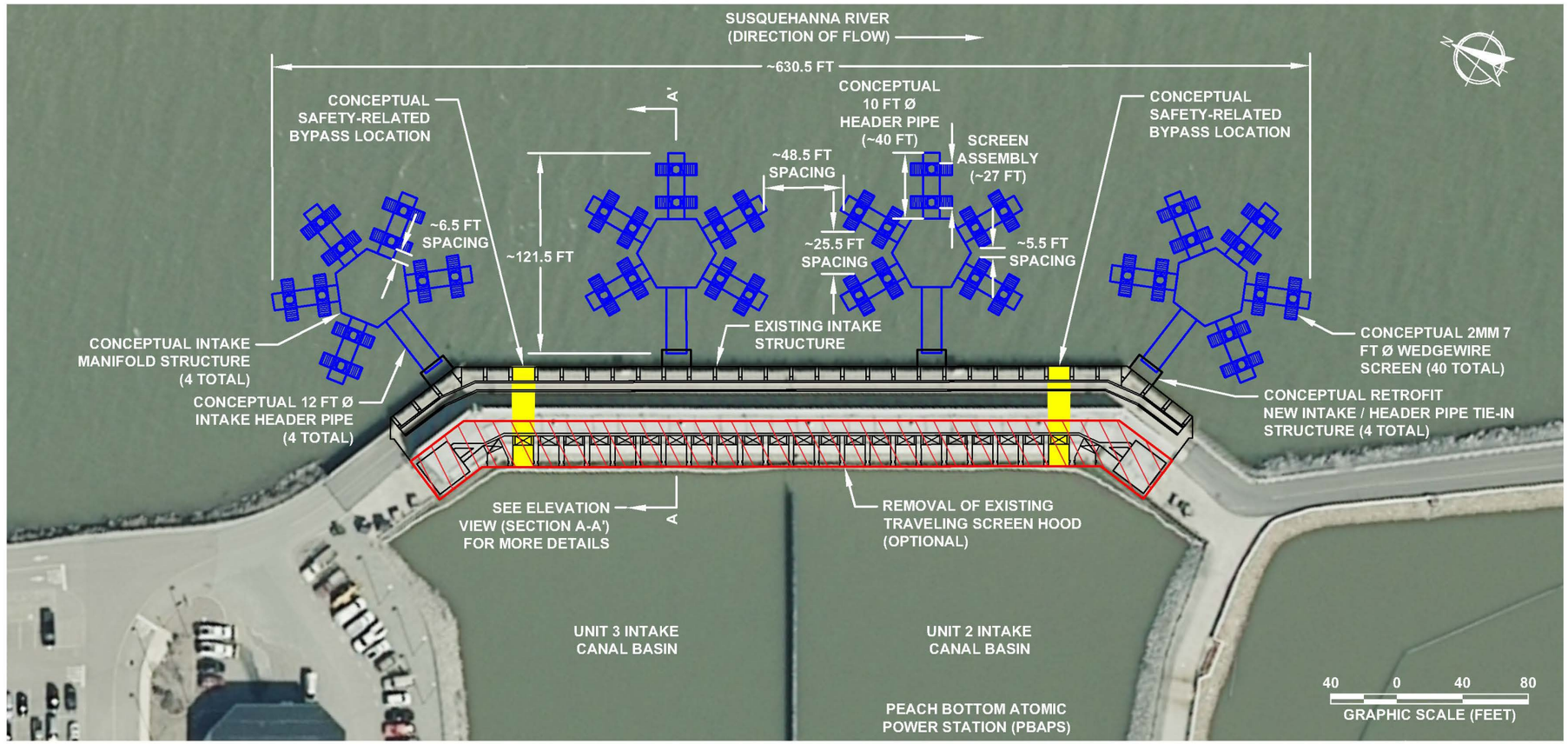
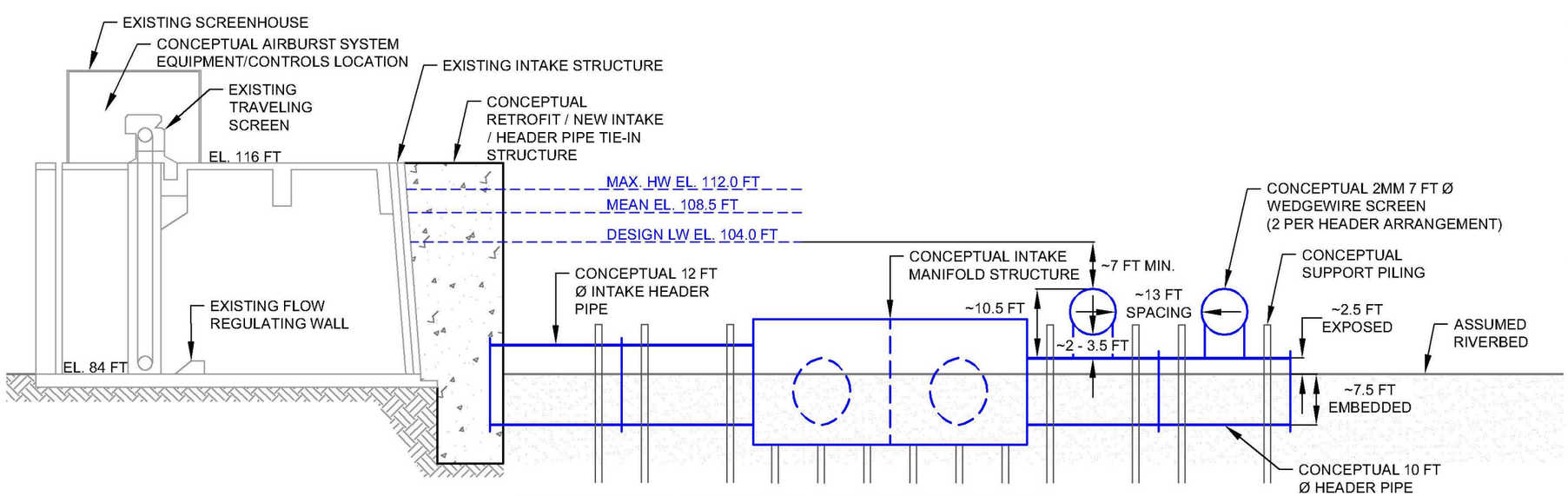
Project Management Initials: Designer: TAK Checked: JLP Approved: JT ANSI B 11" x 17"



CONCEPTUAL INTAKE SCREEN LAYOUT - PLAN VIEW
SCALE: 1 INCH = 80 FEET



CONCEPTUAL INTAKE SCREEN LAYOUT - ELEVATION VIEW (SECTION A-A')
SCALE: 1 INCH = 20 FEET

GENERAL NOTES:

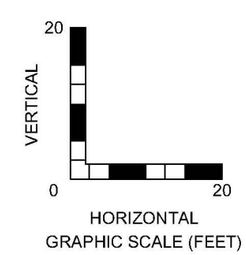
1. THIS FIGURE ILLUSTRATES A CONCEPTUAL INTAKE SCREEN LAYOUT; IT IS NOT INTENDED FOR DESIGN, PERMITTING, OR CONSTRUCTION PURPOSES.
2. HORIZONTAL DATUM REFERENCES THE NORTH AMERICAN DATUM OF 1983 (NAD 83), PENNSYLVANIA SOUTH STATE PLANE COORDINATE SYSTEM (PAS SPCS).
3. VERTICAL DATUM REFERENCES THE NORTH AMERICAN VERTICAL DATUM OF 1988 (NAVD 88).
4. AERIAL IMAGERY REFERENCE: PORTIONS OF THE 2007-2008 DCNR PAMAP PROGRAM ORTHOIMAGERY AVAILABLE THROUGH THE PENNSYLVANIA SPATIAL DATA ACCESS (PASDA) WEBSITE.

CONCEPTUAL LAYOUT BASIS:

5. THE MINIMUM SCREEN SUBMERGENCE IS ASSUMED TO BE ONE (1) SCREEN DIAMETER BELOW THE DESIGN LOW WATER ELEVATION (LW EL.) TO ACCOUNT FOR EITHER MECHANICAL BRUSH OR AIRBURST CLEANING SYSTEMS.
6. THE MINIMUM CLEARANCE FROM THE BOTTOM OF THE SCREEN TO THE BOTTOM OF THE WATER SOURCE (RIVERBED) IS HALF (1/2) SCREEN DIAMETER TO ALLOW ROLLING DEBRIS AT THE BOTTOM OF THE SCREEN TO ROLL PAST AND TO MINIMIZE THE FORMATION OF A STANDING EDDY (SUCKING DEBRIS UP TO THE SCREEN SURFACE FROM THE RIVERBED).
7. THE MINIMUM CLEARANCE FROM A WALL OR OTHER STRUCTURE IS ASSUMED TO RANGE BETWEEN 2 FEET OR HALF (1/2) SCREEN DIAMETER DEPENDING UPON THE TYPE OF CLEANING SYSTEM.
8. THE MINIMUM CLEARANCE BETWEEN SCREENS IS ASSUMED TO BE ONE (1) SCREEN DIAMETER.

CONCEPTUAL LAYOUT SUMMARY:

9. TWENTY (20) TOTAL HEADERS AND FORTY (40) TOTAL WEDGEWIRE SCREENS.
10. THE EXISTING INTAKE STRUCTURE WILL BE RETROFITTED WITH FOUR (4) CAST-IN-PLACE CONCRETE STRUCTURES AND BULKHEADS OR SIMILAR STRUCTURES.
11. STOP LOGS/GATES OR SIMILAR MEANS WILL BE USED TO ISOLATE AND CLOSE EXISTING TRAVELING SCREEN BAYS.
12. AN ARRANGEMENT OF SUPPORT PILINGS WILL BE CONSTRUCTED TO ANCHOR AND PROTECT THE CONCEPTUAL INTAKE SCREEN LAYOUT.



AECOM

Appendix A

CONCEPTUAL INTAKE SCREEN LAYOUT - OPTION B
40 CFR §122.21(r)(10) NPDES APPLICATION REQUIREMENT
FOR FACILITIES WITH COOLING WATER INTAKE STRUCTURES

EXELON GENERATION COMPANY
PEACH BOTTOM ATOMIC POWER STATION
YORK COUNTY, PENNSYLVANIA
Project No.: 60538796 Date: 2018-08-2018

Project Management Initials: Designer: TAK Checked: JLP Approved: JT ANSI B 11" x 17"

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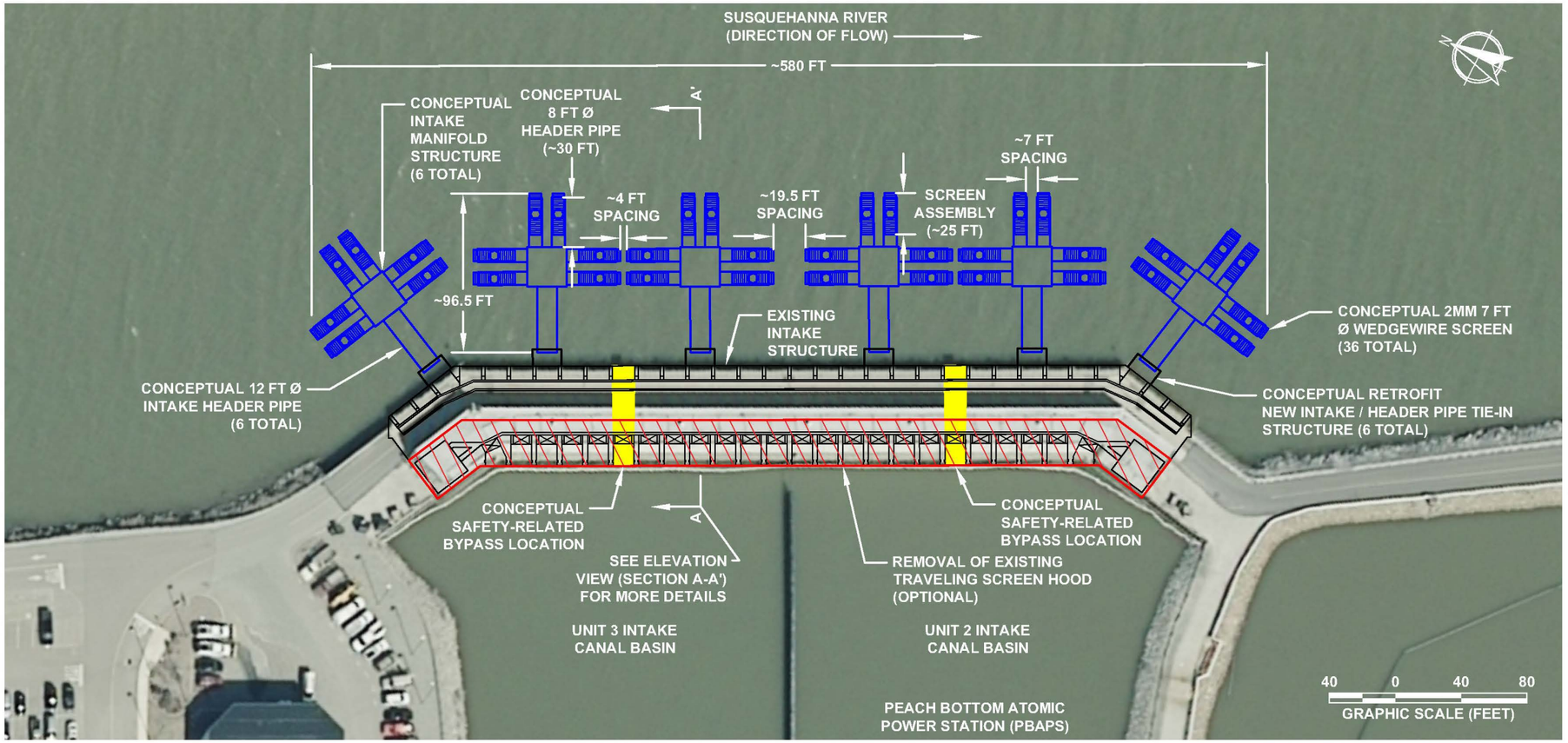
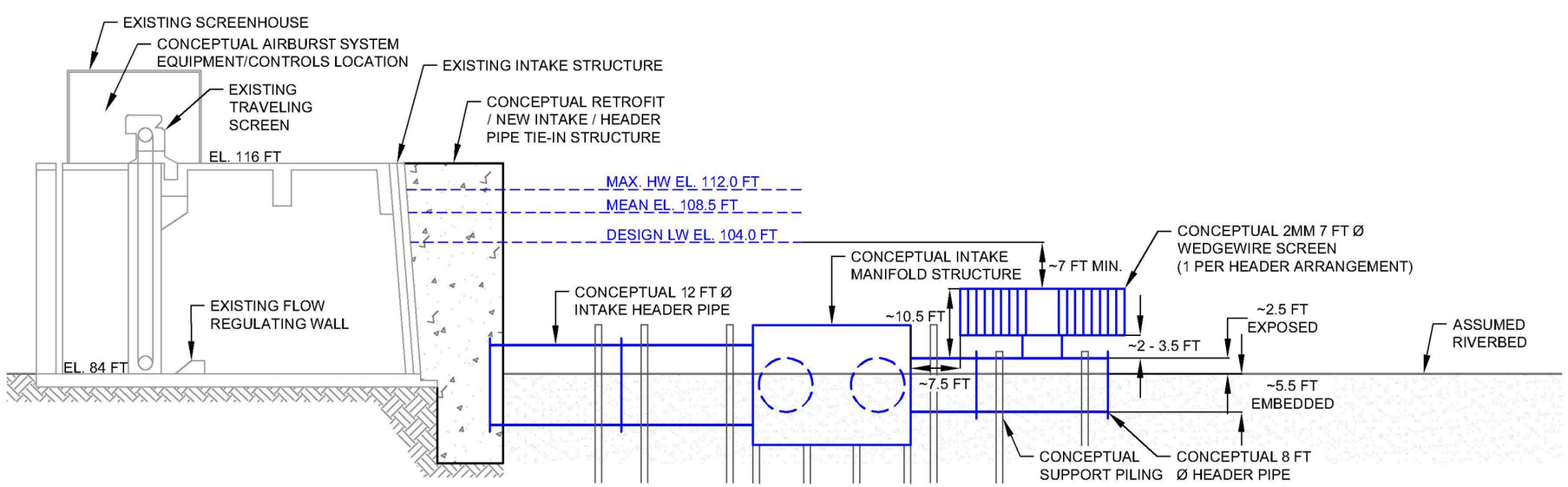


CONCEPTUAL INTAKE SCREEN LAYOUT - PLAN VIEW
SCALE: 1 INCH = 80 FEET



CONCEPTUAL INTAKE SCREEN LAYOUT - ELEVATION VIEW (SECTION A-A')
SCALE: 1 INCH = 20 FEET

GENERAL NOTES:

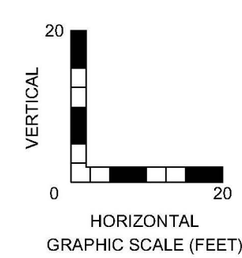
1. THIS FIGURE ILLUSTRATES A CONCEPTUAL INTAKE SCREEN LAYOUT; IT IS NOT INTENDED FOR DESIGN, PERMITTING, OR CONSTRUCTION PURPOSES.
2. HORIZONTAL DATUM REFERENCES THE NORTH AMERICAN DATUM OF 1983 (NAD 83), PENNSYLVANIA SOUTH STATE PLANE COORDINATE SYSTEM (PAS SPCS).
3. VERTICAL DATUM REFERENCES THE NORTH AMERICAN VERTICAL DATUM OF 1988 (NAVD 88).
4. AERIAL IMAGERY REFERENCE: PORTIONS OF THE 2007-2008 DCNR PAMAP PROGRAM ORTHOIMAGERY AVAILABLE THROUGH THE PENNSYLVANIA SPATIAL DATA ACCESS (PASDA) WEBSITE.

CONCEPTUAL LAYOUT BASIS:

5. THE MINIMUM SCREEN SUBMERGENCE IS ASSUMED TO BE ONE (1) SCREEN DIAMETER BELOW THE DESIGN LCW WATER ELEVATION (LW EL.) TO ACCOUNT FOR EITHER MECHANICAL BRUSH OR AIRBURST CLEANING SYSTEMS.
6. THE MINIMUM CLEARANCE FROM THE BOTTOM OF THE SCREEN TO THE BOTTOM OF THE WATER SOURCE (RIVERBED) IS HALF (1/2) SCREEN DIAMETER TO ALLOW ROLLING DEBRIS AT THE BOTTOM OF THE SCREEN TO ROLL PAST AND TO MINIMIZE THE FORMATION OF A STANDING EDDY (SUCKING DEBRIS UP TO THE SCREEN SURFACE FROM THE RIVERBED).
7. THE MINIMUM CLEARANCE FROM A WALL OR OTHER STRUCTURE IS ASSUMED TO RANGE BETWEEN 2 FEET OR HALF (1/2) SCREEN DIAMETER DEPENDING UPON THE TYPE OF CLEANING SYSTEM.
8. THE MINIMUM CLEARANCE BETWEEN SCREENS IS ASSUMED TO BE ONE (1) SCREEN DIAMETER.

CONCEPTUAL LAYOUT SUMMARY:

9. THIRTY-SIX (36) TOTAL HEADERS AND THIRTY-SIX (36) TOTAL WEDGEWIRE SCREENS.
10. THE EXISTING INTAKE STRUCTURE WILL BE RETROFITTED WITH SIX (6) CAST-IN-PLACE CONCRETE STRUCTURES AND BULKHEADS OR SIMILAR STRUCTURES.
11. STOP LOGS/GATES OR SIMILAR MEANS WILL BE USED TO ISOLATE AND CLOSE EXISTING TRAVELING SCREEN BAYS.
12. AN ARRANGEMENT OF SUPPORT PILINGS WILL BE CONSTRUCTED TO ANCHOR AND PROTECT THE CONCEPTUAL INTAKE SCREEN LAYOUT.



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Appendix A

CONCEPTUAL INTAKE SCREEN LAYOUT - OPTION C
40 CFR §122.21(r)(10) NPDES APPLICATION REQUIREMENT
FOR FACILITIES WITH COOLING WATER INTAKE STRUCTURES

EXELON GENERATION COMPANY
PEACH BOTTOM ATOMIC POWER STATION
YORK COUNTY, PENNSYLVANIA
Project No.: 60538796 Date: 2018-08-24

ANSI B 11" x 17"
Approved: JT
Checked: JLP
Designer: TAK
Project Management Initials:
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Plot Scale: 1:1
Plot Date: 2018-08-24
Last Plotted: 2018-08-24
Plotted by: THOMAS.KALEY(2017-12-07)

CONCEPTUAL MODIFIED TRAVELING SCREENS LAYOUT - PLAN VIEW
SCALE: 1 INCH = 80 FEET

GENERAL NOTES:

1. THIS FIGURE ILLUSTRATES A CONCEPTUAL MODIFIED TRAVELING SCREENS LAYOUT; IT IS NOT INTENDED FOR DESIGN, PERMITTING, OR CONSTRUCTION PURPOSES.
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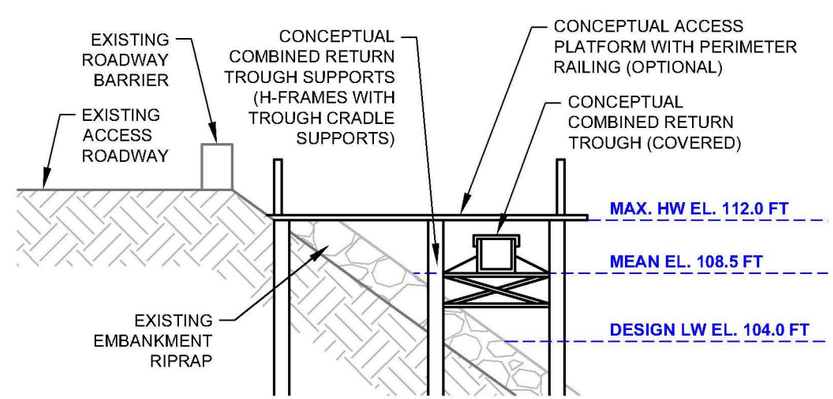
4. AERIAL IMAGERY REFERENCE: PORTIONS OF THE 2007-2008 DCNR PAMAP PROGRAM ORTHOIMAGERY AVAILABLE THROUGH THE PENNSYLVANIA SPATIAL DATA ACCESS (PASDA) WEBSITE.

CONCEPTUAL LAYOUT BASIS:

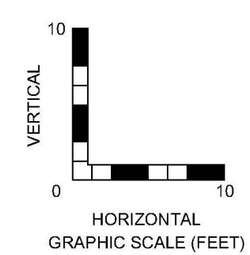
5. THE TOTAL NUMBER OF EXISTING TRAVELING SCREENS TO BE MODIFIED IS TWENTY-FOUR (24).
6. THE CONCEPTUAL SLOPE FOR THE COMBINED RETURN FLUME/TROUGH IS 1/16 INCH PER FOOT (0.52%).

CONCEPTUAL LAYOUT SUMMARY:

7. THE EXISTING INTAKE TRAVELING SCREEN ARRANGEMENT WILL BE REPLACED WITH TWENTY-FOUR (24) NEW MODIFIED TRAVELING SCREENS.
8. AN ARRANGEMENT OF SUPPORT PILINGS (H-FRAMES) WILL BE CONSTRUCTED TO ANCHOR, SUPPORT, AND PROTECT THE CONCEPTUAL ABOVEGROUND COMBINED RETURN TROUGH ALONG THE EXISTING RIPRAP ARMORED SHORELINE.



CONCEPTUAL COMBINED RETURN TROUGH LAYOUT
ELEVATION VIEW (SECTION A-A')
SCALE: 1 INCH = 10 FEET



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Appendix A

CONCEPTUAL MTWS RETURN LAYOUT - OPTION A
40 CFR §122.21(r)(10) NPDES APPLICATION REQUIREMENT
FOR FACILITIES WITH COOLING WATER INTAKE STRUCTURES

EXELON GENERATION COMPANY
PEACH BOTTOM ATOMIC POWER STATION
YORK COUNTY, PENNSYLVANIA
Project No.: 60538796 Date: 2018-08-24

Last saved by: THOMAS.KALEY(2018-08-24) Last Plotted: 2018-08-24
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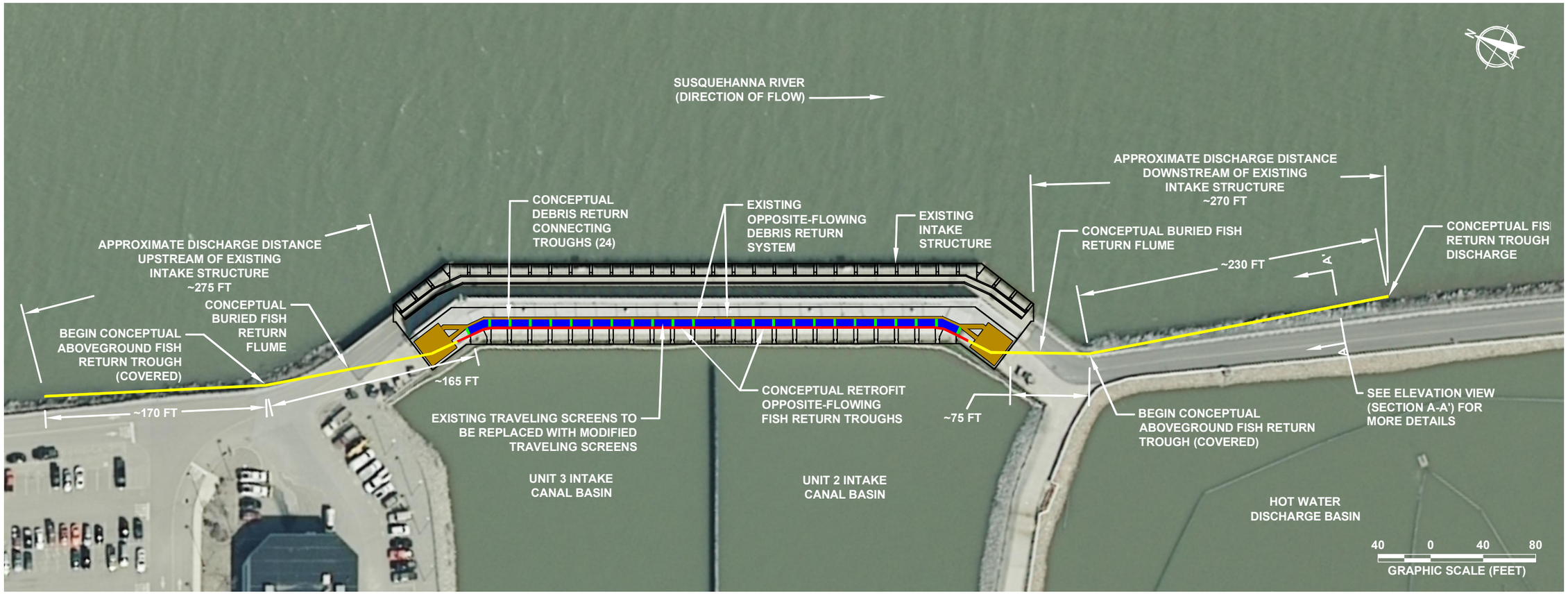
Project Management Initials: Designer: TAK Checked: JLP Approved: JT ANSI B 11" x 17"



CONCEPTUAL MODIFIED TRAVELING SCREENS LAYOUT - PLAN VIEW
SCALE: 1 INCH = 80 FEET

GENERAL NOTES:

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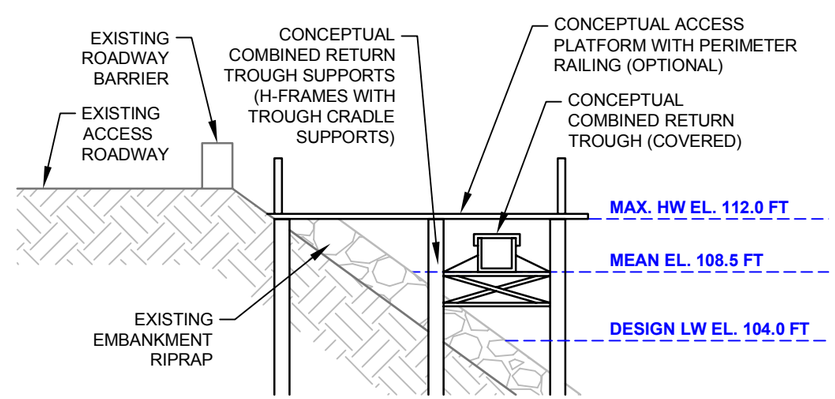
CONCEPTUAL LAYOUT BASIS:

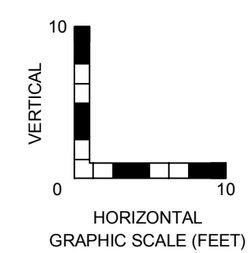
5. THE TOTAL NUMBER OF EXISTING TRAVELING SCREENS TO BE MODIFIED IS TWENTY-FOUR (24).
6. THE CONCEPTUAL SLOPE FOR THE COMBINED RETURN FLUME/TROUGH IS 1/16 INCH PER FOOT (0.52%).

CONCEPTUAL LAYOUT SUMMARY:

7. THE EXISTING INTAKE TRAVELING SCREEN ARRANGEMENT WILL BE REPLACED WITH TWENTY-FOUR (24) NEW MODIFIED TRAVELING SCREENS.
8. AN ARRANGEMENT OF SUPPORT PILINGS (H-FRAMES) WILL BE CONSTRUCTED TO ANCHOR, SUPPORT, AND PROTECT THE CONCEPTUAL ABOVEGROUND COMBINED RETURN TROUGH ALONG THE EXISTING RIPRAP ARMORED SHORELINE.



CONCEPTUAL COMBINED RETURN TROUGH LAYOUT
ELEVATION VIEW (SECTION A-A')
SCALE: 1 INCH = 10 FEET



AECOM
Appendix A

CONCEPTUAL MTWS RETURN LAYOUT - OPTION B
40 CFR §122.21(r)(10) NPDES APPLICATION REQUIREMENT
FOR FACILITIES WITH COOLING WATER INTAKE STRUCTURES

EXELON GENERATION COMPANY
PEACH BOTTOM ATOMIC POWER STATION
YORK COUNTY, PENNSYLVANIA
Project No.: 60538796 Date: 2018-08-24

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Project Management Initials: Designer: TAK Checked: JLP Approved: JT ANSI B 11" x 17"

APPENDIX B

SOCIAL COSTS OF PURCHASING AND INSTALLING ENTRAINMENT REDUCTION TECHNOLOGIES: PEACH BOTTOM ATOMIC POWER STATION

Social Costs of Purchasing and Installing Entrainment Reduction Technologies:

Peach Bottom Atomic Power Station

Prepared for:

Exelon

Prepared by:

Veritas Economics

January 2019

1851 Evans Road
Cary, NC 27513

Office: 919.677.8787
Fax: 919.677.8331

VERITAS
Economic Consulting
VeritasEconomics.com

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1.3 Market Environment 7

1.4 Social Costs of Compliance..... 8

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Appendix C Study of Property Value Impacts for Peach Bottom Atomic Power Station 39

1. The Social Costs of Purchasing and Installing Technologies

Reducing entrainment can generally be accomplished by altering operations; closing the facility; or by purchasing, installing, and operating entrainment reduction technologies. These activities lead to a number of physical changes and financial effects relating to social costs. The Environmental Protection Agency (EPA) defines social costs as the "opportunity cost to society of employing scarce resources to prevent the environmental damage otherwise occurring except for the design and operation of compliance technology" (79 *Fed. Reg.* 158, 48387). These are further delineated as each of the following:

- Real-Resource Compliance Costs—direct purchase installation and operation
- Government Regulatory Costs—monitoring, administration, enforcement
- Environmental Externalities—increased fuel cost impacts from energy penalty and proposed outages.

This report covers each of these social cost categories. Real-Resource Compliance Costs result from purchasing and installing technologies at the Peach Bottom Atomic Power Station (PBAPS). Government Regulatory Costs are developed from EPA's estimates in the national rule (79 *Fed. Reg.* 158, 48300–48439). The social costs of environmental externalities are developed from the Power System Capacity Loss and Offsite Emissions Study, Recreation Study, and Property Value Study conducted at PBAPS. The methods and results of those studies are presented in Appendix A, B, and C of this report.

Figure 1 depicts how expenditures on entrainment reduction technologies would have implications for Exelon's balance sheet and construction activities. As the figure depicts, construction generates nearby economic activity, which can lead to good social outcomes such as more jobs. These economic impacts can be studied via economic input-output analysis techniques. As related local outcomes are typically considered good, they are not measured under social costs and not considered further here.

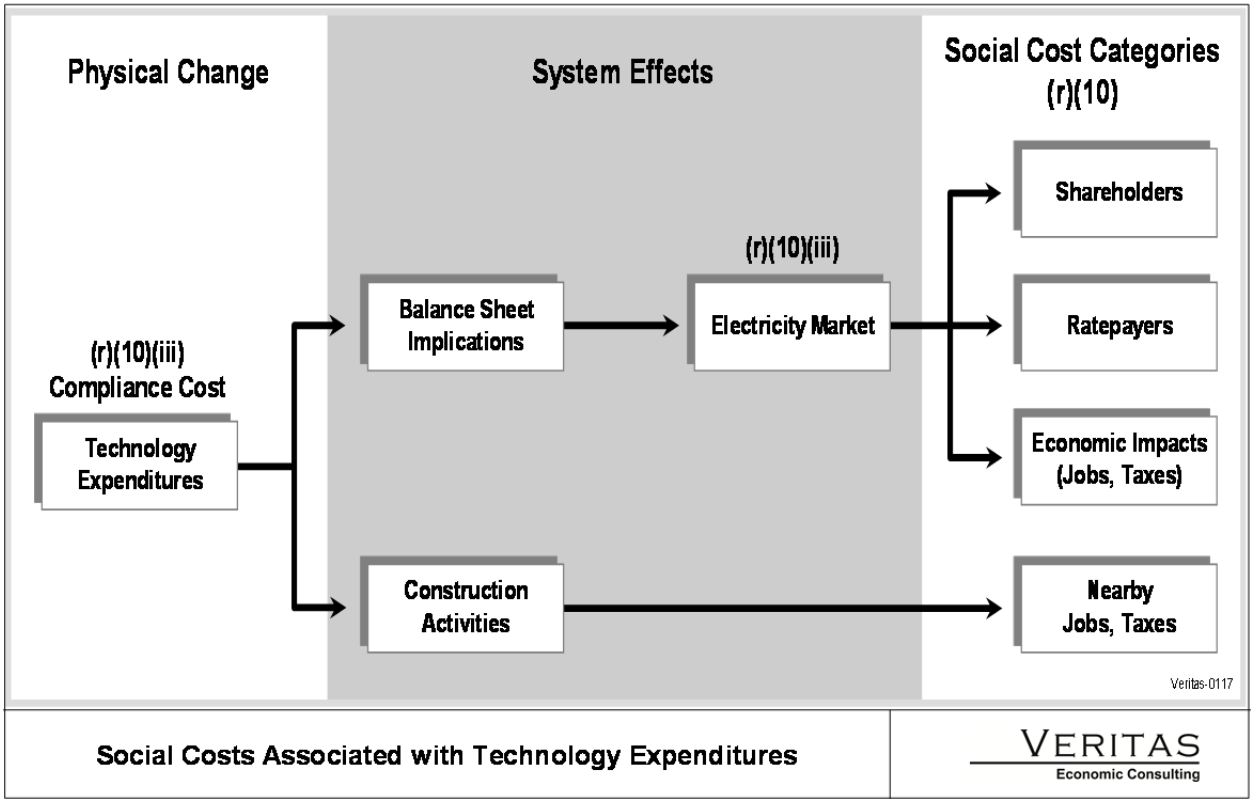

Figure 1: Social Costs Associated with Technology Expenditures

Balance sheet implications are transmitted through financial, electricity, and regulatory markets to register as social costs to shareholders, ratepayers, and the general population. How these are realized as social costs depends upon the regulatory and market environments.

1.1 Entrainment Reduction Technology Options

PBAPS is a nuclear generating plant located in Delta, Pennsylvania approximately 50 miles southeast of Harrisburg, Pennsylvania. The plant sits on the west bank of the Conowingo Reservoir which is fed by the Susquehanna River. The plant consists of three units: Unit 1 was built in 1967 and ceased operations in 1974; Units 2 and 3 were built in 1974 and continue to operate today. Each of the two operating units have a capacity of 1,300MW for a total plant capacity of 2,600MW. AECOM engineers have considered several alternative screen, water reuse, and closed-cycle cooling technologies (AECOM 2017) and have evaluated the following three technological options for PBAPS:

- Closed-cycle cooling
- Fine mesh traveling screens with a fish return (FMS)
- Cylindrical wedge wire screens

Table 1 summarizes the estimated capital costs for each technology.

Table 1
Capital Cost Estimates for Feasible Alternatives at PBAPS

Technology	Capital Cost Estimate
Closed-Cycle Cooling Towers	$1.1B
Fine Mesh Traveling Screens	$36.2M
Cylindrical Wedge Wire Screens	$61.3M

Balance sheet implications would accompany the purchase, installation and operation of any of these entrainment reduction technologies. Costs vary from lower cost FMS technology options to higher cost closed-cycle cooling retrofit options. Detailed costs of the feasible options are presented in Section 1.4 of this report.

1.2 Financial and Regulatory Environment

PBAPS is owned by Exelon, the nation's largest competitive energy provider with corporate headquarters located in Chicago, Illinois. Exelon is the holding company for eight subsidiaries: Atlantic City Electric, Baltimore Gas and Electric (BGE), Commonwealth Edison (ComEd), Delmarva Power, Philadelphia Electric Company (PECO), Potomac Electric Power Company (Pepco), Exelon Generation, and Exelon Constellation, a wholesale and retail energy supplier. Exelon conducts business in 48 states, the District of Columbia, and Canada. Their six utilities collectively serve approximately 10 million customers making Exelon the largest regulated utility in the nation.

Exelon Generation is one of the largest generators of power with over 33,000 megawatts of nuclear, gas, oil, wind, solar and hydroelectric capacity. Located in 18 states and Canada, Exelon Generation's fleet is one of the nation's leaders in producing clean, low-cost energy. Their generation portfolio includes 23 nuclear reactors at 14 nuclear facilities making Exelon the largest owner and operator of nuclear power plants in the United States. Figures 2 and 3 illustrate the geographic location of Exelon Generation's generating fleet along with their fuel type.

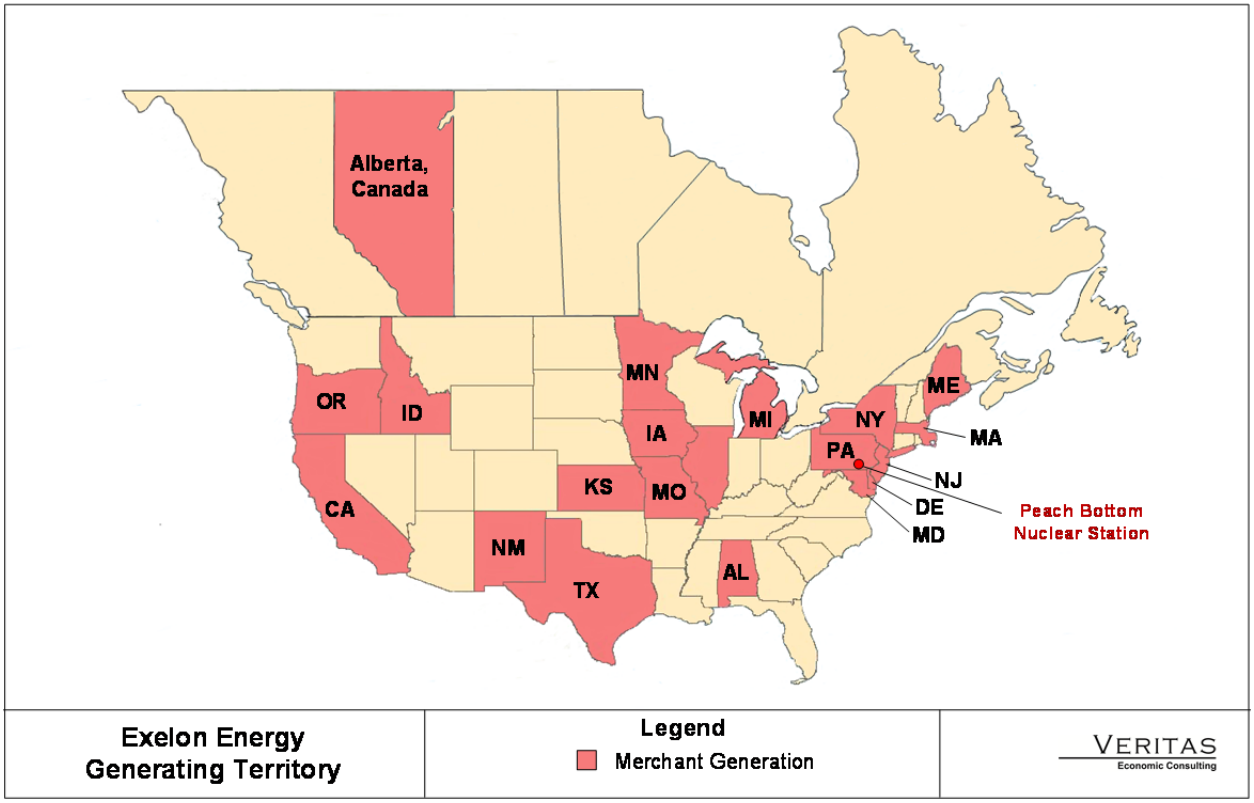

Figure 2: Generating Territory for Exelon Energy

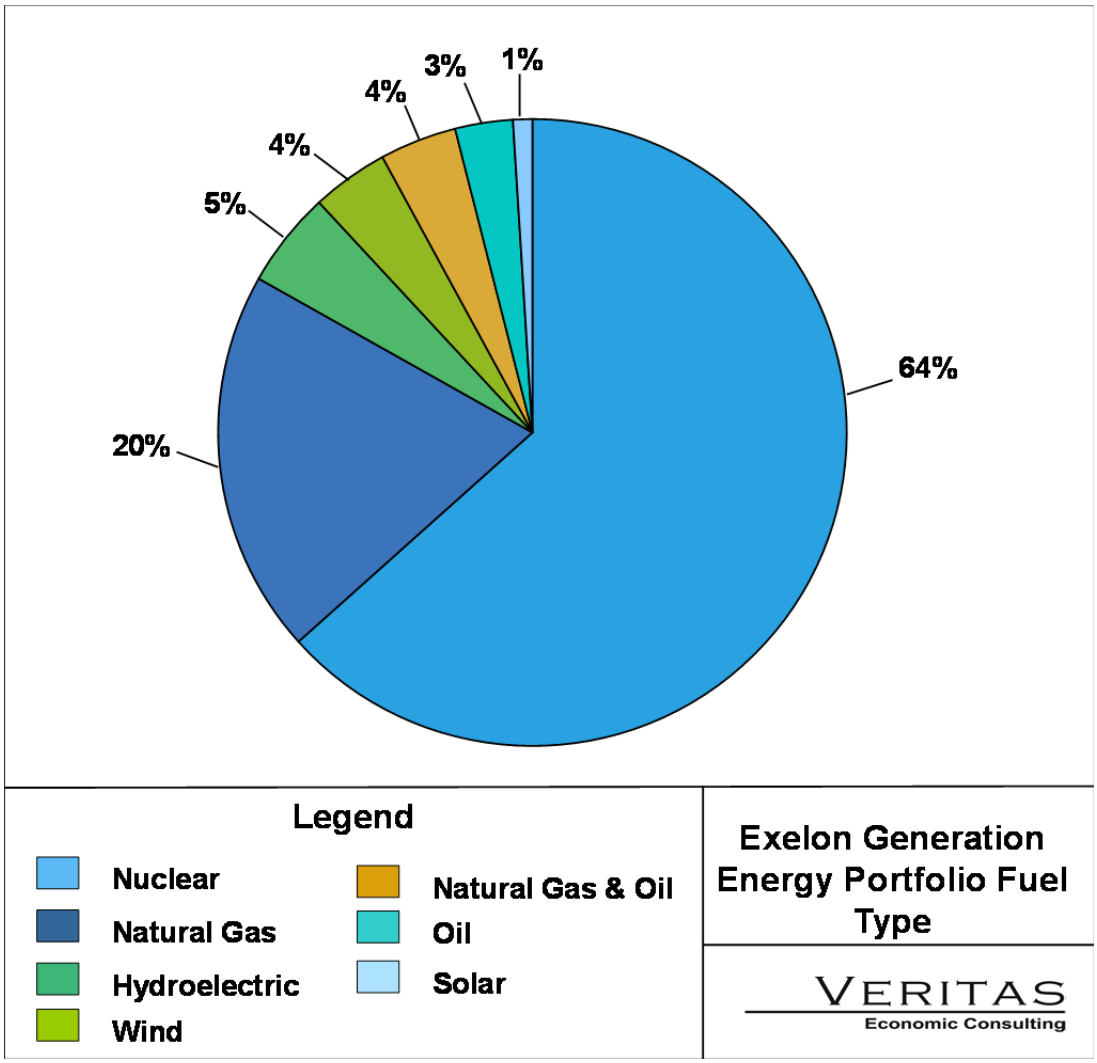

Figure 3: Exelon Generation Portfolio Fuel Type

A traditional, rate-based electric utility generating plant is built by a regulated utility specifically to serve that utilities' customers. Through the ratemaking process, customers are required to pay for the plant's construction, operation and maintenance costs. Investors in the utility are then allowed a fair financial return on the capital investment. However, Exelon's generating plants do not recover costs in this manner. Exelon's subsidiary, Exelon Generation, maintains and operates all the company's generating assets. Electricity generated from the plants is sold to customers in the competitive wholesale power market. The construction, operation and maintenance costs of the plants are funded solely by investors. The financial return investors earn is determined by the competitive marketplace the plants operate in. Approximately 35% of Exelon's earnings come from the unregulated, wholesale market that both Exelon Generation and Exelon Constellation operate in. Exelon's six regulated utilities earn a fair financial return on the capital investment required to transmit and deliver power to

Exelon's 10 million utility customers. Approximately 65% of Exelon's earnings are produced by this regulated side of the business.

The cost of purchasing, installing and operating entrainment reduction technologies are Real-Resource Compliance Costs and would have to be passed onto Exelon's shareholders as an additional cost of operating the PBAPS plant. These costs could result in lower returns for investors depending on future wholesale power market conditions. Lower returns could make Exelon's stock less attractive for investors which could put downward pressure on the stock price, negatively impacting Exelon's ability to raise capital for operations. Exelon's recent financial performance is instructive with respect to the implication of increased costs on the unregulated side of their balance sheet. The ability to absorb these costs without significant negative financial impacts is dependent in large part on the financial health of the overall company. As of April 2017, Exelon was the fifth largest electric utility in the U.S. with a market value of $33 billion and was ranked the number one utility on the Fortune 500 list at #95. Fortune magazine also ranked Exelon #7 on their 2017 list of "Most Admired" electric and gas utilities, their eleventh consecutive year being recognized. Exelon's dividend performance has also been solid. With a current yield of 3.6%, Exelon has paid a quarterly dividend for decades providing a reliable, safe cash flow to investors.

The performance of Exelon's stock has not fared as well. Total returns have under-performed both the S&P 500 and S&P 500 Utilities stock indices consistently for the past 15 years (except for 2016 when the stock outperformed the utility index while continuing to be below the S&P 500 return). Since its peak in July 2008, the price of Exelon stock has fallen 60%. This is due in large part to declining natural gas prices which have negatively impacted profits at Exelon Generation, specifically their large nuclear fleet. Low natural gas prices have significantly depressed wholesale power prices creating a situation where Exelon's nuclear plants have struggled to remain profitable in the competitive marketplace. Competition from clean energy supplies and renewables coupled with slack electric demand due to lagging economic conditions and investments in energy efficiency equipment have also put downward pressure on earnings.

New federal regulations compensating power suppliers for their carbon free attributes were anticipated, but when the passage of national climate change legislation and carbon emission limits fell through, Exelon announced plans to close unprofitable nuclear plants in Illinois and New York. The loss of jobs was projected to have significant negative impacts on the local economies. The Illinois state legislature responded in December 2016 with the passage of the Future Energy Jobs Act that included a zero-emission standard provision that

provides financial compensation in the form of a zero-emission credit (ZEC) of $0.01 per kwh for nuclear generation over a period of ten years. The New York state legislature passed a similar Clean Energy Standard in August 2016 that includes a five-year ZEC. The financial guarantees provided by the ZEC's allowed Exelon to reverse the decision to close the nuclear plants. The Illinois ZEC is projected to have a $0.07 positive impact on earnings per share, per year while the impacts of the New York ZEC are projected to be between $0.08 and $0.10 per share, per year. Other plants in Exelon's nuclear fleet have struggled to remain profitable as well. In May, Exelon announced the closing of its Three Mile Island nuclear plant in 2019 due to the unfavorable economics of operating the plant. The Pennsylvania State Legislature is considering adding nuclear generation to the state's Alternative Energy Portfolio Standard and implementing ZEC's for nuclear plants which could potentially improve the economics of Three Mile Island and possibly allow for its continued operation.

While ZEC's provide a measure of financial stability, persistently low commodity prices will continue to put pressure on the profitability of Exelon's nuclear fleet. In PJM Interconnection's May capacity auction, Exelon's Quad Cities nuclear plant in Illinois failed to clear the market despite being supported by ZEC's. It is projected that Exelon's generation business will produce declining profits over the next few years despite the financial compensation guaranteed by the ZEC's. Projected reductions in capital expenditures on utility operations coupled with solid rate base growth in their regulated business are largely responsible for a forecasted 6%-8% growth in earnings per share through 2020. Annual dividend growth rates of 2.5% are also expected through 2018.

1.3 Market Environment

PBAPS sells electricity into the PJM Interconnection wholesale market. The plant's 2,600MW of capacity has remained profitable despite the challenges facing the competitiveness of nuclear power in the open market. Exelon's commitment to continued operation of the plant is evident in their June 2016 filing for a 20-year operating license extension from the Nuclear Regulatory Commission (Exelon 2016). PBAPS will continue to supply PJM with carbon free capacity which will help meet regional carbon reduction goals. In addition, the plants ability to continue operations during periods of extreme weather and high demand is extremely valuable given the gas supply shortfalls that can arise due to infrastructure constraints. The North American Reliability Council's 2016-2017 Winter Reliability Assessment (NERC 2016) projects the PJM region to have more than adequate reserve margins to meet customer demands. However, projected gas interruptions of up to 4% of installed capacity are possible on extreme cold days or during extended periods of cold weather. PBAPS's nuclear generating capabilities

allow the plant to operate more economically than gas fired generation during extreme weather events by avoiding the need to purchase high cost gas whose price has spiked due to supply constraints. Consequently, PBAPS would be well suited to meet demand during these extreme market conditions and would be highly valued within PJM's least cost dispatch method of transmitting power throughout the region.

PJM's recent market price reform proposal (PJM 2017) will likely reflect favorably on the economic viability of PBAPS. PJM has proposed a method of pricing that will more accurately reflect the marginal cost of serving load and minimize the need to recover costs through ZEC's. The method would compensate for providing reliability services by allowing the marginal cost to be set by the most expensive inflexible unit needed to serve load. PJM estimates an increase in market costs of between 2% and 5% with this pricing model. If this proposal is approved, the plan will likely be submitted to the Federal Energy Regulatory Commission in the fall of 2018 for final approval. This regulatory pricing change will improve the profitability of Exelon's entire nuclear fleet and would improve the economics of the individual plants along with the financial health of the entire company.

1.4 Social Costs of Compliance

The first step in estimating the social costs of compliance is to determine whether the entrainment reducing technology costs result in the plant becoming uneconomic to operate. A pre-mature shutdown of the plant would have social costs related to loss of jobs, loss of income and expenditures, loss of tax base, increased electricity costs due to generation being dispatched at a higher price from less efficient plants, and increased infrastructure costs to maintain grid reliability. Installing entrainment reducing technologies at PBAPS to comply with EPA's 316(b) Final Rule represents an additional financial challenge to Exelon and the profitability of its generating plants. The economics of operating the plant will likely be re-evaluated with this regulatory requirement. Fifteen plants in Exelon's generating portfolio operate with once-through cooling and are subject to the requirements of the Rule (US SEC 2016). It is likely that Exelon will re-evaluate the economics of their entire generating fleet with respect to potential market and regulatory impacts. The fact that PBAPS remains profitable, has a competitive advantage over gas fired plants during periods of extreme weather and associated gas supply constraints, and has recently applied for a 20-year operating license renewal suggests that only an extraordinarily expensive conversion requirement would lead to pre-mature closure. Therefore, this analysis assumes Exelon will incur the entrainment reducing compliance costs and continue to operate the PBAPS plant.

The social costs of installing entrainment reduction technologies are estimated by first determining the design, construction, and installation costs of the evaluated technologies along with the O&M, permitting, and fuel costs. This analysis assumes that all compliance costs at PBAPS would be passed on to Exelon shareholders in the form of lower returns. Table 2 summarizes the results of this evaluation and its implication for social costs.

Following the requirements of the rule, Table 2 evaluates social costs under two discount rates: 3 and 7 percent (79 Fed. Reg. 158, p. 48428). As the first column of Table 2 shows, the top half of the table presents the present value of social costs discounted at 3 percent, and the bottom half presents the social costs discounted at 7 percent. The next column of the table presents each of the feasible technologies evaluated at PBAPS. The third and fourth columns present the engineering costs estimated for each feasible technology. The third column presents the estimated design, construction, and installation costs, and the fourth column presents the annual operation and maintenance (O&M) costs for each feasible technology.

The remaining columns in the table present the individual categories of social costs developed for this analysis: shareholder dividend decreases, fuel costs, externality costs, and permitting costs. The analysis discounts the future stream of each of these social costs at the relevant discount rate and sums them over the years they are specified to occur to develop the Total Social Cost estimate presented in the penultimate column. The table concludes by presenting the Annual Social Cost estimate for each technology. The annual estimate divides the Total Social Cost by the number of years the analysis is conducted over.

Engineering costs are specified as occurring over a thirty-year time period for cooling towers and wedgewire screens and twenty years for fine mesh traveling screens. This follows the timing AECOM developed for each technology (AECOM 2017). Fuel costs are specified to occur during construction, based on outage impacts, and during operation, based on efficiency and auxiliary load impacts. NPDES renewal occurs in 2019. Eight years are required to complete studies and evaluations, and to design, permit, and construct the technologies. Maintenance and power systems costs begin in 2026. The technology life is 30 years for closed cycle cooling and wedgewire screens, and twenty years for fine mesh traveling screens. Table 3 reflects the timing specifications for each of the alternatives evaluated.

Table 2
Total Engineering & Social Costs of Feasible Technology Options at PBAPS

		Engineering[a]		Social Costs[b]					
Discount Rate	Technology Type	Total Design, Construction, & Installation Costs	Annual Maintenance Costs	Shareholder Dividend Decrease	Power System Costs[b]	Externality Costs	Regulatory Permitting Costs[c]	Total Present Value of Social Costs	Annual Social Costs
3%	Closed-Cycle Cooling Retrofit "More Difficult"	$1.1B	$3.9M	$691.5M	$1.2B	$6.9M	$0.2M	$1.3B	$44.2M
	Fine-Mesh Traveling Screens	$36.3M	$1.1M	$35.9M	$1.8M	$0.0M	$0.007M	$37.1M	$1.9M
	Cylindrical Wedge Wire Screens	$61.3M	$0.5M	$41.0M	$139.2M	$0.0M	$0.01M	$117.1M	$3.9M
7%	Closed-Cycle Cooling Retrofit "More Difficult"	$1.1B	$3.9M	$348.2M	$1.2B	$6.9M	$0.2M	$667.6M	$22.3M
	Fine-Mesh Traveling Screens	$36.3M	$1.1M	$20.4M	$1.8M	$0.0M	$0.007M	$21.0M	$1.1M
	Cylindrical Wedge Wire Screens	$61.3M	$0.5M	$20.6M	$139.2M	$0.0M	$0.01M	$59.0M	$2.0M

[a] The engineering compliance costs presented in the table are undiscounted and in 2016 dollars.

[B] The social costs associated with each technology are discounted at 3 and 7 percent using specifications outlined in Table 3. Social costs are presented in 2019 dollars for the perspective of the Reviewer, assumed to be reading this report in 2019.

[C] Regulatory permitting costs itemized in the Social Costs sections of the table are Government permitting costs that include the total additional government costs associated with permitting, monitoring, administering, and enforcing the technology selection and installation. Costs are incurred by the government as the permitting and review process is undertaken. These costs are initially borne by the government, but ultimately paid by taxpayers. Permitting costs are developed from EPA's estimates in the national rule (79 Fed. Reg. 158, 48300-48439) and are specified to be 0.02% of direct capital costs. These costs do not include compliance permitting costs that are borne by the Station.

Table 3
Timing Specified for Feasible Technologies at PBAPS

Entrainment Reducing Technology	Regulatory Documents Submitted	Permitting, Design, Construction & Installation	O&M Costs Begin	Years of Operation
Closed-Cycle Cooling Retrofit	2019	2018-2025	2026	30
Fine-Mesh Traveling Screens	2019	2018-2025	2026	20
Cylindrical Wedge Wire Screens	2019	2018-2025	2026	30

As Table 2 shows, the social costs of each technology include the expected decrease in shareholder dividends associated with each technology, the additional, system-level fuel costs that would be incurred with each technology, the externality costs of each technology, and the permitting costs. As previously noted, the analysis specifies that all the engineering costs are passed on to Exelon's shareholders resulting in lower returns which are quantified in this analysis as lower dividends. To develop the decreased dividends, the design, construction, and installation costs are allocated over the specified construction and installation time period presented in Table 3. Operation and maintenance costs are then added for each year the technology is operational, and the future stream of those costs are discounted by 3 and 7 percent to develop the present value estimate for each discount rate.

Fuel costs represent the additional power needed to operate the new technologies and the additional fuel needed from running less efficient units during installation construction outages. The fuel costs are developed from evaluating backpressure and auxiliary load effects, capacity losses from each of the technologies with estimated outage times, and electricity consumption associated with each technology. Details of the fuel cost estimates are presented in Appendix A.

Permitting costs include the total costs associated with permitting, monitoring, administering, and enforcing the technology selection and installation. Costs are incurred by the government as the permitting and review process is undertaken. These vary with the type of technology, as certain technologies require substantially more permitting. Those with more significant environmental effects would have higher permitting costs. These costs are initially borne by the government, but ultimately paid by taxpayers. Permitting costs are developed from EPA's estimates in the national rule (79 Fed. Reg. 158, 48300-48439) and are specified to be 0.02% of direct capital costs.

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Appendix A
Power System and Off-Site Emissions Study for Peach Bottom Atomic Power Station

Power System and Off-Site Emissions Study for Peach Bottom Atomic Power Station

Prepared for:

Exelon

Prepared by:

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January 2019

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Power System Overview

Many important physical and economic effects of reducing entrainment are transmitted through the power system. These arise from outages for technology installation, electricity consumption, and cooling water temperature related unit-efficiency changes.

Outages

Extended outage times during technology installation are effectively temporary capacity reductions. As depicted in Figure 1, these construction outages lead to system level efficiency and capacity changes. Significant capacity reductions can affect system reliability which can have social costs. Reliability effects are to be evaluated under (r)(12) (12)(v)—Facility Reliability and are a factor that Directors may consider under § 125.98(f)(3)(iv) (May Factor 4—Reliability Impacts). These are unlikely with planned outages but offset costs may be identified if extended outages for multiple units were anticipated. These are not evaluated in this study.

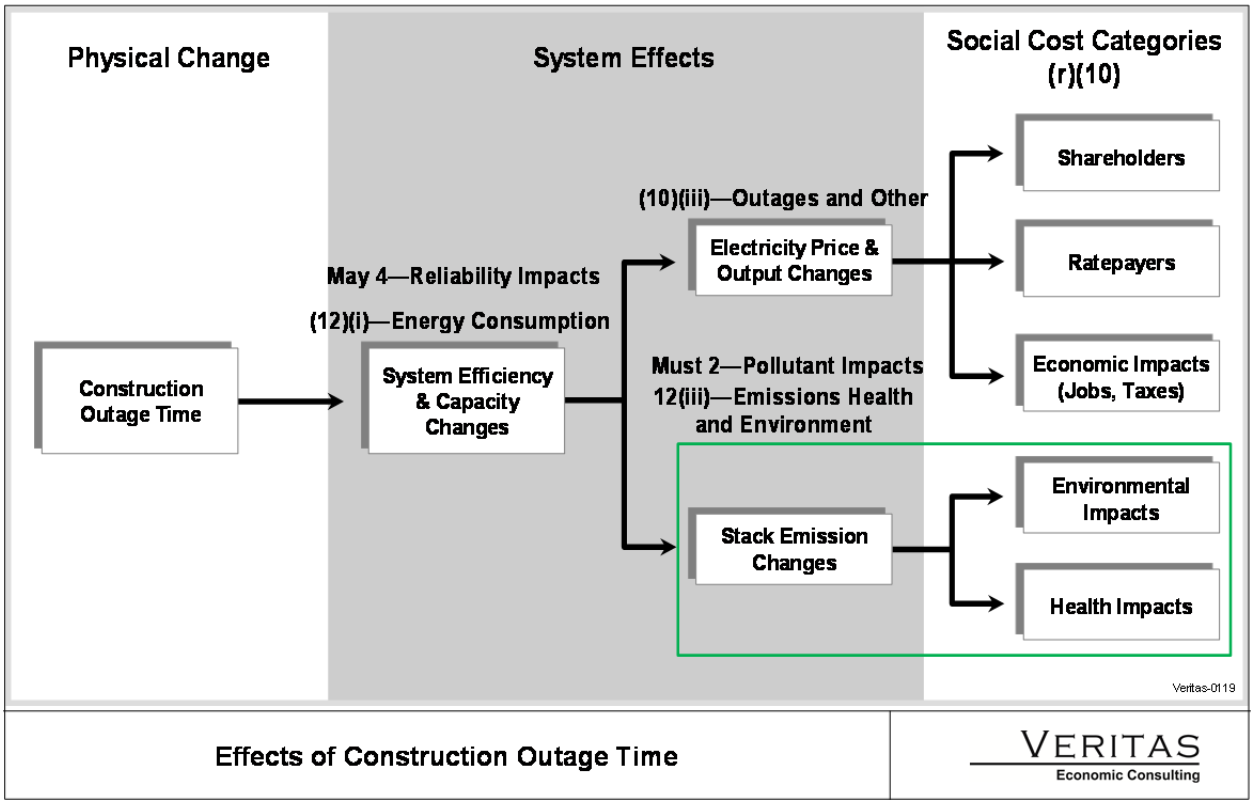

Figure 1: Effects of Construction Outage Time

Outages always lead to a less-efficient dispatch. These lead to changes in energy consumption that are to be assessed under (r)(12) (12)(i)—Energy Consumption. These will impact electricity costs and outputs leading to social costs that must be quantified in (r)(10)(iii)—

Outages Other. Also, the re-dispatch associated with the system-level efficiency changes lead to stack emission changes which are to be studied under (r)(12) (12)(ii)—Emissions Health and Environment. Moreover, these are a factor that Directors are required to consider § 125.98(f)(2)(ii) (Must 2—Pollutant Impacts), and they can have important social costs.

Outages for equipment installation occur as facilities must not be drawing water for certain operations such as connecting cooling towers. When these occur during a time period that is not already scheduled as an outage, opportunity costs result. Outages could potentially be required for any technology but are most significant with cooling towers. The effects depicted in Figure 1 would accompany this outage. These result in system level social costs both in the costs of meeting load and through off-site emissions.

The effect of an outage for equipment installation is evaluated by modeling the outage within the context of the relevant power and economic systems. This is accomplished by developing a counterfactual "With-Construction-Outage" specification in which the capacity at Exelon's Peach Bottom Atomic Power Station (PBAPS) is reduced to zero because the facility is required to have an outage to retrofit with an entrainment reduction technology.

Backpressure and Equipment Load

Certain other effects become important once entrainment reduction is underway. These can occur with most approaches but are typically more pronounced with cooling towers. As depicted in the figure below, when operated, cooling towers require electricity to operate. This leads to net electrical generation efficiency/capacity effects and increases in decibel levels (primarily from operating fans). These effects result in energy consumption that must be identified under (r)(12) (12)(i)—Energy Consumption. As with outages, these energy consumption changes have social costs and lead to stack emission changes. The Rule requires a "detailed" and peer-reviewable assessment of related effects under (r)(12) (12)(i)—Energy Consumption, (12)(ii)—Emissions Health and Environment—and these are a factor Directors must consider (Must 2—Pollutant Impacts). Moreover, there is significant discussion in the preamble indicating the importance of related effects.[1,2,3,4]

[1] "… the social cost of the energy penalty is the cost of generating the electricity that would otherwise be available for consumption except for the energy penalty. Again, an assessment of these costs would be determined under the §122.21(r)(10) demonstration" (79 *Fed. Reg*. 158, p. 48370).

[2] "EPA's review of emissions data … suggests that impacts from these pollutant discharges could be significant. These include the human health and welfare and global climate change effects—all associated with a variety of pollutants that are emitted from fossil fuel combustion" (79 *Fed. Reg*. 158, p. 48341).

[3] "While both of these factors contribute to increased air emissions, the larger contributor to projected increased air emissions is by far the energy penalty" (79 *Fed. Reg*. 158, p. 48341).

[4] "EPA is not able to quantify the frequency with which facilities could experience these local impacts, and therefore has concluded that the proper forum to address such local impacts fully is in a site-specific setting" (79 *Fed. Reg*. 158, p. 48342).

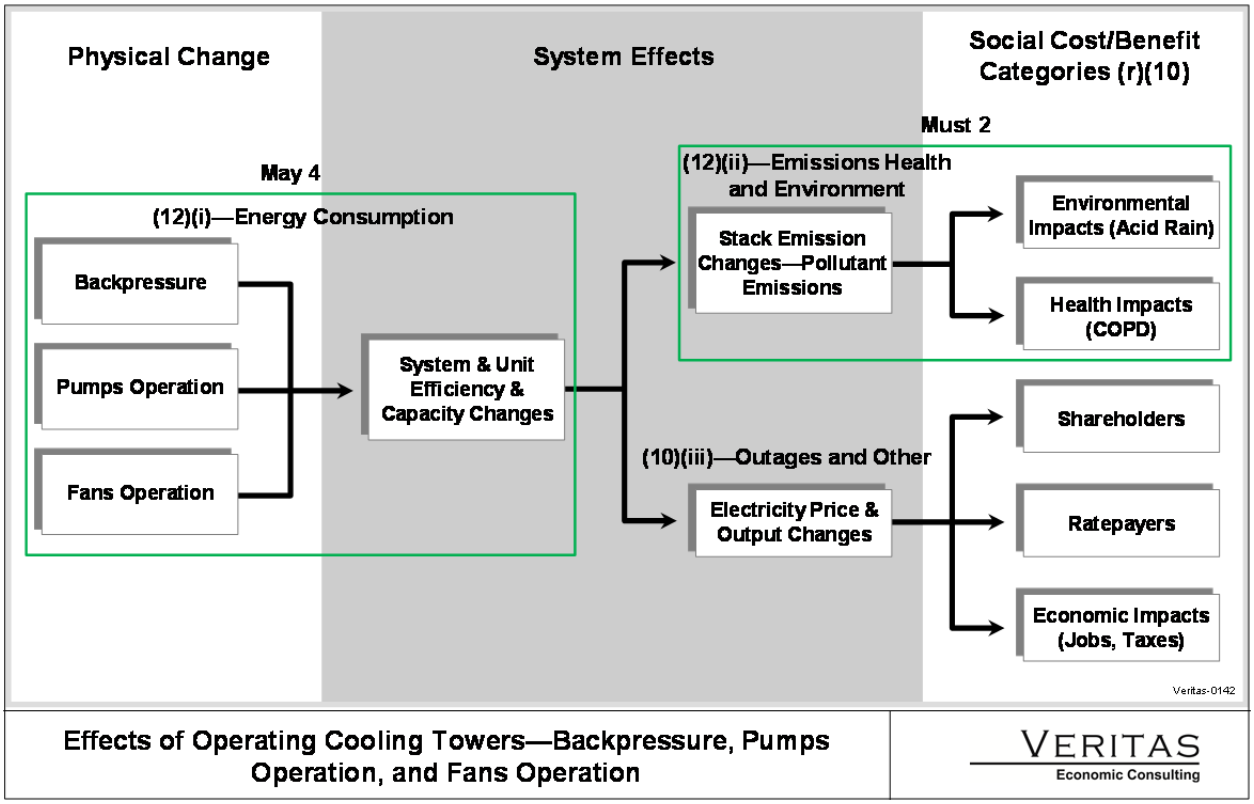

Figure 2: Effects of Operating Cooling Towers—Backpressure, Pumps Operation, and Fans Operation

Power System

The outage and operational implications described previously are initial physical effects. These costs would be reflected in the power system as social costs. Understanding how these physical effects would ultimately be reflected as social costs requires considering the relevant power system.

PBAPS's physical location, grid connections and history provide insight into the power system implications of reductions in output from PBAPS. PBAPS is located just above the Delmarva peninsula. Historically PBAPS was a part of the integrated generation, transmission, and distribution Philadelphia Electric Company (PECO). PBAPS's organizational connection to PECO has changed with Exelon's purchase of PECO and electricity market deregulation. PBAPS is currently owned by Exelon Generation but is still connected to PECO via the 500 KV line that connects through the Limerick Nuclear Station system bus.

Exelon Generation is one of the largest competitive electric generation companies in the United States. It sells power in multiple geographic regions to distribution utilities; municipalities; cooperatives; and commercial, industrial, governmental, and residential

customers in competitive markets. Exelon Generation maximizes its profits independently from PECO, which is rate-of-return regulated. The implication is that as Exelon Generation markets and sells electricity from PBAPS, it does so within the broadest marketplace that it can feasibly reach.

This marketplace is much larger than PECO. Figure 3 depicts the Load Zones within the Mid-Atlantic Market Region of PJM that PBAPS is connected to. PBAPS can easily provide power for Delmarva Power & Light Company (DPL) via the 500kv line that connects PBAPS to the DPL owned Keeney substation. Keeney and the nearby Red Lion substation connect to regions throughout the PJM mid-Atlantic regions including Baltimore Gas and Electric Company, Pepco Holdings LLC, Potomac Electric Power Company, and Atlantic City Electric Company. PBAPS's connection to these PJM Load Zones indicates that the power market that would be most affected by outages and efficiency changes at PBAPS is the PJM Mid-Atlantic region.

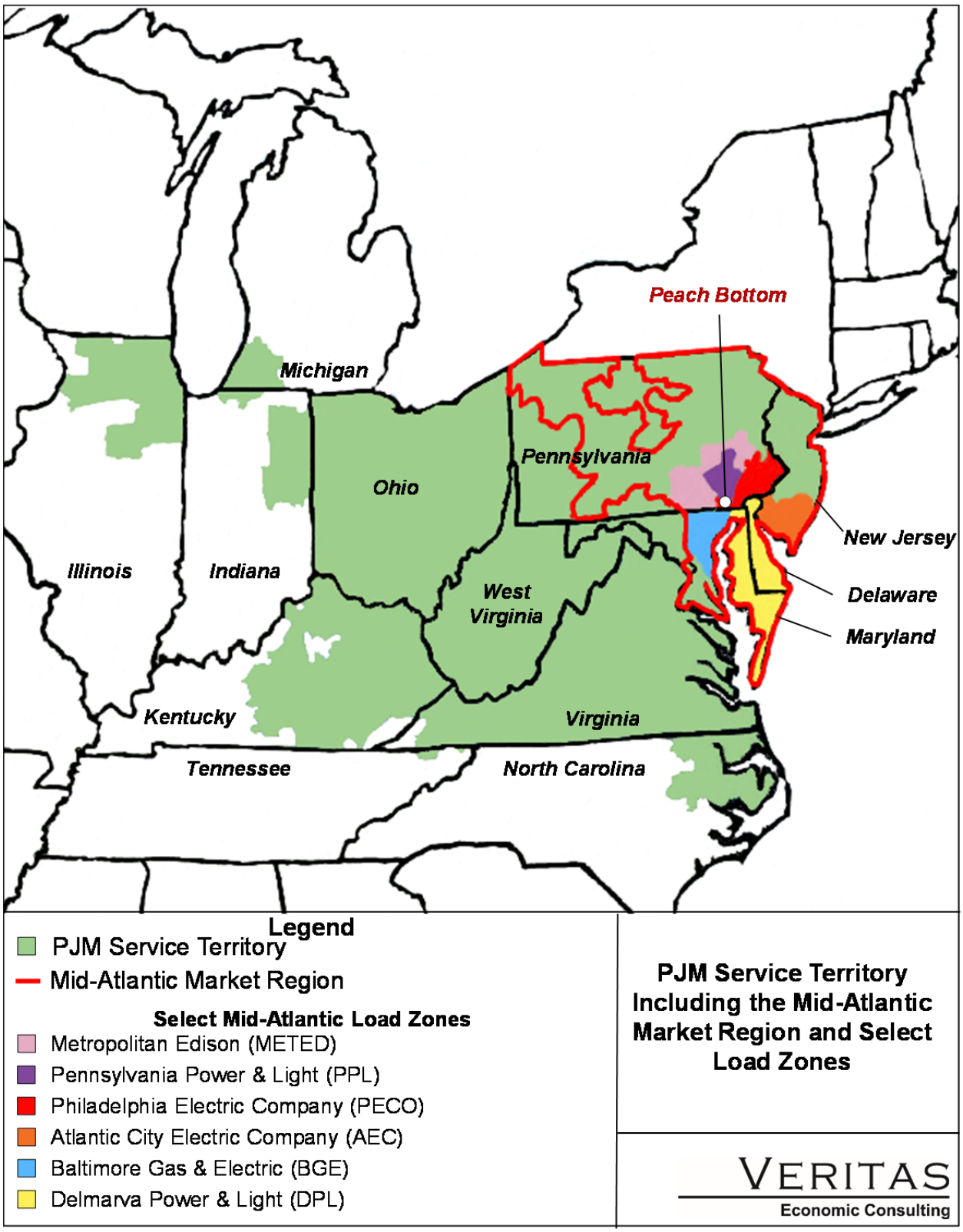

Figure 3: PBAPS in Relation to PJM mid-Atlantic Region

Figures 4 and 5 depict the power system effects that are expected to occur in the PJM Mid-Atlantic Market Region with conversion outages and efficiency changes at PBAPS. In these figures, the vertical bars represent generating units. Their height is their marginal cost and width represents capacity. The figures represent an individual hour out of the 8,760 hours in a year. System electrical load for that hour is represented by the green line.

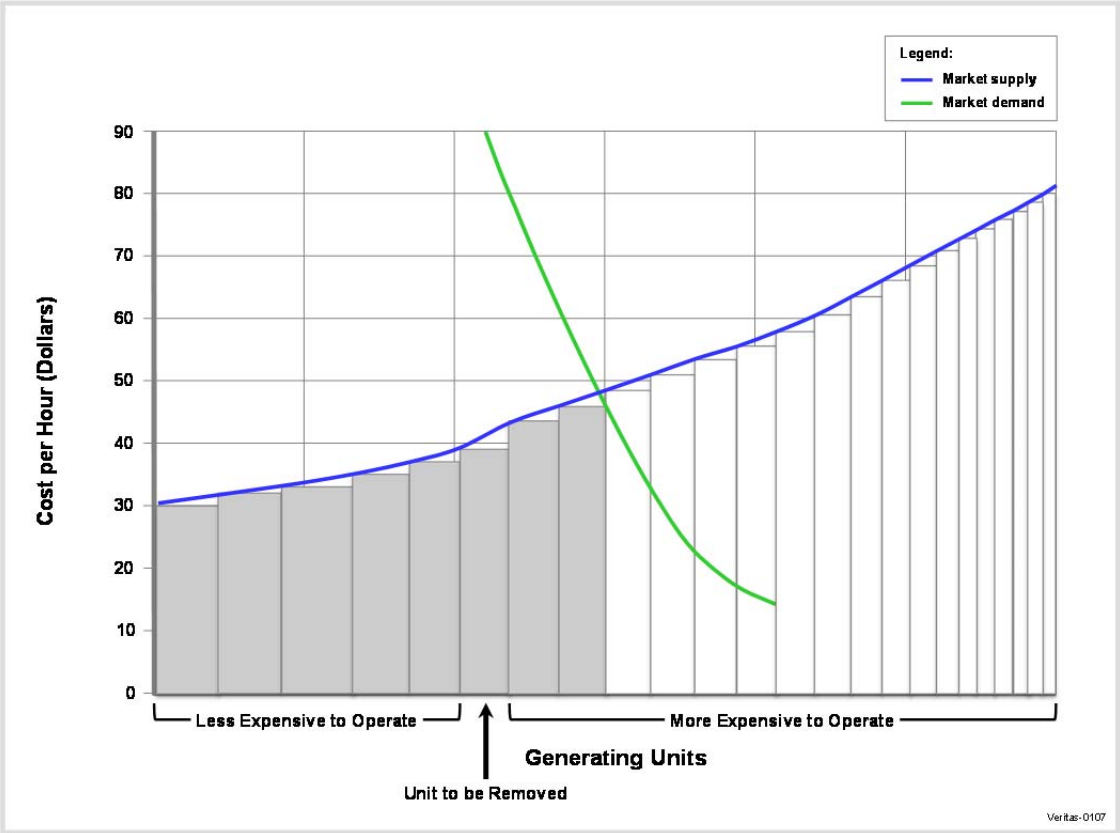

Figure 4: Electricity Market Under Baseline Conditions

Figure 4 represents market outcomes under Baseline conditions for a single hour. The market clearing price is where load intersects the dispatch order (slightly below $50 per MWh in this illustration). The dispatched units (in grey) all produce electricity at this price or less. The units that are not dispatched (in white) are all more expensive to operate than the prevailing electricity price. The total cost of meeting load is represented by the area of the shaded units.

An operating unit (or equivalently an amount of generating capacity) that is to be taken off-line for an entrainment technology retrofit is identified in Figure 4 as “Unit to be Removed.” Figure 5 depicts the power system outcomes when this previously operating capacity is no longer available.

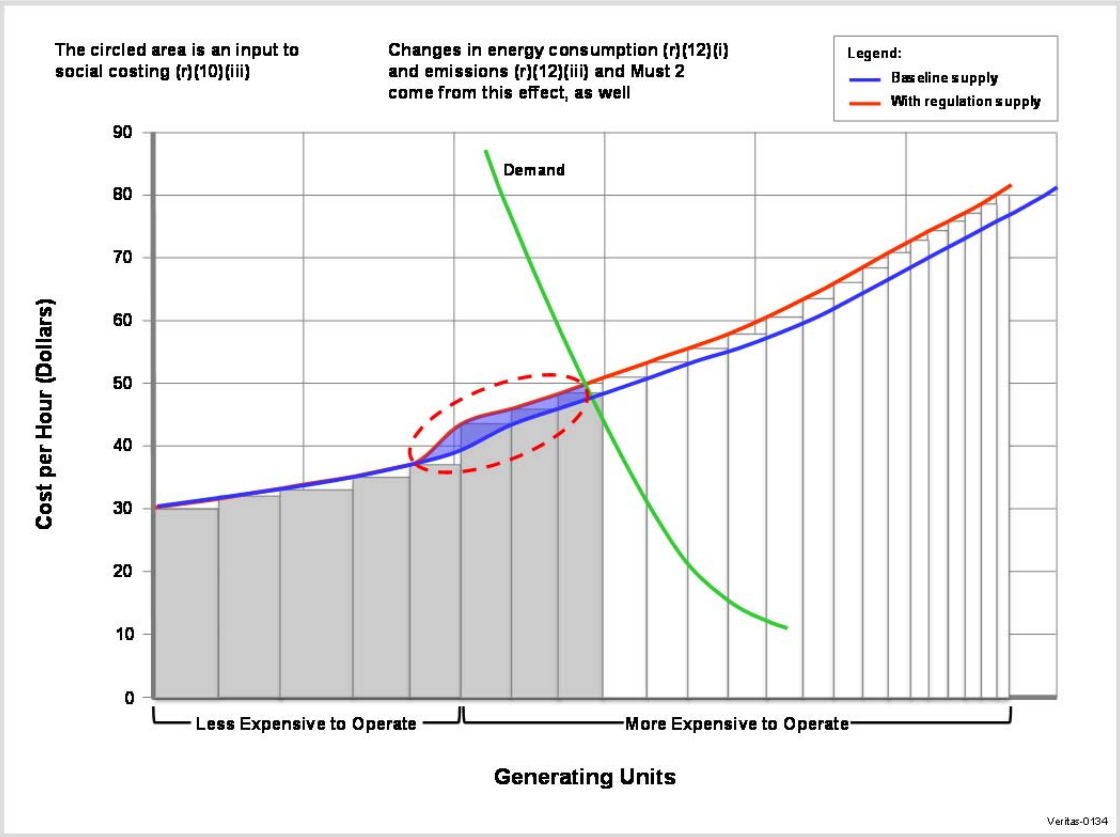

Figure 5: Electricity Market Under With-Regulation Conditions that Reduce Capacity

When a previously operating generation capacity is removed from the stack, previously more expensive units "shift" to the left. Additional capacity must operate to meet the existing load (which is fixed in this one-hour example). During other time periods (not pictured), load moves in and out. Power is more expensive to generate at all load levels above the generation cost of the previously operating unit (slightly under $40 in Figure 5). Additional outcomes include changes in fuel consumption and emissions as different units operate.

These changes in costs are social costs. However, because they occur in the context of price effects in competitive markets, this means there are financial transfers that make it difficult to identify who bears the social costs. Specifically, the figure above also indicates that with lost output from PBAPS (from both conversion outages and capacity losses) there would be an increase in the average electricity price in the PJM Mid-Atlantic Market Region. Knowing that PBAPS has to incur a conversion outage and will incur capacity losses, organizations selling into the PJM Mid-Atlantic Market Region can expect to receive higher prices for their electricity, and entities purchasing electricity from competitive markets within the Mid-Atlantic Market Region could experience higher wholesale electricity prices.

The implications of these price changes vary by organizations. Distribution utilities, municipalities, and cooperatives would endeavor to recover costs through rate increases. Commercial and industrial purchasers would experience reduced profitability. Governmental cost increases would ultimately be passed on to taxpayers.

Power flow modeling has not been conducted for this evaluation. However, PBAPS's close connection to the congested Delmarva peninsula via the Keeney and Red Lion substations suggests the largest potential for locational price changes are at those nodes. DPL is expected to be taking the largest deliveries there. Price effects to DPL would occur in the context of competitive bidding.

The costs associated with new entrainment reduction technologies would be additional costs that could potentially lead to another rate increase filing which would result in higher prices for residential, commercial, and industrial customers. The magnitude of these additional increases could also lead to economic impacts that can accompany electricity price increases (Deschenes 2010). Changes in electricity prices can lead to economy-wide employment impacts through their effect on residential and business electricity consumers. For business electricity impacts, the commercial and industrial sectors are all major users of electricity as an input to production. Electricity price increases would raise the costs of providing final goods and services in these sectors.

Market Environment

Changes in PBAPS's power delivery would be reflected in some of these customers. Details of PBAPS's financial connections to ultimate customers are not public information.

Power System Simulation

The effects of outages for equipment installation, auxiliary loads and unit closures are evaluated by modeling them within the context of the PJM Mid-Atlantic power system. This is accomplished by developing counterfactual specifications that include construction outages and auxiliary load.

In the modeling context, the capacity at Units 2 and 3 are set at zero over the specified outage period during the conversion year. In both years, capacities are adjusted to reflect auxiliary loads occurring after the modeled conversions. With capacity adjusted in this manner, a power system simulation model (Environmental Policy Simulation Model [EPSM]) is operated and differences in operations across Baseline and With Outage conditions are evaluated (Veritas Economics 2011).

The conceptual process described previously is implemented for PBAPS by carrying out the following specific steps:

1. Specify baseline hourly output for PBAPS and operate model to meet load.
2. Specify counterfactual hourly output for PBAPS.
3. Operate model to meet hourly load at minimum cost under counterfactual conditions.
4. Calculate differences in costs.

These steps are implemented as follows.

Specify Baseline Hourly Output for PBAPS Units and Operate Model

Because electricity production costs vary hourly and because important cooling tower effects are hourly, it is useful to model power system effects at the hourly level. For nuclear plants, energy input is relatively constant whereas output varies with water temperature. Water temperature to output relationships for nuclear plants like PBAPS can be characterized by 2nd degree polynomials such as the following equation that relates water temperatures to output.

$$MW = -.0485*temp^2 + 3.0401*temp + 1260 \quad \textbf{(1)}$$

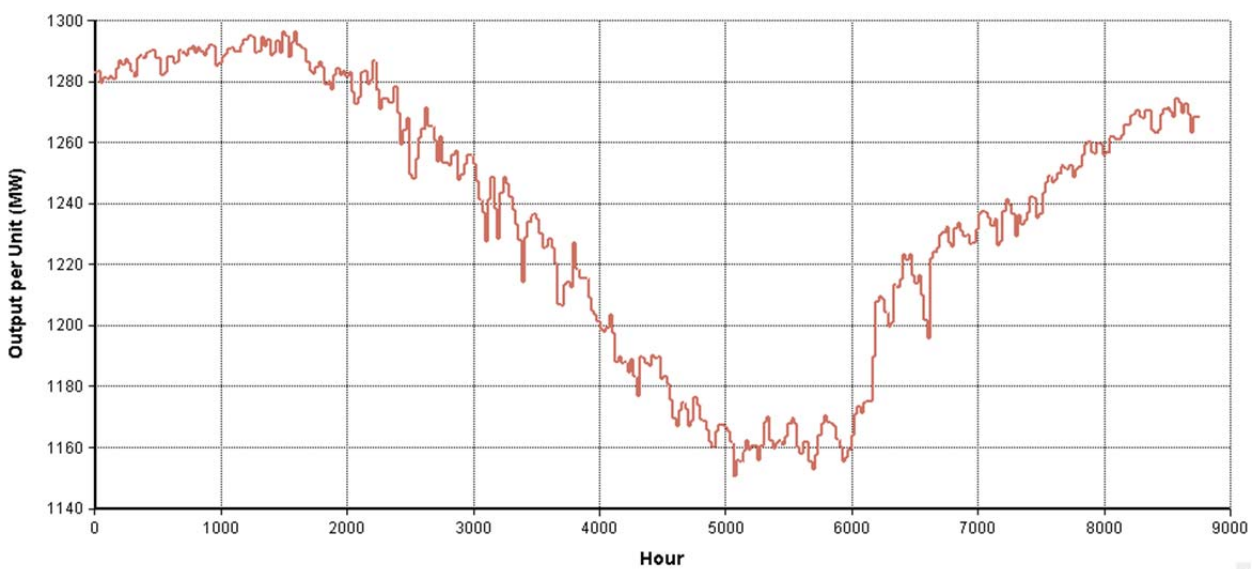

Figure 6: PBAPS Specified Hourly Maximum Generation

To create the baseline model, the output of Figure 6 is specified for both PBAPS units. Hourly load is specified and the minimum cost dispatch model is operated. The simulated dispatch meets load at least cost as shown in Figure 4, except that the figure depicts a single hour out of the 8,760 hours represented in EPSM.

Create Counterfactual PBAPS Capacities

Counterfactual output schedules that arise from least cost dispatch under counterfactual capacities are used to identify the difference between output under Baseline conditions and with cooling towers. Counterfactual net capacities for PBAPS are created for the conversion year and post-conversion "ongoing" years. The conversion year effect for each unit is depicted below.

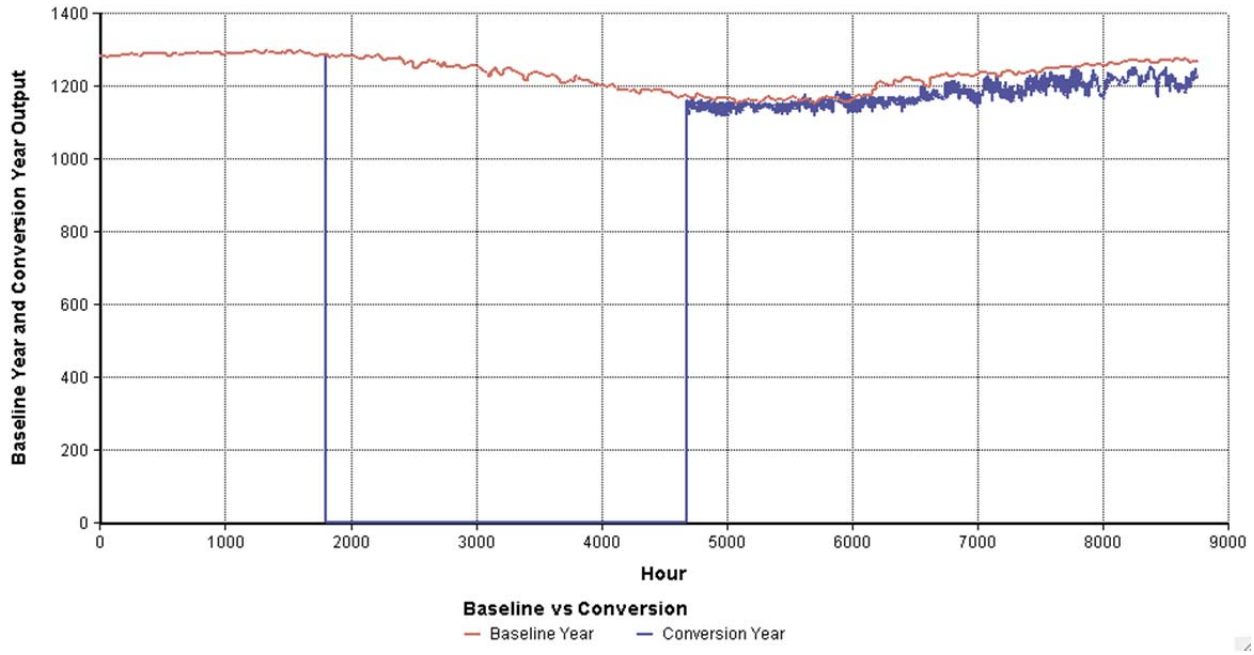

Figure 9: PBAPS Per Unit Output Baseline and Conversion Year

In the conversion year output is identical to the baseline year until the outage occurs. For the conceptual level engineering design a precise outage time was not identified. As described in the engineering evaluation, the average outage time for nuclear plants has been identified as 6 months with a range of 4-22 months.

Based on the low end of this range the outage is specified to take place for 120 days starting in mid-March. It starts in hour 1800 and ends 120 days later at hour 4,680. Post outage the units restart with cooling towers operating. At this point, increased load from pumps and backpressure effects occur as they do for an ongoing year.

The ongoing year effect occurs over all hours and includes pump load and backpressure effects. It is depicted below.

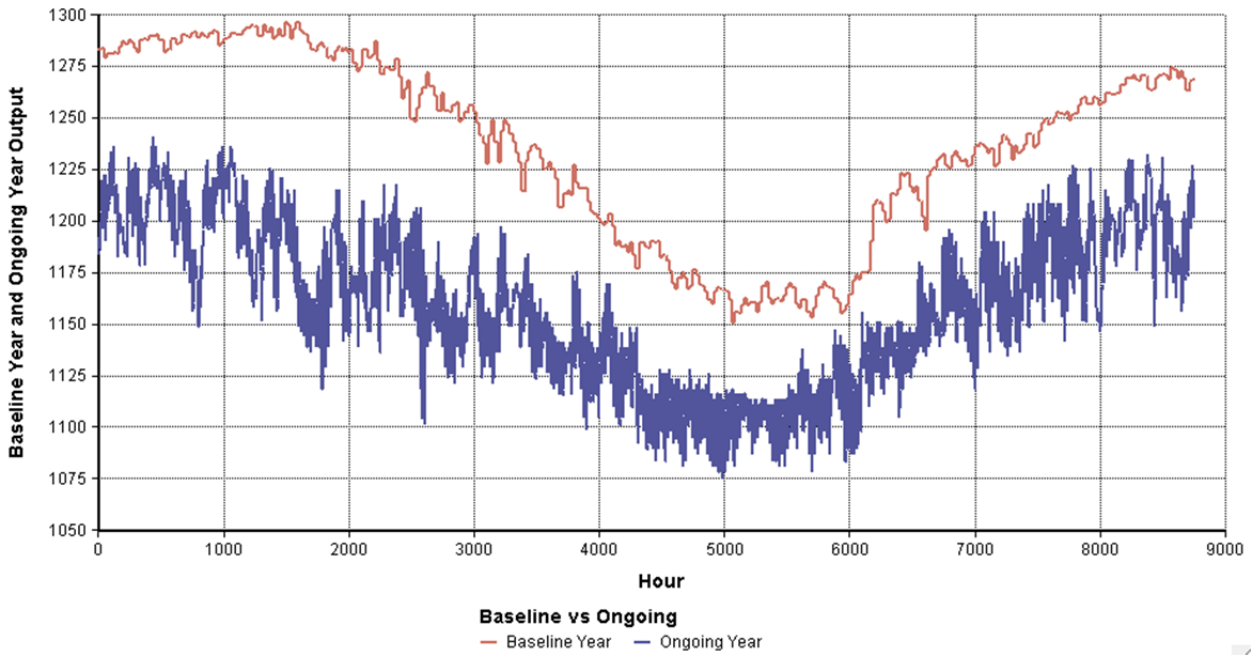

Figure 9: PBAPS Per Unit Output Baseline and Ongoing Year

This effect includes both backpressure and auxiliary load. The backpressure effect is an hourly extension of the engineering evaluation. Hourly wet bulb temperatures were converted to cooling water temperatures based on the engineering design specified cooling tower approach temperature of 10 degrees F and ambient wet bulb temperature of 77 degrees. Cooling temperature to output effects are modeled equivalent to baseline using Equation 1. This approach results in average hourly effects of 2.7 percent which aligns with EPA's Technical Development Document for the Final Section 316(b) Existing Facilities Rule, EPA-821-R-14-002, (EPA 2014), which estimates that retrofitting a closed-cycle cooling system with wet cooling towers results in an estimated 2.5 percent reduction in output at full capacity.

The engineering evaluation indicates that the total pumping power for the closed-cycle recirculating system retrofit is approximately 18.8 MW. Under baseline conditions helper towers operate for a two-and-one-half month period during which incremental increased pumping power is limited to approximately 7.9 MW. In the hourly specification pump load is specified to be 18.8 MW except during the hours between 4300 and 6100 where it is set to be 7.9 MW.

The total fan power for the closed-cycle recirculating system retrofit is about 20.8 MW. During the two-and-one-half month period incremental increased fan power is limited to approximately 13.9 MW. In the hourly specification fan load is specified to be 20.8 MW except during the hours between 4300 and 6100 where it is set to be 13.9 MW.

Run Simulations to Create Counterfactual Dispatch

With capacities from PBAPS specified as described, EPSM is operated to identify the counterfactual outcomes. Counterfactual output schedules are created by setting appropriate capacity limitations and running a linear programming based least cost dispatch in EPSM.[5] Under these counterfactual outcomes, more expensive units are dispatched to make up for lost generation from PBAPS.

The figure below portrays the net increases in hourly costs that occur in the conversion year.

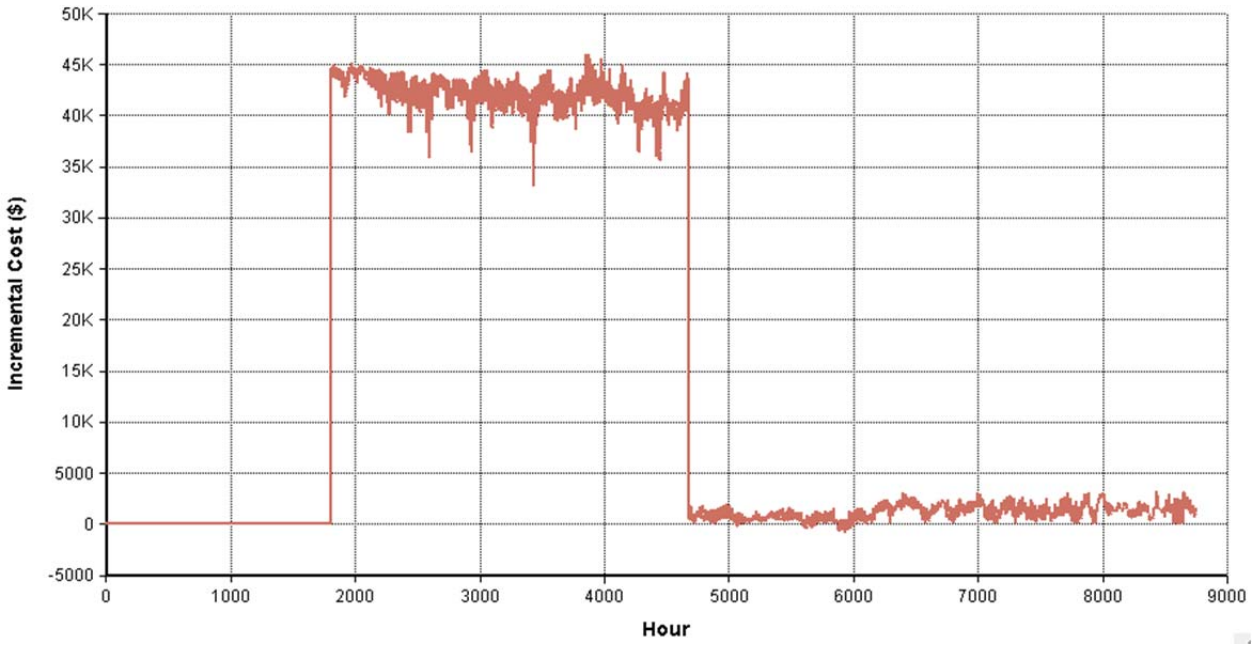

Figure 10: Conversion Year Change in Hourly Cost

Prior to the outage there is no net cost as there is no difference in operations. At hour 1800 the conversion outage begins and costs go to over $45K per hour as more expensive units make up for PBAPS being offline. At hour 4680 PBAPS comes online. Costs drop but generally remain in the low thousands of dollars per hour. The total incremental cost for the conversion year is $126.9M.

The figure below portrays the net increases in hourly costs that occur in post-conversion "on-going" years.

[5] Optimization is conducted using Analytica Optimizer and Premium Solver Platform licensed by Frontline Systems, Inc.

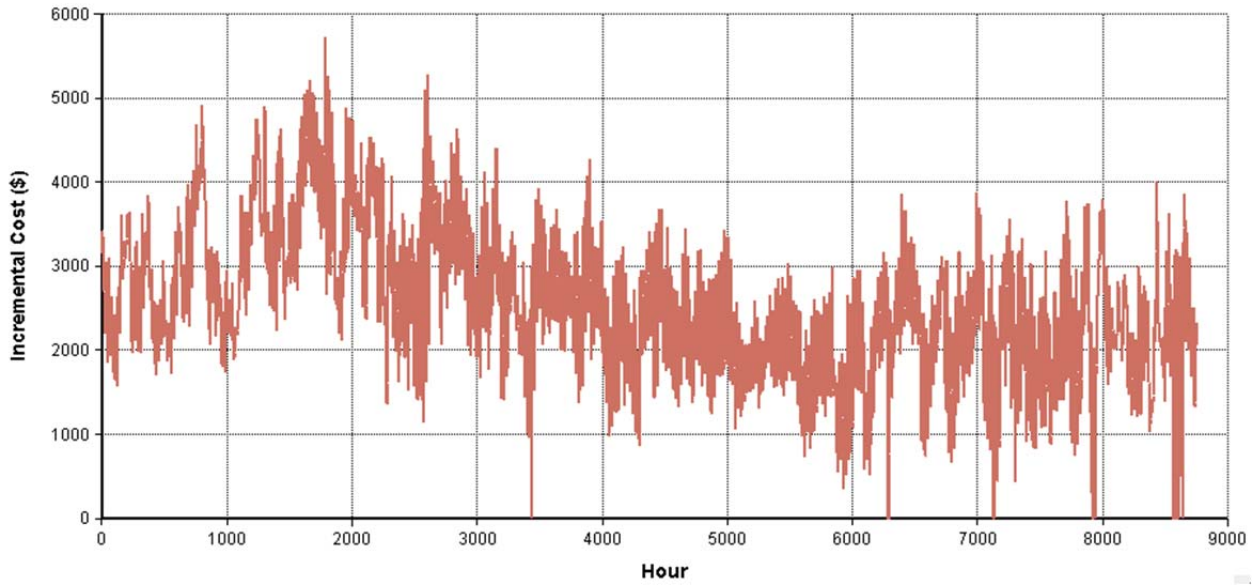

Figure 10: Ongoing Year Change in Hourly Cost

As the figure depicts, net system costs range from nearly $6K in cost per hour to $0 per hour. For the year, costs average $4,035 per hour. The annual total for ongoing years is $35.34M.

Screen Based Power System Costs

Screening technologies evaluated include wedgewire screens and fine mesh traveling screens. Wedgewire screens are expected to have a four-month outage. No outage was identified for traveling screens. Wedgewire screens consume 1,053 MWh annually (0.12 MW per hour) and traveling screens consume 9,804 MWh annually (1.12 MW per hour).

Using the approach applied for cooling towers, outage costs for wedgewire screens are estimated to be $122.20M. Ongoing costs for wedgewire screens are estimated to be $62.66K per year and ongoing costs for fine mesh traveling screens are estimated to be $584.80K.

3. References

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Appendix B
Study of Recreation Effects for Peach Bottom Atomic Power Station

Recreation Effects from a Closed Cycle Cooling Conversion:

Peach Bottom Atomic Power Station

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Recreation Effects

The Peach Bottom Atomic Power Station (Peach Bottom or PBAPS) is located on the west bank of the Conowingo Reservoir on the Susquehanna River in Delta, Pennsylvania. The plant consists of three units: Unit 1 was built in 1967 and ceased operations in 1974; Units 2 and 3 were built in 1974 and continue to operate today. Each of the two operating units have a capacity of 1,300MW for a total plant capacity of 2,600MW. This report assesses changes in recreation values attributable to a closed-cycle cooling conversion at PBAPS. The focus of this analysis is cooling tower effects from cooling tower plumes. Figure 1 below depicts the location of PBAPS and surrounding recreation areas. Nearby recreation areas include Susquehannock State Park, Dorsey Park, Peach Bottom Marina, and the Line Bridge Access.

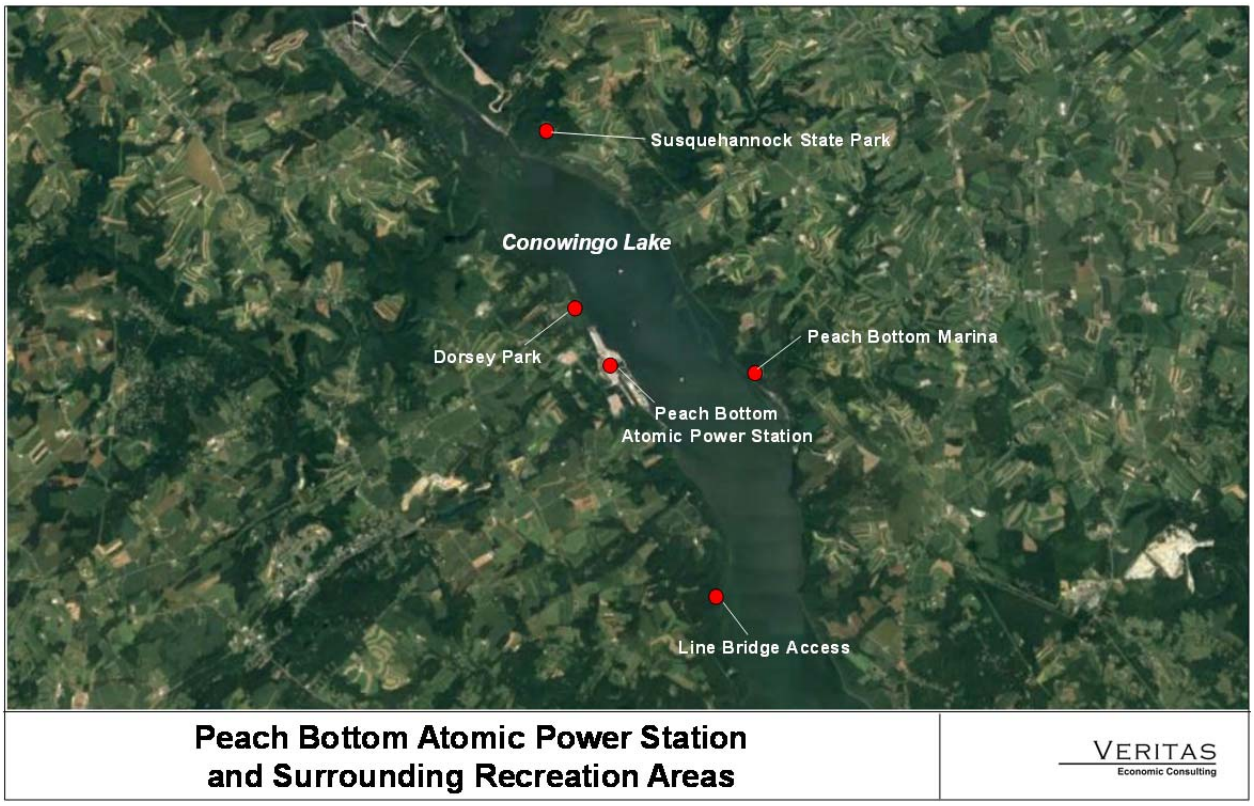

Figure 1: Aerial View of Peach Bottom Atomic Power Station and Nearby Recreation Areas

Nature of the Issue and Identifying Possible Effects

Evaluated entrainment reduction technologies include closed-cycle cooling, fine-mesh traveling screens, and wedgewire screens. Of these, mechanical draft cooling towers are expected to have the most recreational value impacts. Physical effects from the other two evaluated technologies are limited and not expected to impact recreation values. Recreational

value effects are expected to be most pronounced when physical effects from cooling towers impact the quality of visits to recreational sites. The primary pathways for this include change in viewshed and noise levels. These linkages and related studies required for 316(b) permitting are depicted in Figure 2 below.

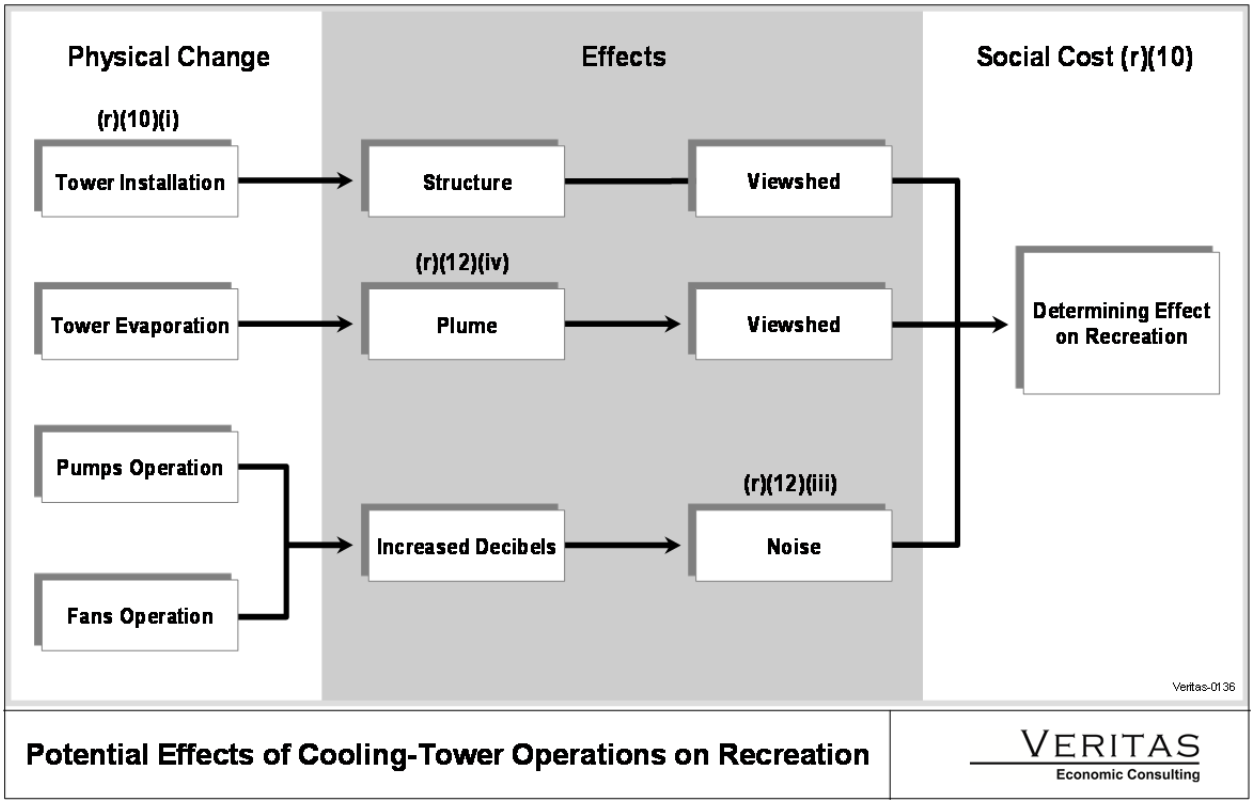

Figure 2: Potential Effects of Cooling-Tower Operations on Recreation

The view from a recreational site could be impacted by the profile of a cooling tower and by the presence of a visible plume. Noise levels at a recreational site could be impacted by the operation of cooling tower pumps and fans. As depicted in Figure 2, cooling tower noise and plume are studied under §122.21(r)(12) (iii) and (iv) and the dimensions of cooling towers will be determined from the cost and feasibility studies that are conducted under §122.21(r)(10)(i).

Approach and Available Information

The effects of cooling tower plumes and noise on recreational trips have not been the subject of primary studies. The most comprehensive work in this area was conducted by the Electric Power Research Institute (EPRI) (2011) which studied viewshed deterioration and noise as quality-of-life issues associated with cooling towers. EPRI (2011) evaluated willingness to pay (WTP) to avoid possible impacts to non-local users of recreational areas based on

"incremental changes to consumer surplus associated with varying site attributes." Proceeding similarly, this study evaluates recreational trip value losses using the following five steps:

1. Identify relevant cooling tower options
2. Identify differences in viewshed between Baseline and With-Cooling-Tower conditions.
3. Identify the number and value of recreational trips that could have viewshed effects.
4. Where meaningful changes in viewshed are expected to occur to recreational sites, characterize them and identify changes in value.

Relevant Cooling Tower Options

Closed-cycle cooling tower options for PBAPS were evaluated by AECOM (2017). The feasible cooling tower option being considered for PBAPS is the all-wet closed-cycle recirculating system with a mechanical-draft cooling tower.

Viewshed Effects

Various factors can alter a viewshed, including topography, distance to objects, haze, humidity, background landscape, atmospheric conditions, and weather (Development Partners Funding I, LLC 2013). The tower option under consideration could impact the viewshed through presence of a plume.

The profile of a tower is simply the physical space the equipment occupies in a viewshed. Mechanical draft towers are relatively low profile. The height of the towers at PBAPS is proposed to be 50 feet (AECOM 2017). The mechanical draft towers would generate a visible plume.

A visible plume from a cooling tower is composed of water vapor and a small amount of water droplets. Viewshed effects of a visible plume would apply over a much larger distance than would noise effects and tower height and plume height are important factors in determining this distance. Several studies have modeled viewshed effects using these factors:

- Saratoga Associates (2009) used a 10-mile distance for modeling viewshed effects of plumes rising 1,200 feet above a cooling tower.
- Niagara Mohawk Power Corporation et al. (1984) considered a 10-mile viewshed to be appropriate for estimating visibility of plumes rising from a 536-foot natural draft cooling tower.
- Development Partners Funding I, LLC (2013) estimated that plumes from a proposed facility with mechanical draft cooling towers would potentially be visible in a community 7.2 miles from the site.

- Tronaas (2002) estimated that a residential population had a moderate view of 470-foot-high plumes from mechanical draft cooling towers 4 miles away.
- EPRI (2011) cited a 6-mile distance for viewshed effects.

EPRI (2011) used the Seasonal Annual Cooling Tower Impact (SACTI) model to estimate the potential for fogging, icing, and shadowing impacts from cooling towers. EPRI (2011) included illustrations and summaries of plume fogging impacts for several representative facilities. Summaries for some facilities focused on a 1.2-mile distance used in calculating viewshed effects from cooling towers, and others cited a 6-mile distance for those effects.

Recreational Value at Risk

The plumes generated by the cooling towers being considered for PBAPS would have a significant impact to the viewshed. The distance from which plumes can be seen depends upon topography and visibility. Application of the Pythagorean Theorem indicates that at sea level an object 500 feet tall could be seen up to 27.4 miles away.[6] As described previously, cooling tower plume viewshed effects have been studied at distances ranging from 4 to 10 miles. This analysis uses the 6-mile distance from EPRI (2011) as this falls within the range of estimated distances.

Table 1 characterizes activities and economic values for nearby recreational areas that could experience degraded viewsheds with a mechanical draft cooling towers at PBAPS. Recreation sites located within six miles of PBAPS are Susquehannock State Park, Dorsey Park, Line Bridge Access, and Peach Bottom Marina. Table 1 includes the number of trips per year taken to each site and the value of each trip. All of these recreation sites produce approximately $1.4 million in recreational value under Baseline conditions.

[6] Based on earth radius of 20.9 million feet $((20.9M + 500)^2 - (20.9M)^2)^{1/2}$ = 144,672ft or 27.4 miles.

Table 1
Recreation Sites within 6 Miles of PBAPS with Potential Viewshed Degradation

Site Name	Activities Available at Site	Recreational Value per Visit	Estimated Annual Attendance	Annual Value at Risk
Dorsey Park	Boat launch, picknicking	$104.26 motorized boating	1,672	$174,344
Line Bridge Access	Carry-in launch access point	$43.32 non-motorized boating	1,115	$48,293
Peach Bottom Marina	Boat launch, vendor-provided boat maintenance, fueling, and docking services	$104.26 motorized boating	2,787	$290,573
Susquehannock State Park	Overlooks, more than 80 picnic tables and 20 grills, hiking trails, overlooks, playground, horseback riding	$37.92 other recreation	24,957	$946,369
Total			30,531	$1,459,579

Sources: Hicks and Hill (2011a); Rosenberger (2016); Support Conowingo Dam (undated); Penn. Dept. of Conservation and Natural Resources (2014).

Changes in Value at Recreation Sites

As Table 1 shows, there are approximately $1.5 million of consumer surplus at risk. However, a plume will not be present every day. Therefore, the analysis has to consider the percentage of days the plume will most likely be in place, how many trips would be affected, how much loss in consumer surplus would occur. Based the results from EPRI (2011), the analysis specifies that a plume would be present approximately 1.25 percent of the time. This is based on using the generic analysis EPRI (2011) conducted using a representative facility in the Northeast that is most comparable to PBAPS and assessed across all wind directions. The visible vapor plume would be directly overhead for a greater percentage of the year in downwind areas. Assuming recreation visits occur proportionally throughout the year, 1.25 percent of the annual recreation trips at these parks could be potentially impacted due to the presence of a plume.

There is a lack of primary studies monetizing cooling tower plume impacts to recreational trip values. EPRI (2011) estimated a 1.8-percent reduction in the value of each recreational visit attributable to the introduction of a plume based on a hedonic study of industrial plume and odor impacts on housing values presented in Anstine (2003). Anstine (2003) studied the impacts of a plume and odor from two manufacturing facilities in Tennessee and found that these two disamenities caused a maximum reduction in home values of 7.32 percent. EPRI (2011) calculated the midpoint of Anstine's (2003) range to be 3.6 percent then

divided it in half to estimate the decreased home value from one disamenity, or 1.8 percent. While Anstine (2003) does not specifically evaluate recreational impacts from a plume, EPRI (2011) applied the 1.8 percent property value decrease to losses in consumer surplus from the effect of a plume on recreational trips.

Table 2 provides preliminary estimates of losses in consumer surplus from plume visibility using EPRI's (2011) 1.8 percent estimate. The present value of recreational losses ranges from $3,795 (7% discount rate) to $8,130 (3% discount rate).[7]

Table 2
Recreational Sites with Potential Viewshed Degradation from a Cooling Tower at PBAPS

					Present Value of Recreational Losses	
Total Annual Trips to Parks within 6 Miles of PBAPS	Percent of Year Plume is Visible	Number of Trips Affected	Decrease in Trip Value with Plume	Total Annual Loss in Consumer Surplus	3% Discount Rate	7% Discount Rate
30,531	1.25%	611	1.8%	$525	$8,130	$3,795

Sources: Hicks and Hill (2011a); Rosenberger (2016); Support Conowingo Dam (undated); Penn. Dept. of Conservation and Natural Resources (2014); EPRI (2011).

[7] Recreation trips that occur when there is no visible plume will not be negatively impacted. The number of hours each day that a plume is visible will vary due to changes in weather conditions and plant operating schedules. For this reason, this estimate can be assumed to be the maximum potential impact.

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Appendix C
Study of Property Value Impacts for Peach Bottom Atomic Power Station

Peach Bottom Atomic Power Station: Study of Property Value Impacts from a Closed Cycle Cooling Conversion

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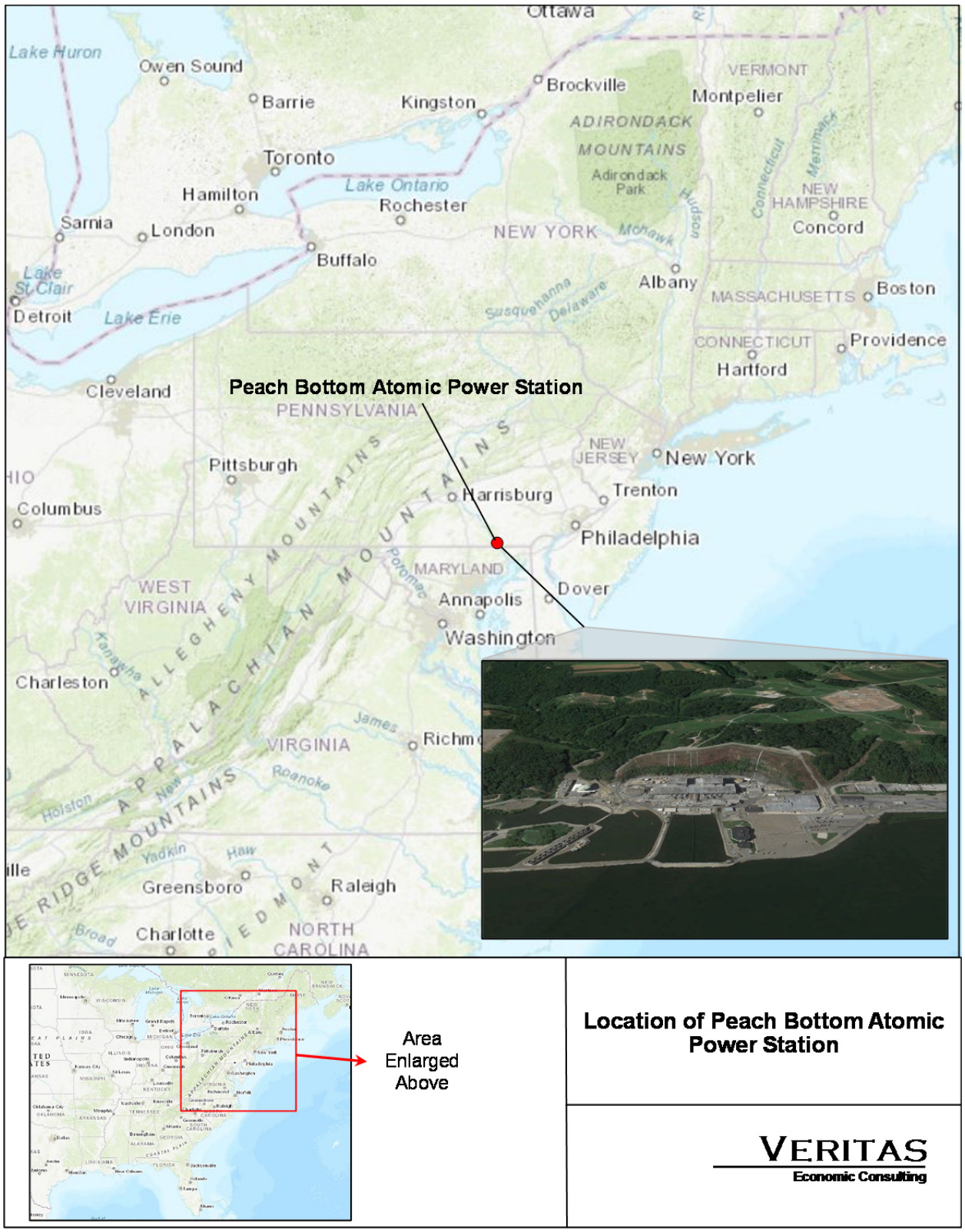
Property Value Effects

The Peach Bottom Atomic Power Station (PBAPS) is located on the west bank of the Conowingo Reservoir on the Susquehanna River in Delta, Pennsylvania. The plant consists of three units: Unit 1 was built in 1967 and ceased operations in 1974; Units 2 and 3 were built in 1974 and continue to operate today. Each of the two operating units have a capacity of 1,300MW for a total plant capacity of 2,600MW. The focus of this analysis is cooling tower effects from tower profile and cooling tower plumes. Figure 1 depicts the generating station and immediate surroundings. This report assesses changes in property values attributable to a closed-cycle cooling conversion at PBAPS focusing on effects from tower profile and cooling tower plumes.

The generating plant is located in a rural farming community approximately 50 miles southeast of Harrisburg, PA and approximately 40 miles northeast of Baltimore, MD. Less than 2,000 people live in the immediate vicinity of the plant.

Significant changes to the site could potentially impact the quality of life on nearby properties and thereby impact the value of those properties. Residential properties are expected to be most impacted (EPRI 2011). Population centers that are close to PBAPS include the Borough of Delta (population about 720), Susquehanna Trails CDP (population about 7,000), and Wakefield CDP (population about 600) (U.S. Census Bureau 2017).



Area Enlarged Above

Location of Peach Bottom Atomic Power Station

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Figure 1: Location of PBAPS and Surrounding Communities

Nature of the Issue and Identifying Possible Effects

Evaluated entrainment reduction technologies include closed-cycle cooling, fine-mesh traveling screens, and wedgewire screens. Of these, mechanical draft cooling towers are expected to have the most property value impacts. Property value effects are expected to be most pronounced when physical effects from cooling towers impact the quality of life of residential property owners. The primary pathways considered include change in viewshed. These linkages and related studies required for 316(b) permitting are depicted in Figure 2 below.

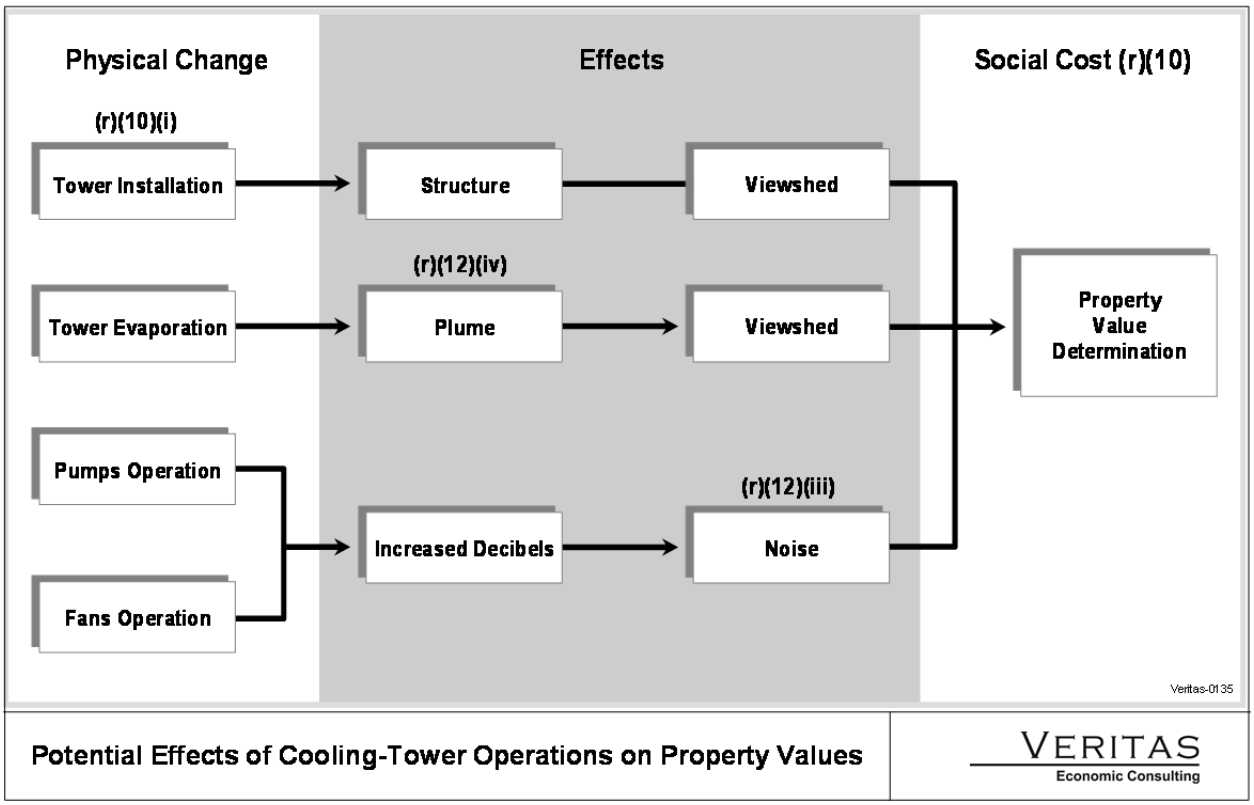

Figure 2: Potential Effects of Cooling-Tower Operations on Property Values

The view from a property could be impacted by the profile of a cooling tower structure and by the presence of a visible plume. Noise levels on a property could be impacted by the operation of cooling tower pumps and fans. As depicted in Figure 2, cooling tower noise and plume are studied under §122.21(r)(12) (iii) and (iv) and the dimensions and design of cooling towers will result from the cost and feasibility studies that are conducted under §122.21(r)(10)(i).

Approach and Available Information

Scientific studies to understand the determinants of property values typically apply the hedonic modeling approach (Freeman 2003). In such studies, statistical modeling is used to relate the price of a property to its characteristics (such as size, features, and condition) and characteristics of the surrounding neighborhood (such as accessibility to schools and shopping, value of other homes). These studies have also been used to identify the impact that environmental dis-amenities such as industrial sites and noise (i.e., from roadways and airports) have on property values.

The hedonic concept that a property's value arises from its individual components has intuitive appeal. The approach also has strong economic foundations and support in numerous applications (Freeman 2003). The results are derived from market exchanges and hedonic studies are consistently able to rigorously and statistically separate effects. However, hedonic studies can be data and resource intensive. Moreover, independent of effort requirements, it is not technically feasible to develop an original hedonic study for the 316(b)-permitting context. The primary reason for this is that hedonic property value studies are by nature empirical whereas the 316(b)-permitting process is forward looking; because the towers have not been installed, site-specific empirical studies are not possible.

Given this situation, some sort of transfer approach is required. That is, results from one or more other studies of *realized* effects must be applied to evaluate *likely* effects. Under the study transfer paradigm, high-quality transfer studies are important, as is coherence between the nature of effects from the transfer site and the study site. Here additional challenges arise. Closed-cycle-cooling conversions are a very particular type of incremental change to an existing industrial site. Although hedonic studies of nearby property values that include transactions before and after a conversion can estimate the incremental effect of installing and operating cooling towers, no such studies have been conducted. As a result, the best feasible methods currently available for studying cooling tower impacts to property value must rely on inferring a reduction in property value rather than empirically identifying one.

Viewshed Effects

Various factors can alter a viewshed, including topography, distance to objects, haze, humidity, background landscape, atmospheric conditions, and weather (Development Partners Funding I, LLC 2013). Residential properties located nearest to PBAPS are most likely to receive negative property value effects from viewshed impacts. A study of the influence of viewsheds on residential home sales found that residential property owners value larger total

views and larger continuous view segments (Hindsley, Hamilton, and Morgan 2013). The proximity of residential properties to the visible plume is an important aspect in determining negative impacts.

A visible plume from a cooling tower is composed of water vapor and a small amount of water droplets. Viewshed effects of a visible plume would apply over a much larger distance than would noise effects and tower height and plume height are important factors in determining this distance. Several studies have modeled viewshed effects using these factors:

- Saratoga Associates (2009) used a 10-mile distance for modeling viewshed effects of plumes rising 1,200 feet above a cooling tower.
- Niagara Mohawk Power Corporation et al. (1984) considered a 10-mile viewshed to be appropriate for estimating visibility of plumes rising from a 536-foot natural draft cooling tower.
- Development Partners Funding I, LLC (2013) estimated that plumes from a proposed facility with mechanical draft cooling towers would potentially be visible in a community 7.2 miles from the site.
- Tronaas (2002) estimated that a residential population had a moderate view of 470-foot-high plumes from mechanical draft cooling towers 4 miles away.

EPRI (2011) used the Seasonal Annual Cooling Tower Impact (SACTI) model to estimate the potential for fogging, icing, and shadowing impacts from cooling towers. EPRI (2011) included illustrations and summaries of plume fogging impacts for several representative facilities. Summaries for some facilities focused on a 1.2-mile distance used in calculating viewshed effects from cooling towers, and others cited a 6-mile distance for those effects.

Viewshed Effect Quantification

The viewshed near PBAPS would be affected by both a visible tower and plume. Engineering studies have evaluated the installation of mechanical draft cooling towers at PBAPS with the height of the towers proposed to be 50 feet (AECOM 2017). Residential properties located nearest to the plant are the most likely to receive negative effects from cooling towers. The quantification of property value losses from cooling tower related viewshed effects is accomplished by conducting three steps:

1. Identify changes in viewshed under Baseline and With-Cooling-Towers conditions by characterizing changes at PBAPS, including cooling tower profile and plume.
2. Identify the value of property that could have viewshed effects.
3. Where meaningful changes in viewshed are expected to occur to residential properties, characterize them and assign related changes in value.

As currently configured, PBAPS has helper towers that are once through and used to reduce heat discharge during certain of the warmest times of year. The new towers would be closed-cycle and would operate whenever the plant is running. The plume from a new CCRS would be a significant change at the site.

This analysis considers effects of cooling tower plumes within a six-mile radius of the site. Under certain conditions, fogging could extend six miles in any direction from PBAPS. Farms and residential properties are located within the most immediate area of the plant. Other properties located within six miles of PBAPS are parks, a marina, two airports, several churches, and numerous roadways.

Figure 3 below depicts cities and census tracts located within six miles of the PBAPS plant that potentially could be affected by a visible plume from cooling towers at the site. Cooling tower plume viewshed effects have been studied at distances ranging from 4 to 10 miles. This analysis uses the 6-mile distance from EPRI (2011) as this falls within the range of estimated distances. Also, the view from Google Earth shows open or agricultural land in Maryland and few, if any, residences within 6 miles of the plant. In this figure, the total residential property value for each Census tract near the power plant is depicted, as are the nearby population centers.

Residential properties located within six miles of PBAPS are collectively valued at approximately $385.4 million. The value of these properties could potentially be negatively impacted by changes in viewshed from a visible plume. EPRI (2011) applied results from an industrial site with a vapor plume to infer a 1.8-percent reduction in affected property values. As no such study is available for cooling towers, this report provisionally specifies the 1.8-percent from EPRI (2011) to properties within 6 miles to estimate a potential negative property value impact of $6.9 million.

Additional visible plume modeling results and discussion on visible vapor plumes is summarized in Section 1.4 of the § 122.21(r)(12) report.

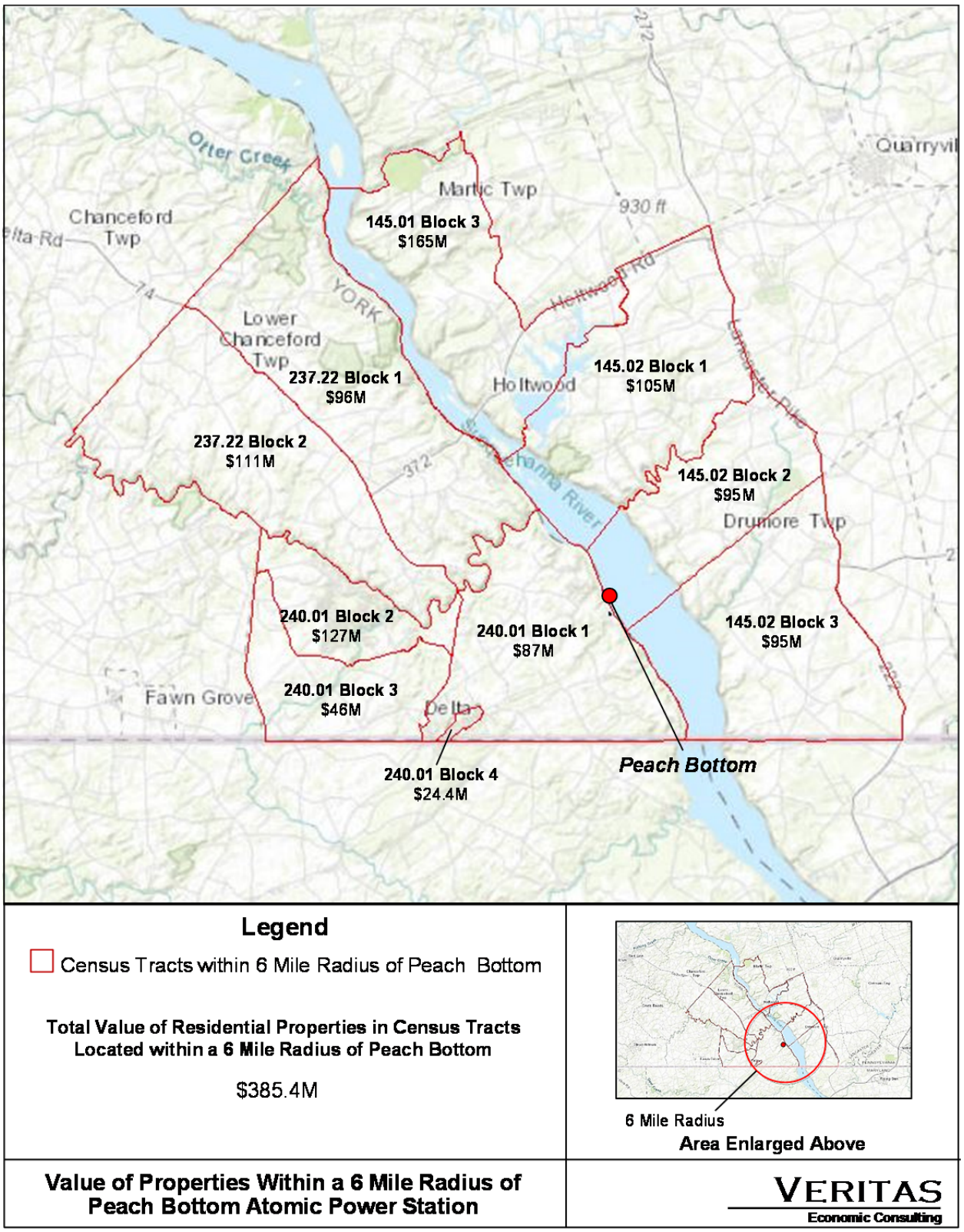

Figure 3: Value of Properties within 6 miles of PBAPS

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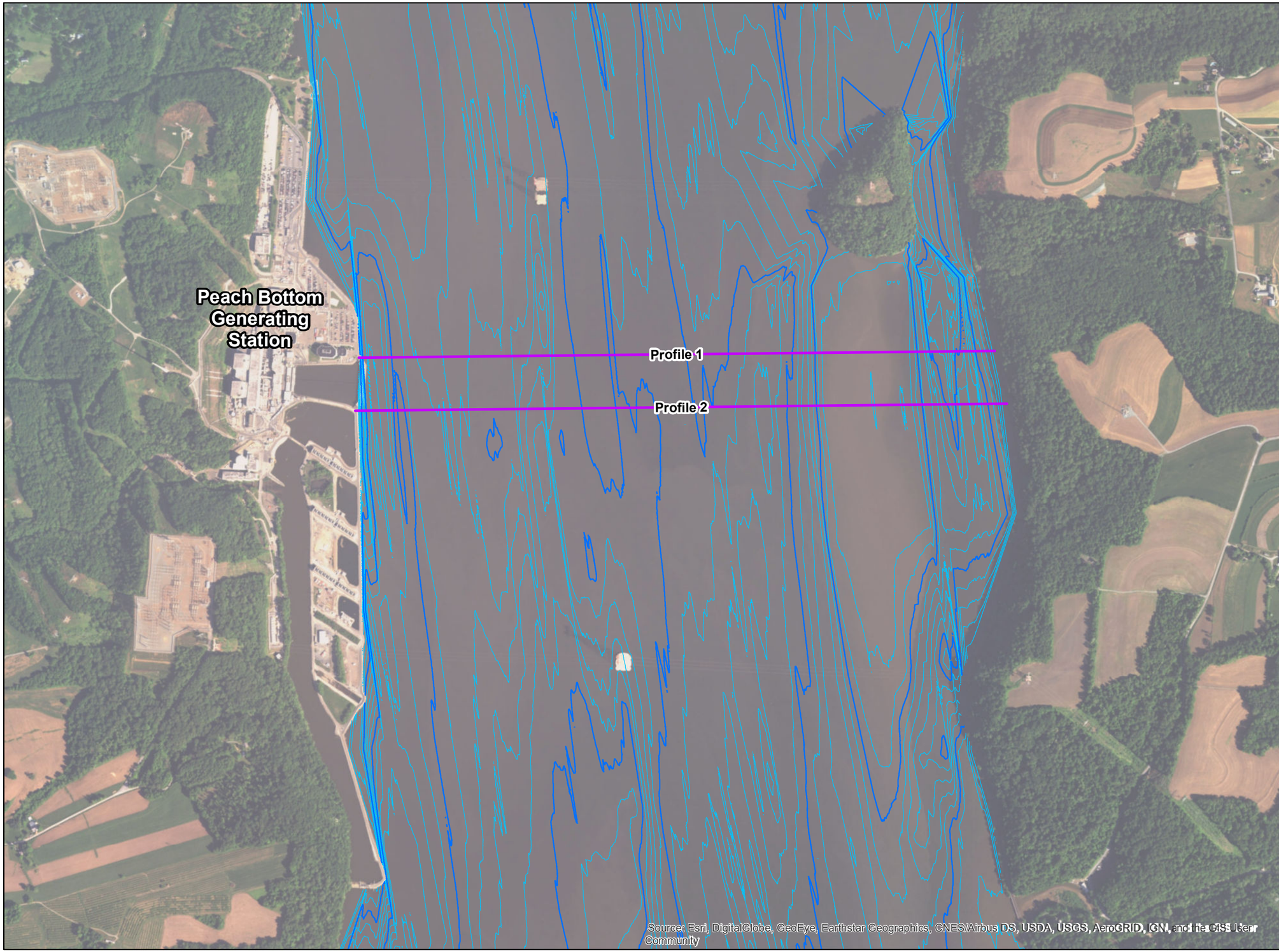
APPENDIX C
BATHYMETRY DATA



Legend

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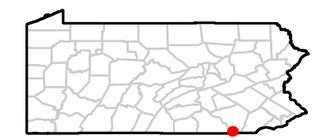
- 2ft Contour Interval
- 10ft Contour Interval



Key Map Not to Scale

N

0 1,000 2,000 Feet

1 in = 1,000 ft

MAP FORMATTED FOR B-SIZE SHEET (11" X 17")
SCALE NOT VALID FOR DIFFERENT PAGE SIZE

AECOM

625 West Ridge Pike, Suite E-100
Conshohocken, PA 19428

Bathymetry Map
Conowingo Pond
Peach Bottom Atomic
Power Station

Prepared By: BSF	Job: 60538796
Checked By: BS	Date: 11/3/2017

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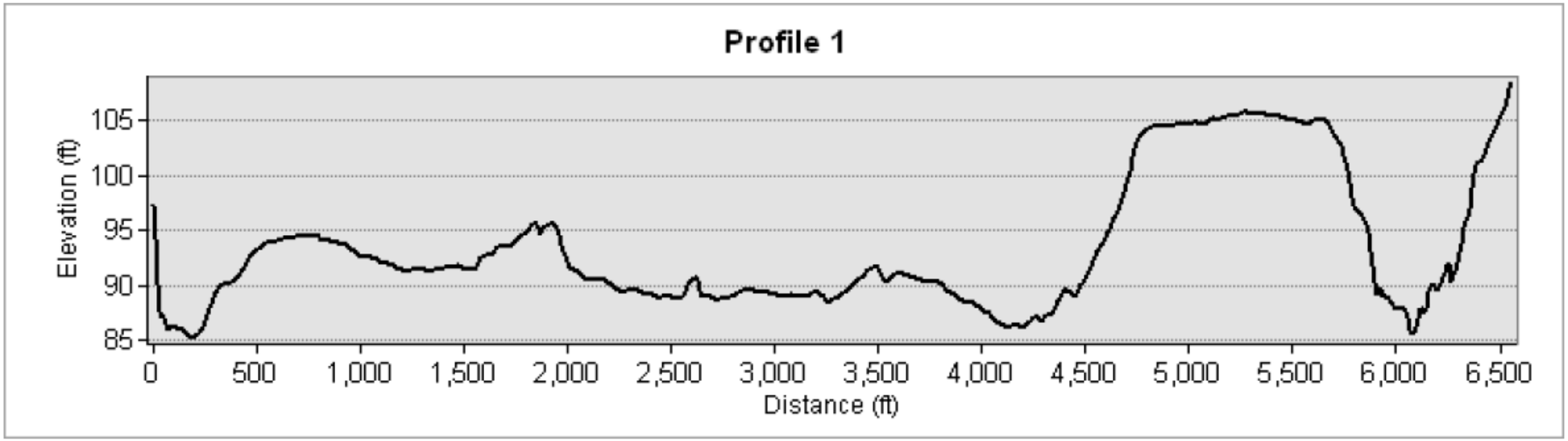

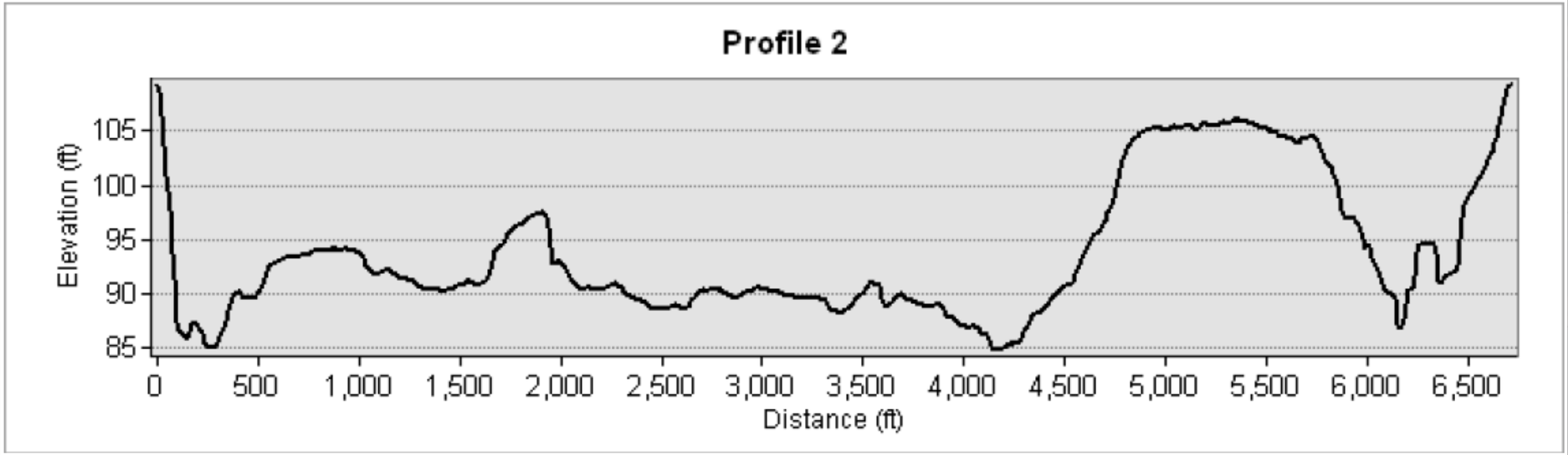

AECOM

625 West Ridge Pike, Suite E-100
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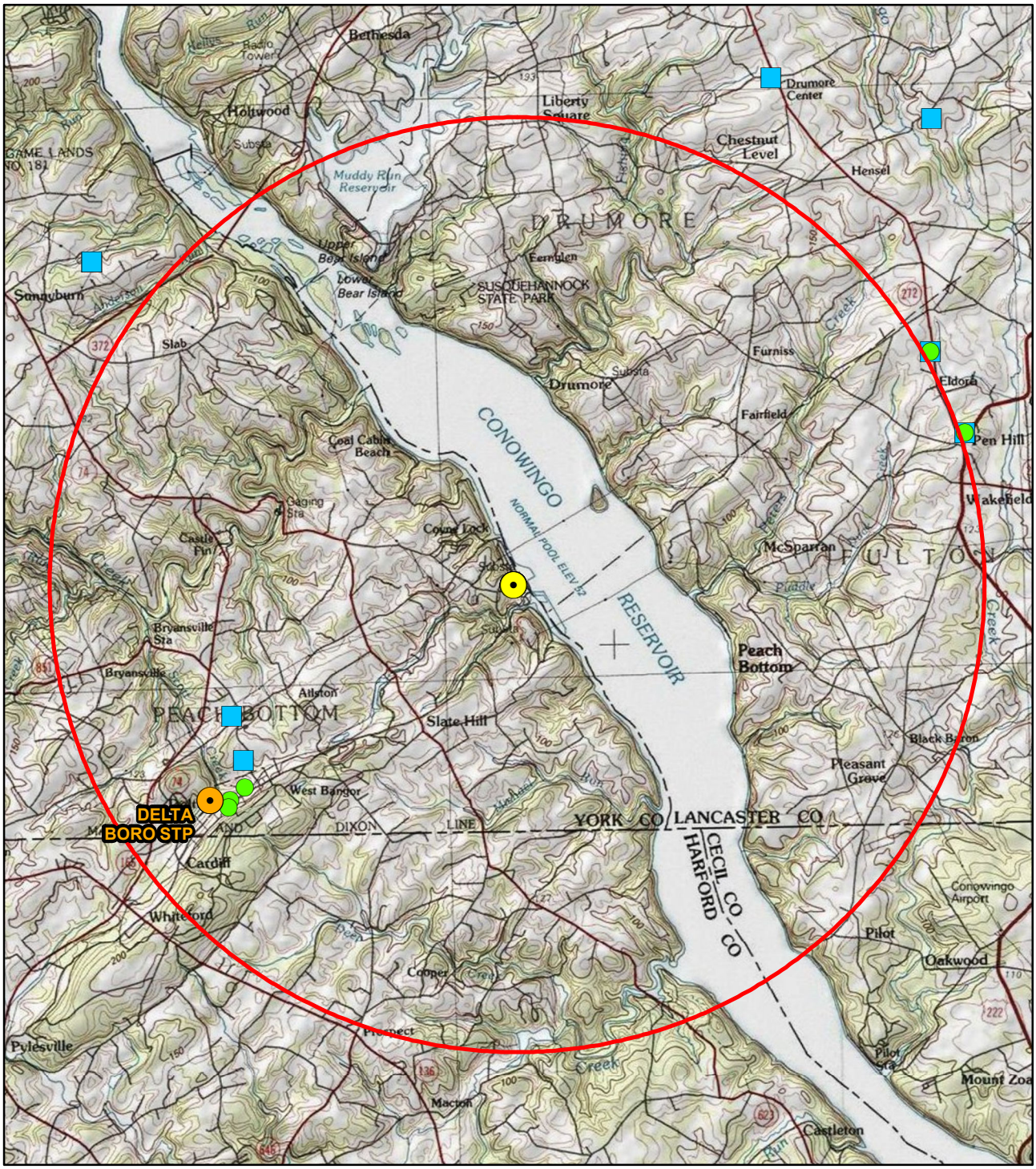
Bathymetry Profiles
Conowingo Pond
Peach Bottom Atomic
Power Station

Prepared By: TK/BS	Job: 60538796
Checked By:	Date: 12/07/2017

APPENDIX D

ALTERNATIVE COOLING WATER SOURCES
PEACH BOTTOM ATOMIC POWER STATION



Legend

- Peach Bottom Site
- Delta STP
- 5 mile buffer

Facility Type

- Septic
- Well

0 2.5 5
Miles

NAD 1983 State Plane Pennsylvania South
Projection: Lambert Conformal Conic
Linear Unit: US Foot

Reference:
Water Resources (PADEP, 2017)
USA Topographic Map (ESRI)

AECOM
625 West Ridge Pike, Suite E-100
Conshohocken, PA 19428
Phone: (610) 832-3500 Fax: (610) 832-3501

Job: 60538796	Alternative Cooling Water Sources Peach Bottom Atomic Power Station
Prepared by: DCB	1848 Lay Rd, Delta, PA 17314
Checked by: SEA	
Date: 8/8/2018	

Path: S:\Projects\Private-Sector\Exelon\19998907_CWA_316b\Data\2017\Peach Bottom 122.21r 10-12\122.21r 10-12 Reports\Cooling Tower Retrofit for 122.21r10\GIS\Peach Bottom\PeachBottom_WaterResources

ENCLOSURE 06

Exelon Generation Company LLC. 2019. PA0009733 NPDES Permit Renewal Application, Appendix F, CWA 316(a) Thermal Variance. March 2019. 236 p.

APPENDIX F

CWA §316(a) Thermal Variance

Summary Memorandum – CWA §316(a) Variance Request

Attached Reports and Documentation:

1. Normandeau Associates, Inc. and ERM, Inc. 2017. Final Report for Post-EPU Thermal and Biological Monitoring: Peach Bottom Atomic Power Station, Exelon Generation, February, 2017.
2. Pennsylvania Department of Environmental Protection. 2017. Response to Final Report for Post-EPU Thermal and Biological Monitoring and Notice of Planned Measurement Uncertainty Recapture Uprate, Peach Bottom Atomic Power Station (PBAPS) NPDES Permit No. PA0009733. May 3, 2017.
3. Exelon Generation. 2017. Letter to PADEP re: PBAPS Cooling Tower Operation and Measurement Uncertainty Recapture Uprate Thermal Monitoring. August 18, 2017.
4. Exelon Generation. 2016. Letter to Federal Energy Regulatory Commission (FERC) re: 2016 Results for the Water Temperature Monitoring Plan for Conowingo Pond by Order Modifying and Approving Non-Project Use of Project Lands and Waters (Order 152 FERC ¶ 62,142, issued September 2, 2015), Conowingo Hydroelectric Project No. 405-113. December 15, 2016.
5. Exelon Generation. 2017. Letter to Federal Energy Regulatory Commission (FERC) re: 2017 Results for the Water Temperature Monitoring Plan for Conowingo Pond by Order Modifying and Approving Non-Project Use of Project Lands and Waters (Order 152 FERC ¶ 62,142, issued September 2, 2015), Conowingo Hydroelectric Project No. 405-113. December 26, 2017.
6. Exelon Generation. 2018. Letter to Federal Energy Regulatory Commission (FERC) re: 2018 Results for the Water Temperature Monitoring Plan for Conowingo Pond by Order Modifying and Approving Non-Project Use of Project Lands and Waters (Order 152 FERC ¶ 62,142, issued September 2, 2015), Conowingo Hydroelectric Project No. 405-113. December 18, 2018.
7. Federal Energy Regulatory Commission. 2018. Letter to Exelon Generation, LLC: Water Temperature Monitoring Report – Article 409. February 23, 2018.
8. Federal Energy Regulatory Commission. 2019. Letter to Exelon Generation, LLC: Water Temperature Monitoring Report. January 10, 2019.

Attachment A – List of Reports and Documentation

Exelon Generation Company, LLC
1848 Lay Rd
Delta, PA 17314

To:
Ms. Maria D. Bebenek
Environmental Program Manager
Pennsylvania Department of
Environmental Protection

Re:
NPDES Permit No. PA0009733

Date:
March 29, 2019

Appendix F CWA §316(a) Thermal Variance

Section 316(a) of the federal Clean Water Act (CWA) provides the opportunity for an owner or operator of a facility with a thermal effluent, and subject to the provisions of Section 301 or Section 306 of the CWA, to request a modification or waiver of a thermal effluent limit. This modification would be based on demonstrating that the effluent limits are more stringent than necessary to ensure the protection and propagation of a balanced, indigenous community (also called a balanced, indigenous population [BIP]) of shellfish, fish, and wildlife in the receiving waterbody. The owner or operator may present evidence for consideration by the State in the form of a § 316(a) Thermal Variance Demonstration Study conducted in accordance with United States Environmental Protection Agency (USEPA) Draft Interagency 316(a) *Technical Guidance Manual and Guide for Thermal Effects Sections of Nuclear Facilities Environmental Impact Statements* (USEPA 1977).

Peach Bottom Atomic Power Station (PBAPS) has demonstrated that the effluent limits are more stringent than necessary to ensure the protection and propagation of a BIP and is allowed to operate under an agency-issued thermal variance. The Conowingo Reservoir is among the most widely studied bodies of water in Pennsylvania. Experts have conducted numerous biological monitoring studies over the past 50+years, both prior to operation of PBAPS in 1974 and in the subsequent operational periods. Sampling has been performed upstream, downstream and in the immediate vicinity of the station. These studies suggest a balanced indigenous aquatic community has existed and continues to exist in the Conowingo Reservoir. A list of the technical studies conducted on the Conowingo Reservoir can be found in Attachment A of this section.

The more recent biological studies include a four-year 316(a) Demonstration Study completed in 2013, and a Post-Extended Power Uprate (EPU) Thermal and Biological Study (Post-EPU Study) and report completed in 2017. The Post-EPU field studies included water temperature and dissolved oxygen monitoring, benthic macroinvertebrate sampling, and fish community surveys in thermally and non-thermally affected areas of Conowingo Reservoir. The Post-EPU Study also included desktop evaluations of juvenile American shad migration past the PBAPS

thermal plume and the seasonal distribution of gizzard shad in Conowingo Reservoir relative to the PBAPS thermal discharge. The Post-EPU monitoring confirmed the predicted biological outcomes, validated thermal model assumptions and results, and demonstrated, as expected, the balanced, indigenous community (or BIP) in the receiving waterbody has been maintained during post-EPU conditions with cooling tower mitigation.

Additional temperature monitoring was also conducted in 2018 to assess the impacts of a Measurement Uncertainty Recapture (MUR) at PBAPS. During 2018, a 12-month water temperature monitoring study was implemented in Conowingo Reservoir to evaluate the water temperature changes associated with the MUR. The temperature monitoring study was requested by PADEP to validate the station's assumption of a maximum 0.4°F increase in the plant intake to discharge temperature (ΔT) following implementation of the MUR.

The MUR was implemented during mid-January 2018[1]. However, due to boat ramp icing and river ice, the installation of the temperature monitoring equipment was delayed until conditions improved on February 15, 2018. Water temperature loggers were installed at 13 locations. Three loggers were installed onsite at PBAPS in the intake, at the head of the discharge canal, and at the end of the discharge canal. Ten temperature loggers were installed in Conowingo Reservoir within the thermal plume, both along shallow shoreline areas and at several buoy transects across Conowingo Reservoir. The water temperature loggers were set to continuously record water temperature on an hourly basis and data downloads occurred on a monthly basis.

Preliminary data have been evaluated through October 26, 2018. Data recovery varied substantially depending on the monitoring location and was hampered by environmental conditions. Due to the significant flood events that occurred during 2018, several of the buoy transects were lost and the temperature data were not recovered. Overall, data recovery varied from 46% to 100%. The lowest recovery rate occurred at one of the buoy transect locations where the loggers and associated equipment were lost multiple times. Preliminary analyses indicated a ΔT of approximately 0.3°F, within the predicted value of 0.4°F. Upon completion of the 12-month monitoring period, a report will be completed that provides an analysis of the individual location monitoring data and the actual increases in water temperatures at these locations associated with the MUR.

No biological monitoring was conducted in Conowingo Reservoir during 2018 to evaluate the PBAPS thermal discharge. However, based on previous biological observations, temperature analyses, and the current water temperature monitoring data, no adverse impacts are expected on migrating fish in Conowingo Reservoir. No adverse impacts to migrating fish were observed by biological field crews working in Conowingo Reservoir during 2018.

[1] Unit 3 MUR was reached on 1/10/2018; Unit 2 MUR was reached on 1/13/2018.

The 2017 Post-EPU Study and preliminary 2018 results from the post-MUR Study therefore support the continuance of the existing thermal variance. Furthermore, the data collected during 2018 reflected excessive river flows during extended periods of the summer months. When these flows occur, the thermal discharge from PBAPS is fully assimilated within the Susquehanna River water body with less than a 3°F resultant temperature increase and well below the water quality standard for warm water fisheries. Therefore, PBAPS is requesting PADEP to consider modifying the thermal variance, as described below.

Existing NPDES Permit – CWA Section 316(a) Alternate Thermal Limitations

In accordance with Part C.I of the current permit (effective date of October 1, 2014), seasonal operation of PBAPS' cooling towers constitutes a thermal variance under Section 316(a) of the CWA:

Cooling towers shall be operated for the combined operation of Units 2 and 3 during the period of June 15 through August 31 of each year, according to the sequential order. Average intake temperatures listed below are based on the prior two day rolling average using Unit 2 or Unit 3 circulating water intake temperature instrumentation:

- *One tower shall commence operation on June 15 and shall operate continuously through August 31. Should environmental conditions warrant, the Permittee may request that DEP authorize a delay in commencement of such tower operation.*
- *A second cooling tower shall commence operation within 48 hours of average intake temperatures being equal to or greater than 83°F. Once operation has commenced, the second tower shall operate continuously through August 31. Should environmental conditions warrant, the Permittee may request that DEP authorize the termination of the second tower operation prior to August 31.*
- *A third cooling tower shall commence operation within 48 hours of average intake temperatures being equal to or greater than 86°F. The tower shall operate continuously for seven days, and shall cease operation on the first day, following the seven days, when the average intake temperature is less than 86°F. Thereafter, the third tower shall commence and cease operations when the conditions set forth herein reoccur.*

Revisions per Exelon Letter to PADEP Dated August 16, 2017

On August 16, 2017, PADEP requested that PBAPS extend the cooling tower operation beyond the permit-required termination date of August into September, if elevated river temperatures and low-flow conditions occur. PBAPS agreed to extend cooling tower operations from the end of August through September 30th (all based on 48-hour averages):

1. One tower will operate continuously through September 30, if temperature is equal to or greater than 81°F. If temperature lowers to 81°F the one remaining operational tower may be secured.

2. A second tower will continue operation or commence operation within 48 hours of average intake temperatures being equal to or greater than 83°F. When intake temperature is less than 83°F, operation of the second cooling tower will cease.

3. A third cooling tower will operate conditionally in accordance with the language in the current NPDES permit.

<u>Proposed Changes to CWA Section 316(a) Alternate Thermal Limitations</u>

Exelon is requesting that the thermal variance be modified to initiate cooling tower operation based on temperature and flow conditions in the river rather than the date June 15. High river flow and/or low river temperature conditions, such as those observed in 2018, may occur that eliminate the need for the cooling towers to operate in order for the downstream temperature water quality criteria to be met. In 2018, river flows in excess of 35,000 cfs and over 350,000 cfs were observed during an extended period between June 15 and September 30 (i.e., flows that were 10 to 100 times the low-flow $Q_{7\text{-}10}$ river conditions). During such periods of high river flow and/or low river temperature conditions, the assimilative capacity of the river increases and the 'allowable' heat rejection rate or waste load allocation from PBAPS will increase. Cooling tower operation should not be required if, at PBAPS' discharge at maximum flow (2,240.6 MGD) and permitted instantaneous discharge temperature (110°F[2]), the water quality criterion can be met in the river after the discharge is fully mixed with river flow.

Exelon has therefore developed the following proposed revised conditional cooling tower operation:

Cooling towers shall be operated for the combined operation of Units 2 and 3 during the period of June 15 <u>through September 30</u> of each year, according to the following sequential order:

- *One tower shall operate when river temperature is equal to or greater than 81°F or the river flow is less than or equal to 35,000 cfs as measured at the Marietta Gage Station. The cooling tower can be secured when the temperature is less than 81°F and flow is greater than 35,000 cfs. Thereafter, a tower shall commence and cease operations when the conditions set forth herein reoccur.*
- *A second cooling tower shall operate when temperature is equal to or greater than 83°F and the river flow is less than or equal to 35,000 cfs as measured at the Marietta Gage Station. Thereafter, the second tower shall commence and cease operations when the conditions set forth herein reoccur.*
- *A third cooling tower shall commence operation when average intake temperatures are equal to or greater than 86°F. The tower shall operate continuously for seven days, and shall cease operation on the first day, following the seven days, when the average intake*

[2] PBAPS' actual discharge temperature is typically well below the instantaneous temperature limit of 110 °F unless ambient river temperatures are above 85 to 87 °F.

temperature is less than 86°F. Thereafter, the third tower shall commence and cease operations when the conditions set forth herein reoccur

Average intake temperatures listed above are based on the prior two-day rolling average using Unit 2 or Unit 3 circulating water intake temperature instrumentation. Cooling tower operation must commence within 48 hours of a temperature or flow trigger. Should environmental conditions warrant, the Permittee may request that DEP authorize a delay in commencement of tower operation or termination of tower operation.

This request for the continuation of the thermal variance with minor modifications is supported with the attached recent reports and documentation providing results of comprehensive physical and biological field data collection in Conowingo Reservoir. A comprehensive list of the technical studies conducted on the Conowingo Reservoir can be found in Attachment A of this section. Additional calculations can be provided at PADEP's request to support the recommended changes to the thermal variance.

List of Attached Reports and Documentation

Normandeau Associates, Inc. and ERM, Inc. 2017. Final Report for Post-EPU Thermal and Biological Monitoring: Peach Bottom Atomic Power Station, Exelon Generation, February, 2017.

Pennsylvania Department of Environmental Protection. 2017. Response to Final Report for Post-EPU Thermal and Biological Monitoring and Notice of Planned Measurement Uncertainty Recapture Uprate, Peach Bottom Atomic Power Station (PBAPS) NPDES Permit No. PA0009733. May 3, 2017.

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Exelon Generation. 2017. Letter to Federal Energy Regulatory Commission (FERC) re: 2017 Results for the Water Temperature Monitoring Plan for Conowingo Pond by Order Modifying and Approving Non-Project Use of Project Lands and Waters (Order 152 FERC ¶ 62,142, issued September 2, 2015), Conowingo Hydroelectric Project No. 405-113. December 26, 2017.

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Federal Energy Regulatory Commission. 2018. Letter to Exelon Generation, LLC: Water Temperature Monitoring Report – Article 409. February 23, 2018.

Federal Energy Regulatory Commission. 2019. Letter to Exelon Generation, LLC: Water Temperature Monitoring Report. January 10, 2019.

FINAL REPORT FOR POST-EPU THERMAL AND BIOLOGICAL MONITORING

PEACH BOTTOM ATOMIC POWER STATION

Exelon Generation®

February 2017

FINAL REPORT
FOR POST-EPU THERMAL AND BIOLOGICAL MONITORING

PEACH BOTTOM ATOMIC POWER STATION

Prepared for:

Exelon Generation®

Prepared by: Normandeau Associates, Inc. and ERM, Inc.

February 2017

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Executive Summary

The Post-EPU Thermal and Biological Study (Post-EPU Study) supports the monitoring requirements set forth in the Station's NPDES Permit. The study evaluated increases in water temperature after implementation of the extended power uprate (EPU) and assessed the resulting effects on the biological community. Field studies included water temperature and dissolved oxygen monitoring, benthic macroinvertebrate sampling, and fish community surveys in thermally and non-thermally affected areas of Conowingo Pond. The study also included desktop evaluations of juvenile American Shad migration past the PBAPS thermal plume and the seasonal distribution of Gizzard Shad in Conowingo Pond relative to the PBAPS thermal discharge.

The Post-EPU Study is the follow-up to the four-year 316(a) Demonstration Study (Pre-EPU Demonstration Study) completed in 2013. The Pre-EPU Demonstration Study concluded that under pre-EPU operations, a balanced, indigenous community (BIC) existed in Conowingo Pond. Modeling and analysis performed during the Pre-EPU Demonstration Study concluded that after EPU implementation with cooling towers operating, a BIC would continue to be maintained. The Pre-EPU Demonstration Study also recommended that thermal and biological monitoring be continued to evaluate post-EPU conditions against predictions made during the Pre-EPU Demonstration Study.

Susquehanna River flows and temperatures during the 2016 study period were at extreme levels (i.e., low flows in combination with high ambient water temperatures) and were thus ideal for direct measurement of temperature increases. Comparisons showed that predicted temperature increases provided an upper bound to those observed in the field. Field observations also showed that the average post-EPU condenser temperature rise was less than the assumed value (i.e., 22.1°F actual compared with 22.4°F modeled). Observations also showed that each cooling tower performed better than expected (2.2°F temperature reduction per tower instead of the modeled value of 1.6°F). Overall, field observations show that cooling tower operation as specified in the current NPDES permit effectively mitigates the post-EPU increase in thermal load.

Water temperature observations at the biological monitoring locations were generally consistent with pre-EPU observations. Monitoring of dissolved oxygen (DO) concentrations indicated that DO was protective of the aquatic community and DO concentrations would not block fish migration past PBAPS.

Evaluation of the Pre-EPU Demonstration Study model output indicated that a BIC would be maintained after the implementation of the EPU. Post-EPU monitoring indicated that the measurable spatial and temporal impacts of the thermal plume to the biota of Conowingo Pond were similar to those observed during pre-EPU sampling, as expected. Similar to pre-EPU study results, the temporal patterns of fish avoidance and decline in benthos diversity were related to high water temperatures.

Both the fish and benthic macroinvertebrate community composition and relative abundance were similar to those observed during Pre-EPU monitoring. Indices used to describe the community structure of the biological community showed that thermally influenced and non-thermally influenced stations were similar biologically during pre- and post-EPU monitoring. Field observations showed that, as expected, a BIC has been maintained during post-EPU conditions with cooling tower mitigation.

The time-varying hydrothermal model used for the temperature predictions was subsequently used to predict the areas in Conowingo Pond with water temperatures that would impede juvenile American Shad emigration. The analysis indicated that virtually the entire Pond is available for juvenile American Shad emigration with no potential for thermal blockage. In Conowingo Pond, Gizzard Shad tolerate temperatures < 2.2 °C (< 36.0 °F) and do not appear to need a “thermal refuge” to sustain the population. The winter electrofishing catch supports a conclusion that the PBAPS thermal plume is not interfering with the fall outmigration of Gizzard Shad or attracting excessively large numbers of this species during the winter months.

1 Introduction

Exelon Generation, LLC's (Exelon) Peach Bottom Atomic Power Station (PBAPS) is a power generating facility located in York County, Pennsylvania. The Station operates under National Pollutant Discharge Elimination System (NPDES) Permit No. PA0009733 and a Federal Clean Water Act (CWA) §316(a) variance for its thermal discharge to Conowingo Pond.

This study supports the monitoring requirements set forth in the NPDES Permit under Part C, Alternate Thermal Limitations. The purpose of this study is to evaluate the increase in water temperature after implementation of the Extended Power Uprate (EPU) and to determine potential changes to the thermal plume and its effects on the biological community. After completion and acceptance of the pre-EPU 316(a) Demonstration Study (Normandeau and ERM 2014), Exelon developed a Post-EPU Study Plan that outlined the technical requirements necessary to confirm results of the Pre-EPU Demonstration Study. The Plan was subsequently reviewed and revised in coordination with the Pennsylvania Department of Environmental Protection (PADEP). The final, approved Study Plan was submitted to PADEP on April 25, 2016. The sampling program was initiated shortly thereafter.

The goal of the Post-EPU Study is to use physical and biological field data to confirm predicted biological outcomes and to validate model assumptions and results from the pre-EPU 316(a) Demonstration Study. The 2016 physical and biological field dataset are similar to the datasets used for the pre-EPU 316(a) Demonstration Study. The 2016 dataset is focused on critical areas and issues that were identified in the Pre-EPU Demonstration Study. In addition to the biological and temperature monitoring, the Post-EPU Study Plan included continuous dissolved oxygen monitoring, a desktop study to evaluate juvenile American Shad migration past the PBAPS thermal plume, and a desktop study to address concerns over Gizzard Shad seasonal distribution in Conowingo Pond relative to the PBAPS thermal discharge.

This Post-EPU Study is the follow-up to the four-year pre-EPU 316(a) Demonstration Study as described in the Post-EPU Study Plan (Normandeau and ERM 2016). In the pre-EPU 316(a) Demonstration Study, an extensive set of physical and biological field data were collected and analyzed to show the effects of PBAPS's thermal discharge. To estimate the impacts of increased heat loads to Conowingo Pond when each of the two generating units was equipped for EPU operations, a three-dimensional hydrothermal model was used to simulate the extent of the thermal plume for average and extreme ambient conditions with EPU operating conditions. The model also has the capability to simulate temperature in Conowingo Pond during the operation of one, two or three of the cooling towers located along the PBAPS discharge canal.

The approved NPDES permit for EPU operation required a summertime cooling tower operating schedule that balanced the additional heat load from the EPU against the heat reduction from the operation of the cooling towers. The cooling tower operating schedule also specified use of cooling towers during episodic, naturally-occurring high river temperature events.

The main components of the present study include water temperature monitoring, dissolved oxygen monitoring, and biological sampling of shore zone benthic macroinvertebrates and the

resident fish community in Conowingo Pond. Field data collection was completed for the months of May through September, the main period for fish reproduction and growth, as well as the period with the highest ambient and discharge water temperatures.

Section 2 of this report provides background information about previous thermal and biological studies conducted relative to PBAPS. Sections 3 through 6 discuss water temperature, biological, and dissolved oxygen monitoring results and analysis. Sections 7 and 8 provide information related to juvenile American Shad migration and seasonal distribution of Gizzard Shad in Conowingo Pond relative to PBAPS's thermal plume.

2 Background

This section summarizes important background information on the Station (including the EPU and cooling tower operations), Conowingo Pond's physical features and biota, and the main conclusions from the pre-EPU 316(a) Demonstration Study.

2.1 The Peach Bottom Atomic Power Station

Exelon operates two nuclear reactors at the Peach Bottom site. Unit 2 began commercial operation in June 1974; Unit 3 entered commercial service in December 1974[1]. PBAPS withdraws water for condenser cooling from Conowingo Pond (Pond) through an intake structure using six circulating water pumps (three per unit, 557 cubic feet per second (cfs) per pump) and for service water needs using six service water pumps (three per unit, 31.2 cfs per pump). After passing through the plant, water exits at the head of the 4,700-ft long discharge canal into Conowingo Pond. The discharge structure is designed for rapid mixing of the heated effluent into ambient Conowingo Pond water and an immediate reduction in temperature. Three cooling towers are located along the canal, each of which is capable of reducing the temperature by approximately 1.6 to 2.2°F, depending on meteorological conditions, especially humidity and wind speed.

The design temperature rise across the condensers is 22°F and across the service water system is 10.7°F. As noted in the Pre-EPU Demonstration Study, the actual temperature rise for the combined condenser and service water flow as observed in the study averaged 19.4°F at the head of the discharge canal during the two warmest months of the year, July and August.

Exelon began uprating Unit 2 in 2014 and Unit 3 in 2015, with the uprate for each Unit fully implemented about one year later (2015 and 2016, respectively). Variable cooling tower operation, discussed later in this report, began in the summer of 2015. The additional waste heat added when both uprated reactors are operating results in a 3°F increase in the temperature rise.

2.2 Conowingo Pond

Conowingo Pond, the lowermost of four hydroelectric impoundments on the lower Susquehanna River, was formed in 1928 by construction of Conowingo Hydroelectric Station at River Mile 10 (RM 10). Conowingo Hydroelectric Station is a modified run-of-river facility with limited storage for peaking hydropower generation. Conowingo Pond is bounded upstream by Holtwood Dam (RM 24) built in 1914. PBAPS at RM 17 is about equidistant between the two dams.

Conowingo Pond has a surface area of about 9,000 acres and is about 14 miles long and averages 1 mile wide. The elevation at normal full Pond is 108.5 ft and the elevation is normally

[1] Unit 1 was a small experimental reactor shut down in 1974.

maintained at 106.5 ft or higher for recreational use on weekends between Memorial Day and Labor Day and at levels no less than 104.5 ft at other times for operation of PBAPS.

Long-term monitoring that began around 1960 has shown that the Pond is not thermally stratified but that at summer water temperatures and low Susquehanna River (<12,000 cfs), dissolved oxygen stratification can occur in deeper areas of the Pond. Since monitoring pre-dates PBAPS operations, dissolved oxygen stratification is a natural phenomenon, common for this type of waterbody.

The circulation in the Pond is influenced by outflows and inflows that can occur on a daily or hourly basis from controlled inflows of up to 32,000 cfs from Holtwood Hydroelectric Dam and up to 32,000 cfs (during generation) from Muddy Run Pumped Storage Facility (MRPSF) at RM 22. Controlled outflows of up to 85,000 cfs occur at Conowingo Hydroelectric Station and of up to 28,000 cfs (during pumping) at Muddy Run.

2.3 Biota of Conowingo Pond

The biota of Conowingo Pond has been studied intensely for many years. Long-term thermal and biological monitoring studies have been completed in Conowingo Pond since 1966, both prior to operation of PBAPS in 1974 and in the subsequent operational period. Sampling has been performed upstream and downstream from PBAPS and in areas within the heated plume. The numerous long-term studies documented species composition, relative abundance and distribution of fishes within Conowingo Pond. The most recent thermal studies in the form of a pre-EPU 316(a) Demonstration Study were completed from 2010 to 2013. These studies included temperature monitoring and extensive fish community monitoring in Conowingo Pond. Since 1966, approximately 60 species have been captured in the Pond and the tributary streams.

2.4 Summary of 2014 316(a) Demonstration Study

The pre-EPU 316(a) Demonstration Study served multiple purposes:

- to study an alternative thermal effluent limitations under §316(a) of the CWA;
- to evaluate changes in the thermal plume created by operation of up to three helper cooling towers, and
- to predict changes to the thermal plume associated with planned uprates to Units 2 and 3 and to design the cooling tower protocol.

2.4.1 <u>316(a) Demonstration Study Description</u>

The Pre-EPU Demonstration Study was completed with extensive coordination with PADEP. The main components of the study were temperature monitoring, hydrothermal modeling, sampling of macroinvertebrates and of the resident fish community, and integrated analysis of the temperature and biological data. Each component was used to make an independent

assessment of the PBAPS thermal discharge and to evaluate the applicability of a thermal variance.

Monitoring and sampling were performed April through October, the main period of fish reproduction and growth as well as highest ambient and discharge water temperatures. Data collection began in 2010 and continued through 2013. No towers were operated during the summer of 2010, one tower was operated in 2011, two towers in 2012, and three towers in 2013. The resulting datasets provided all the information necessary to evaluate the temperature reduction effects of cooling tower operation.

2.4.2 316(a) Demonstration Study Results

Temperature Monitoring

- The towers performed as designed; each tower cooled the discharge by about an additional 1.6°F, measured from the head to the end of the discharge canal.
- Operation of the towers reduced water temperatures in Conowingo Pond by consistent and measurable amounts within 1.2 miles of the discharge and near the western shoreline and by smaller amounts beyond 1.2 miles.

Benthic Macroinvertebrate Community

- The composition and relative abundance of the benthic community was similar during all 4 years of the study.
- Temporary impact, in terms of lower IBI scores, was observed at Stations 214 and 215 in July and August after a sustained period of high water temperatures, but was followed by recovery.
- Benthic community changes resulting from the thermal plume are localized and temporary and limited to a small proportion of the available shallow shoreline habitat within Conowingo Pond.
- There was no observed impact to the benthic community at the three thermally-influenced Stations (189, 216 and 217) that are 1.3 miles or more downstream from the discharge canal.

Fish Community

- Inter-annual variation in relative abundance of the Representative Important Species (RIS) and other species did not appear to be related to differences in water temperature resulting from cooling tower operation.
- Metrics used to describe fish community structure show no clear differences in the fish community between thermally influenced and non-thermally influenced locations.
- Limited avoidance by selected species was observed at Stations 161, 214, and 215 which are closest to the end of the discharge canal, during the periods of highest water temperature in July and/or August.
- Little or no habitat avoidance occurs in May and early June, the peak spawning period for most fishes in Conowingo Pond.

- The observed fish avoidance for select species occurred mostly in July and August when either the species move out of the area or for most RIS, have completed spawning activity.
- Relative abundance of most RIS from 2010 through 2013 was within the range of values observed previously in Conowingo Pond.

Hydrothermal Model

- The model accurately reproduced the hydrodynamics and thermal structure of the Pond relative to the PBAPS thermal plume and other dynamic input parameters.
- The agreement of modeled and observed temperatures over the range of conditions that occurred in 2010, 2011 and 2012 allows the model to predict the thermal structure in the pond for other-than-observed conditions and to establish the cooling tower operating schedule shown in the NPDES Permit, Part C.
- EPU modeling results for the *typical summer condition* show that areas of potential fish avoidance would be small, localized, and temporary in nature.
- Most of the potential avoidance areas for the *typical summer condition* modeling scenario would occur at the water surface near to the west shoreline immediately downstream from the discharge canal.
- EPU modeling results for the *extreme summer condition* show that areas of potential fish avoidance would be sizable for several species with most of the elevated water temperatures and avoidance areas at the surface or in the immediate vicinity of the discharge canal.
- Cross-sections of the thermal plume for both modeling scenarios indicated that sufficient areas of the channel would be available at water temperatures less than the avoidance temperatures for the RIS and will allow for their movement within the Pond.

2.4.3 316(a) Demonstration Study Overall Conclusions

The Pre-EPU Demonstration Study concluded that under pre-EPU operations, a balanced, indigenous community (BIC) in Conowingo Pond existed. Modeling and analysis performed during the Pre-EPU Demonstration Study also concluded that after EPU implementation with cooling towers operating using the agreed schedule, a BIC would continue to be maintained. The Pre-EPU Demonstration Study also suggested that thermal and biological monitoring after EPU implementation should be continued to evaluate post-EPU conditions against predictions made during the Pre-EPU Demonstration Study.

3 Temperature Monitoring Program

This section of the report presents the results of the 2016 thermal plume monitoring organized by deliverables listed in the Post-EPU Study Plan. For the thermal plume monitoring, the deliverables are:

- Temperature data in electronic format
- Duration and frequency of high temperatures
- Temperature changes due to cooling tower operations
- Transition period temperatures
- Model verification

The Susquehanna River flows and temperatures that occurred in 2016 are important in understanding the temperature and biological data presented in this study. The 2016 flows and temperatures are discussed below relative to those observed during the four year Pre-EPU Demonstration Study, historical values, and values used to model post-EPU conditions.

3.1 Characteristics of the 2016 Post-EPU Study Year

Table 3-1 shows monthly average 2016 Susquehanna River flows compared to the long-term mean and the four years of the Pre-EPU Demonstration Study. Shaded cells are those flows below the long-term mean. The table shows that the years 2010, 2012 and 2016 stand out as low flow years. July and September are important because those flows are very near or below the 7000 cfs flow chosen for the “extreme” scenario modeled for the Pre-EPU Demonstration Study.

Table 3-1 Monthly average Susquehanna River flows: Historical, Demonstration Study, and Post-EPU Study years.

Month	Average Susquehanna River flow, cfs					
	1932-2011	2010	2011	2012	2013	2016
April	78,600	46,385	149,867	23,704	53,462	33,210
May	48,500	34,392	110,399	52,547	29,717	34,010
June	28,900	17,508	35,079	29,693	31,949	15,640
July	16,200	10,060	13,202	8,730	37,117	6,947
August	12,700	8,808	17,797	10,275	15,692	9,857
September	15,800	6,142	141,479	11,222	12,266	5,506
October	18,800	40,228	80,023	18,378	18,853	13,821

Table 3-2 is shows monthly average temperatures in a similar format, but in this table the shaded months identify temperatures greater than the long-term mean. Like many of the months in the Demonstration Study, 2016 is also characterized by warm temperatures. September 2016 is unusual – not only are temperatures more than 5°F higher than all Septembers shown in the table, September 2016 most resembles temperatures typically seen in August.

Overall, 2016 resembles 2010; both are warmer and dryer than most years. September 2016 is unique, characterized by very low flows and unusually high temperatures.

Table 3-2 Monthly average Susquehanna River temperatures: Historical, Demonstration Study, and Post-EPU Study years.

Month	Average Susquehanna River temperatures, °F					
	1999-2013	2010	2011	2012	2013	2016
June	74.8	78.8	76.2	75.0	75.1	77.3
July	81.1	84.0	83.3	83.8	81.2	83.6
August	80.1	82.3	80.1	81.8	77.2	84.4
September	73.1	75.1	68.1	74.2	73.8	80.1

In the Pre-EPU Demonstration Study, the flows and temperatures for the typical and extreme modeling scenarios were based on the 10% and 1% frequency of occurrence of combinations of low Susquehanna River flows and high Susquehanna River temperatures. Table 3-3 characterizes July, August and September 2016 in the same fashion. The table shows, of all historical combinations of Susquehanna River flows and temperatures (1956-2012, all months), 97% of the months had either higher flows or lower temperatures than occurred in September 2016, making its combination of flows and temperatures unusual, but less so than the extreme scenario modeled for the Pre-EPU Demonstration Study.

Table 3-3 Frequency of occurrence of combinations of low Susquehanna River flows and high Susquehanna River temperatures.

Case	Monthly mean intake temperature, °F	Monthly mean Susquehanna River flow, cfs	Fraction of months this combination is exceeded
Extreme Modeling Scenario	86	7000	99%
Typical Modeling Scenario	80	13000	90%
July 2016	84	7051	98%
August 2016	84	9954	97%
September 2016	80	5587	97%

The fact that 2016 was both a low flow and a high temperature year makes it a unique year in which to collect both temperature and biological data and to measure cooling tower performance and the response of the aquatic communities to near-extreme conditions.

3.2 Thermal Plume Monitoring

The 316(a) Demonstration Study measured temperatures with 0, 1, 2, and 3 towers in operation to determine the rate of cooling in the canal and downstream, modeled 1% and 10% combinations of flow and ambient temperature to estimate post-EPU downstream temperatures for extreme conditions, and used the model to help design the cooling tower operating schedule published in Part C of the NPDES permit.

The Post-EPU Study used observations to show that the expected downstream cooling occurs and compared modeled and observed temperatures to demonstrate the model correctly predicted temperatures for extreme events ("verification").

The use of cooling towers after implementation of the EPU is based on the concept that a healthy fishery existed in Conowingo Pond prior to EPU implementation and that the same healthy fishery post-EPU will be maintained if the additional heat from the EPU is offset by operation of the cooling towers. This offset can be demonstrated by comparing the temperature increase at the head of canal due to the EPU (3°F) with the temperature decrease from operating two cooling towers, each reducing the temperature by 1.6°F for a total of 3.2°F.

3.2.1 Data Program

Monitoring Station Descriptions

Temperature monitoring for the Post-EPU Study used a subset of the stations used in the Pre-EPU Demonstration Study, as approved by PA DEP in consultation with the US Fish and Wildlife Service. Figure 3-1 shows the location of these monitoring stations. The location, data, and analysis of the biological monitoring stations are discussed in "Biological Station Temperature Monitoring."

Figure 3-2 shows the monitoring stations in the discharge canal.

Water Temperature Data

All water temperature data have been provided to PA DEP, as required, in a separate spreadsheet and transmittal. The period of record is May 1 through September 30, 2016; data are measured hourly and retrieved monthly.

Loss of Data

There were 30 monitoring stations taking data hourly for a total of 110,160 (= 30 stations x 153 days x 24 hours) possible data points over the five month monitoring period. Nearly all temperature data were recovered and available for analysis as 99% data recovery was achieved.

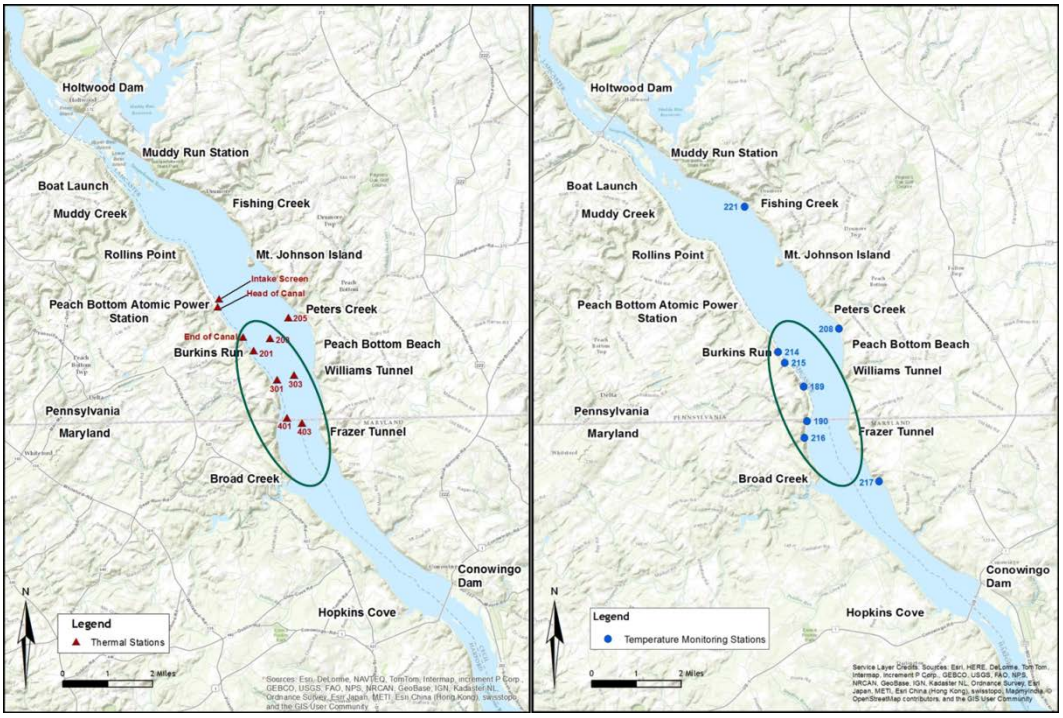


Figure 3-1 Location of 2016 temperature monitoring stations.

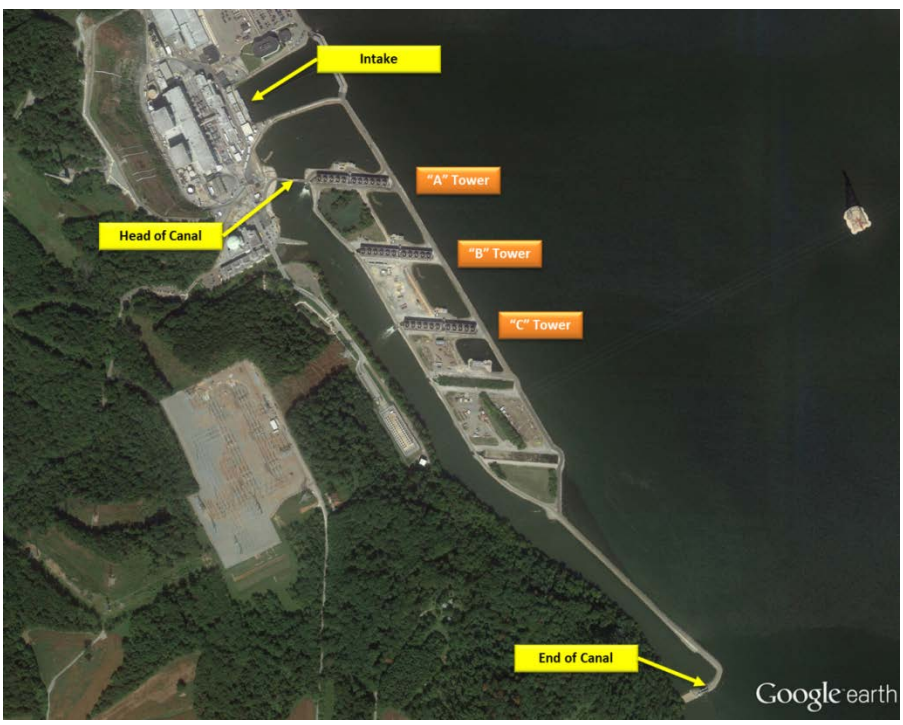


Figure 3-2 Location of 2016 intake and discharge canal temperature monitoring stations.

3.2.2 Temperature Data Analysis

There are four analytical deliverables, each of which is discussed below.

Duration and Frequency of High Temperatures

Because the Pre-EPU Demonstration Study presents the duration and frequency of high temperatures as part of the analysis of the biological data, the corresponding Post-EPU Study data are reported in Section 6.

Temperature Changes Due to Cooling Tower Operations

This section of the report quantifies temperature changes during cooling tower operations, first from the head of the discharge canal to the end, then at monitoring stations immediately downstream of the canal. During the post-EPU 2016 study period PBAPS operated at full load with the EPU and the cooling towers operated as set forth in Part C of the NPDES Permit (Figure 3-3).

> Cooling towers shall be operated for the combined operation of Units 2 and 3 during the period of June 15 through August 31 of each year, according to the sequential order. Average intake temperatures listed below are based on the prior two day rolling average using Unit 2 or Unit 3 circulating water intake temperature instrumentation:
>
> (1) One tower shall commence operation on June 15 and shall operate continuously through August 31. Should environmental conditions warrant, the Permitee may request that DEP authorize a delay in commencement of such tower operation.
>
> (2) A second cooling tower shall commence operation within 48 hours of average intake temperatures being equal to or greater than 83°F. Once operation has commenced, the second tower shall operate continuously through August 31. Should environmental conditions warrant, the Permitee may request that DEP authorize the termination of the second tower operation prior to August 31.
>
> (3) A third cooling tower shall commence operation within 48 hours of average intake temperatures being equal to or greater than 86°F. The tower shall operate continuously for seven days, and shall cease operation on the first day, following the seven days, when the average intake temperature is less than 86°F. Thereafter, the third tower shall commence and cease operations when the conditions set forth herein reoccur.

Figure 3-3 Excerpt from the NPDES Permit, Part C describing the cooling tower operating schedule.

In the following discussion, temperatures will generally be presented as temperature differences, e.g., increases over ambient[2] or reductions from the temperature measured at the head of the canal. This approach facilitates year-to-year and model-to-observations comparisons.

[2] Ambient is assumed to be equivalent to the temperature measured at the PBAPS intake.

Cooling tower performance, measured by temperature reductions in the canal, is discussed next, followed by a discussion of temperature reductions in Conowingo Pond downstream of the discharge with respect to the number of cooling towers operating.

Figure 3-4 shows the number of towers in operation through the summer of 2016, with start-up and shutdown times highlighted in Table 3-4. This table shows dates beginning five days before start-up of the first tower and ending five days after shutdown of the last tower.

Figure 3-5 shows observed temperatures at the intake, head of canal, and end of canal[3] for May through September 2016. Temperatures at Monitoring Station 214 are also shown for reference. Figure 3-5 shows that there is only a small temperature reduction from the head to the end of canal through June 15th (orange and black lines), but that the temperature reduction increases as each tower starts up (note the separation of orange and black lines).

Figure 3-6 shows the same locations but the temperatures in this figure are shown as <u>increases</u> above intake temperature.

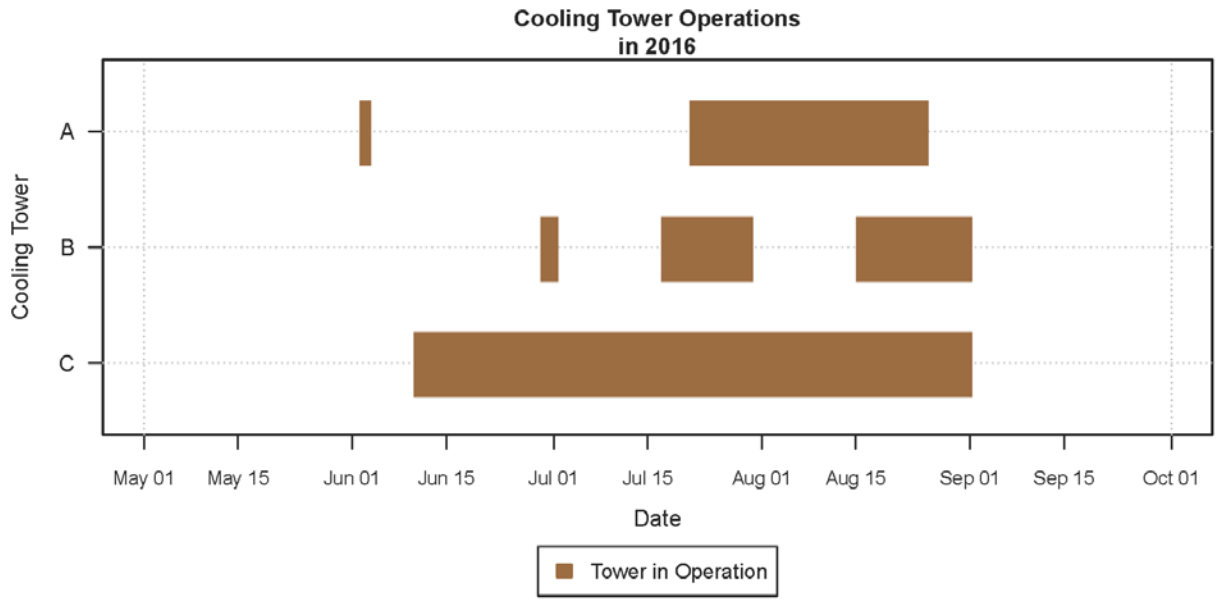


Figure 3-4 Summer 2016 cooling tower operations.

Table 3-4 Cooling tower start-up and shutdown dates.

Date	Cooling Tower A Status	Cooling Tower B Status	Cooling Tower C Status
6/6/2016	Off	Off	Off
6/7/2016	Off	Off	Off
6/8/2016	Off	Off	Off
6/9/2016	Off	Off	Off

[3] The end of canal monitoring station is called Outfall 001 in the NPDES Permit.

Date	Cooling Tower A Status	Cooling Tower B Status	Cooling Tower C Status
6/10/2016	Off	Off	Off
6/11/2016	Off	Off	**On**
6/12/2016	Off	Off	Off
6/13/2016	Off	Off	Off
6/14/2016	Off	Off	**On**
6/15/2016	Off	Off	**On**
6/16/2016	Off	Off	**On**
6/17/2016	Off	Off	**On**
6/18/2016	Off	Off	**On**
6/19/2016	Off	Off	**On**
6/20/2016	Off	Off	**On**
6/21/2016	Off	Off	**On**
6/22/2016	Off	Off	**On**
6/23/2016	Off	Off	**On**
6/24/2016	Off	Off	**On**
6/25/2016	Off	Off	**On**
6/26/2016	Off	Off	**On**
6/27/2016	Off	Off	**On**
6/28/2016	Off	Off	**On**
6/29/2016	Off	Off	**On**
6/30/2016	Off	**On**	**On**
7/1/2016	Off	**On**	**On**
7/2/2016	Off	Off	**On**
7/3/2016	Off	Off	**On**
7/4/2016	Off	Off	**On**
7/5/2016	Off	Off	**On**
7/6/2016	Off	Off	**On**
7/7/2016	Off	Off	**On**
7/8/2016	Off	Off	**On**
7/9/2016	Off	Off	**On**
7/10/2016	Off	Off	**On**
7/11/2016	Off	Off	**On**
7/12/2016	Off	Off	**On**
7/13/2016	Off	Off	**On**
7/14/2016	Off	Off	**On**
7/15/2016	Off	Off	**On**
7/16/2016	Off	Off	**On**
7/17/2016	Off	**On**	**On**
7/18/2016	Off	**On**	**On**
7/19/2016	Off	**On**	**On**
7/20/2016	Off	**On**	**On**
7/21/2016	Off	**On**	**On**

Date	Cooling Tower A Status	Cooling Tower B Status	Cooling Tower C Status
7/22/2016	**On**	**On**	**On**
7/23/2016	**On**	**On**	**On**
7/24/2016	**On**	**On**	**On**
7/25/2016	**On**	**On**	**On**
7/26/2016	**On**	**On**	**On**
7/27/2016	**On**	**On**	**On**
7/28/2016	**On**	**On**	**On**
7/29/2016	**On**	**On**	**On**
7/30/2016	**On**	**On**	**On**
7/31/2016	**On**	Off	**On**
8/1/2016	**On**	Off	**On**
8/2/2016	**On**	Off	**On**
8/3/2016	**On**	Off	**On**
8/4/2016	**On**	Off	**On**
8/5/2016	**On**	Off	**On**
8/6/2016	**On**	Off	**On**
8/7/2016	**On**	Off	**On**
8/8/2016	**On**	Off	**On**
8/9/2016	**On**	Off	**On**
8/10/2016	**On**	Off	**On**
8/11/2016	**On**	Off	**On**
8/12/2016	**On**	Off	**On**
8/13/2016	**On**	Off	**On**
8/14/2016	**On**	Off	**On**
8/15/2016	**On**	Off	**On**
8/16/2016	**On**	**On**	**On**
8/17/2016	**On**	**On**	**On**
8/18/2016	**On**	**On**	**On**
8/19/2016	**On**	**On**	**On**
8/20/2016	**On**	**On**	**On**
8/21/2016	**On**	**On**	**On**
8/22/2016	**On**	**On**	**On**
8/23/2016	**On**	**On**	**On**
8/24/2016	**On**	**On**	**On**
8/25/2016	**On**	**On**	**On**
8/26/2016	Off	**On**	**On**
8/27/2016	Off	**On**	**On**
8/28/2016	Off	**On**	**On**
8/29/2016	Off	**On**	**On**
8/30/2016	Off	**On**	**On**
8/31/2016	Off	**On**	**On**
9/1/2016	Off	Off	Off

Date	Cooling Tower A Status	Cooling Tower B Status	Cooling Tower C Status
9/2/2016	Off	Off	Off
9/3/2016	Off	Off	Off
9/4/2016	Off	Off	Off
9/5/2016	Off	Off	Off

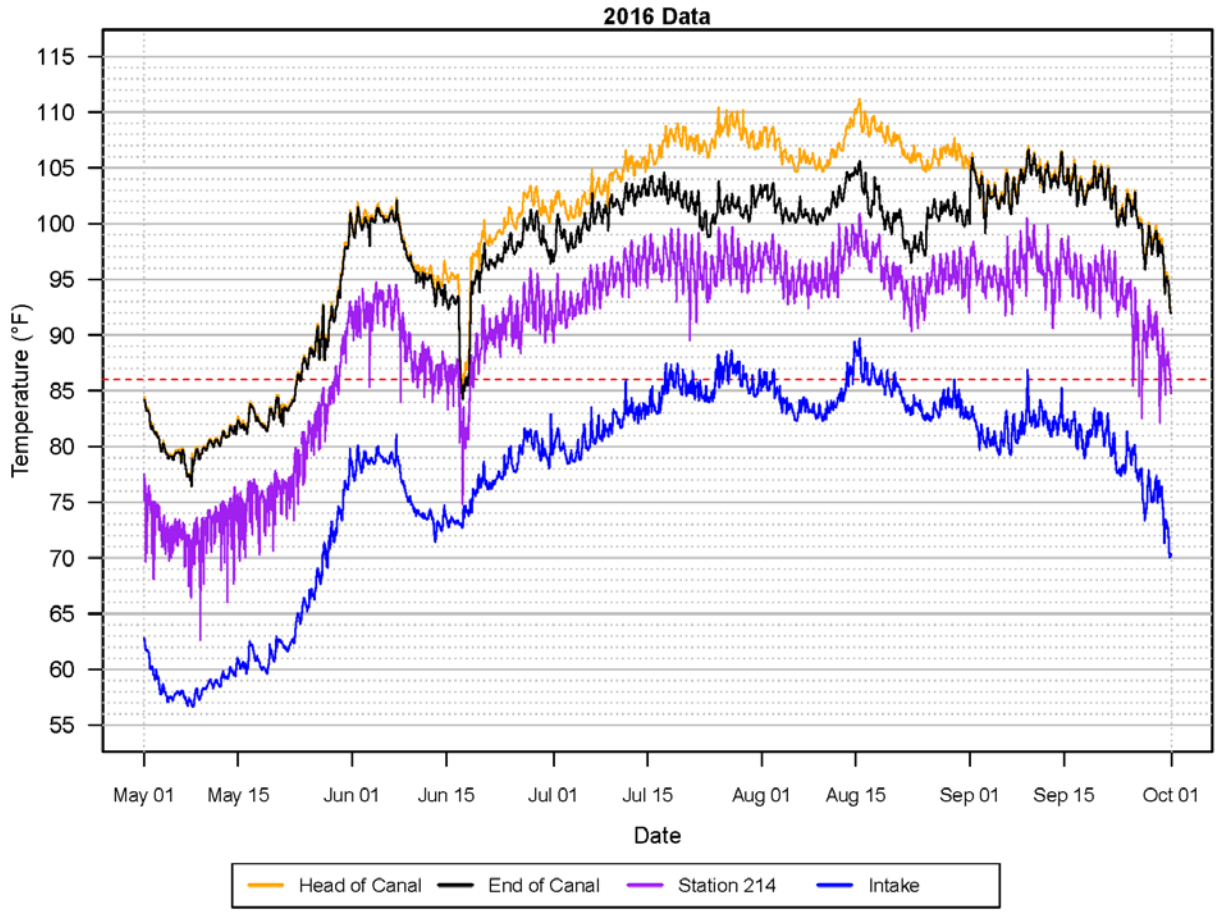


Figure 3-5 Temperatures in the discharge canal and at Monitoring Station 214.

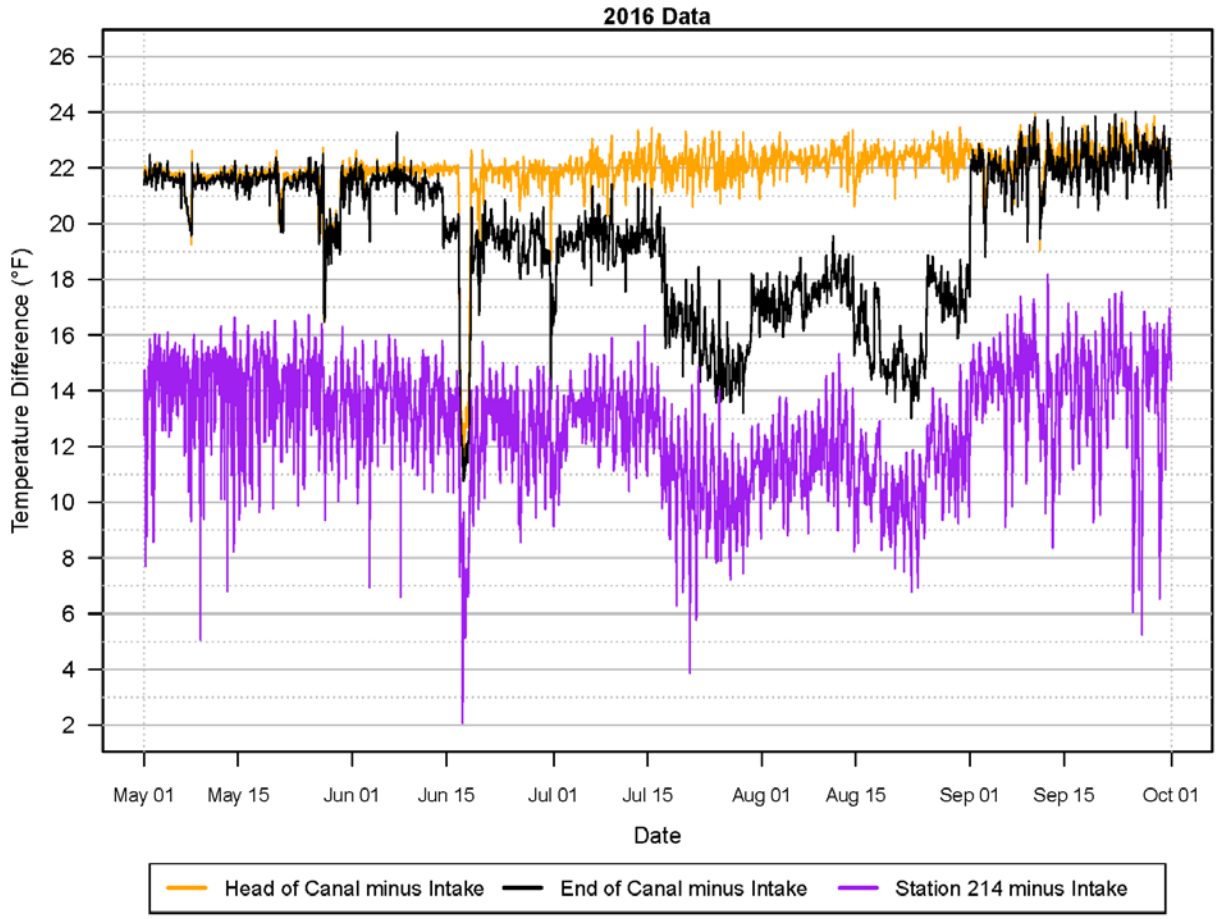


Figure 3-6 Summer 2016 temperatures presented as increases above intake temperature.

The mean temperature increase from intake to head of canal was 22.1°F which is to be compared to the post-EPU condenser temperature rise of 22.4°F used in the Pre-EPU Demonstration Study. The condenser temperature rise is an important parameter because it, along with the condenser flow rate, represents the heat released by PBAPS to Conowingo Pond. As was the case for the data taken during the Pre-EPU Demonstration Study, there was some variation in this number in 2016, as shown in Table 3-5, with occasional, short duration exceedances of 22.4°F.

Table 3-5 Temperature increases from the intake to the head of canal for 2016

Period	Temperature increase (°F) from the intake to head of canal		
	Min	Mean	Max
All Months	18.7	22.1	24.0
April	19.2	21.6	22.7
May	19.3	21.7	22.6
June	18.7	21.9	22.7
July	20.3	22.0	23.4
August	20.6	22.4	23.4

Period	Temperature increase (°F) from the intake to head of canal		
	Min	Mean	Max
September	19.0	22.5	24.0

In 2016 there was one period with one tower in operation, two periods with two cooling towers in operation, and two periods with three cooling towers in operation. By analyzing each period separately, cooling tower temperature reductions on a per tower basis can be calculated. This calculation shows that the value of the per tower temperature decrease in the canal was 2.2°F, which exceeds the 1.6°F found for the 2010 through 2013 Pre-EPU Demonstration Study dataset. The reason for the improvement is believed to be maintenance upgrades performed on the cooling towers. The decrease in temperature in the canal absent cooling towers was 0.2°F, identical to the value found in the Pre-EPU Demonstration Study.

As noted in Section 3.4 of the Pre-EPU Demonstration Study (Table 3-5) observed temperature reductions in Conowingo Pond downstream of the discharge canal ranged from 2.1°F to 0.0°F and were highly variable (Section 3.4 "Effectiveness of Cooling Towers in Reducing Downstream Temperatures" in that same report). Similar values and variability were found in the 2016 data period, summarized in Table 3-6 below.

Temperature changes at downstream stations due to cooling tower operation are further discussed in “Model Verification,” below.

Table 3-6 Temperature reduction as a function of number of cooling towers in operation at downstream stations.

Monitoring Station	Temperature reduction per cooling tower (°F)			
	1 tower	2 towers	3 towers	Average
214	1.2	1.2	1.3	1.2
215	1.2	1.1	1.0	1.1
301S	0.9	0.8	0.8	0.8
189	0.5	0.6	0.6	0.6

Transition Period Temperatures

This section of the Post-EPU Study report presents observed temperatures changes in the discharge canal and downstream in Conowingo Pond during cooling tower start-ups and shutdowns.

In general there are six common transitions (three start-ups and three shutdowns) built into the cooling tower operating schedule (Figure 3-3):

- Start-up of the first cooling tower operation on June 15 and shutdown on August 31st
- Start-up of the second cooling tower when intake temperatures reach 83°F; shutdown on August 31st
- Start-up of the third cooling tower when intake temperatures reach 86°F; operation for at least seven days; shutdown when temperatures are below 86°F (multiple start-ups and shutdowns of the third tower in a single summer are possible).

Examples of all six common transitions occurred in 2016. Figure 3-6 and Table 3-4 show the start-up and shutdown dates for each cooling tower in the summer of 2016. From the table, three periods in 2016 which capture all six common transitions were selected for further analysis:

- Start-up of the first tower in mid-June 2016
- Start-up of the second and third towers, shutdown of the third tower in the second half of July 2016
- Shutdown of all three towers in the second half of August.

Temperature reductions and increases associated with these transitions are shown in Figure 3-7, Figure 3-8, and Figure 3-9. The figures show temperature reductions (or increases when a tower shuts down) relative to intake temperatures at the end of the canal, at Monitoring Station 214, and the number of towers in operation (right hand vertical scale). Taken together these figures span a period that begins five days prior to the first transition and ends five days after the last transition. Each figure focuses on a particular type of transition (e.g., from one to two towers). The noticeable decrease in temperature on June 17th (Figure 3-7) is not related to cooling tower operations, but instead to a sudden reduction in generation that results in the discharge of less waste heat.

Although temperature changes at the end of the canal are reasonably clear in all three figures, the changes are less obvious at Monitoring Station 214. Operation of the cooling towers reduce temperatures at Monitoring Station 214 when viewed over a multi-day period, but these changes are obscured when viewed on an hourly basis by fluctuations due the daily cycle of pumpback and generation operations at MRPSF, by heat loss to the atmosphere, and variable entrainment of cooler ambient water.

Numerical values of temperature reductions and increases corresponding to the figures are tabulated in Table 3-7, Figure 3-8 and Table 3-9.

The simulations conducted for the Pre-EPU Demonstration Study were stationery-state, i.e., all input parameters were held constant except for pumpback and generation at MRPSF. Stationery-state means that a repeating cycle of flows and temperatures in Conowingo Pond was calculated. The length of the repeating cycle is dictated by the frequency of operations at MRPSF. Cooling tower operations in the model were held constant throughout the simulation periods and for this reason transition period temperatures were not explicitly modeled.

The model does compute velocities from which estimates of the travel time to downstream stations can be obtained. These times are shown in Table 3-10 which shows that travel times are short – less than half an hour to Monitoring Station 214 and less than four hours to Monitoring Station 189. That the hourly observations cannot distinguish the arrival time of cooler water is a consequence of the short travel time.

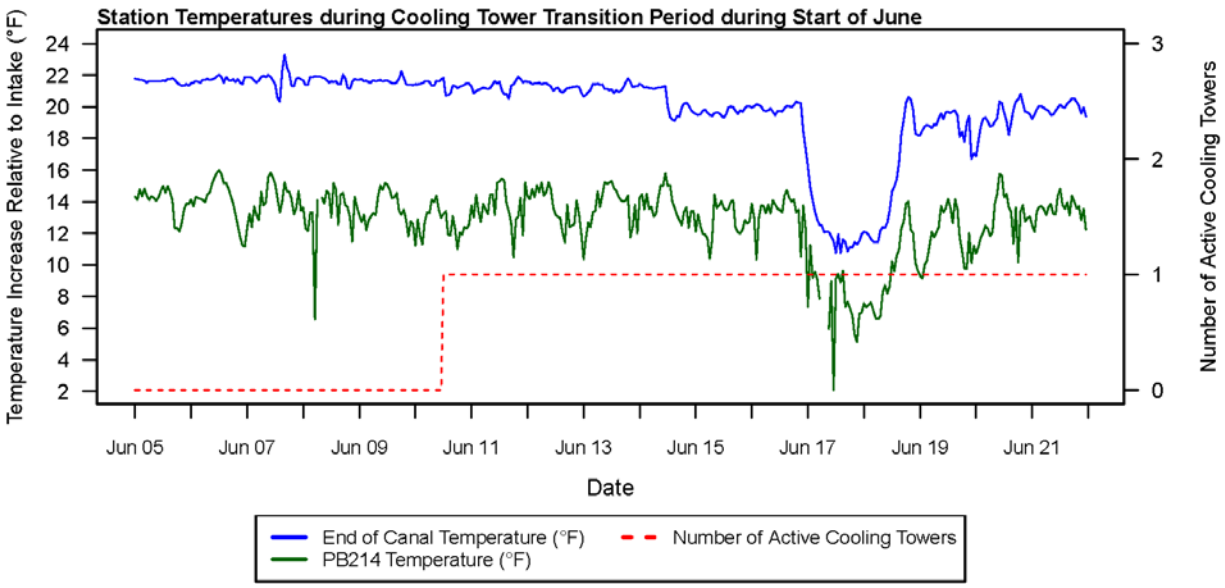


Figure 3-7 End of canal and 214 temperatures during startup of the first cooling tower.

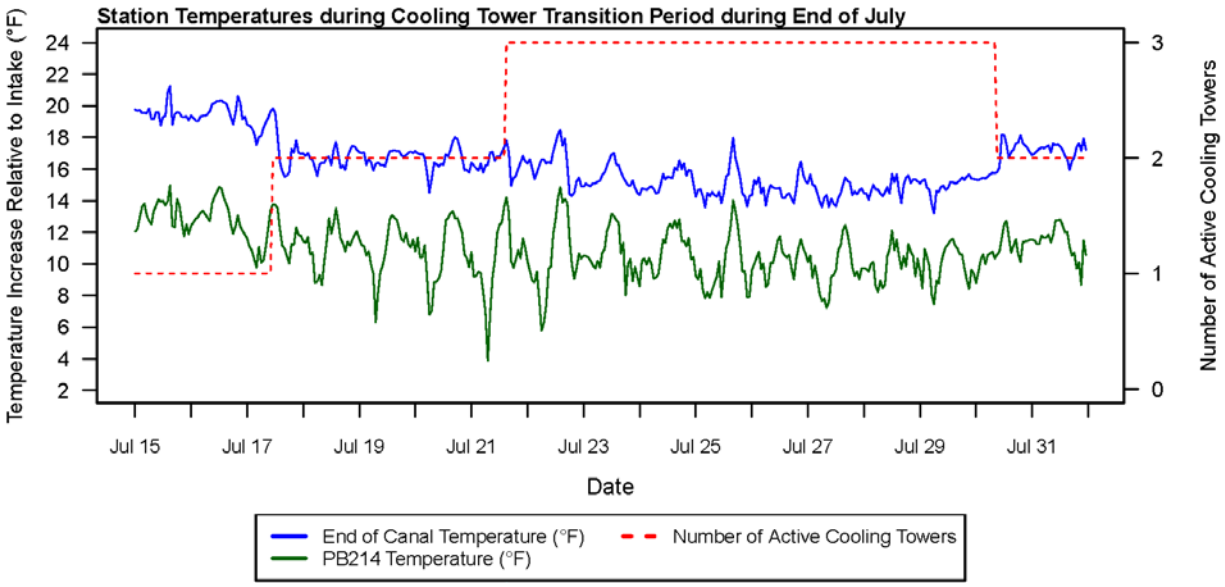


Figure 3-8 End of canal and 214 temperatures during the transitions from two to three to two cooling towers.

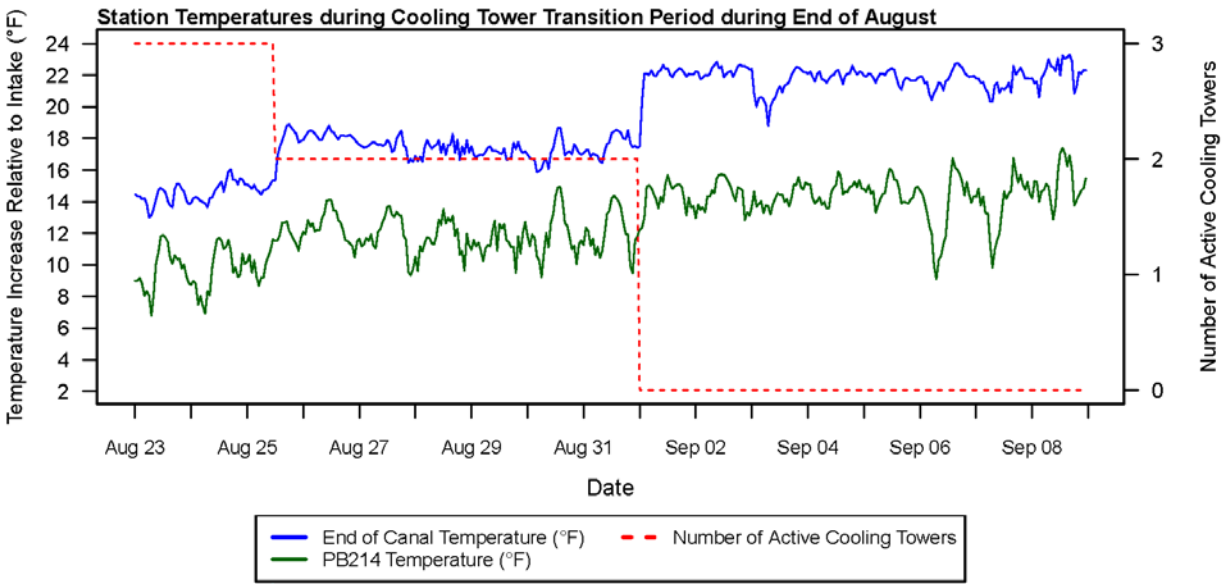


Figure 3-9 End of canal and 214 temperatures during shutdown of all three towers.

Table 3-7 End of canal and 214 daily average, minimum, and maximum temperatures relative to intake temperatures during startup of the first cooling tower.

Date	End of Canal Difference Relative to Intake (°F)			PB214 Difference Relative to Intake (°F)		
	Min	Mean	Max	Min	Mean	Max
6/5/2016	21.3	21.6	21.8	12.1	14.0	15.0
6/6/2016	21.4	21.7	22.0	11.2	14.1	16.0
6/7/2016	20.3	21.8	23.3	12.4	14.1	15.8
6/8/2016	21.1	21.7	22.0	6.6	13.4	15.2
6/9/2016	21.4	21.6	22.3	11.8	13.6	15.2
6/10/2016	20.7	21.4	21.8	11.0	12.6	14.4
One cooling tower starts up, one now running						
6/11/2016	20.5	21.3	21.9	10.5	13.7	15.5
6/12/2016	20.9	21.3	21.6	11.4	13.7	15.2
6/13/2016	20.6	21.2	21.8	10.4	13.7	15.3
6/14/2016	19.1	20.5	21.5	12.4	13.9	15.8
6/15/2016	19.3	19.7	20.0	10.4	12.8	14.5
6/16/2016	17.4	19.8	20.3	10.3	13.4	14.7
6/17/2016	10.8	12.2	16.2	2.1	7.7	11.3
6/18/2016	11.4	15.1	20.6	6.6	9.6	14.0
6/19/2016	16.7	18.8	19.8	9.1	11.8	14.2
6/20/2016	16.9	19.3	20.8	10.1	13.0	15.8
6/21/2016	19.2	19.9	20.5	12.1	13.5	14.8

Table 3-8 End of canal and 214 daily average, minimum, and maximum temperatures during transitions from two to three then back to two cooling towers in operation.

Date	End of Canal Difference Relative to Intake (°F)			PB214 Difference Relative to Intake (°F)		
	Min	Mean	Max	Min	Mean	Max
7/15/2016	18.8	19.5	21.2	11.7	13.2	15.0
7/16/2016	18.8	19.7	20.6	11.9	13.2	14.9
One cooling tower starts up, two now running						
7/17/2016	15.5	17.8	19.8	9.8	11.5	13.8
7/18/2016	15.6	16.7	17.7	8.7	11.2	13.5
7/19/2016	15.9	16.8	17.2	6.3	11.0	13.1
7/20/2016	14.5	16.6	18.0	6.8	10.7	13.3
7/21/2016	15.0	16.4	17.8	3.9	10.2	14.2
One cooling tower starts up, three now running						
7/22/2016	14.3	16.3	18.5	5.8	10.4	14.9
7/23/2016	14.5	15.5	17.0	8.0	10.7	13.2
7/24/2016	14.4	15.3	16.6	8.6	10.9	12.8
7/25/2016	13.6	14.9	18.0	7.8	9.8	14.0
7/26/2016	13.7	14.8	16.5	8.5	10.3	11.8
7/27/2016	13.6	14.5	15.6	7.2	9.7	12.5
7/28/2016	13.8	14.9	15.7	8.2	10.0	12.1
7/29/2016	13.2	15.0	15.7	7.5	9.9	11.6
One cooling tower shuts down, two now running						
7/30/2016	15.3	16.6	18.2	8.8	10.9	12.7
7/31/2016	15.9	17.2	17.9	8.7	11.4	12.8

Table 3-9 End of canal and 214 daily average, minimum, and maximum temperatures during shutdown of all three towers.

Date	End of Canal Difference Relative to Intake (°F)			PB214 Difference Relative to Intake (°F)		
	Min	Mean	Max	Min	Mean	Max
8/23/2016	13.0	14.3	15.1	6.8	9.7	11.9
8/24/2016	13.6	14.8	16.1	6.9	9.6	11.7
One cooling tower shuts down, two now running						
8/25/2016	14.5	16.4	18.9	8.7	10.9	12.8
8/26/2016	17.8	18.2	18.8	10.5	12.5	14.1
8/27/2016	16.5	17.5	18.5	9.3	12.0	13.7
8/28/2016	16.5	17.4	18.3	9.6	11.7	13.5
8/29/2016	16.7	17.2	17.8	9.5	11.5	12.8
8/30/2016	15.9	17.1	18.7	9.2	11.9	14.9
8/31/2016	16.4	17.6	18.5	9.5	12.1	14.4
Two cooling towers shut down, none now running						
9/1/2016	17.5	21.9	22.7	12.2	14.3	15.7
9/2/2016	21.8	22.3	22.9	12.8	14.4	15.7
9/3/2016	18.8	21.2	22.5	13.2	14.2	15.6
9/4/2016	21.4	22.0	22.6	13.6	14.7	15.9
9/5/2016	21.1	21.9	22.4	13.3	14.6	16.1
9/6/2016	20.4	21.8	22.8	9.1	13.6	16.7
9/7/2016	20.3	21.5	22.6	9.8	13.9	16.8
9/8/2016	20.6	22.2	23.3	12.9	15.1	17.4

Table 3-10 Travel time to reach the monitoring stations

Station	Incremental distance from the next upstream station (mi)	Average velocity from the next upstream station (ft/s)	Total travel time to reach the monitoring station (hours)
End of canal	0.37	-	-
214	0.28	1.39	0.4
215	0.67	0.78	0.9
189	0.37	0.33	3.9

Model Verification

Model verification was performed in two steps: (1) validation of model assumptions and (2) comparison of modeled and observed temperatures. There were two model assumptions that in combination quantify the amount of heat released to Conowingo Pond: (1) the post-EPU temperature rise from the intake to the head of canal and (2) the performance of the cooling towers.

For the post-EPU temperature rise, the model assumed a temperatures rise of 22.4°F from the PBAPS intake to the head of canal. The value of 22.4°F is the sum of the pre-EPU rise of 19.4°F and the post-EPU temperature increase of 3.0°F. The assumed pre-EPU rise of 19.4°F was based on the observed rise for all July's and August's from 2010 to 2013 (typically the warmest months). As shown in Table 3-5, the 2016 values of 22.1°F (entire summer) and 22.2°F (July and August) were measured. The mean post-EPU temperature rise from the intake to the head of the canal for July and August of 22.2°F is less than the 22.4°F assumed value, thus validating this model assumption.

The second model assumption is the extent to which temperatures in the discharge canal are reduced, both from natural cooling and from operation of the cooling towers. The model assumed natural cooling in the discharge canal (i.e., with no cooling towers operating) to be 0.2°F based on the 2010 – 2013 dataset. This same value was measured in 2016. For temperature reduction in the discharge canal, the model assumed 1.6°F for each cooling tower, a value also based on the 2010 – 2013 dataset. The observations showed that in 2016, the per tower discharge canal cooling was 2.2°F, greater than that assumed for the typical and extreme modeling scenarios and showing that the value assumed in the modeling was conservative.

For the comparisons of modeled and observed temperature increases at downstream stations, data for the four monitoring stations shown in Figure 3-10 were examined. These stations were identified in the Pre-EPU Demonstration Study as those which experienced the warmest temperatures, the clearest effects of cooling tower operations and the largest biological impacts. That the warmest temperatures occur at these monitoring stations is a consequence of the fact that the thermal plume generally follows along the western shore.

Figure 3-10 Monitoring stations used for the model verification.

There are hourly observations at each monitoring station for five months in the 2016 dataset available for comparison with the modeled results published in the Pre-EPU Demonstration Study. However the Pre-EPU Demonstration Study only predicts post-EPU temperatures for typical (10%) and extreme (1%) flow and temperature conditions (see Section 3.1 for definitions). Among the observations are relatively few instances where the combination of Susquehanna River flows and temperatures approach those used for the typical and extreme condition scenarios. To verify the model, therefore, it is sufficient to show that all observed temperature increases are no larger than the modeled results.

The 2016 observations are shown as the cumulative frequency of exceedance of temperature increases above ambient, expressed as a percentage of all observations in Figure 3-11, Figure

3-12, Figure 3-13, and Figure 3-14. Model results are shown as the blue band that is bounded at the top by modeled extreme temperature increases and at the bottom by modeled average temperature increases.

These figures show that nearly all of the observed temperature increases are below the modeled values (extreme conditions; right side of each panel). The exceptions are

- for Monitoring Station 214, 3 cooling towers in operation: 1 exceedence out of 456 observations (0.2%)
- for 215, no cooling towers: 5 exceedences out of 1696 observations (0.3%)
- for 215, 1 cooling tower: 1 exceedence out of 816 observations (0.1%)
- for 215, 3 cooling towers, 2 exceedences out of 448 observations (0.4%).

These exceedances do no impair the overall functionality of the model in bounding the modeled upper temperatures.

The figures show all the 2016 data, including observations at higher flows and lower temperatures than the flows and temperatures used in the model. These observations are shown on the left side of each panel and typically represent about 10% of the observations.

In the figures, the comparisons are shown by the number of cooling towers operating for each monitoring station. Temperatures decrease as more cooling towers are in operation, as expected, and decrease in the downstream direction, also as expected. The fact that observed temperature increases fall into or below the modeled values can be taken as evidence that the model results agree well with observed values.

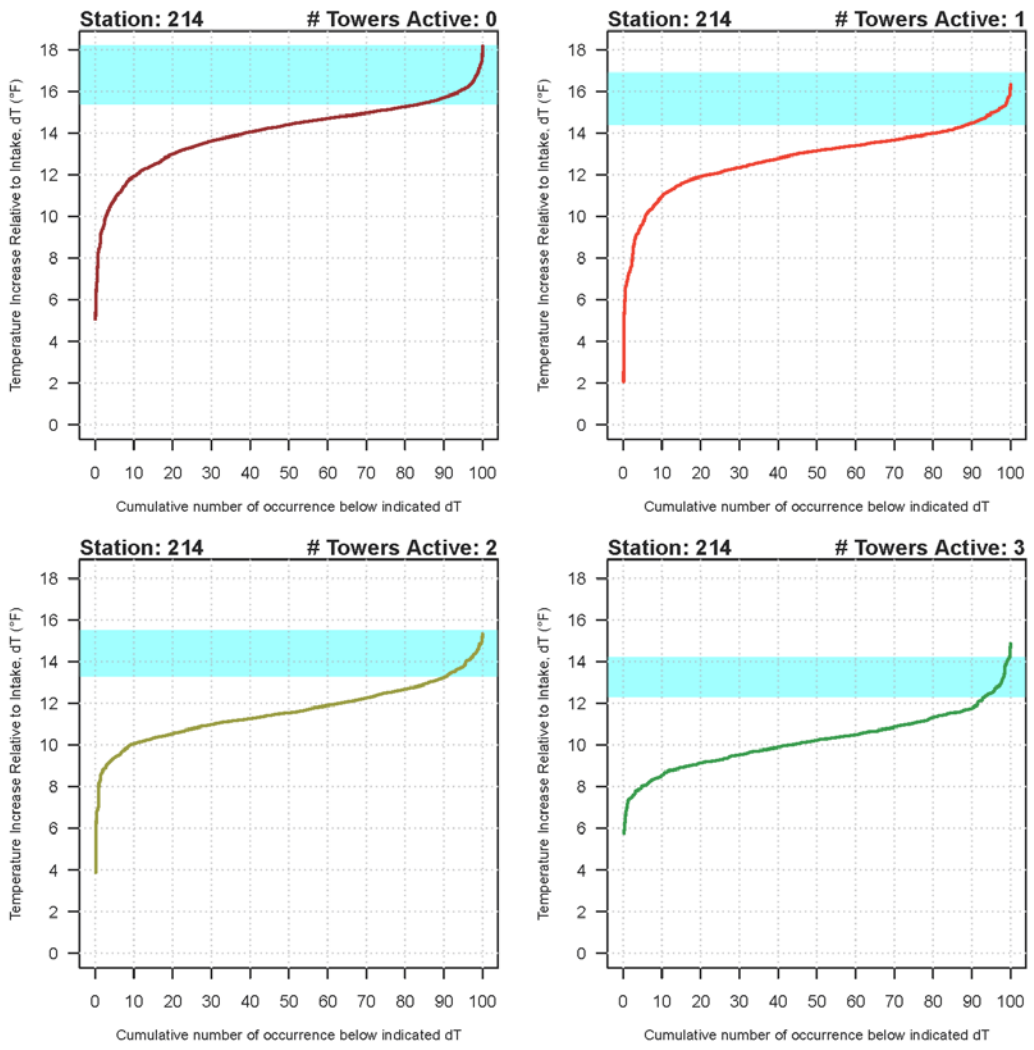


Figure 3-11 Comparisons of modeled and observed temperature increases at 214.

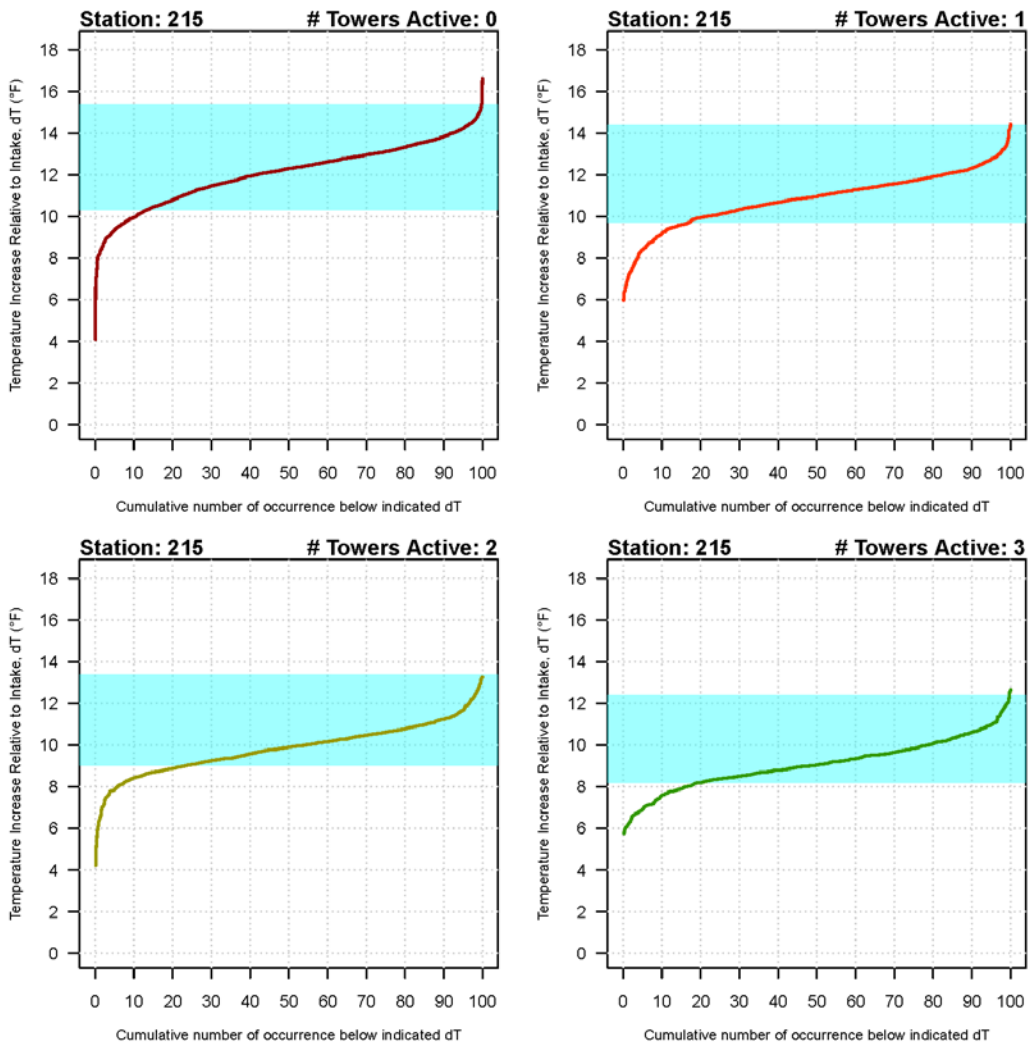


Figure 3-12 Comparisons of modeled and observed temperature increases at 215.

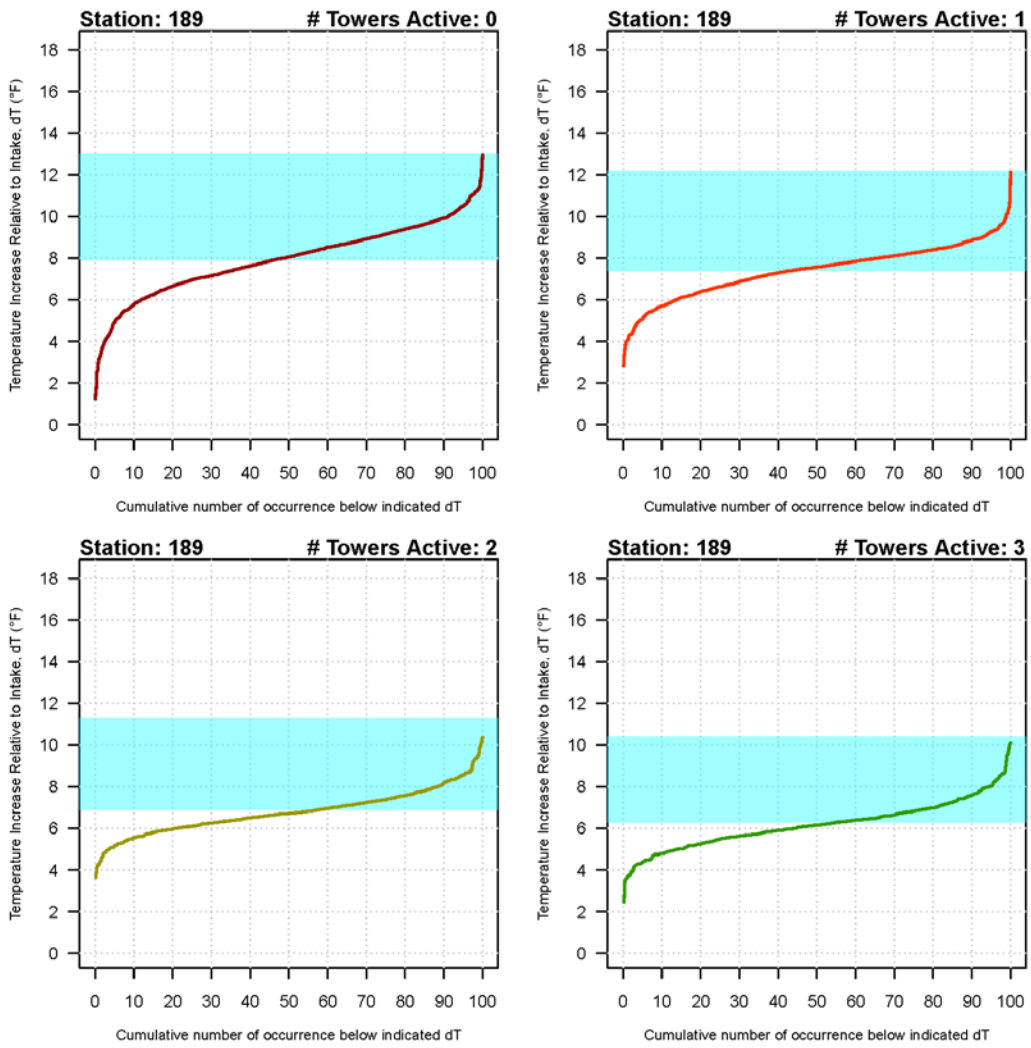


Figure 3-13 Comparisons of modeled and observed temperature increases at 189.

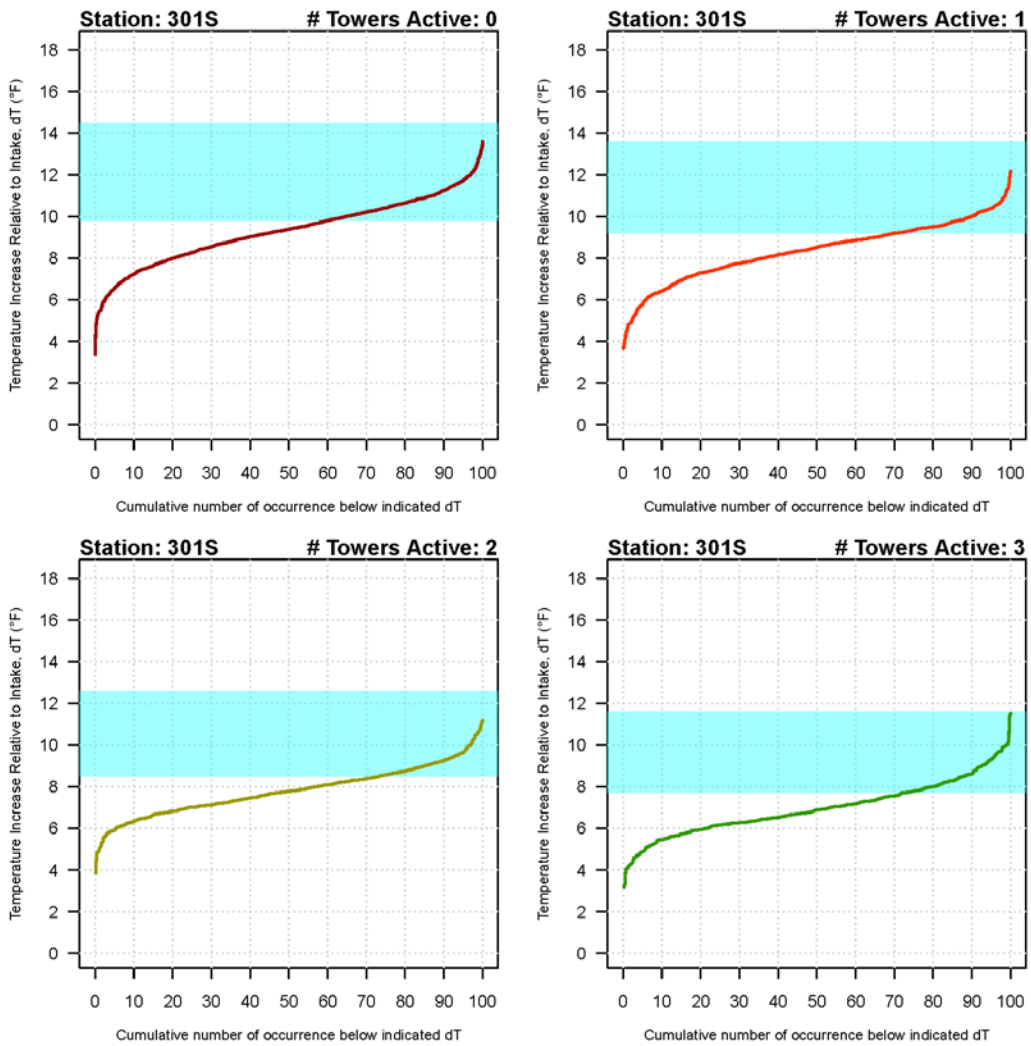


Figure 3-14 Comparisons of modeled and observed temperature increases at 301S.

3.2.3 Thermal Plume Monitoring Conclusions

The year 2016 featured Susquehanna River flows and temperatures that were at extreme values. For that reason, 2016 was ideally suited as the follow-on study year to the Pre-EPU Demonstration Study because extreme temperatures occurred and temperatures increases due to the EPU, temperature reductions when cooling towers operate, and resulting net temperature increases in Conowingo Pond could be directly measured.

The Pre-EPU Demonstration Study model assumptions were validated as each cooling tower provided more cooling than expected (2.2°F instead of 1.6°F) and the temperature increase from the intake to the head of canal was 22.1°F, less than the assumed post-EPU condenser temperature rise of 22.4°F. The observed temperatures at the warmest, most biologically sensitive monitoring stations were less than modeled temperatures for extreme conditions presented in the 316(a) Demonstration Study. The modeled temperatures had been used in the

Pre-EPU Demonstration Study as the basis for the biological assessment of post-EPU conditions and therefore, were sufficiently conservative.

The field observations show that operation of the cooling towers effectively mitigates the additional heat generated by the EPU during the summer period.

4 Biological Station Temperature Monitoring

The temperature record observed at the biological stations is critical to understanding the influence of the PBAPS thermal plume on the biological community. Continuous temperature monitoring was completed at all of the benthic macroinvertebrate and fish seining collection stations, and four of the six electrofishing stations (no monitoring at Stations 165 and 187) (Figure 4-1). Monitoring was performed *in situ* using Onset HOBO® Pro v2 Water Temperature Data Loggers. These instruments are accurate to 0.36°F in the range 32°F to 122°F and have a five-minute response time in water. The loggers recorded water temperature every hour and were located on the river bottom in shallow shoreline locations (<5 ft water depth) where complete mixing of the water column occurs.

This analysis characterizes the biological water temperature monitoring stations. Monitoring locations are divided into those stations that are not influenced by the thermal plume (208, 221, PBAPS Intake) and those stations that are thermally influenced (214, 215, 189, 190, 216, and 217). The PBAPS Intake monitor was installed specifically for this study and is used as an ambient temperature reference. Note that although Station 208 is located along the east shoreline of the Pond and upstream from the end of the discharge canal, it does experience an increase in water temperature resulting from the PBAPS thermal discharge at low river flows during the summer months. This phenomenon is coincident with River flows less than 12,000 cfs and MRPSF pumpback operations (Normandeau and Gomez and Sullivan Engineers 2012). Thermally affected electrofishing Station 161 is characterized by the monitoring at Station 214 (a seine and benthos station). Thus, a separate water temperature monitor was not installed at Station 161.

The analysis provided herein includes post-EPU biological water temperature monitoring in 2016 and pre-EPU biological water temperature monitoring from 2010 through 2013. Comparison of water temperature observations at these locations is completed to identify differences in the duration and frequency of elevated water temperatures during each year of monitoring.

Ambient water temperatures measured in Conowingo Pond over the course of the 2016 study period (May 1 to September 30) followed a typical seasonal pattern for the Susquehanna River for most of the monitoring period with warmest temperatures observed during July and August (Figure 4-2) Water temperature during mid-August through September was elevated from the typical seasonal pattern with extraordinarily warm and dry and conditions during September.

Figure 4-2 through Figure 4-19 provide daily mean and daily instantaneous maximum water temperatures for each monitoring location during each year. The highest water temperatures at the biological monitoring stations were observed in July and August at Station 214, which is located along the west shoreline and is the monitoring station closest to the end of the PBAPS discharge canal (Figures 4-4 and 4-13). Water temperatures decreased in a downstream direction at monitoring locations farther downstream from the end of the discharge canal. The lowest ambient water temperatures were observed at Station 221, which is located upstream from the PBAPS intake along the east shoreline (Figure 4-3). Station 221 is located at the

confluence of Fishing Creek with Conowingo Pond. This monitoring location is strongly influenced by Fishing Creek. During periods of low pond elevation (MRPST pumpback or Conowingo Hydroelectric Station generation), this monitor essentially measured Fishing Creek water temperature.

Ambient water temperatures in 2016 were much warmer than previous years from mid-August through the end of September (Figure 4-3). The mean water temperature measured in September 2016 at the PBAPS intake was 5 °F warmer than the highest average termperature measured previously in September at the intake (Table 4-1).

Table 4-2 through Table 4-6 provide a summary of the of the number of exceedances (days) of both 80 and 90 °F threshholds for instantaneous maximum and mean daily water temperatures for the monitoring locations during each year of the study. The basis for these two water temperature values is that 80°F corresponds to a normal summer condition and 90°F corresponds to a temperature that does not typically occur under natural conditions in the Pond. The purpose is to provide a comparison of these two temperature points among the monitoring stations.

In 2016, water temperatures were warmer than previous years, with a greater number of days that the ambient water temperatures exceeded 80°F as instantaneous maximum or daily mean (Table 4-2). Similarly, the thermally influenced stations in 2016 had a greater number of days exceeding 90°F as instantaneous or daily mean compared to previous years. Overall, the monitoring data indicate that the warmest water temperatures were observed during a greater number of days in 2016 for all locations, compared to the other years. However, the water temperatures observed in 2010 were also high but the monitoring period was abbreviated (not initiated until July 28) and not directly comparable to other years in terms of absolute number of days exceeding 80 or 90°F.

As noted above, the highest water temperatures were observed to occur in July and August in 2010 through 2013 and July through September in 2016. Therefore, analyses of potential thermal effects on benthic macroinvertebrates and fish will focus on these months. However, the cumulative effects of elevated temperatures during the course of the year will also be considered. These types of cumulative effects, as opposed to just the highest temperatures in July, August, and September may potentially alter the aquatic assemblage, in particular, at the near-field stations (Stations 161, 214 and 215). Cumulative effects of elevated water temperatures will be evaluated for fish by documenting body condition, disease occurrence, length/age structure, and retrospective analysis of relative abundance. In addition, cumulative effects will be evaluated in comparisons of fish and benthic macroinvertebrate community composition (e.g. species richness, and diversity) between thermally influenced and non-thermally influenced collection locations.

The final data set was compiled into an Excel spreadsheet and the raw water temperature data and a list of collected daily average, minimum and maximum water temperatures was provided to PADEP in electronic format.

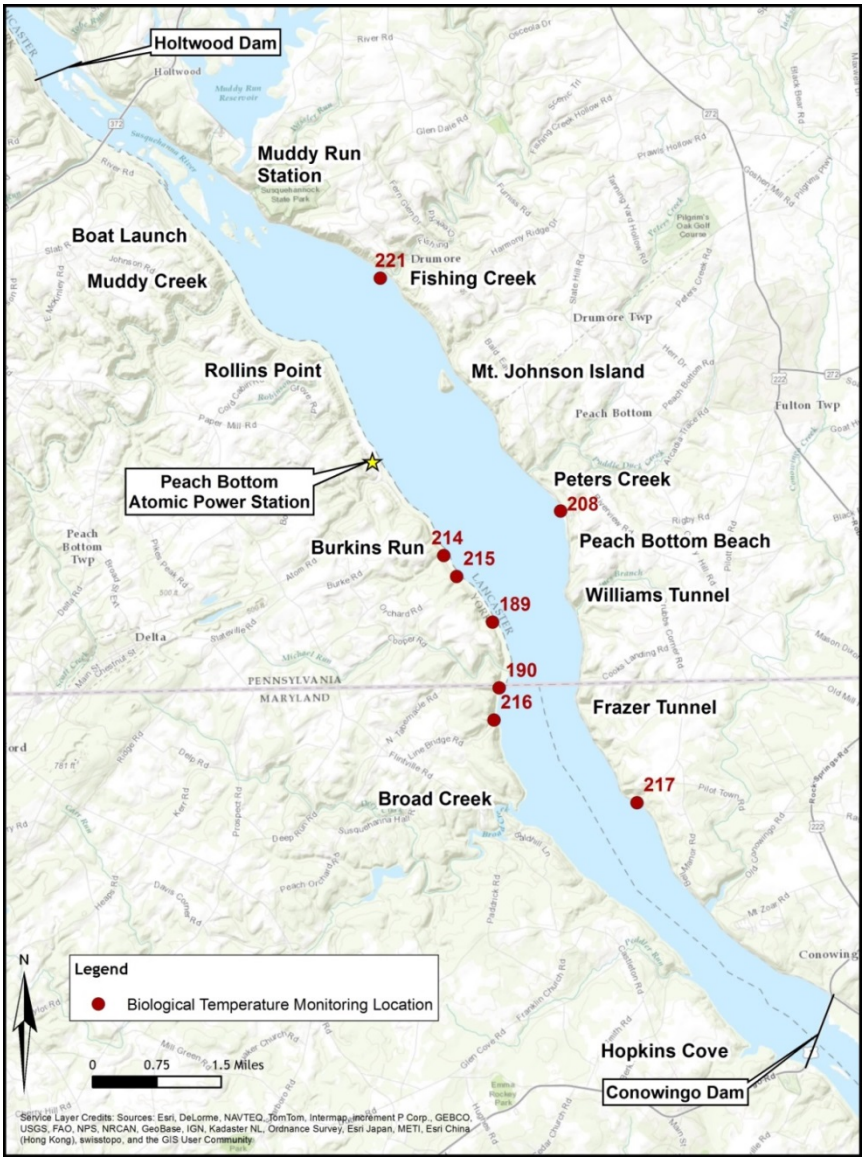


Figure 4-1. Location of biological water temperature collection stations.

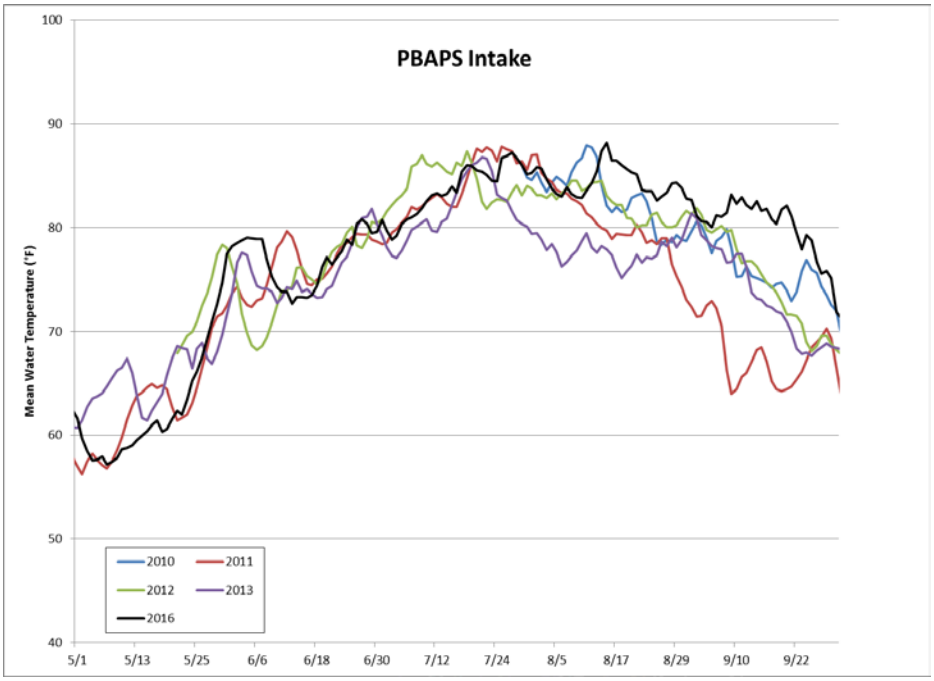


Figure 4-2. Daily mean water temperature measured at PBAPS Intake, 2010-2016.

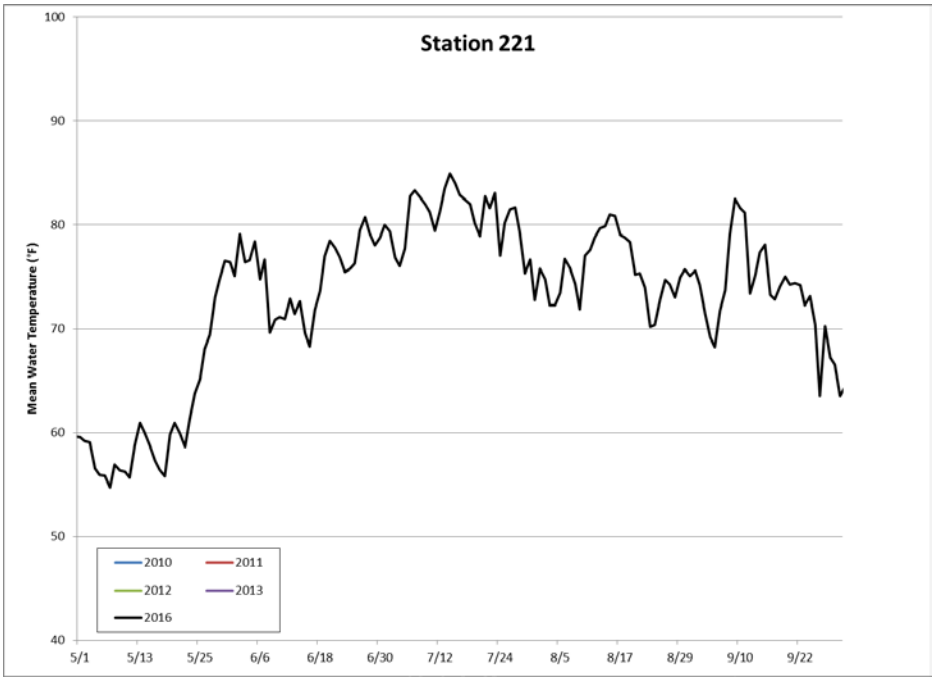


Figure 4-3. Daily mean water temperature measured at Station 221 in 2016.

Note: no monitoring occurred during 2010-2013 at this location; location added for 2016 monitoring

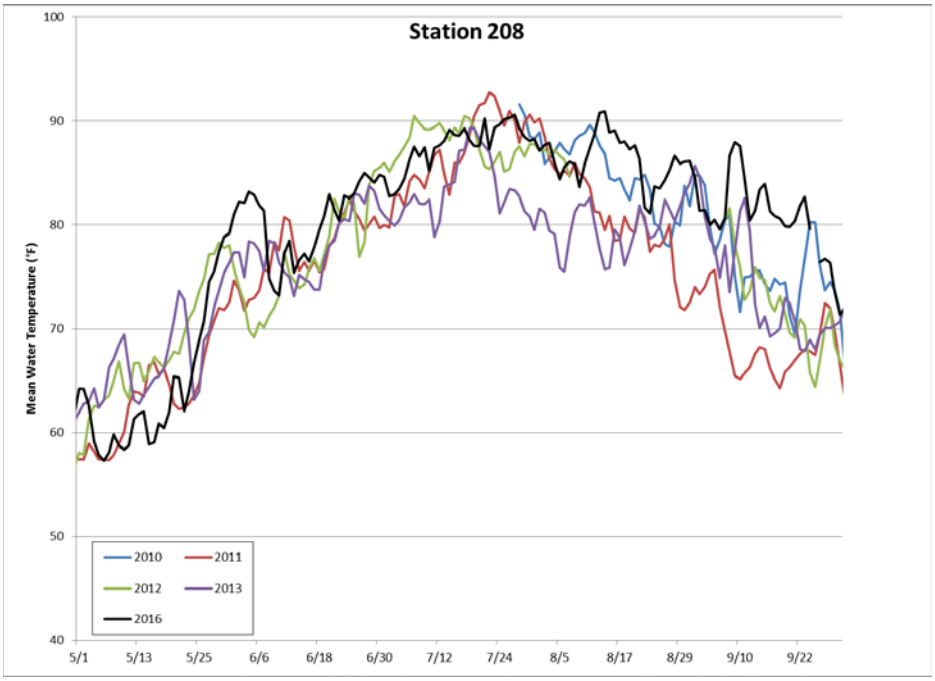


Figure 4-4. Daily mean water temperature measured at Station 208, 2010-2016.

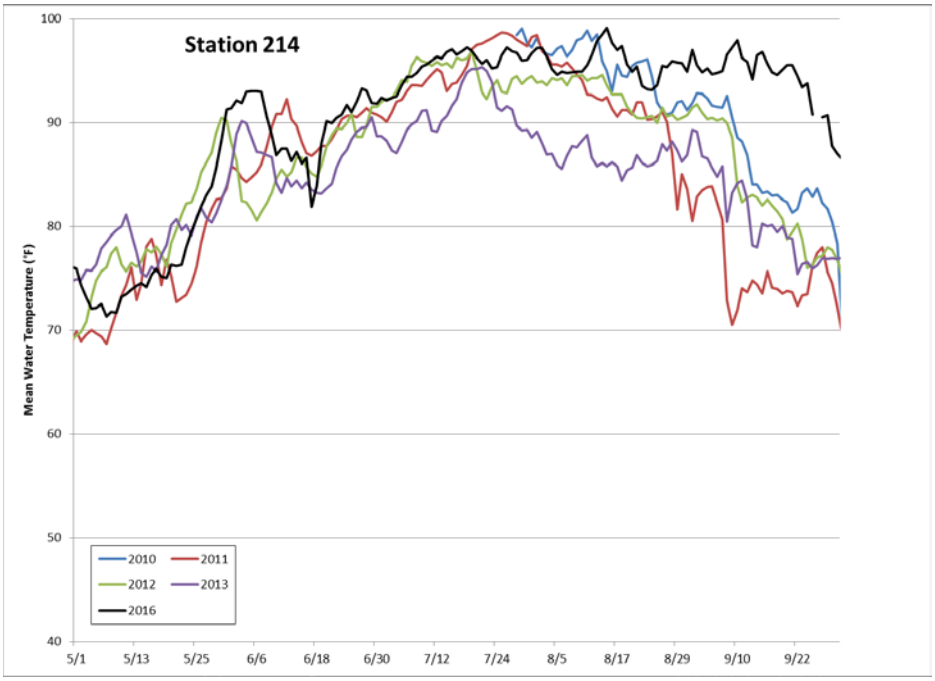


Figure 4-5. Daily mean water temperature measured at Station 214, 2010-2016.

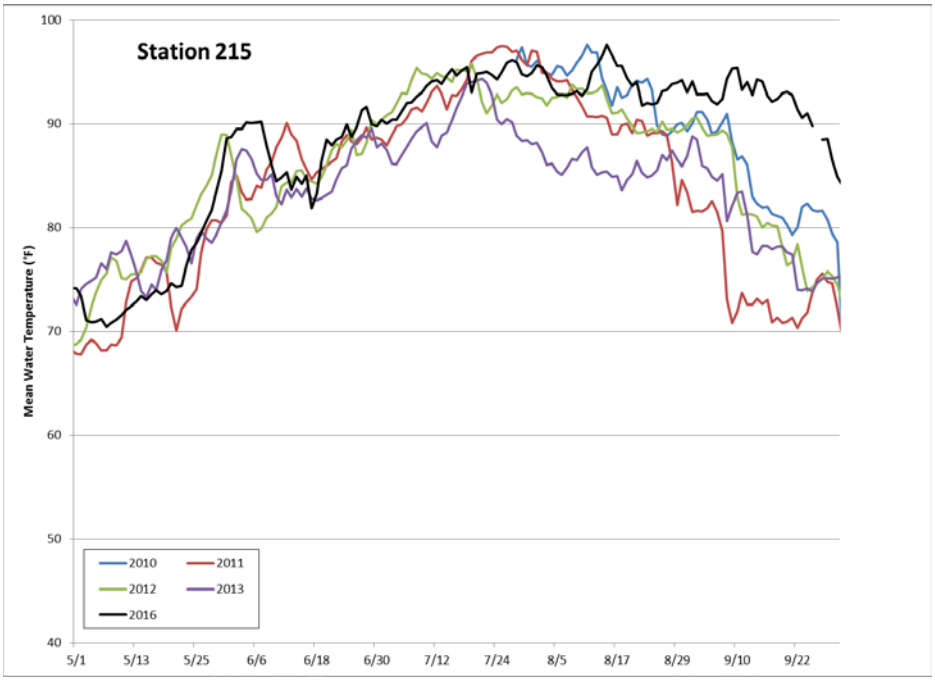


Figure 4-6. Daily mean water temperature measured at Station 215, 2010-2016.

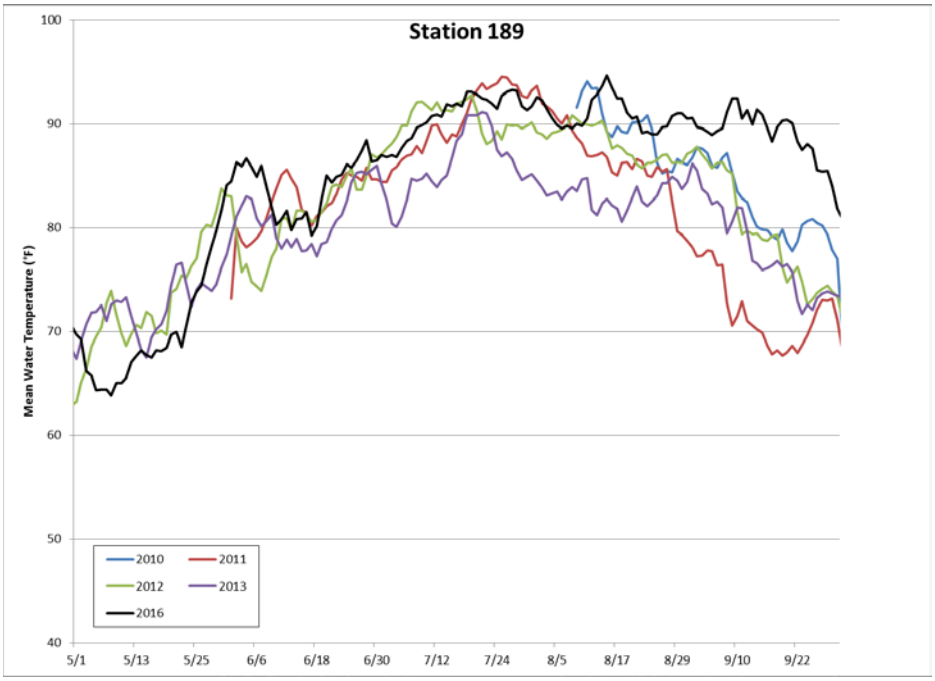


Figure 4-7. Daily mean water temperature measured at Station 189, 2010-2016.

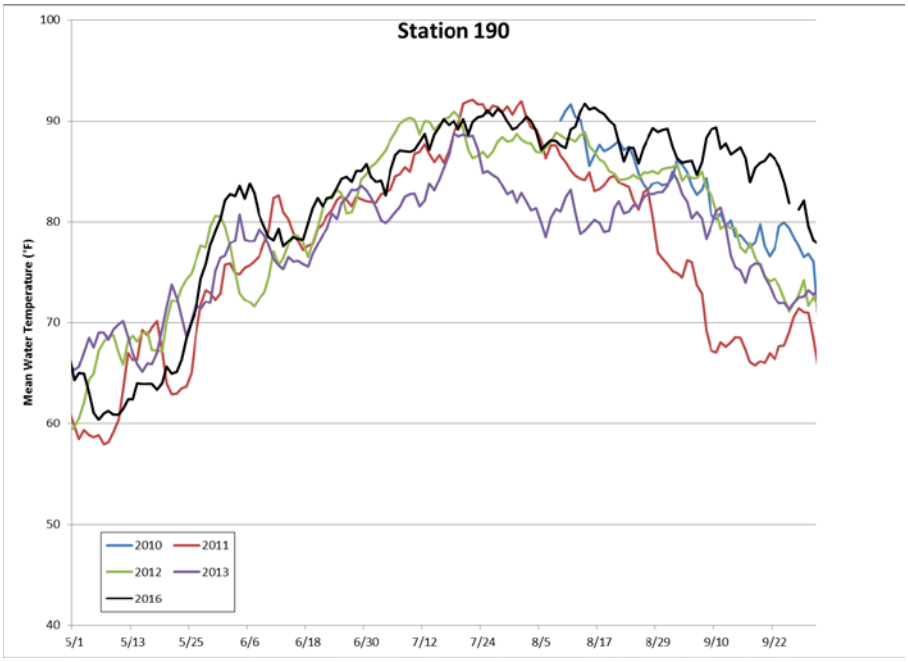


Figure 4-8. Daily mean water temperature measured at Station 190, 2010-2016.

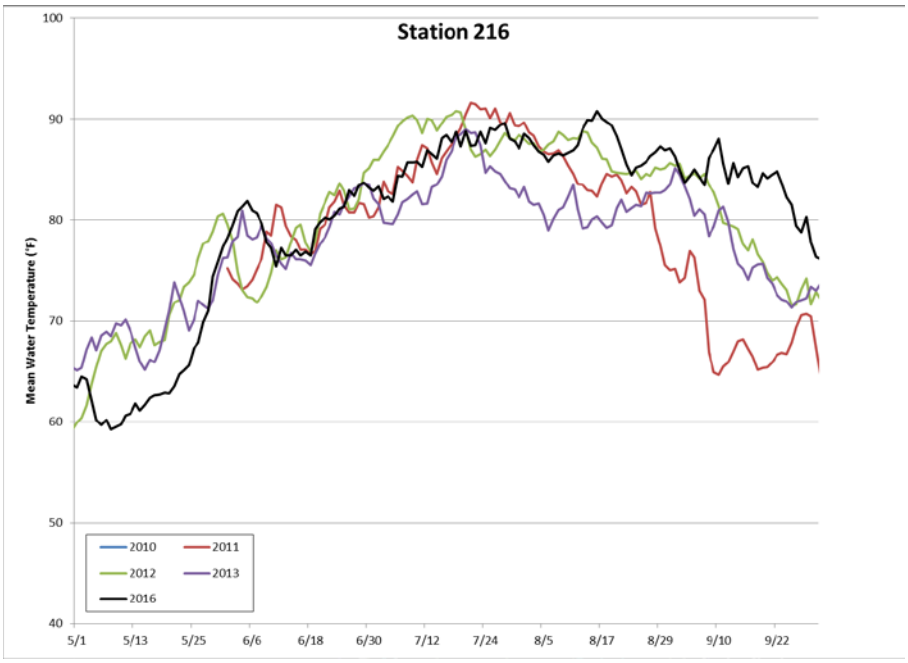


Figure 4-9. Daily mean water temperature measured at Station 216, 2010-2016.

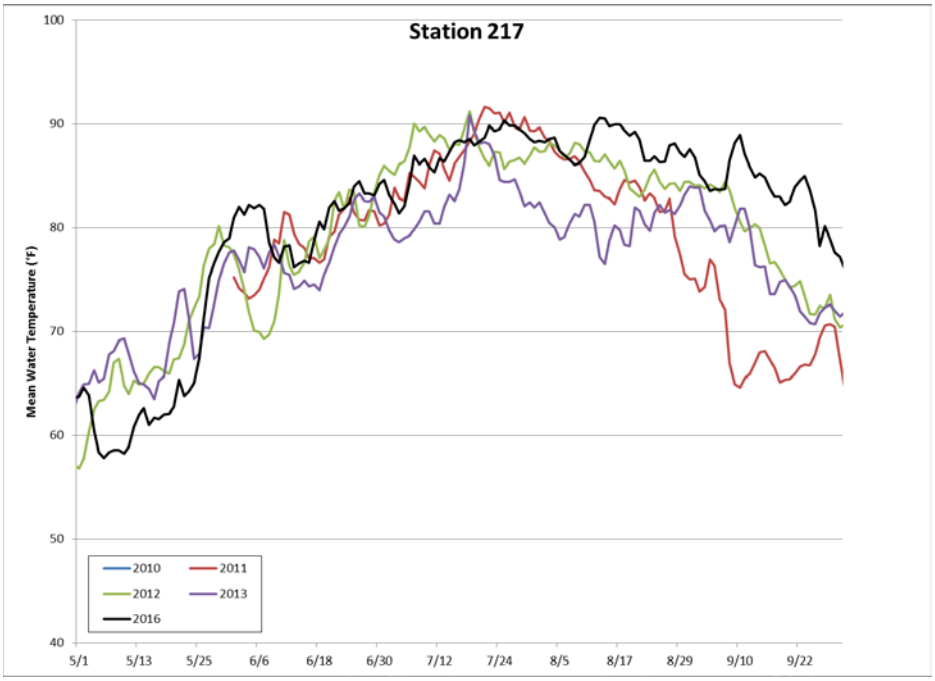


Figure 4-10. Daily mean water temperature measured at Station 217, 2010-2016.

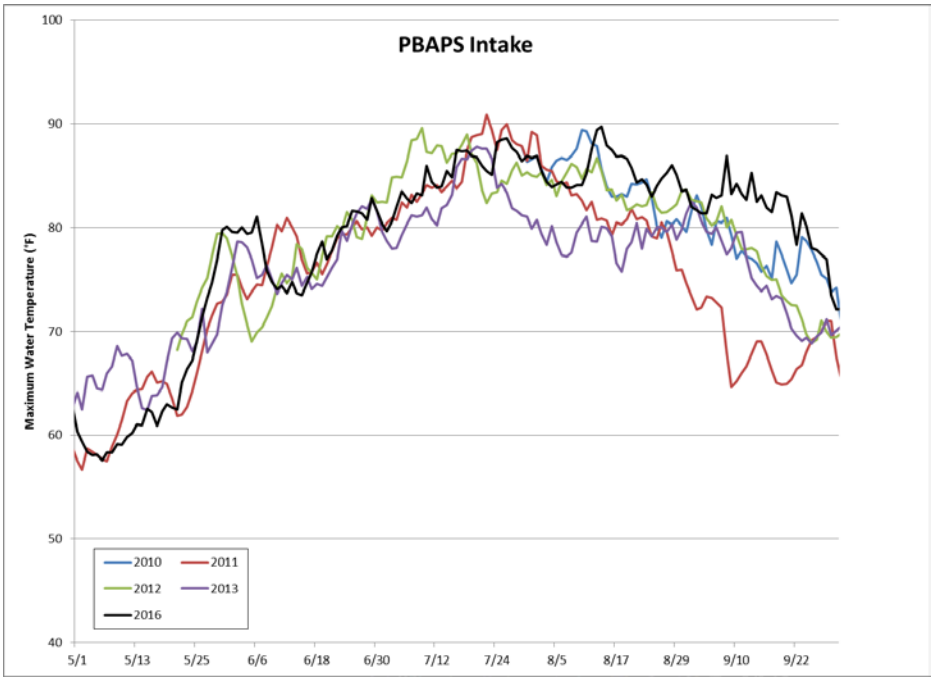


Figure 4-11. Daily maximum instantaneous water temperature measured at PBAPS Intake, 2010-2016.

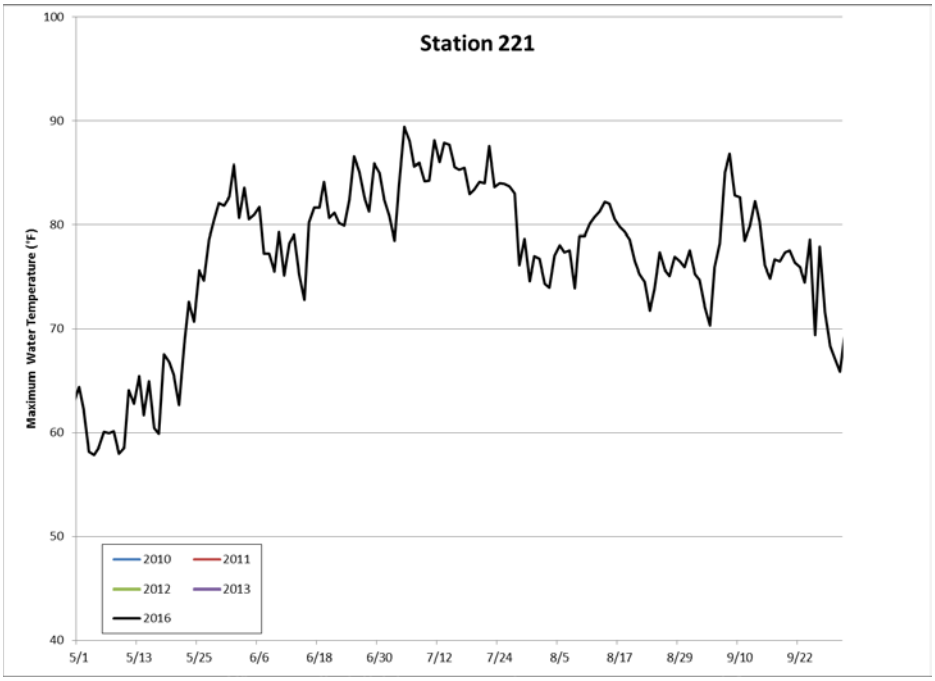


Figure 4-12. Daily maximum instantaneous water temperature measured at Station 221 in 2016.

No monitoring occurred during 2010-2013 at this location; location added for 2016 monitoring

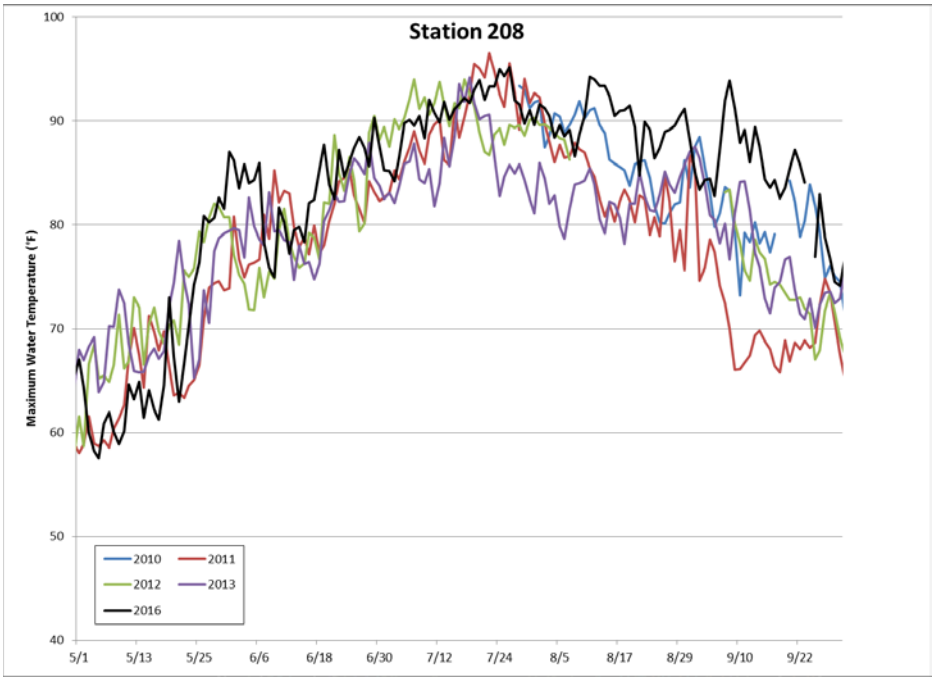


Figure 4-13. Daily maximum instantaneous water temperature measured at Station 208, 2010-2016.

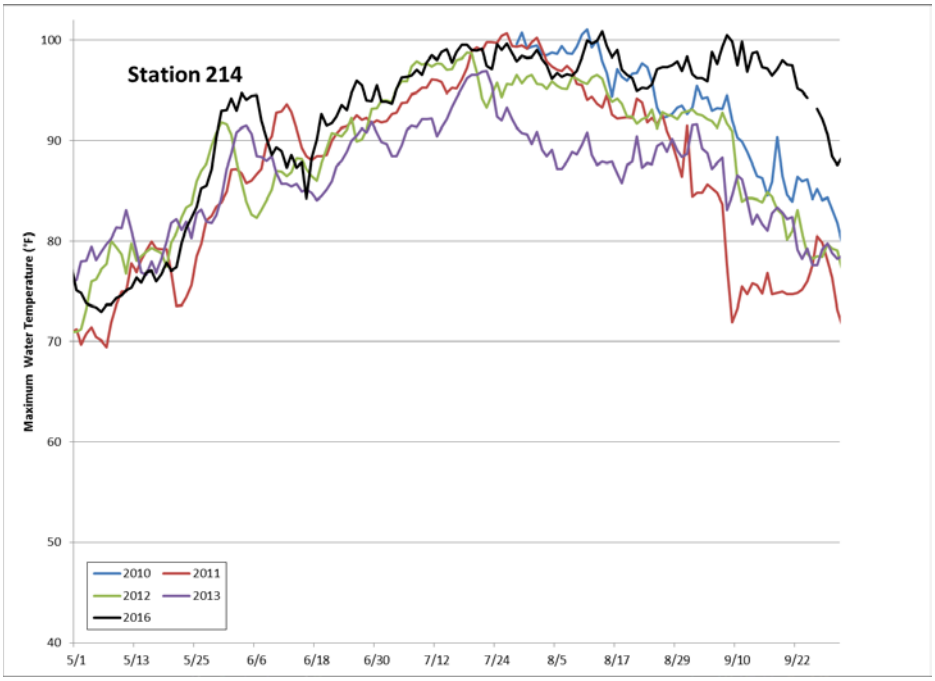


Figure 4-14. Daily maximum instantaneous water temperature measured at Station 214, 2010-2016.

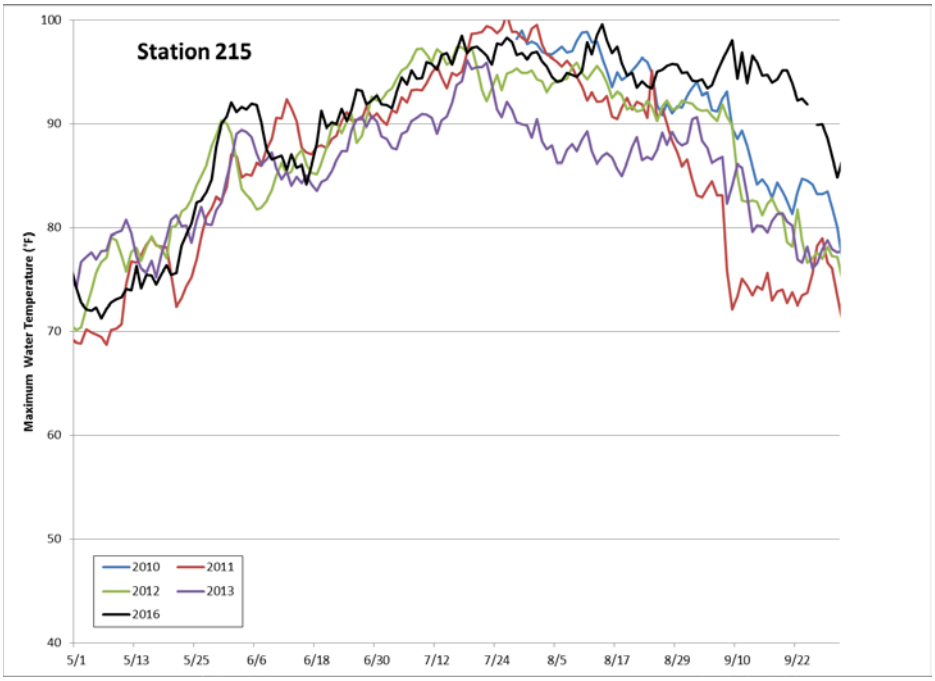


Figure 4-15. Daily maximum instantaneous water temperature measured at Station 215, 2010-2016.

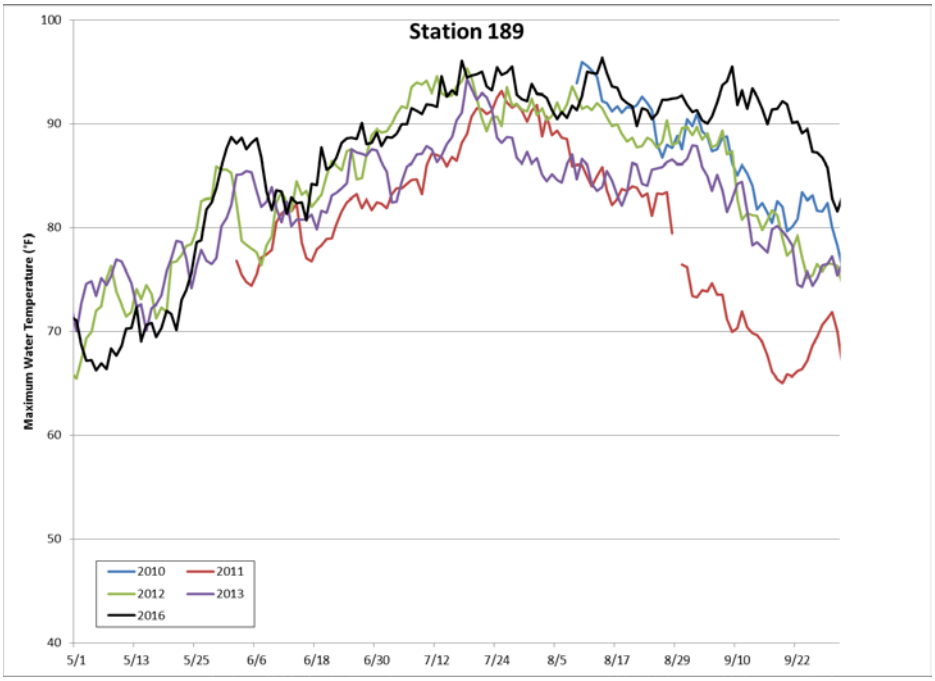


Figure 4-16. Daily maximum instantaneous water temperature measured at Station 189, 2010-2016.

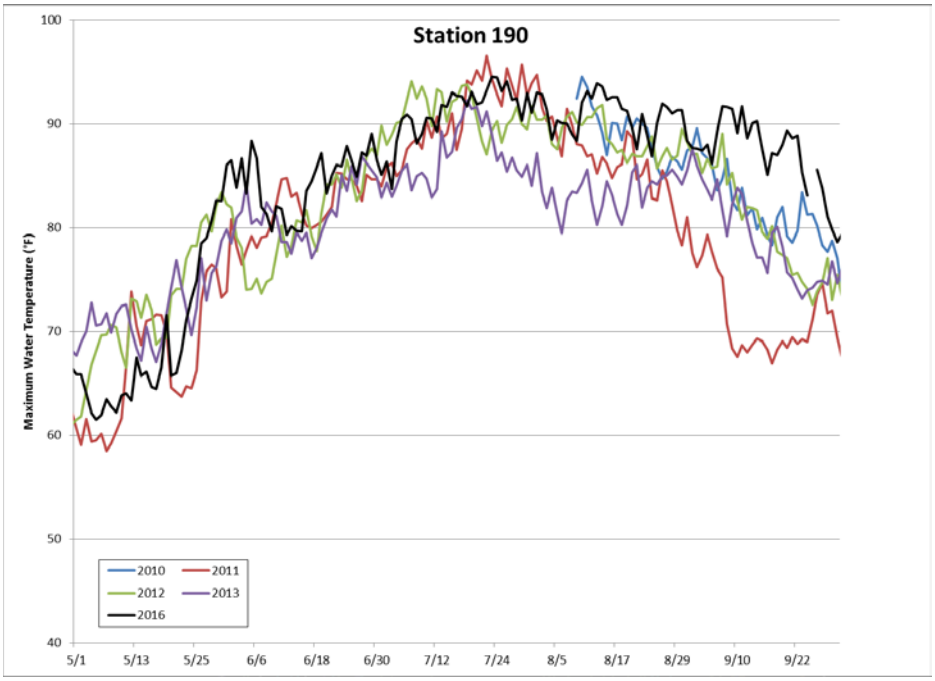


Figure 4-17. Daily maximum instantaneous water temperature measured at Station 190, 2010-2016.

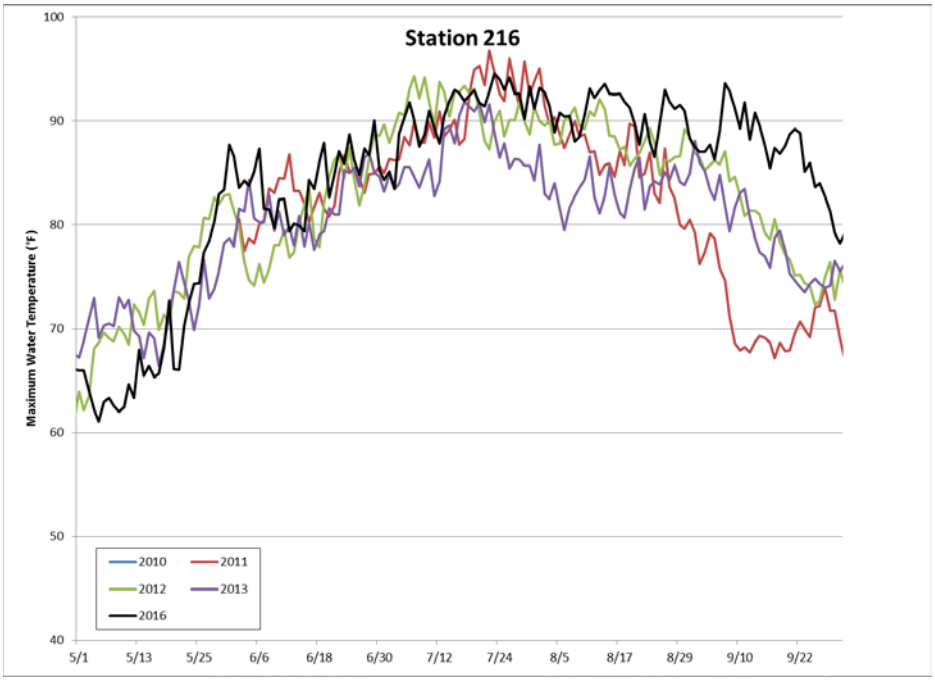


Figure 4-18. Daily maximum instantaneous water temperature measured at Station 216, 2010-2016.

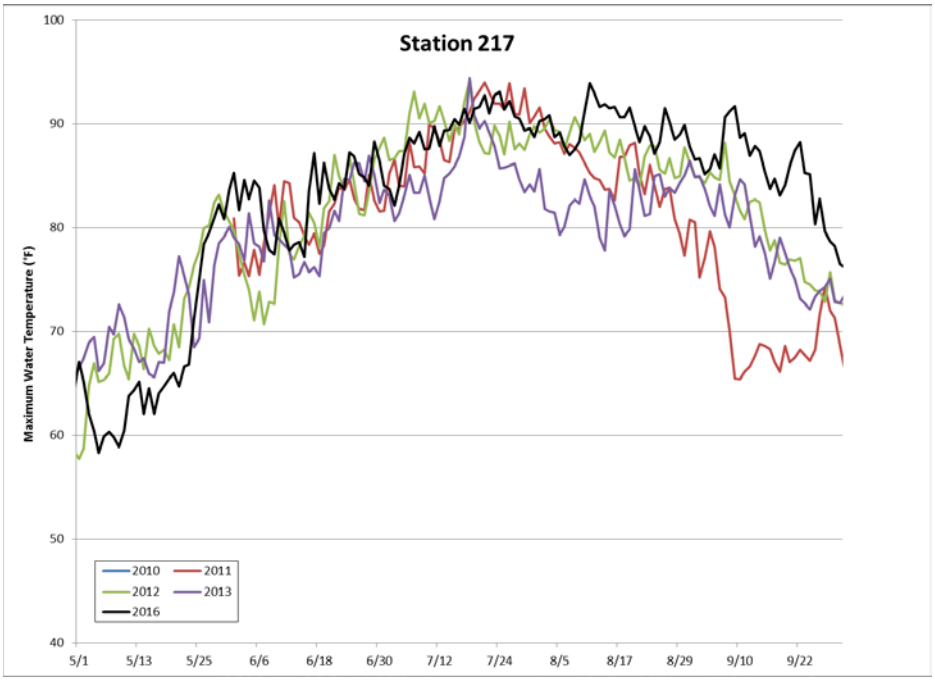


Figure 4-19. Daily maximum instantaneous water temperature measured at Station 217, 2010-2016.

Table 4-1. Monthly mean water temperature measured at the biological monitoring locations and PBAPS intake, May through September, 2010-2013, and 2016.

2010	214	215	189	190	216	217	221	Intake	208
May	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Jun	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Jul	98.0	96.2	N/A	N/A	N/A	N/A	N/A	85.4	89.2
Aug	95.3	93.5	89.3	86.9	N/A	N/A	N/A	82.8	84.8
Sep	85.9	84.3	82.0	80.1	N/A	N/A	N/A	75.2	76.4
2011	214	215	189	190	216	217	221	Intake	208
May	74.8	73.6	N/A	64.9	N/A	N/A	N/A	63.0	63.5
Jun	88.5	86.6	82.2	79.1	79.4	78.3	N/A	76.6	77.4
Jul	95.2	93.7	90.2	87.8	88.0	87.2	N/A	83.9	87.0
Aug	91.9	90.5	86.8	84.3	84.5	83.7	N/A	80.5	81.0
Sep	76.0	74.6	72.0	69.6	69.7	68.8	N/A	68.2	68.8
2012	214	215	189	190	216	217	221	Intake	208
May	79.0	78.0	73.0	70.0	70.0	68.0	N/A	72.9	67.9
Jun	86.3	85.0	80.9	78.0	78.3	77.4	N/A	75.1	76.6
Jul	94.5	93.4	90.3	88.4	88.5	87.6	N/A	84.0	87.8
Aug	92.5	91.3	88.2	86.4	86.5	85.8	N/A	82.4	86.6
Sep	83.1	81.4	79.5	78.2	78.3	77.9	N/A	75.1	72.1
2013	214	215	189	190	216	217	221	Intake	208
May	78.4	76.8	72.1	69.0	69.0	68.1	N/A	65.2	66.7
Jun	86.3	85.0	80.7	78.5	78.5	77.8	N/A	75.5	77.8
Jul	91.0	89.9	86.0	83.9	84.0	83.2	N/A	81.5	83.3
Aug	86.8	86.0	83.2	81.1	81.2	80.6	N/A	77.6	79.6
Sep	81.1	80.0	78.1	77.1	77.2	76.8	N/A	73.9	74.3
2016	214	215	189	190	216	217	221	Intake	208
May	76.8	75.2	69.9	66.2	66.2	64.6	61.3	62.5	64.3
Jun	89.8	87.7	84.0	81.6	81.6	80.6	75.1	76.9	80.4
Jul	95.6	93.8	90.8	88.3	88.3	87.1	80.4	83.6	87.6
Aug	95.7	94.0	91.0	88.9	89.0	88.0	75.6	84.4	86.4
Sep	94.4	92.1	89.0	85.4	85.4	83.6	73.3	80.1	80.9

Table 4-2. Summary of instantaneous maximum and daily mean water temperature data for multiple locations within Conowingo Pond in 2016.

	Number of Days Exceeding			
	Instantaneous Maximum Temperature		Mean Temperature	
Station	>80°F	>90°F	>80°F	>90°F
221 [a]	62	0	25	0
PBAPS Intake	95	0	83	0
208	115	40	101	6
214	132	113	131	108
215	131	105	129	92
189	129	77	125	53
190	119	53	110	17
216	120	51	111	17
217	114	31	107	3

[a] station was not monitored previously

Table 4-3. Summary of instantaneous maximum and daily mean water temperature data for multiple locations within Conowingo Pond in 2010.

	Number of Days Exceeding			
	Instantaneous Maximum Temperature		Mean Temperature	
Station	>80°F	>90°F	>80°F	>90°F
220	34	0	28	0
PBAPS Intake	38	0	29	0
208	50	14	38	2
214	65	46	64	44
215	65	43	62	34
189	51	18	42	10
190	43	10	35	5
216	*	*	*	*
217	*	*	*	*

*stations not monitored in 2010

Table 4-4. Summary of instantaneous maximum and daily mean water temperature data for multiple locations within Conowingo Pond in 2011.

	Number of Days Exceeding			
	Instantaneous Maximum Temperature		Mean Temperature	
Station	>80°F	>90°F	>80°F	>90°F
220	55	3	38	0
PBAPS Intake	60	1	41	0
208	75	17	56	10
214	105	74	104	70
215	104	70	102	45
189	96	32	82	21
190	82	22	72	14
216	87	20	72	15
217	80	16	69	8

Table 4-5. Summary of instantaneous maximum and mean water temperature data for multiple locations within Conowingo Pond in 2012.

	Number of Days Exceeding			
	Instantaneous Maximum Temperature		Mean Temperature	
Station	>80°F	>90°F	>80°F	>90°F
220	76	0	55	0
PBAPS Intake	77	0	69	0
208	58	18	48	3
214	127	84	122	73
215	124	78	117	54
189	108	43	97	19
190	99	30	84	8
216	99	30	85	7
217	96	14	84	1

No data recovered for Station 208 from 8/8/12 to 9/6/12

Table 4-6. Summary of instantaneous maximum and mean water temperature data for multiple locations within Conowingo Pond in 2013.

	Number of Days Exceeding			
	Instantaneous Maximum Temperature		Mean Temperature	
Station	>80°F	>90°F	>80°F	>90°F
220	43	0	25	0
PBAPS Intake	45	0	29	0
208	82	7	57	0
214	133	40	117	20
215	124	28	106	13
189	106	8	89	5
190	93	5	71	0
216	93	6	71	0
217	82	3	63	1

5 Dissolved Oxygen Monitoring

Introduction

Aquatic life in Pennsylvania freshwater waterbodies is protected by dissolved oxygen (DO) criteria, which are found in PA Code Chapter 93.7. The criteria were established to protect aquatic organism from adverse impacts associated with low DO. For warmwater fisheries (WWF) the PA Code criteria for concentration of DO are a minimum 7-day average of 5.5 mg/L and instantaneous minimum of 5.0 mg/L. These criteria were developed to be protective of the entire aquatic community, in particular, all life stages of warmwater fish. The criteria specifically are protective of early life stages of fish, such as embryonic and larval stages, which are generally more sensitive to low DO concentrations than adult life stages (PADEP 2016).

Methods

Dissolved oxygen monitoring was conducted in shallow shoreline areas along the west shoreline downstream of the PBAPS discharge canal at Stations 215 and 189 and upstream of the PBAPS discharge canal on the east shoreline at Station 208 (Figure 5-1). Monitoring was completed June 1 through September 30, 2016. A HACH HL4 Sonde with luminescent dissolved oxygen (LDO) sensor was used to record hourly DO concentrations. The accuracy of this instrument is ±0.1 mg/L for DO between 0 and 8 mg/L and ±0.2 mg/L for DO more than 8 mg/L. This monitoring period was selected to focus on the typical seasonal periods of low-flow and high water temperature that occur in Conowingo Pond which could result in low DO concentrations. Monitoring at Station 208 was completed to determine whether sufficient DO concentrations were present in waters typically outside of the thermal plume. The objective of this monitoring was to determine if there are periods when there is a low DO barrier spanning the width of the pond during low flows, high water temperatures, and upstream migration of the thermal plume due to MRPSF pumping. These areas are thought to be important to provide a refuge or zone of passage for resident and migratory fish migrating upstream or downstream past the PBAPS.

A single monitoring device was installed toward the bottom of the water column at each monitoring location. Monitors were installed in water with depth less than 10 ft with the intent of monitoring to be near the bottom of the water column. Each monitor was attached to a buoy which was attached by cable to an anchor. Challenges associated with fluctuations in Conowingo Pond water elevation (range between 105 and 109 ft during monitoring period at the Conowingo Dam forebay) occurred during the monitoring period. During several different occasions at low Pond elevation the LDO sensor contacted the bottom which resulted in the sensor being covered in sediment or touching the bottom substrate, and provided erroneous DO data. The hourly DO data sets were reviewed for the entire monitoring period in relation to hourly Conowingo Pond elevation in order to determine whether DO data was representative of actual DO at each monitoring location and obvious erroneous data were removed from the final data set before analysis was completed. In addition, the Sonde deployed at Station 208 malfunctioned and was removed for repair from August 23 to 29.

The final data set was compiled into an Excel spreadsheet and the raw DO data and the revised data set along with a list of collected daily mean, minimum, and maximum dissolved oxygen concentrations was provided to PADEP in electronic format. This data set also included hourly Conowingo Pond water surface elevation data measured at the Conowingo Dam forebay.

Results

The number of valid hourly DO measurements varied among the three stations: Station 208: 2,338; Station 215: 2,500, and Station 189: 2,537 (Table 5-1). The total number of days that the daily mean DO was less than 5.5 mg/L varied from 3 days at Station 208 to 11 days at Station 215. The 7-day mean DO criterion of 5.5 mg/L was not exceeded at any of the three monitoring locations. However, at Station 215 there were 26 occurrences of the 7-day mean DO equal to the minimum of 5.5 mg/L. The lowest minimum daily average DO (5.0 mg/L) recorded among the stations was at Stations 208 and 215. The total number of hourly DO measurements less than 5.0 mg/L varied from 18 at Station 189 to 98 at Station 215 with a majority of these measurements occurring during September. The total number of days that at least one hourly DO measurement was less than 5.0 mg/L (the instantaneous minimum criterion) varied from 9 days at Station 189 to 35 days at Station 215.

Figure 5-2 through Figure 5-4 provide a time series of the hourly DO measurements for each monitoring location. The lowest instantaneous minimum DO measurement was 4.4 mg/L and occurred at all three stations.

Discussion

Dissolved oxygen (DO) concentrations in the subsurface waters of Conowingo Pond are important in assessing the potential suitability of fish habitat. Low DO can result in stressful conditions that fish may avoid or could potentially result in higher rates of disease. Dissolved oxygen concentrations were measured in the shallow shoreline areas directly downstream from the PBAPS discharge and at an upstream location and evaluated to determine whether sufficient DO was present within these areas to be protective of aquatic life. This monitoring occurred during the typical seasonal periods of low-flow and high water temperature that occur in Conowingo Pond which could result in low DO concentrations. DO concentrations were similar among the three stations over the course of the monitoring period. Nearly all measurements were above the instantaneous DO criterion of 5.0 mg/L. Similarly, DO concentrations were always equal to or above the 7-day mean criterion of 5.5 mg/L. The monitoring did not indicate that DO concentrations were low and restrictive to aquatic organism movement or use of shallow shoreline areas within the Pond. In addition, the monitoring at Station 208 indicated that DO concentrations do not cause a low DO barrier that would prevent fish from migrating past PBAPS.

Most of the lowest instantaneous DO measurements were recorded in August and September. This was an extremely low flow period in Conowingo Pond. Although DO concentrations were occasionally below the water quality instantaneous minimum criterion of 5.0 mg/L it is unlikely that the lowest observed concentration (4.4 mg/L) were injurious or caused stress to fish. Low DO concentration is an environmental stressor that may predispose fish to viral or bacterial

infections. Section 6.3 of this report discusses disease occurrence in Conowingo Pond fish. The instantaneous criterion for DO is protective of the most sensitive life stages of fish (eggs and larvae); these life stages of fish are not present in August and September. Thus DO during this time period needs to be protective of only juvenile/adult life stages of fish which can tolerate DO less than 5.0 mg/L for short periods of time without measurable negative effects.

Nutrient enrichment of the lower Susquehanna River and Chesapeake Bay from upstream sources is a long-term concern for the health of the aquatic ecosystem. Increases in nutrients have been linked to increased biomass of aquatic macrophytes, which can lead to wide swings and depressions of DO during the growing season. Aquatic macrophytes produce DO during daytime hours when photosynthesis is occurring, but then use the DO for respiration during the nighttime hours. A large amount of aquatic macrophyte biomass in a water body can lead to DO depression or sag during early morning hours particularly during summer time. This pattern was observed in the current study and occurs throughout the Susquehanna River particularly in portions of the river where macrophytes are abundant (SRBC 2013). Low DO concentrations occur in many portions of the Susquehanna River well upstream of PBAPS and are a result of multiple factors including river flow, nutrient enrichment, and aquatic macrophyte growth and decomposition (PADEP 2012).

Conclusions

Monitoring during 2016 under the prevailing high water temperature and low flow conditions indicated that sufficient DO concentrations existed in Conowingo Pond with the EPU to protect the aquatic community. No exceedances of the 7-day average criterion were observed and few exceedances of the instantaneous minimum criterion (1.9% of total measurements) were observed. The exceedances of the instantaneous minimum criterion were few and did not occur over consecutive hours and were not of extended duration. The DO concentrations observed during actual EPU conditions in an extreme high temperature and low flow year were protective of the aquatic community. The monitoring also indicated that DO was sufficiently high as to not block fish migration past PBAPS. DO concentrations were sufficient to maintain fish habitat and did not indicate the monitored locations would be unavailable for use by fish or other aquatic organisms.

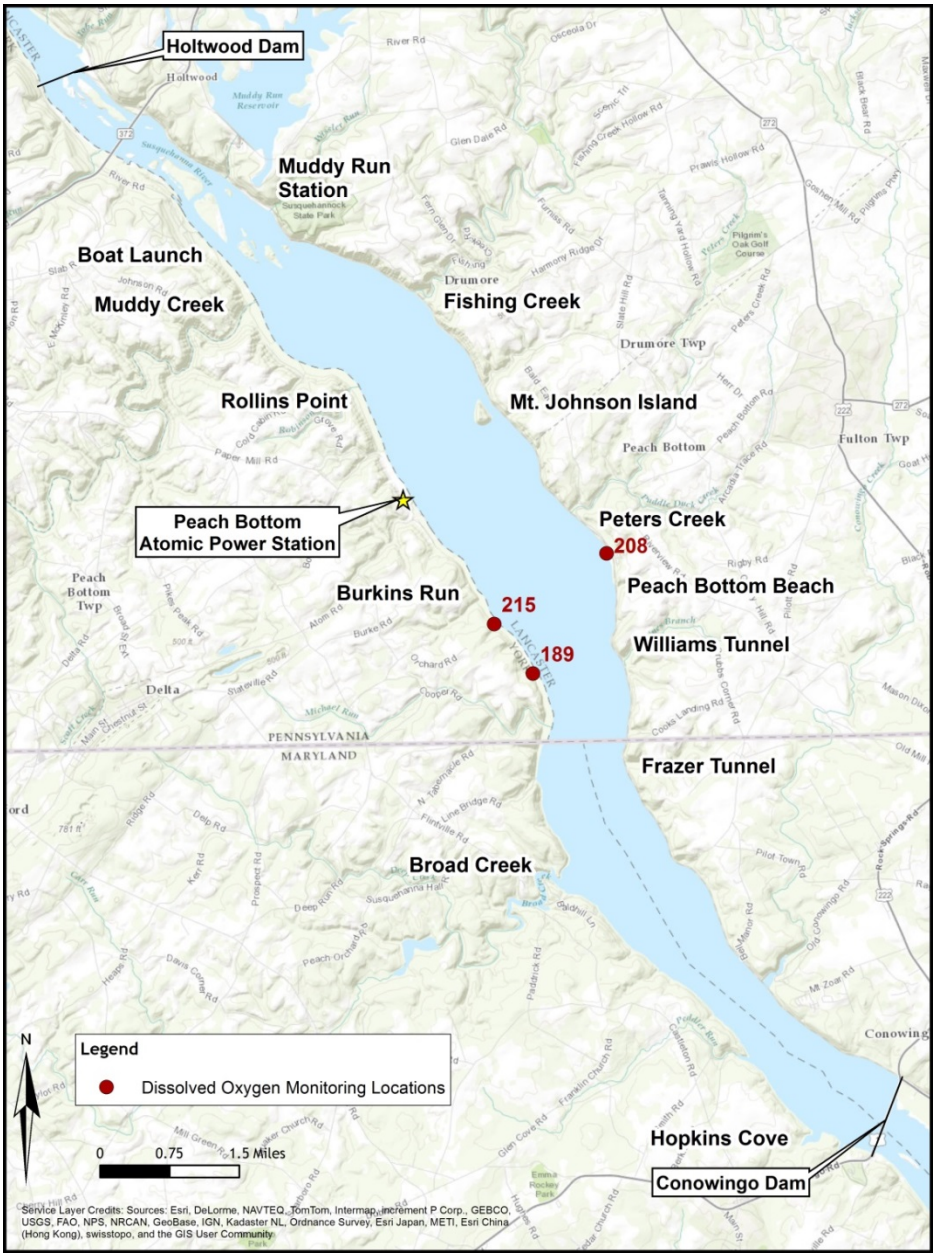


Figure 5-1. Dissolved Oxygen monitoring locations in Conowingo Pond during 2016.

Table 5-1. Descriptive statistics for dissolved oxygen monitoring in Conowingo Pond, June through September 2016.

	Station		
Dissolved Oxygen (mg/L) [1]	208	215	189
Total Number of Hourly Measurements	2,338	2,500	2,537
Total Number Hourly Measurements < 5.0 mg/L	26	98	18
Total Days with Hourly Measurements <5.0 mg/L	13	35	9
Minimum Daily Average	5	5.0	5.2
Total Days Daily Average < 5.5 mg/L	3	11	5
Number of Occurences 7-day Average < 5.5 mg/L	0	0 [2]	0
Instantaneous Maximum	11.4	8.5	9.3
Instantaneous Minimum	4.4	4.4	4.4

[1] *§ 93.7. Specific water quality criteria for Warm Water Fishery (WWF): 7-day average 5.5 mg/L; instantaneous minimum 5.0 mg/L.*

[2] *A total of 26 occurrences of 7-day average of 5.5 mg/L*

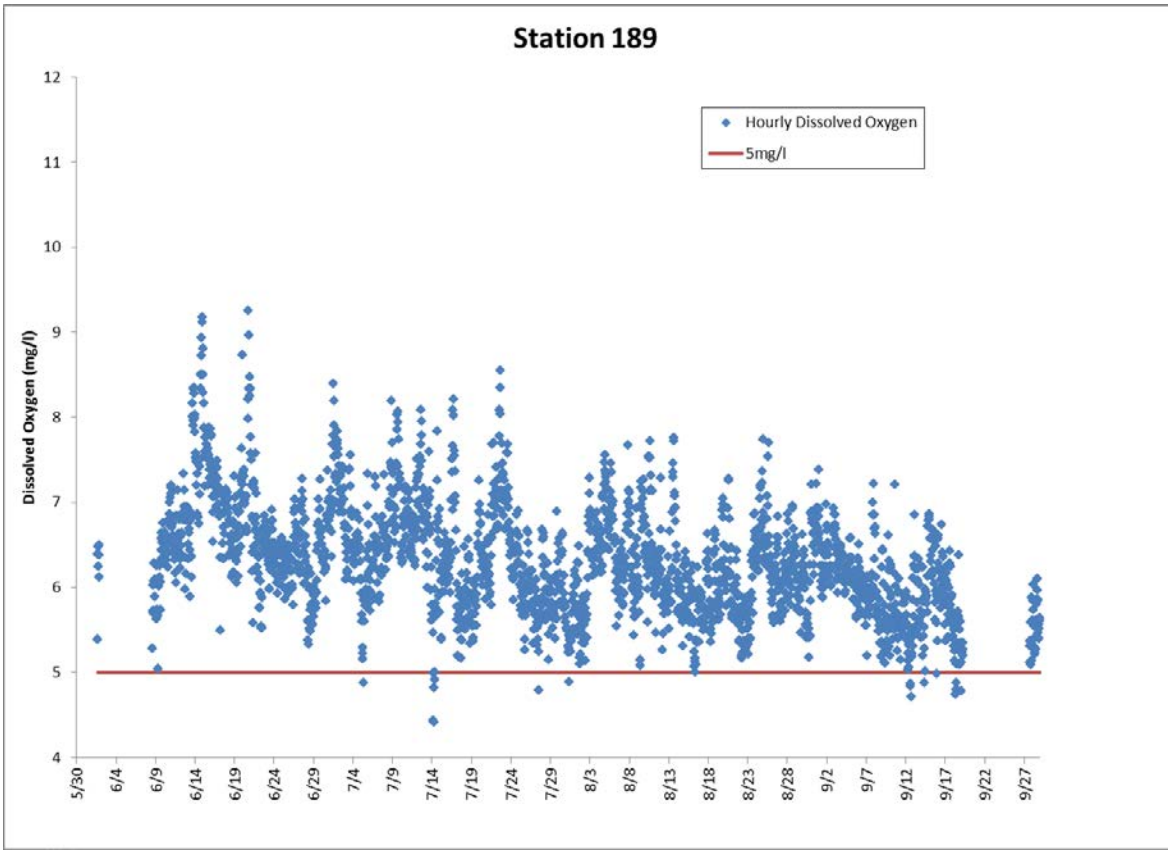


Figure 5-2. Hourly dissolved oxygen measurements at Station 189, June through September 2016.

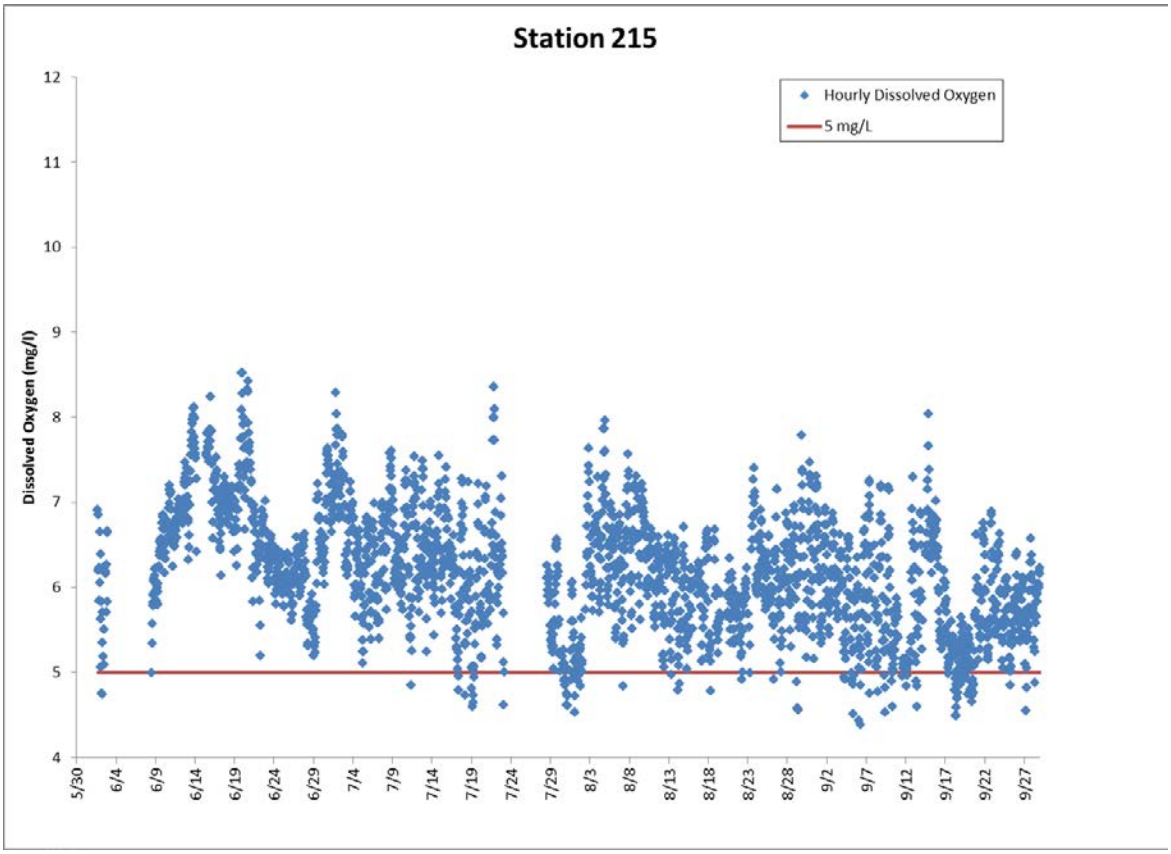


Figure 5-3. Hourly dissolved oxygen measurements at Station 215, June through September 2016.

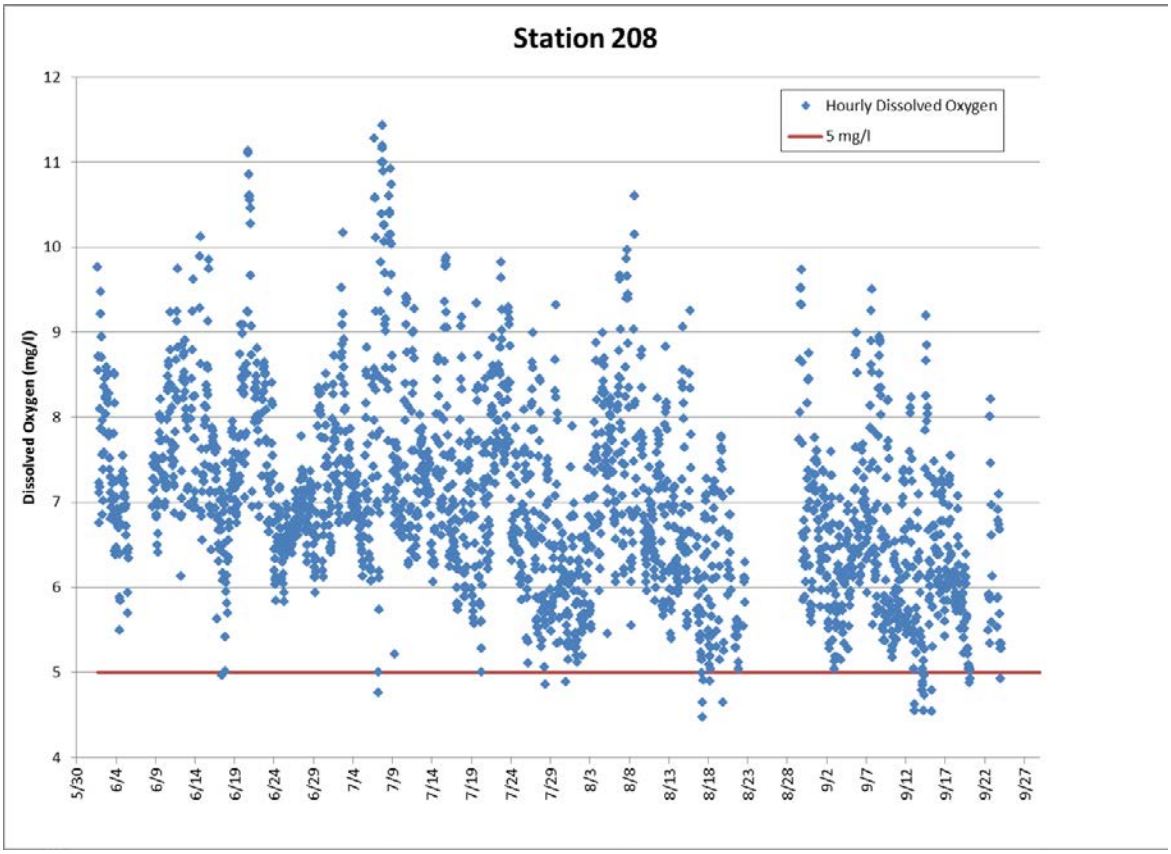


Figure 5-4. Hourly dissolved oxygen measurements at Station 208, June through September 2016.

6 Biological Monitoring and Assessment

6.1 Introduction

This section describes the benthic macroinvertebrate and fisheries components of the Post-EPU Study. As described in the Post-EPU Study Plan, the primary objective of the biological monitoring component of the study was to determine the characteristics of the fish and benthic macroinvertebrate communities after implementation of the EPU. The characteristics of the communities observed in 2016 Post-EPU Study will be compared to Pre-EPU Demonstration Study observations completed from 2010-2013 during the 316a Demonstration Study (Normandeau and ERM 2014). These comparisons will focus on whether any discernable changes have occurred to the aquatic communities that resulted from the increase in water temperature associated with the EPU.

Sampling and data collection for the 2016 monitoring program was performed from May 1 through September 30. A total of 35 benthic macroinvertebrate samples were collected at seven stations (Figure 6-1) Fish community surveys were completed to determine distribution and relative abundance within and outside of the thermal plume. A total of 25 collections were completed using a seine at five stations (Figure 6-2) and 30 collections were completed using a boat electrofisher at six stations (Figure 6-3). Table 6-1 provides a description of seine, benthos, electrofishing, and water temperature stations and the distance each station is from the PBAPS discharge canal.

Methodologies and analyses for the benthic macroinvertebrate community sampling, and fish community surveys are summarized below.

6.2 Benthic Macroinvertebrate Community

A study of the benthic macroinvertebrate community was conducted to determine the influence of the thermal plume post-EPU on the composition and relative abundance of the benthic macroinvertebrate, or benthos, community inhabiting shallow-water shoreline habitat in Conowingo Pond. Previous benthos surveys were conducted at the same monitoring locations using identical methodology during 2010-2013. Comparison between the pre-EPU and post-EPU communities was completed to evaluate the potential effect of the temperature rise associated with the EPU. The benthic macroinvertebrate sampling included an assessment of habitat quality each month at each of the collection locations.

Methods

Habitat Assessment

The quality, quantity, and variety of physical habitat are well-known determinants of macroinvertebrate community composition. When comparing sample stations, habitat assessments are used to infer whether observed differences in macroinvertebrate communities are the result of water quality degradation (in this case, increases in temperature) or due to

variations in habitat. The PADEP methodology used for this study is for low gradient streams and is referenced in the Post-EPU Study Plan. The methodology involves visual inspection and quantification of nine habitat parameters listed below.

Habitat Parameters	
Epifaunal Substrate/Available Cover	Bank Vegetative Protection
Channel Alteration	Sediment Deposition
Pool Substrate Characterization	Riparian Vegetative Zone Width
Bank Stability	Channel Flow Status
Pool Variability	

Each habitat parameter is awarded a score between 0 and 20 for a possible maximum total of 180. The resulting values can be used to rate habitat quality into four categories: Optimal (166-180), Sub-optimal (113-153), Marginal (60-100), and Poor (<47). Scores falling between these ranges are given a dual rating.

Macroinvertebrate Collection and Analysis

Macroinvertebrates were collected monthly from May through September 2016 with a D-frame kick net according to a PA DEP (2007) multi-habitat protocol. Benthic macroinvertebrates were collected from seven locations throughout Conowingo Pond, spatially covering a large portion of the Pond (Figure 6-1). Two locations were well upstream from PBAPS and not influenced by the thermal plume. Station 208 was located across from PBAPS and is exposed to thermal plume during low-flow conditions during MRPSF pumpback operations. The other four stations (214, 215, 189, and 216) are located downstream from PBAPS along the west shoreline and are within the thermal plume during the entire year.

Each multi-habitat sample was a composite of 10 “kicks,” collected from five habitat types including cobble/gravel, snag, coarse particulate organic matter, submerged aquatic vegetation, and sand/fine sediment. Where all five habitat types were present, two “kicks” were taken from each to produce the composite. If one or more habitat types were absent, the “kicks” that would have been assigned to them were proportioned according to the predominant habitat types remaining.

Samples were sorted and identified following the methods described in PADEP (2007) multi-habitat protocol. The resulting data were condensed to six ecological metrics developed by PADEP (2007). The metrics are Total Richness, EPT Richness, Beck’s 4 Index, Shannon Diversity, Mayfly Taxa Richness, and Caddisfly Taxa Richness. Table 6-2 provides a brief summary of the metrics and whether their values increase or decrease in response to water or habitat quality degradation. Standardized scores for each metric were used to produce an Index

of Biotic Integrity (IBI) value for each station. The IBI is a means to integrate information from the metrics into a station score ranging between 0 and 100.

Habitat Assessment

Results and Discussion

The results of the habitat assessment are provided in Table 6-3. Average station scores ranged from 95 to 133 producing similar descriptors of sub-optimal/marginal or marginal at each location. Placed into context, the habitat constraints observed in the Conowingo Pond are essentially due to channel alteration inherent to impoundment; i.e., a free-flowing section of the Susquehanna River has been transformed into a reservoir where shoreline habitat is much less varied and the current is much slower than it would be in a natural state. This habitat alteration would be expected to produce a negative response in what was initially a riverine benthic community; one which should be, and is, characterized by low IBI scores. Because the station scores show habitat quality to be relatively similar at each sample location, differences in the benthic community resident in the thermally influenced versus the non-thermally influenced locations may be considered, in part, attributable to temperature increase. However, other habitat features such as the amount of submerged aquatic vegetation (SAV), water velocity, and spatial location in reference to tributaries or other Pond features are not accounted for in the habitat assessment.

Macroinvertebrates

2016 Results

Benthic macroinvertebrate collections made at seven stations in 2016 yielded a total of 7,097 organisms that were processed and identified. A total of 59 taxa were collected. The identity of common macroinvertebrate taxa (>1% of total organisms) was similar among collection locations and six to 12 common taxa were collected at individual stations (Table 6-4). The samples contained taxa expected to be found in a lentic environment, including representatives of most of the orders of aquatic insects as well as worms (Oligochaeta), snails (*Elimia*, *Ferrissia*, and *Gyraulus*, etc.), clams (*Corbicula*), and crustaceans (*Caecidotea* and *Gammarus*) (Table 6-5).

A few benthic macroinvertebrate taxa comprised a large proportion of all organisms collected at each of the stations. With few exceptions, Chironomidae, *Gammarus*, and Oligochaeta were among the most abundant organisms at all stations (Table 6-5).

Other common taxa included *Corbicula*, *Physella,* Hydrachnidea, and *Caenis*. No Plecoptera (stoneflies) and few Trichoptera (caddisflies) were collected. The mayfly *Caenis* was the only mayfly commonly collected among stations. Other Ephemeroptera and Trichoptera that comprised >1% of total organisms included *Stenonema, Stenacron, Oecetis, Hexagenia, Orthotrichia*, and *Maccaffertium*. Differences were observed in composition of common taxa among stations. Fewer common taxa were collected at Station 214, compared to the other locations. Chironomidae, Oligochaeta and *Corbicula* comprised a greater proportion (88%) of

the benthic community at Station 214 compared to the other stations (Table 6-5). In contrast, Chironomidae, Oligochaeta and *Corbicula* comprised the lowest proportion (34.5 %) of the benthic community at Station 220.

2016 IBI and Metrics

IBI scores were generally low for all stations within and outside of the thermal plume and ranged between 11.5 and 49.4 (Figure 6-4). The lowest IBI scores were observed at Stations 214 (IBI score 11.5) in September and 221 (IBI Score 14.9) in June. However, IBI scores at the other thermal and non-thermal stations were similar with IBI scores generally higher from July through September for all stations. Other slight spatial differences were observed both between and within non-thermal and thermal station groups. The highest scores at the non-thermal stations were observed at Station 220 and for the thermally influenced stations the highest scores varied from month to month.

Individual metrics that comprised the IBI scores were also evaluated for each monthly collection. Table 6-7 through Table 6-12 provide the monthly metric values for each station. Total richness values were higher during July, August, and September for most stations with the most taxa observed at Station 220 (n= 17) during July and September. However, the fewest taxa (n = 5) were observed at Station 214 during September. EPT Richness values followed the general pattern of Total Richness with the highest values observed from July through September for all stations. The EPT Richness values ranged between zero to seven taxa among stations. Similar to EPT Richness, Ephemeroptera Richness values were low and variable, ranging zero to five taxa among stations. Few Trichoptera were collected, as indicated by low richness values for all stations with the highest richness (5 taxa) observed at Station 220 in July (Figure 6-7). Modified Beck's Index values were similar among stations with the highest value observed at Station 220 in August. Shannon Diversity ranged between 0.63 for Station 214 in September to 2.33 for Station 220 in September. Shannon Diversity values were generally lower for Station 214 during most months.

Water Temperature vs IBI scores all years

The observed IBI scores in relation to mean water temperature for the month of collection were similar between post-EPU and pre-EPU monitoring. Figure 6-10 provides a scatter plot which illustrates the relation between mean water temperature and IBI score for each month during pre-EPU and post-EPU monitoring. Generally, similar patterns were observed for IBI scores across the range of measured water temperatures. Except for the low post-EPU September IBI score, the IBI scores tended to be higher during post-EPU period for temperatures >90 °F. The post-EPU scores clustered between 25 and 40, whereas; the pre-EPU scores were between 10 and 25. A consistent trend between water temperatures and IBI score was not observed. However, a seasonal pattern was observed with lowest scores occurring during May at most Stations and during August at the thermally influenced stations (Stations 214 and 215) with the highest water temperatures. The lowest scores (<10) recorded during pre-EPU monitoring occurred in May and August. Generally for both pre- and post-EPU monitoring IBI Scores were highest during July through September at water temperatures between 80 and 90 °F. The lowest September IBI score occurred post-EPU (Station 214) at temperature >90 °F.

Post-EPU IBI Score Comparison to Pre-EPU

Comparison of post-EPU IBI scores during 2016 to the pre-EPU IBI scores (2010-2013) allows for inspection of potential differences that may have been a result of the increase in temperature from the EPU. Figure 6-5 through Figure 6-9 provide box plots of IBI scores by month and by station from May through September. The May post-EPU IBI scores were within the range of IBI scores observed pre-EPU for all stations except 189 which was lower than pre-EPU. June post-EPU IBI scores were within the range of IBI scores observed pre-EPU for all stations except 189 (thermally influenced) and 221 (non-thermal) which were lower than pre-EPU and just outside of the interquartile (IQ) range. July post-EPU IBI scores were within the range of IBI scores and most were higher than pre-EPU observations with the exception of Station 208 which was lower than pre-EPU scores and outside of the IQ range. For August generally higher IBI scores were observed during the Post-EPU Study as compared to the pre-EPU study. The Station 216 (thermal) post-EPU score in August was lower than all pre-EPU observations and just outside of the IQ range. In September similar IBI scores were observed during pre- and post-EPU except for Stations 214 and 215 which were both outside the IQ range. The lowest IBI Score observed during September occurred at Station 214 during post-EPU monitoring. For most months and stations the IBI scores were generally higher during the post-EPU monitoring except for Stations 214 and 215 in September.

Post-EPU Metric Comparison to Pre-EPU

Similar to IBI scores, a comparison of pre-EPU and post-EPU metric values allows for inspection of potential differences that may have been a result of the increase in temperature from the EPU. Figure 6-11 through Figure 6-15 provide box plots of the six metrics that comprise the IBI Score. pre- and post-EPU metric values for Total Richness, EPT Richness and Ephemeroptera Richness were comparable for most stations with the exception of Station 189. Lower values for all three metrics at this station were observed during May post-EPU monitoring. For all other stations Total Richness, EPT richness and Ephemeroptera richness metric values were comparable or higher during the post-EPU monitoring period. For Trichoptera richness the post-EPU values were within the range observed pre-EPU. Similarly, Shannon Diversity values were comparable to or higher during the post-EPU monitoring period. Beck's Index values were also comparable between pre- and post-EPU monitoring. The only exception was station 189 which had one monthly value (May collection) below the range of values observed pre-EPU. All other station post-EPU values were within the range of the pre-EPU observations. Benthic community composition as measured by these six metrics was similar to pre-EPU monitoring with no measurable impacts from the EPU on the community.

Discussion

The macroinvertebrate community composition and relative abundance observed in 2016 was similar to the pre-EPU observations. Most of the macroinvertebrate taxa collected in this study prefer lentic habitats and are considered fairly tolerant of water/habitat quality degradation. Few intolerant taxa were collected. The observed taxa are representative of a warmwater aquatic community in a lentic waterbody. The most abundant taxa were Chironomidae, *Gammarus*, and Oligochaeta. During September when measurable impacts of the thermal plume were observed

at Stations 214 and 215 several taxa were not present or present in low numbers including Ephemeroptera and Trichoptera. Overall, few taxa were present in September at these two stations and the benthic community was predominated by Oligochaeta, Chironomidae, and *Enallagma*.

Station 214 is the benthic macroinvertebrate station located closest to the end of the discharge canal. The IBI scores for May through August 2016 at Station 214 were comparable to the other non-thermal and thermal stations and higher than most pre-EPU observations at this station for July and August. However, the lowest IBI Score for all stations was observed at Station 214 in September indicating benthos effects attributable to the heated effluent. Station 215 is the next closest station to the PBAPS discharge canal. IBI scores at Station 215 were not substantially different from the other thermal or non-thermal stations from May through August. However, similar to Station 214, a low IBI score was observed at this station during September as compared to the other stations. For both stations a decline in benthic community diversity was observed in September.

Metric and IBI scores indicate that the thermal effect to the benthos community from the PBAPS thermal plume is confined to the western shoreline at Stations 214 and 215. Low IBI scores were observed at Stations 214 and 215 during September after a prolonged period of high water temperatures. Based on previous observations from pre-EPU monitoring (Normandeau and ERM 2014) improvement in both IBI scores and metric values occurred during subsequent months, indicating re-colonization and recovery of the benthic community at these stations. Metric values and IBI scores during post-EPU monitoring indicated no measurable impact to the benthic community at monitoring locations downstream from Stations 214 and 215.

These results show only a short-term seasonal effect attributable to the discharge for Stations 214 and 215 during the month of September. The shoreline area between Stations 214 and 215 likely experiences similar conditions and similar changes to the benthic community as the stations that bracket this area. Moreover, observations of IBI scores and metric values at Stations 214 and 215 were similar to the non-thermal stations. Station 215 benthic community observations were not substantially different from the non-thermal stations.

Conclusions

Benthic community effects resulting from the thermal plume are localized and temporary and consistent with the observations during pre-EPU monitoring. The area of measurable impact was limited to Station 214 and 215 and small in comparison to the amount of similar non-thermally impacted Conowingo Pond shoreline.

Benthic macroinvertebrate collections were successfully completed during 2016. The data indicate that:

- The composition and relative abundance of the benthic community observed in 2016 was similar to pre-EPU observations.
- The benthic community was characterized by similar diversity both within and outside of the thermal plume.

- IBI scores for individual monitoring stations were similar between the pre-EPU and post-EPU monitoring.
- Temporary impact, in terms of lower IBI scores, was observed at Stations 214 and 215 in September. The lower IBI scores during post-EPU monitoring occurred after a sustained period of high water temperatures. In contrast, the lowest scores for these stations during pre-EPU monitoring occurred during July and August. Relatively high IBI scores at these stations were observed in July and August during post-EPU monitoring.
- There was no observed impact to the benthic community at the two thermally-influenced Stations (189 and 216) that are farther downstream from the discharge canal.
- Similar to pre-EPU observations the benthic community effects resulting from the thermal plume are local and temporary.
- The biological modeling results for the Pre-EPU Demonstration Study were bounded by the actual sampling results during EPU operation in an extreme flow and temperature period.
- There is a balanced indigenous benthic community within Conowingo Pond.

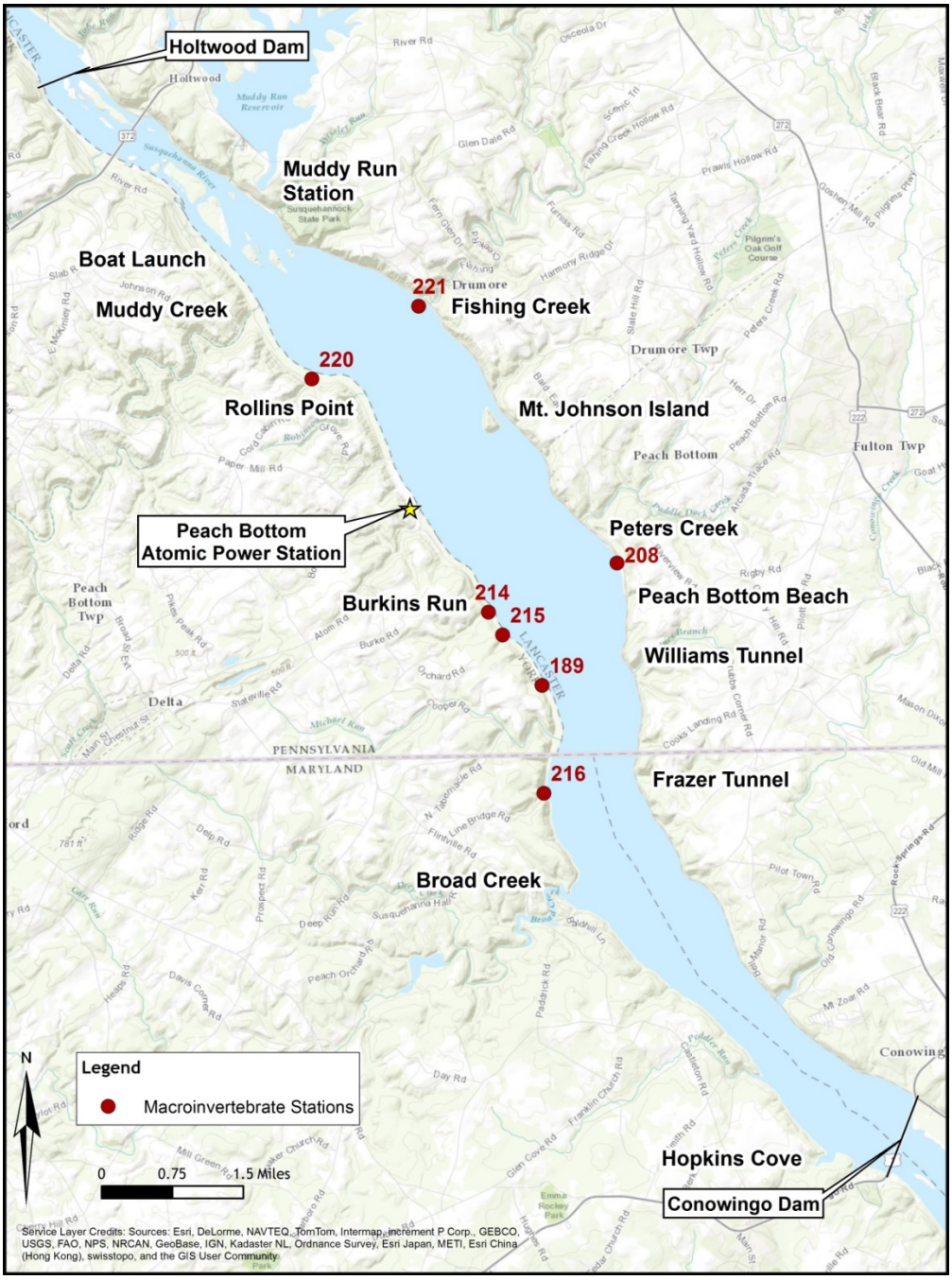


Figure 6-1. Location of benthic macroinvertebrate collection stations.

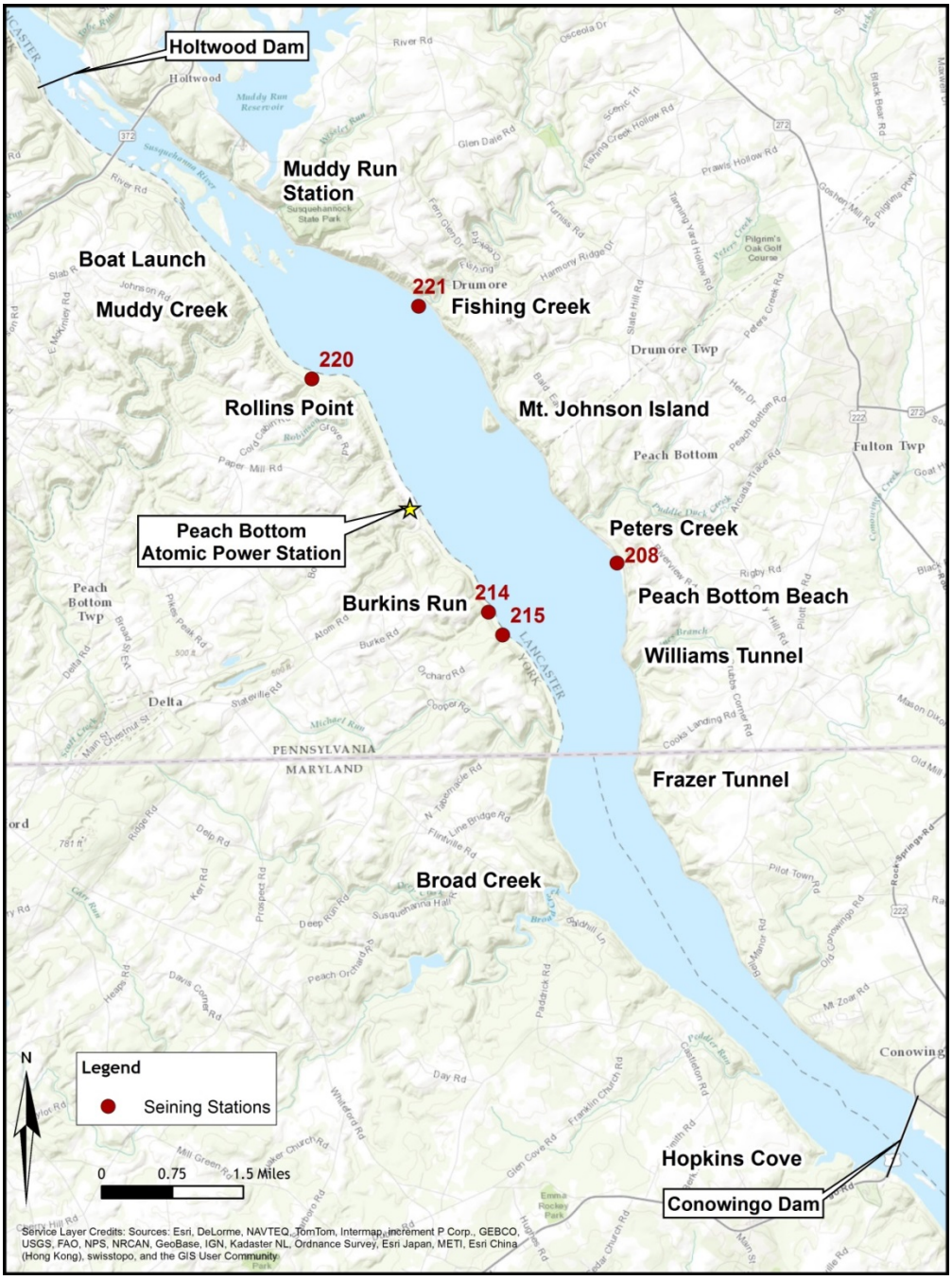


Figure 6-2 Location of seine collection stations.

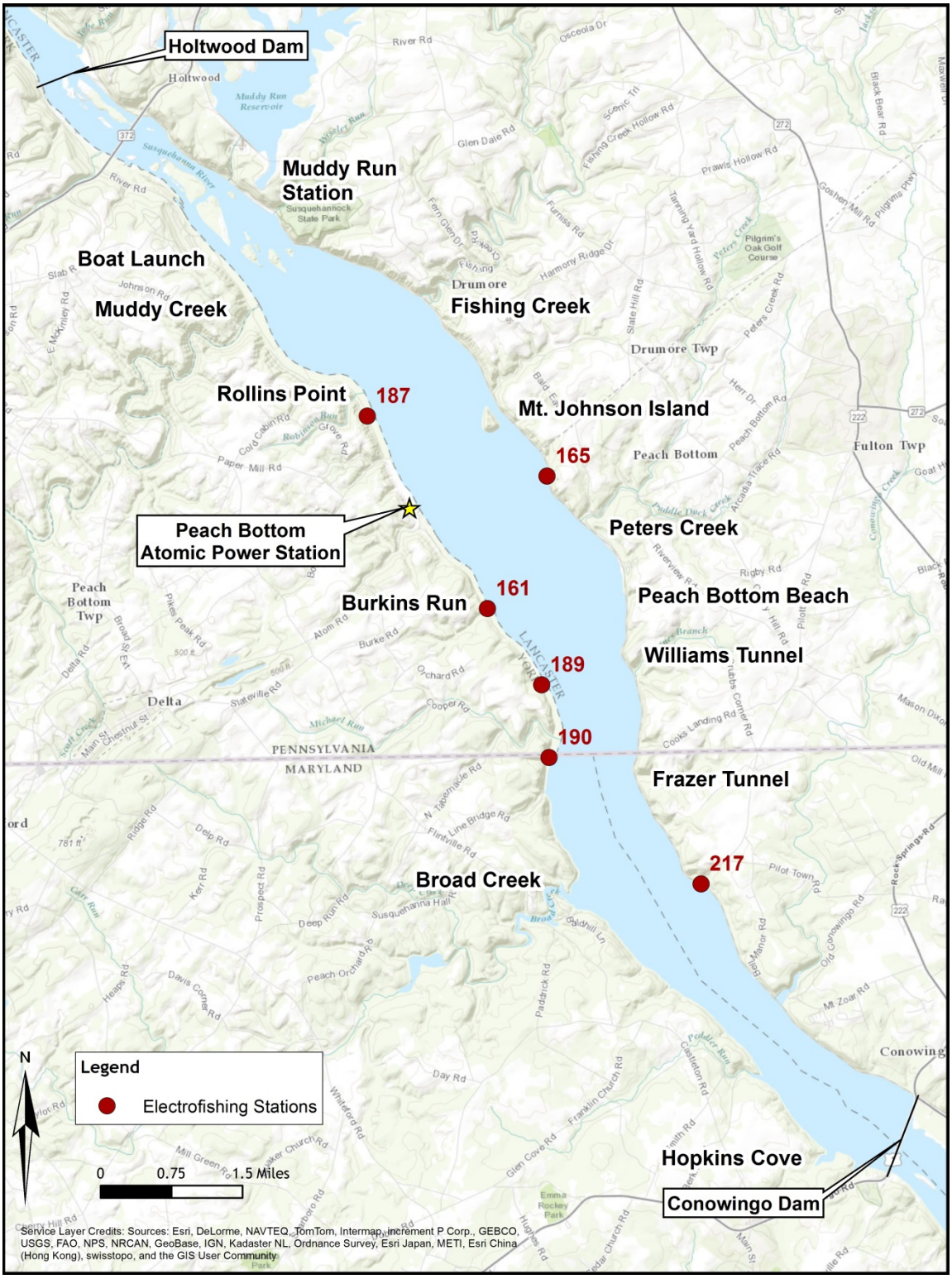


Figure 6-3. Location of electrofishing collection stations.

Table 6-1. Description of seine, benthos, electrofishing, and water temperature stations in Conowingo Pond (negative values indicate distance upstream from the discharge canal).

Station	Monitoring Description	Description	Distance From End Of Discharge Canal	
			Meters	Miles
221	B, S, T	Fishing Creek confluence - northwest side of shoal.	-4,765	-2.96
220	B, S, T	Coal Cabin boat launch.	-4,410	-2.74
187	E	South of Rollins Point to first cabin.	-3,325	-2.07
208	B, S, T	Peach Bottom Beach.	-2,449	-1.52
165	E	East shoreline above Peters Creek.	-2,159	-1.34
161	E, T[1]	Rock outcropping above Burkins Run to PBAPS discharge structure.	545	0.34
214	B, S, T	Beach at the mouth of Burkins Run.	591	0.37
215	B, S, T	Campground boat launch' - about 250 m below the mouth of Burkins Run.	1,049	0.65
189	B, E, T	Rock outcropping at north side of Michael's Run to 'McClellan's Rock'.	2,128	1.32
190	E, T	First cabin below Michaels Run to mouth.	3,285	2.04
216	B, T	Below site 190, small cove at end of Line Bridge Road	3,919	2.44
217	E, T	2,000 m above the mouth of Conowingo Creek.	6,466	4.02

S = Seine, F = Electrofish, B = Benthos, T = Temperature

[1] *Station 214 temperature monitoring representative of this location*

Table 6-2. Descriptions of benthic macroinvertebrate community metrics.

Metric	Description	Response to Impairment
Richness	The total number of taxa. The PA DEP 95th percentile value is 31 taxa.	decreases
EPT Index	A count of the number of mayfly (Ephemeroptera), stonefly (Plecoptera), and caddisfly (Trichoptera) genera. The PA DEP 95th percentile value is 17 genera.	decreases
Modified Beck's 4 Index	A weighted count of taxa with Pollution Tolerance Values between 0 and 4. Taxa with Tol. Values of 0 or 1 are given 2 points. Taxa with Tol. Values between 2 and 4 are given 1 point. The PA DEP 95th percentile index value is 22.	decreases
Shannon Diversity (H')	A measure of community balance in base e based on the distribution of the taxa present ($H = - \text{Sum} P_i \log P_i$). The PA DEP 95th percentile index value is 2.43.	decreases
Number of Mayfly Taxa	A count of the number of genera in the order Ephemeroptera. The PA DEP 95th percentile value is 6 genera.	decreases
Number of Caddisfly Taxa	A count of the number of genera in the order Trichoptera. The PA DEP 95th percentile value is 11 genera.	decreases

Table 6-3 Average habitat assessment scores for the seven benthic macroinvertebrate collection locations, May through September 2016.

	Non-Thermal Stations			Thermal Stations			
Parameter	220	221	208	214	215	189	216
Epifaunal Substrate/Available Cover	13	10	14	13	15	11	13
Pool Substrate Characterization	17	14	15	16	16	11	15
Pool Variability	13	3	11	9	14	12	13
Channel Alteration	16	6	11	10	17	16	13
Sediment Deposition	10	10	11	10	11	10	11
Channel Flow Status	14	17	7	14	15	18	16
Condition of Banks	11	9	12	11	17	6	14
Bank Vegetative Protection	5	14	9	12	15	17	15
Riparian Vegetative Zone Width	3	18	5	12	14	18	13
Total Score	101	102	95	107	133	120	124

Table 6-4. Total number of benthic macroinvertebrates collected at each station in Conowingo Pond from May through September 2016.

	Station							
Taxon	214	215	216	189	208	220	221	Total Number
Amnicola						1		1
Anthopotamus						1		1
Argia		1	25	17	1	2		46
Baetis							1	1
Bezzia					1			1
Caecidotea			30	45	2			77
Caenis	36	18	46	11	254	31	41	437
Callibaetis	1		1		5	1	5	13
Ceraclea					1	5		6
Ceratopogon						1		1
Cheumatopsyche		1						1
Chironomidae	479	548	438	361	267	316	307	2716
Cipangopaludina			3			4		7
Climacia					2			2
Corbicula	152	68	28	89	11	27	50	425
Cyrnellus		1						1
Dasyhelea							1	1
Dromogomphus						1		1
Dubiraphia						2	1	3
Dugesia	2			1				3
Elimia			18		2	21	1	42
Enallagma	2	45	6		13	18	31	115
Erpobdella				1				1
Ferrissia			5	1		39		45
Galba		1				1	1	3
Gammarus	2	79	182	245	95	218	152	973
Gloiobdella		2						2
Gyraulus	8	1	6	1	29	161	100	306

Table 6-4. Continued.

	Station							
Taxon	214	215	216	189	208	220	221	Total Number
Helobdella			1		1		1	3
Hexagenia		56	1	3	5	7	3	75
Hyalella					1			1
Hydrachnidea	13	41	31	35	101	21	73	315
Hydroptila	1	3	1	1	4	7		17
Leptoxis							1	1
Libellulidae	1				2			3
Maccaffertium	1	8	2	11	5	1		28
Microcylloepus		1						1
Micromenetus			4	1	3	16	14	38
Nematoda			2	1			2	5
Nigronia	1							1
Oecetis	3	8	6	14	10	3	3	47
Oligochaeta	287	56	155	71	106	8	118	801
Orconectes				1	1	3		5
Orthotrichia				5	13	1		19
Oxyethira					3			3
Paraleptophlebia						1		1
Phylocentropus						1		1
Physella	45	50	12	54	80	52	65	358
Pisidium			1					1
Planorbella			2		1	1	2	6
Pleurocera			1		2	2	5	10
Probezzia		1						1
Prostoma		1						1
Sialis		1	4			1	1	7
Stenacron	3	25	13	18		13		72
Stenelmis	2	9		1				12
Stenonema		8	16			6		30
Triaenodes						1		1
Tricorythodes	2							2
Total Number	1,041	1,033	1,040	988	1,021	995	979	7,097
Total Taxa	19	25	28	23	29	36	24	59
Total Ephemeroptera Taxa	4	4	5	3	3	7	4	9
Total Trichoptera Taxa	2	3	2	3	5	6	1	8

Table 6-5. Percent composition of common benthic macroinvertebrates (>1% of total organisms) collected from Conowingo Pond, May through September 2016.

	Station						
Taxon	214	215	189	216	208	220	221
Argia			1.7	2.4			
Caecidotea			4.6	2.9			
Caenis	3.5	1.7	1.1	4.4	24.9	3.1	4.2
Chironomidae	46.0	53.0	36.5	42.1	26.2	31.8	31.4
Corbicula	14.6	6.6	9.0	2.7	1.1	2.7	5.1
Elimia				1.7		2.1	
Enallagma		4.4			1.3	1.8	3.2
Ferrissia						3.9	
Gammarus		7.6	24.8	17.5	9.3	21.9	15.5
Gyraulus					2.8	16.2	10.2
Hexagenia		5.4					
Hydrachnidea	1.2	4.0	3.5	3.0	9.9	2.1	7.5
Maccaffertium			1.1				
Micromenetus						1.6	1.4
Oecetis			1.4				
Oligochaeta	27.6	5.4	7.2	14.9	10.4		12.1
Orthotrichia					1.3		
Physella	4.3	4.8	5.5	1.2	7.8	5.2	6.6
Stenacron		2.4	1.8	1.3		1.3	
Stenonema				1.5			
Total Taxa	6	10	12	12	10	12	10
Total EPT Taxa	1	3	4	3	1	2	1

Table 6-6. Percent composition of common benthic macroinvertebrates (>1%) collected from Conowingo Pond, May through September 2010-2013.

	Station						
Taxon	214	215	189	216	208	220	221
Acariformes	1.2	2.9	3.8	2.7	14.4	2.6	4.5
Caecidotea			2.3	1.7			
Caenis	5.0	2.9		13.2	17.8	12.7	1.5
Callibaetis					1.3		
Chironomidae	55.1	45.3	39.5	32.2	30.2	43.8	49.9
Corbicula	14.9	20.1	12.0	5.2	2.0	5.8	2.4
Crangonyx				1.6			
Enallagma							1.3
Fossaria	3.5	1.6					
Gammarus	1.6	4.7	26.5	14.1	10.0	11.7	5.6
Gyraulus					5.6	3.0	6.1
Helisoma							2.1
Hexagenia		2.8	1.5			1.2	
Oecetis					1.2		
Oligochaeta	10.7	9.5	4.6	20.9	7.5	11.2	18.6
Orthotrichia					1.7		
Physa	3.2	4.6	1.2		2.0		1.1
Stenacron			2.5				
Stenelmis		1.5					
Stenonema				2.3			
Total Taxa	8	10	9	9	11	8	10
Total EPT Taxa	1	2	2	2	4	2	1

Table 6-7. Total Richness values by month for benthic macroinvertebrate collection locations in Conowingo Pond, May through September 2016.

	Station						
Month	214	215	216	189	208	220	221
May	8	12	9	7	9	15	7
June	8	14	10	9	10	13	8
July	10	15	16	14	9	17	10
August	11	13	14	15	16	15	14
September	5	9	16	12	19	17	13
Mean	8.4	12.6	13.0	11.4	12.6	15.4	10.4

Table 6-8. EPT Richness values by month for benthic macroinvertebrate collection locations in Conowingo Pond, May through September 2016.

	Station						
Month	214	215	216	189	208	220	221
May	1	3	2	0	2	2	1
June	3	6	3	2	3	3	0
July	4	6	5	5	4	7	3
August	3	5	4	6	6	6	3
September	1	3	5	4	6	6	4
Mean	2.4	4.6	3.8	3.4	4.2	4.8	2.2

Table 6-9. Ephemeroptera Richness values by month for benthic macroinvertebrate collection locations in Conowingo Pond, May through September 2016.

	Station						
Month	214	215	216	189	208	220	221
May	1	3	1	0	1	1	1
June	1	4	2	2	1	2	0
July	4	4	3	3	2	2	3
August	2	4	3	4	3	5	2
September	1	2	5	2	2	5	3
Mean	1.8	3.4	2.8	2.2	1.8	3.0	1.8

Table 6-10. Trichoptera Richness values by month for benthic macroinvertebrate collection locations in Conowingo Pond, May through September 2016.

	Station						
Month	214	215	216	189	208	220	221
May	0	0	1	0	1	1	0
June	2	2	1	0	2	1	0
July	0	2	2	2	2	5	0
August	1	1	1	2	3	1	1
September	0	1	0	2	4	1	1
Mean	0.6	1.2	1.0	1.2	2.4	1.8	0.4

Table 6-11. Modified Beck's Index values by month for benthic macroinvertebrate collection locations in Conowingo Pond, May through September 2016.

	Station						
Month	214	215	216	189	208	220	221
May	3	3	2	1	1	4	2
June	1	4	2	3	1	2	2
July	3	3	4	3	1	3	2
August	2	4	3	4	6	7	2
September	1	3	3	3	3	4	2
Mean	2.0	3.4	2.8	2.8	2.4	4.0	2.0

Table 6-12. Shannon Diversity values by month for benthic macroinvertebrate collection locations in Conowingo Pond, May through September 2016.

	Station						
Month	214	215	216	189	208	220	221
May	1.08	1.83	1.32	1.56	1.30	1.29	1.34
June	1.11	1.87	1.68	1.26	1.43	1.62	1.32
July	1.56	1.66	1.97	1.72	1.36	2.11	1.71
August	1.48	1.09	1.48	1.62	1.62	1.75	2.24
September	0.63	1.29	1.65	1.67	2.04	2.33	1.89
Mean	1.17	1.55	1.62	1.56	1.55	1.82	1.70

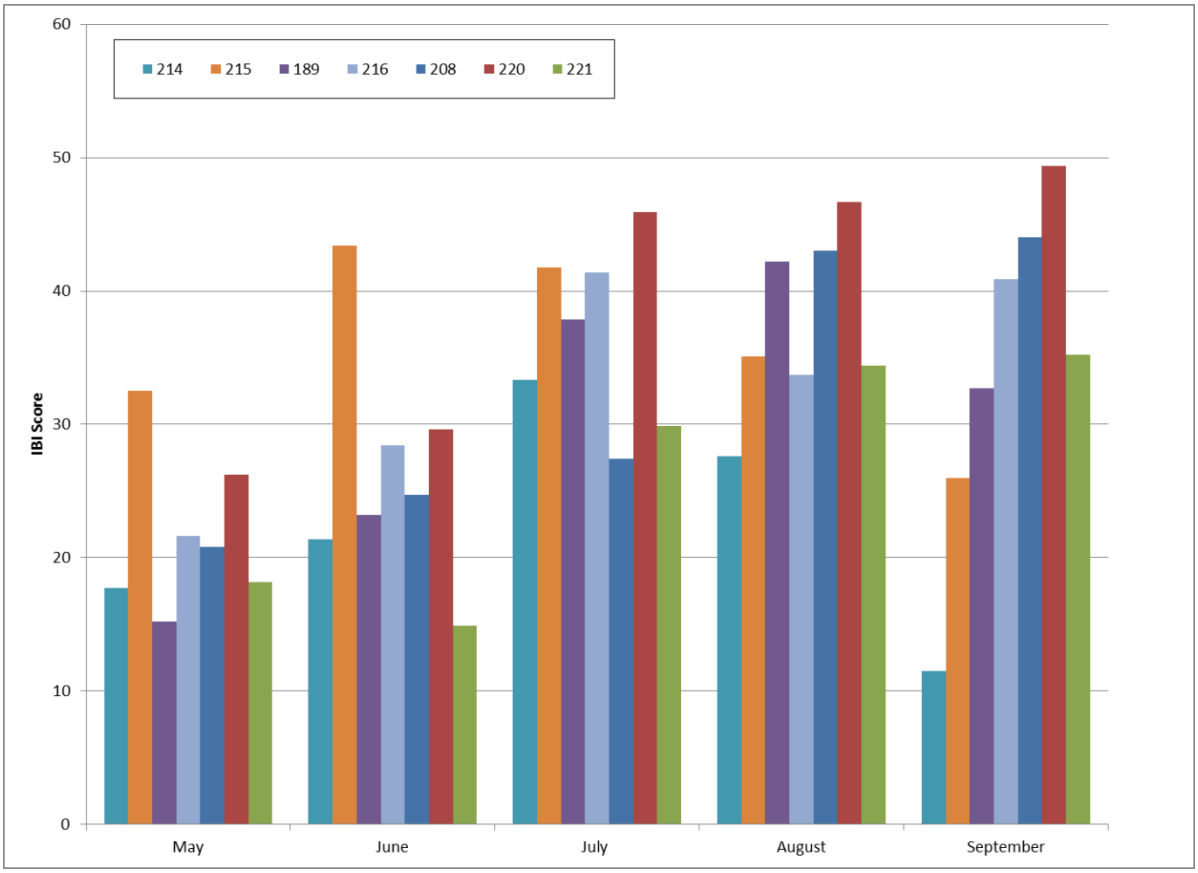


Figure 6-4. Bar chart showing the IBI scores for each station by month, May through September 2016.

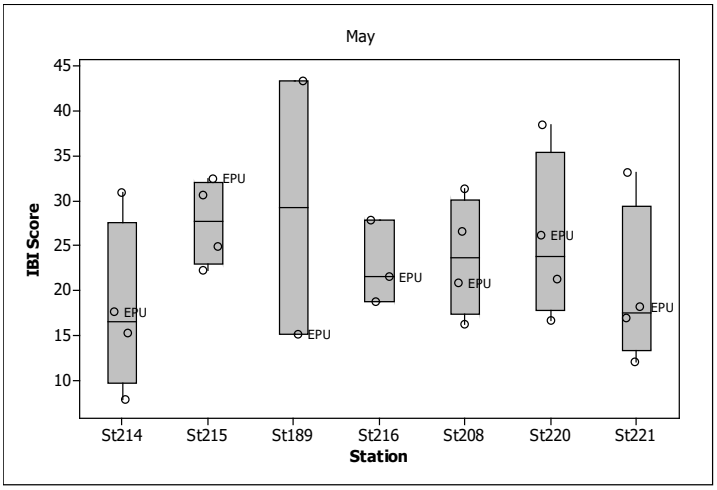


Figure 6-5. Box plot of May IBI scores for all stations during pre-EPU (2010-2013) and post-EPU (2016) monitoring. Stations 208, 220, and 221 are considered non-thermal.

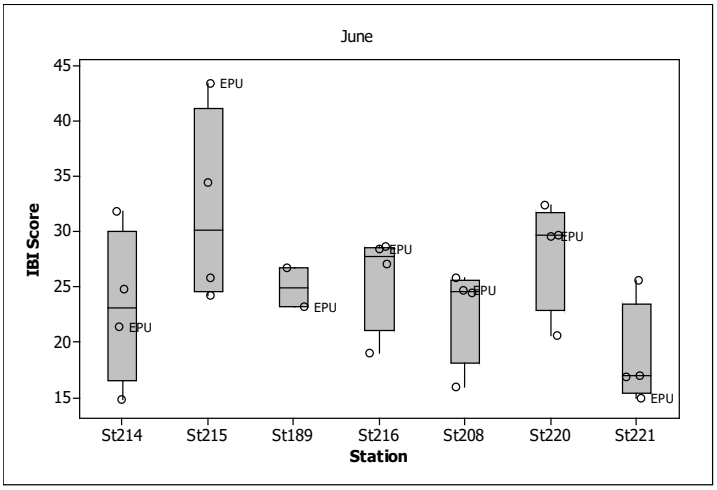


Figure 6-6. Box plot of June IBI scores for all stations during pre-EPU (2010-2013) and post-EPU (2016) monitoring. Stations 208, 220, and 221 are considered non-thermal.

(boxes = interquartile range containing 50% of the values, the line across the box = median value, vertical lines extending from the box = highest and lowest values, open circle = IBI score, the post-EPU value is labeled EPU, and asterisk = outlier)

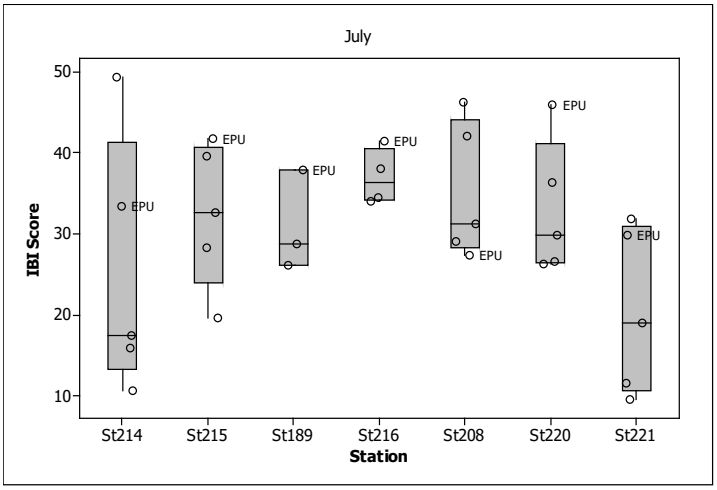


Figure 6-7. Box plot of July IBI scores for all stations during pre-EPU (2010-2013) and post-EPU (2016) monitoring. Stations 208, 220, and 221 are considered non-thermal.

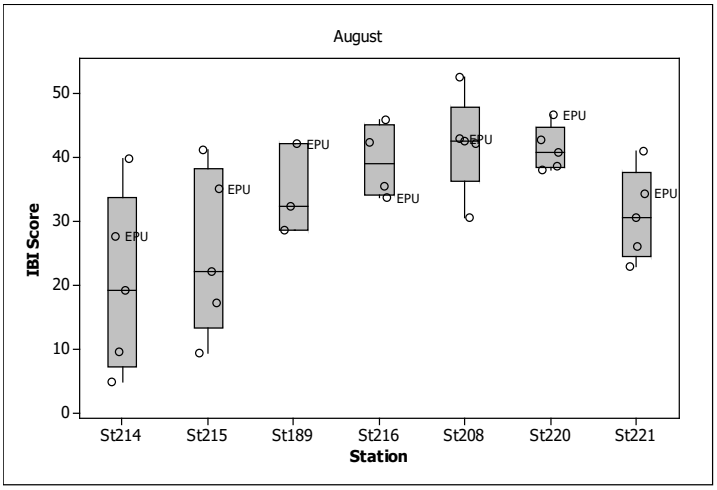


Figure 6-8. Box plot of August IBI scores for all stations during pre-EPU (2010-2013) and post-EPU (2016) monitoring. Stations 208, 220, and 221 are considered non-thermal.

(boxes = interquartile range containing 50% of the values, the line across the box = median value, vertical lines extending from the box = highest and lowest values, open circle = IBI score, the post-EPU value is labeled EPU, and asterisk = outlier)

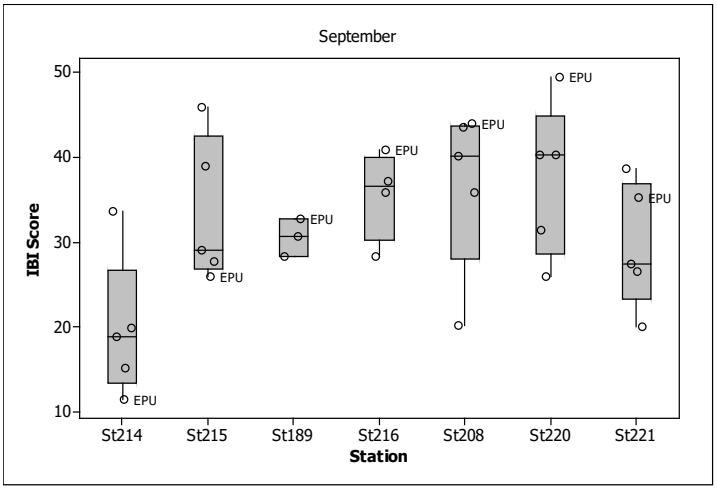


Figure 6-9. Box plot of September IBI scores for all stations during pre-EPU (2010-2013) and post-EPU (2016) monitoring. Stations 208, 220, and 221 are considered non-thermal.

(boxes = interquartile range containing 50% of the values, the line across the box = median value, vertical lines extending from the box = highest and lowest values, open circle = IBI score, the post-EPU value is labeled EPU, and asterisk = outlier)

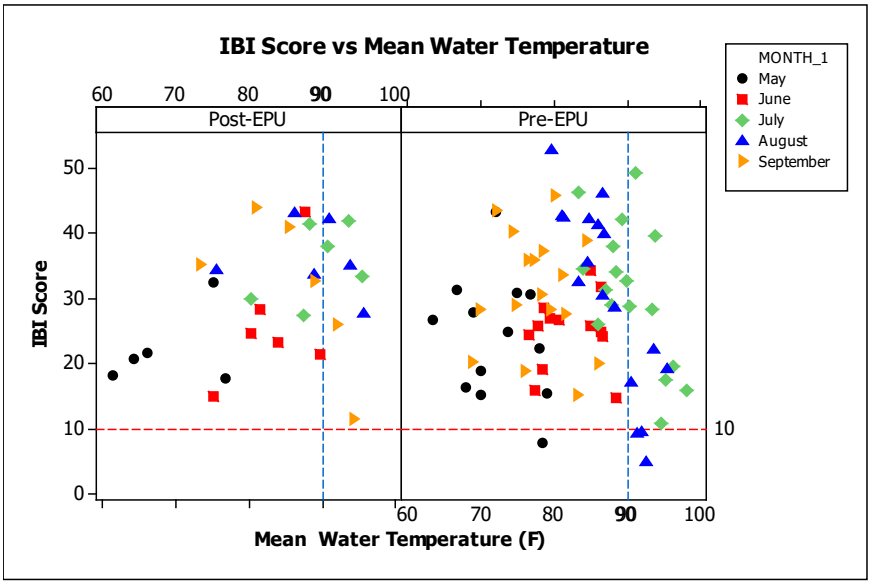


Figure 6-10. Relation of mean water temperature measured during the month of benthos collection to the corresponding IBI Score for that month for post-EPU (left panel) and pre-EPU (right panel) monitoring, May through September 2010-2016.

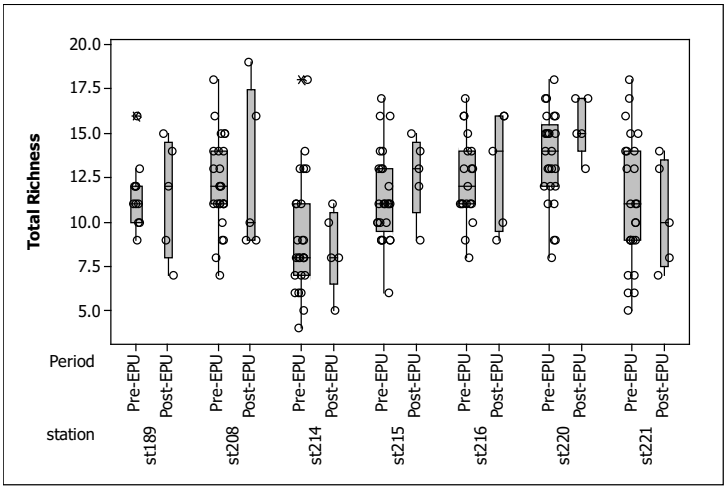


Figure 6-11. Box plot of Total Richness for all stations during pre-EPU (2010-2013) and post-EPU (2016) monitoring, May through September. Stations 208, 220, and 221 are considered non-thermal.

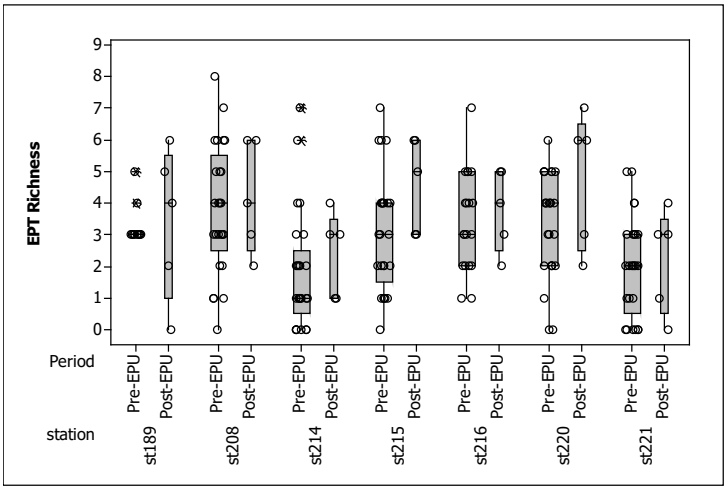


Figure 6-12. Box plot of EPT Richness for all stations during pre-EPU (2010-2013) and post-EPU (2016) monitoring, May through September. Stations 208, 220, and 221 are considered non-thermal.

(boxes = interquartile range containing 50% of the values, the line across the box = median value, vertical lines extending from the box = highest and lowest values, open circle = metric value, and asterisk = outlier)

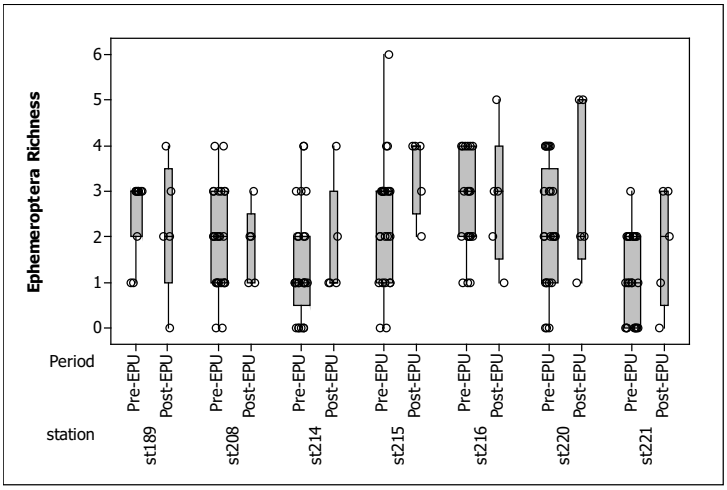


Figure 6-13. Box plot of Ephemeroptera Richness for all stations during pre-EPU (2010-2013) and post-EPU (2016) monitoring, May through September. Stations 208, 220, and 221 are considered non-thermal.

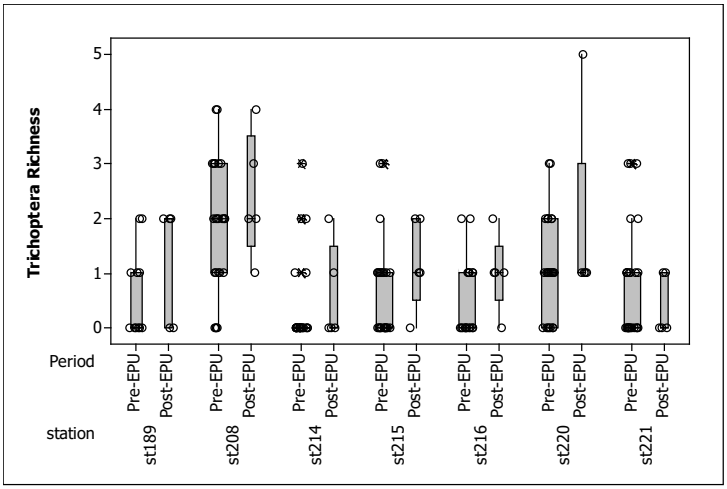


Figure 6-14. Box plot of Trichoptera Richness for all stations during pre-EPU (2010-2013) and post-EPU (2016) monitoring, May through September. Stations 208, 220, and 221 are considered non-thermal.

(boxes = interquartile range containing 50% of the values, the line across the box = median value, vertical lines extending from the box = highest and lowest values, open circle = metric value, and asterisk = outlier)

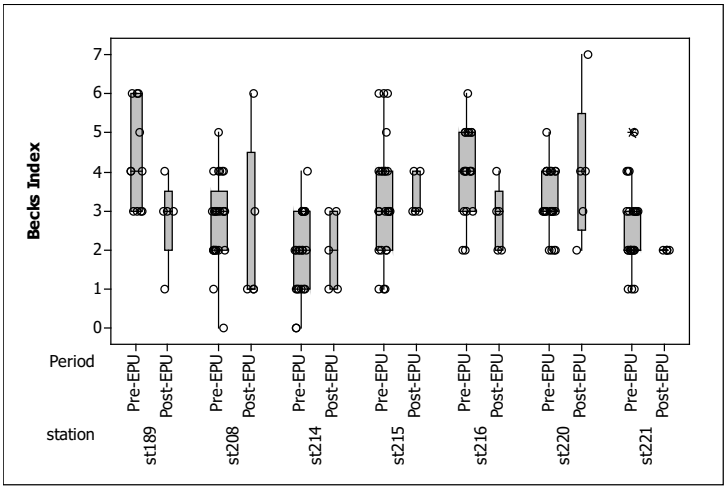


Figure 6-15. Box plot of Beck's Index for all stations during pre-EPU (2010-2013) and post-EPU (2016) monitoring, May through September. Stations 208, 220, and 221 are considered non-thermal.

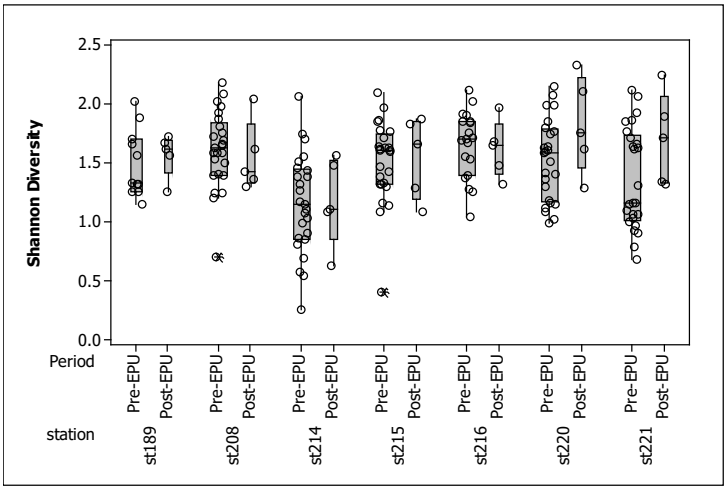


Figure 6-16. Box plot of Shannon Diversity for all stations during pre-EPU (2010-2013) and post-EPU (2016) monitoring, May through September. Stations 208, 220, and 221 are considered non-thermal.

(boxes = interquartile range containing 50% of the values, the line across the box = median value, vertical lines extending from the box = highest and lowest values, open circle = metric value, and asterisk = outlier)

6.3 Fish Community

The spatial and temporal distribution of fish was evaluated in Conowingo Pond by monthly sampling at both thermally influenced and non-thermally influenced locations from May through September 2016. Sampling sites were separated into non-thermal and thermal stations based on their location in relation to the PBAPS thermal plume. Stations downstream of the discharge canal that experience elevated water temperatures above ambient water temperature for the entire collection period are considered to be thermally influenced (electrofisher Stations 161, 189, 190, and 217; seine Stations 214 and 215). Stations located upstream of the PBAPS thermal discharge that experience natural water temperature conditions are considered non-thermal (electrofisher Stations 165 and 187; seine Stations 208, 220, and 221). As previously discussed seine Station 208 does experience elevated water temperatures during a portion of the year resulting from thermal plume movement upstream during low flow conditions; however, this station is considered non-thermal because it does not experience a prolonged year-round thermal influence.

The relative abundance of all fish was determined by standardizing the number of individuals of each species collected per unit of collection effort for each sampling gear. Comparison between the pre-EPU and post-EPU communities was completed to evaluate the potential effect of the temperature rise associated with the EPU on the fish community.

Eleven fish species were previously designated as representative important species (RIS) for the most recent pre-EPU 316a Demonstration Study (Normandeau and ERM 2014). The species were agreed upon with PADEP. Most of these species are appropriate representative species for assessment of potential thermal impact consistent with the concept of RIS, as established by the USEPA (1977), e.g., recreational value, representative of the balanced indigenous community, or an important food item for other RIS. The eleven RIS were Bluegill, Bluntnose Minnow, Channel Catfish, Gizzard Shad, Largemouth Bass, Chesapeake Logperch, Smallmouth Bass, Spotfin Shiner, Walleye, White Crappie, and White Sucker. The composition and relative abundance of the RIS at each of the monitoring stations are evaluated and compared between pre- and post-EPU monitoring. The selected RIS did not include migratory fish species.

6.3.1 Methods

Electrofishing

Electrofishing was conducted at night at six stations located along the shores of Conowingo Pond (Table 6-1 and Figure 6-3). The electrofishing system consisted of a Smith-Root VVP-15B variable voltage pulsator, powered by a 3.5-kW generator, and mounted in an 18-ft aluminum boat equipped with a bow-mounted T-boom cathode array and flood lights. Fishes were collected using pulsed direct current to minimize fish injury. Sampling at each location consisted of a 30-minute run and was typically completed in one pass through the sampling location. The electrofishing boat was maneuvered slowly through the site, as close to shore as possible.

Stunned fish were netted at the bow and placed in a live well. Large stunned specimens of Common Carp and Quillback were not netted, but were counted by the netting crew and recorded. At the end of 30 minutes, the boat was returned to the center of the station, and the catch processed. Each fish was identified to species, measured to the nearest millimeter (mm) total length (TL), weighed to the nearest gram, and released. When a large number (>50) of a single species was collected, a subsample of 50 specimens was measured into 10 mm TL intervals, batch weighed, and an exact count was made of the remainder and released.

Seine

Seining was conducted at five shoreline stations (Table 6-1, Figure 6-1) Conowingo Pond. A 10 x 4-ft straight seine with ¼-inch mesh was used. The seine was deployed and moved parallel to shore for a short distance, then moved into shore to trap fish; this effort constituted one seine haul. Since size and habitat of seine stations varied, an effort was made to collect a representative sample based on complete coverage of all available habitats, limiting the number of hauls at each station to five. All specimens were identified, counted, and released near the capture site. Specimens that were too small to accurately identify to species in the field were only identified to genus.

Catch Overview

This section provides a general summary of the fish catch information produced by the seine, and electrofishing sampling conducted in 2016. Table 6-13 provides a list of common and scientific names of fish species observed in Conowingo Pond during the course of this study. The sampling methods used in this study were deployed in similar habitats but targeted certain species and sizes of fish. Seining targeted small-bodied fishes (Cyprinidae) and young of year of large-bodied fishes (Centrarchidae). Electrofishing was effective for both large and small fish.

A total of 14,568 individuals representing 34 species was collected in this study by seining and electrofishing in Conowingo Pond. A diverse warmwater fish community was represented by eight families of fish with three families (Cyprinidae, Centrarchidae, and Percidae) predominating the catch. Twenty-four of the species collected were within these three families.

The summary of the electrofishing data, with the results grouped by thermally affected and non-thermally affected stations, are presented in Table 6-14. A total of 12,879 individuals and 31 species was collected with boat electrofisher in 2016. Bluegill and Gizzard Shad was the most numerous species taken by boat electrofisher. Other numerous species included Channel Catfish, Comely Shiner, Green Sunfish, Smallmouth Bass, and Spotfin Shiner. Table 6-15 through Table 6-19 provide the monthly electrofishing catch for each station.

The summary of the seine data, with the results grouped by thermally affected and non-thermally affected stations are presented in Table 6-20. A total of 1,689 individuals and 17 species was collected with seine in 2016. Bluegill and Spotfin Shiner was the most numerous species taken by seine. Other numerous species included Banded Killifish, Golden Shiner, and Comely Shiner. Table 6-21 through Table 6-25 provide the monthly seine catch for each station.

Table 6-13. List of common and scientific names of fishes collected in Conowingo Pond, May through September 2016.

Anguillidae	**Eels**
Anguilla rostrata	American eel
Clupeidae	**Herrings**
Dorosoma cepedianum	Gizzard shad
Cyprinidae	**Carps and minnows**
Campostoma anomalum	Central stoneroller
Cyprinella spiloptera	Spotfin shiner
Cyprinus carpio	Common carp
Notemigonus crysoleucas	Golden shiner
Notropis amoenus	Comely shiner
Notropis hudsonius	Spottail shiner
Notropis volucellus	Mimic shiner
Pimephales notatus	Bluntnose minnow
Rhinichthys atratulus	Blacknose dace
Semotilus corporalis	Fallfish
Catostomidae	**Suckers**
Carpiodes cyprinus	Quillback
Catostomus commersoni	White sucker
Hypentelium nigricans	Northern hogsucker
Moxostoma macrolepidotum	Shorthead redhorse
Ictaluridae	**Bullhead catfishes**
Ictalurus punctatus	Channel catfish
Pylodictis olivaris	Flathead catfish
Cyprinodontidae	**Killifishes**
Fundulus diaphanus	Banded killifish
Percichthyidae	**Temperate basses**
Morone americana	White perch
Centrarchidae	**Sunfishes**
Ambloplites rupestris	Rock bass
Lepomis auritus	Redbreast sunfish
Lepomis cyanellus	Green sunfish
Lepomis gibbosus	Pumpkinseed
Lepomis macrochirus	Bluegill
Micropterus dolomieu	Smallmouth bass
Micropterus salmoides	Largemouth bass
Pomoxis annularis	White crappie
Percidae	**Perches**
Etheostoma blennioides	Greenside darter
Etheostoma olmstedi	Tessellated darter
Perca flavescens	Yellow perch
Percina bimaculata	Chesapeake logperch
Percina peltata	Shield darter
Stizostedion vitreum	Walleye

Table 6-14. Total number of fish collected with boat electrofisher from Conowingo Pond, May through September 2016.

Taxon	Thermally Affected				Non-thermally Affected		Total Number
	161	189	190	217	165	187	
American Eel			1				1
Banded killifish					1		1
Bluegill	**168**	**384**	**615**	**1141**	**364**	**2194**	**4866**
Bluntnose minnow		**16**	**12**	**1**	**12**	**33**	**74**
Channel catfish	**97**	**34**	**58**	**74**	**83**	**60**	**406**
Comely shiner	119	26	73	2	116	25	361
Common carp	19	10	11	17	3	9	69
Fallfish		2				2	4
Flathead catfish	8	12	9		5	4	38
Gizzard shad	**1010**	**170**	**1620**	**291**	**81**	**1128**	**4300**
Golden shiner		137	22	51	1		211
Green sunfish	156	126	234	235	100	19	870
Greenside darter			1				1
Largemouth bass	**3**	**25**	**18**	**38**	**12**	**10**	**106**
Chesapeake Logperch		**3**	**7**	**21**	**17**	**24**	**72**
Northern hogsucker						2	2
Pumpkinseed		1	2	1	2	1	7
Quillback	1			1	1		3
Redbreast sunfish		1		1			2
Rock bass	2	12	9	42	80	94	239
shield darter					2		2
Shorthead redhorse		4	1	7	1	5	18
Smallmouth bass	**45**	**88**	**149**	**176**	**209**	**117**	**784**
Spotfin shiner	**70**	**48**	**94**	**17**	**13**	**37**	**279**
Spottail shiner		1	2	13	9	20	45
Tessellated darter				3	3	20	26
Walleye	**1**	**1**	**1**	**2**	**2**	**30**	**37**
White crappie						**1**	**1**
White perch	18			6		3	27
White sucker				**1**			**1**
Yellow perch		6			3	17	26
Total Number	1717	1101	2939	2141	1117	3838	12879
Total Species	14	20	20	22	22	22	31
Total RIS species	5	6	7	7	8	8	10

Species designated as Representative Important Species (RIS) during the 316a Demonstration Study are represented with bold font

Table 6-15. Total number (no./0.5 hour) of fish collected with boat electrofisher from Conowingo Pond, May 2016.

Taxon	Thermally Affected				Non-thermally Affected		Total Number
	161	189	190	217	165	187	
American Eel			1				1
Bluegill	**71**	**31**	**107**	**128**	**35**	**14**	**386**
Bluntnose minnow		**2**	**5**		**2**	**17**	**26**
Channel catfish	**8**	**13**	**28**	**26**	**14**	**10**	**99**
Comely shiner	113	1	4		1	22	141
Common carp	15	2	2	2		1	22
Fallfish		2				2	4
Flathead catfish	5	4					9
Gizzard shad	**300**	**7**	**14**	**12**	**1**		**334**
Golden shiner		1	1	4			6
Green sunfish	28	14	80	13	14	2	151
Largemouth bass	**3**	**22**	**17**	**22**	**11**	**7**	**82**
Northern hogsucker						1	1
Pumpkinseed			2	1	1		4
Rock bass	2	4	4	15	36	35	96
Shorthead redhorse		4				3	7
Smallmouth bass	**26**	**26**	**59**	**73**	**76**	**35**	**295**
Spotfin shiner	**56**	**7**	**1**		**5**	**18**	**87**
Spottail shiner						7	7
Tessellated darter					1	15	16
Walleye	**1**	**1**	**1**	**1**	**2**	**12**	**18**
White crappie						**1**	**1**
White perch	18			6		3	27
White sucker				**1**			**1**
Yellow perch		6			3	13	22
Total Number	646	147	326	304	202	218	1843
Total Species	13	17	15	13	14	19	25
Total RIS species	7	8	8	7	8	8	10
Shannon Diversity	1.71	2.35	1.83	1.74	1.86	2.55	
Maximum Diversity	2.56	2.83	2.71	2.56	2.64	2.94	
Evenness	0.67	0.83	0.67	0.68	0.70	0.87	

Species designated as Representative Important Species (RIS) during the 316a Demonstration Study are represented with bold font

Table 6-16. Total number (no./0.5 hour) of fish collected with boat electrofisher from Conowingo Pond, June 2016.

Taxon	Thermally Affected				Non-thermally Affected		Total Number
	161	189	190	217	165	187	
Banded killifish					1		**1**
Bluegill	**2**	**31**	**64**	**93**	**8**	**3**	**201**
Bluntnose minnow		**5**					**5**
Channel catfish	**4**	**4**	**8**	**8**	**18**	**7**	**49**
Comely shiner	4	5	11	1		1	**22**
Common carp	1			2			**3**
Flathead catfish	2	6	5		1	1	**15**
Gizzard shad	**3**	**1**				**29**	**33**
Green sunfish	30	14	34	30	8	1	**117**
Largemouth bass					**1**	**1**	**2**
Chesapeake Logperch			**2**	**2**	**1**	**1**	**6**
Northern hogsucker						1	**1**
Pumpkinseed		1					**1**
Quillback	1						**1**
Redbreast sunfish				1			**1**
Rock bass		1	1	5	17	32	**56**
Shorthead redhorse				1		1	**2**
Smallmouth bass	**13**	**10**	**25**	**10**	**33**	**35**	**126**
Spotfin shiner	**5**	**14**	**36**	**3**		**4**	**62**
Spottail shiner						1	**1**
Walleye				**1**		**1**	**2**
Yellow perch						1	**1**
Total Number	65	92	186	157	88	120	708
Total Species	10	11	9	12	9	16	22
Total RIS Species	5	6	5	6	5	8	9
Shannon Diversity	1.70	1.96	1.74	1.38	1.65	1.83	
Maximum Diversity	2.30	2.40	2.20	2.48	2.20	2.77	
Evenness	0.74	0.82	0.79	0.55	0.75	0.66	

Species designated as Representative Important Species (RIS) during the 316a Demonstration Study are represented with bold font

Table 6-17. Total number (no./0.5 hour) of fish collected with boat electrofisher from Conowingo Pond, July 2016.

Taxon	Thermally Affected				Non-thermally Affected		Total Number
	161	189	190	217	165	187	
Bluegill	**27**	**67**	**300**	**331**	**55**	**19**	**799**
Bluntnose minnow		**7**	**3**		**3**	**6**	**19**
Channel catfish	**72**	**7**	**3**	**3**	**30**	**15**	**130**
Comely shiner		17	36		22	1	76
Common carp	2	4	3	1	2	5	17
Flathead catfish	1	1	3		3	2	10
Gizzard shad		**27**	**390**	**17**	**23**	**4**	**461**
Golden shiner		69	9	29			107
Green sunfish	40	49	64	52	20	10	235
Largemouth bass		**3**	**1**	**8**			**12**
Chesapeake Logperch		**3**	**4**	**17**	**8**	**20**	**52**
Quillback				1			1
Redbreast sunfish		1					1
Rock bass		5	1	15	17	20	58
shield darter					2		2
Shorthead redhorse				4			4
Smallmouth bass	**1**	**20**	**25**	**25**	**39**	**32**	**142**
Spotfin shiner	**3**	**21**	**26**	**7**	**1**	**6**	**64**
Spottail shiner		1	2	13	3	8	27
Tessellated darter				3	1	5	9
Walleye						**14**	**14**
Yellow perch						3	3
Total Number	146	302	870	526	229	170	2243
Total Species	7	16	15	15	15	16	22
Total RIS Species	4	8	8	7	6	7	9
Shannon Diversity	1.22	2.16	1.44	1.48	2.19	2.48	
Maximum Diversity	1.95	2.77	2.71	2.71	2.71	2.77	
Evenness	0.63	0.78	0.53	0.55	0.81	0.89	

Species designated as Representative Important Species (RIS) during the 316a Demonstration Study are represented with bold font

Table 6-18. Total number (no./0.5 hour) of fish collected with boat electrofisher from Conowingo Pond, August 2016.

Taxon	Thermally Affected				Non-thermally Affected		Total Number
	161	189	190	217	165	187	
Bluegill	**34**	**160**	**82**	**223**	**142**	**2050**	**2691**
Bluntnose minnow		**2**	**4**			**6**	**12**
Channel catfish	**9**		**6**	**4**	**10**	**7**	**36**
Comely shiner	2	3	9	1	50	1	66
Common carp		2	2	2		1	7
Flathead catfish		1	1		1		3
Gizzard shad	**79**	**81**	**1094**	**236**	**35**	**1047**	**2572**
Golden shiner		26	6	17			49
Green sunfish	34	25	26	2	44		131
Largemouth bass				**1**		**1**	**2**
Logperch				**1**	**4**		**5**
Rock bass		2	1	1	4	2	10
Shorthead redhorse			1	1			2
Smallmouth bass	**5**	**10**	**13**	**39**	**19**	**5**	**91**
Spotfin shiner	**6**	**5**	**14**	**1**		**4**	**30**
Spottail shiner						4	4
Tessellated darter					1		1
Walleye						**1**	**1**
Total Number	169	317	1259	529	310	3129	5713
Total Species	7	11	13	13	10	12	18
Total RIS Species	5	5	6	7	5	8	9
Shannon Diversity	1.43	1.43	0.61	1.18	1.61	0.71	
Maximum Diversity	1.95	2.40	2.56	2.56	2.30	2.48	
Evenness	0.74	0.60	0.24	0.46	0.70	0.29	

Species designated as Representative Important Species (RIS) during the 316a Demonstration Study are represented with bold font

Table 6-19. Total number (no./0.5 hour) of fish collected with boat electrofisher from Conowingo Pond, September 2016.

Taxon	Thermally Affected				Non-thermally Affected		Total Number
	161	189	190	217	165	187	
Bluegill	**34**	**95**	**56**	**366**	**124**	**108**	**783**
Bluntnose minnow				**1**	**7**	**4**	**12**
Channel catfish	**4**	**10**	**13**	**33**	**11**	**21**	**92**
Comely shiner			13		43		56
Common carp	1	2	4	10	1	2	20
Flathead catfish						1	1
Gizzard shad	**628**	**54**	**122**	**26**	**22**	**48**	**900**
Golden shiner		41	6	1	1		49
Green sunfish	24	24	30	138	14	6	236
Greenside darter			1				1
Largemouth bass				**7**		**1**	**8**
Chesapeake Logperch			**1**	**1**	**4**	**3**	**9**
Pumpkinseed					1	1	2
Quillback					1		1
Rock bass			2	6	6	5	19
Shorthead redhorse				1	1	1	3
Smallmouth bass		**22**	**27**	**29**	**42**	**10**	**130**
Spotfin shiner		**1**	**17**	**6**	**7**	**5**	**36**
Spottail shiner					6		6
Walleye						**2**	**2**
Total Number	691	249	292	625	291	218	2366
Total Species	5	8	12	13	16	15	20
Total RIS Species	3	4	6	7	7	7	9
Shannon Diversity	0.39	1.63	1.79	1.32	1.81	1.59	
Maximum Diversity	1.61	2.08	2.48	2.56	2.77	2.71	
Evenness	0.24	0.78	0.72	0.52	0.65	0.59	

Species designated as Representative Important Species (RIS) during the 316a Demonstration Study are represented with bold font

Table 6-20. Total number of fish collected in seine collections from Conowingo Pond, May through September 2016.

Taxon [1]	Station [2]					Total Number
	Thermally Affected		Non-thermally Affected			
	214	215	208	220	221	
Banded killifish	53	1	19	1	208	282
blacknose dace	1					1
Bluegill	**193**	**76**	**105**	**180**	**2**	**556**
Bluntnose minnow	**3**	**9**	**3**	**18**	**1**	**34**
central stoneroller	1					1
Comely shiner	92	1		5		98
Gizzard shad			**1**			**1**
Golden shiner	187					187
Green sunfish	24	9	4	5		42
Largemouth bass			**1**			**1**
Chesapeake Logperch				**2**		**2**
Mimic shiner	1			1		2
Pumpkinseed			1			1
Rock bass			2	9		11
Smallmouth bass			**2**	**1**		**3**
Spotfin shiner	**165**	**108**	**3**	**157**	**12**	**445**
Spottail shiner		3		11	6	20
Tessellated darter			2			2
Total Number	720	207	143	390	229	1689
Total Species	10	7	10	11	5	17
Total RIS	3	3	6	5	3	7

[1] Representative Important Species represented with bold font

[2] Five seine hauls completed during each month at each station; therefore, total number equivalent to CPUE

Table 6-21. Total number (CPUE) of fish collected with seine from Conowingo Pond, May 2016.

Taxon [1]	Station [2]					Total Number
	Thermally Affected		Non-thermally Affected			
	214	215	208	220	221	
Banded killifish	40	1	2	1	155	199
Blacknose Dace	1					1
Bluntnose minnow	**3**				**1**	**4**
Comely shiner	92					92
Mimic shiner	1					1
Spotfin shiner	**34**	**20**				**54**
Total Number	171	21	2	1	156	351
Total Species	6	2	1	1	2	6
Total RIS	2	1	0	0	1	2
Shannon Diversity	1.13	0.19	0.00	0.00	0.04	
Maximum Diversity	1.79	0.69	0.00	0.00	0.69	
Evenness	0.63	0.28	0.00	0.00	0.06	

[1] Representative Important Species represented with bold font

[2] Five seine hauls completed at each station; therefore, total number equivalent to CPUE

Table 6-22. Total number (CPUE) of fish collected with seine from Conowingo Pond, June 2016.

Taxon [1]	Station [2]					Total Number
	Thermally Affected		Non-thermally Affected			
	214	215	208	220	221	
Banded killifish	6		2		15	23
Bluegill	**1**			**3**		**4**
Bluntnose minnow				**1**		**1**
Largemouth bass			**1**			**1**
Rock bass			1	1		2
Smallmouth bass			**2**			**2**
Spotfin shiner	**10**	**1**	**2**	**7**	**2**	**22**
Spottail shiner		1				1
Total Number	17	2	8	12	17	56
Total Species	3	2	5	4	2	8
Total RIS	2	1	3	3	1	5
Shannon Diversity	0.85	0.69	1.56	1.08	0.36	
Maximum Diversity	1.10	0.69	1.61	1.39	0.69	
Evenness	0.77	1.00	0.97	0.78	0.52	

[1] Representative Important Species represented with bold font

[2] Five seine hauls completed at each station; therefore, total number equivalent to CPUE

Table 6-23. Total number (CPUE) of fish collected with seine from Conowingo Pond, July 2016.

Taxon [1]	Station [2]					Total Number
	Thermally Affected		Non-thermally Affected			
	214	215	208	220	221	
						17
Banded killifish	2		1		14	214
Bluegill	**97**	**52**	**2**	**63**		**6**
Bluntnose minnow		**6**				**1**
central stoneroller	1					3
Comely shiner				3		187
Golden shiner	187					18
Green sunfish	16	1		1		1
Mimic shiner				1		1
Smallmouth bass				**1**		**146**
Spotfin shiner	56	56		31	3	15
Spottail shiner		**2**		**7**	**6**	**609**
Total Number	359	117	3	107	23	1201
Total Species	6	5	2	7	3	12
Total RIS	1	3	1	3	1	4
Shannon Diversity	1.17	0.98	0.64	1.08	0.92	
Maximum Diversity	1.79	1.61	0.69	1.95	1.10	
Evenness	0.65	0.61	0.92	0.56	0.84	

[1] Representative Important Species represented with bold font

[2] Five seine hauls completed at each station; therefore, total number equivalent to CPUE

Table 6-24. Total number (CPUE) of fish collected with seine from Conowingo Pond, August 2016.

Taxon [1]	Station [2]					Total Number
	Thermally Affected		Non-thermally Affected			
	214	215	208	220	221	
Banded killifish			12		14	26
Bluegill	**12**	**20**	**37**	**85**	**2**	**156**
Bluntnose minnow			**3**	**2**		**5**
Gizzard shad			**1**			**1**
Green sunfish		8		2		10
Pumpkinseed			1			1
Rock bass				8		8
Spotfin shiner	**24**	**8**	**1**	**29**	**7**	**69**
Spottail shiner				4		4
Tessellated darter			1			1
Total Number	36	36	56	130	23	281
Total Species	2	3	7	6	3	10
Total RIS	2	2	4	3	2	4
Shannon Diversity	0.64	1.00	1.05	1.02	0.88	
Maximum Diversity	0.69	1.10	1.95	1.79	1.10	
Evenness	0.92	0.91	0.54	0.57	0.80	

[1] Representative Important Species represented with bold font

[2] Five seine hauls completed at each station; therefore, total number equivalent to CPUE

Table 6-25. Total number (CPUE) of fish collected with seine from Conowingo Pond, September 2016.

Taxon [1]	Station [2]					Total Number
	Thermally Affected		Non-thermally Affected			
	214	215	208	220	221	
Banded killifish	5		2		10	17
Bluegill	**83**	**4**	**66**	**29**		**182**
Bluntnose minnow		**3**		**15**		**18**
Comely shiner		1		2		**3**
Green sunfish	8		4	2		14
Chesapeake Logperch				**2**		**2**
Rock bass			1			1
Spotfin shiner	**41**	**23**		**90**		**154**
Tessellated darter			1			1
Total Number	137	31	74	140	10	392
Total Species	4	4	5	6	1	9
Total RIS	2	3	1	4	0	4
Shannon Diversity	0.95	0.82	0.47	1.03	0.00	
Maximum Diversity	1.39	1.39	1.61	1.79	0.00	
Evenness	0.69	0.59	0.29	0.58	0.00	

[1] Representative Important Species represented with bold font

[2] Five seine hauls completed at each station; therefore, total number equivalent to CPUE

Fish Metrics and CPUE

Comparison of catch per unit effort (CPUE) and community based metrics among collection locations is useful in describing differences in the fish community among stations. Gear specific CPUE normalizes the catch based on level of effort and, therefore, allows standardized comparisons of relative abundance. Several metrics that describe the fish community at individual stations were calculated for the seine and electrofishing collections. Monthly metric values were compared among locations to determine if differences existed between individuals stations.

For this analysis stations are discussed as either non-thermal or thermal based on their location in relation to the PBAPS thermal plume. Electrofishing Stations 161, 189, 190, and 217 are considered thermally influenced and Stations 187 and 165 are considered non-thermal. Seine Stations 214 and 215 are considered thermally influenced and Stations 220, 221, and 208 are considered non-thermal. As previously discussed, Station 208 does experience elevated water

temperatures during a portion of the year resulting from thermal plume movement upstream during low flow conditions. However, this station is considered non-thermal because it does not experience a prolonged thermal influence.

6.3.2 Electrofishing Results 2016

Four metrics were calculated to provide a description of the fish community among stations and across monthly collections in Conowingo Pond from May to September 2016. Table 6-26 through Table 6-29 provide the metric values for each station and Figure 6-17 through Figure 6-20 provide box plots which graphically illustrate the monthly metric values among stations. Catch per unit effort (no./0.5 hour) was generally similar among stations during each month with the lowest CPUE of 65 fish observed at Station 161 in June and the highest CPUE of 3,129 fish observed at Station 187 in August. CPUE for most stations was highest in August with exception of Station161 which had the highest catch during September. Total species richness ranged from five species at Station 161 in September to 19 species at Station 187 in May. Species richness was highest for most stations during May and July. The highest total richness was observed at Station 187 (non-thermal) during most months. Total richness at Station 161 was noticeably lower (range between five and seven species) during July through September compared to all other stations. RIS richness ranged from three species at Station 161 in September to eight species collected at multiple stations during June to August. Similar to species richness, RIS richness was highest for most stations during May and July. RIS richness for Station 187 was generally higher or equal to the other stations for each month of collection. Shannon Diversity values ranged from 0.39 at Station 161 in September to 2.55 at Station 187 in May. Shannon Diversity values were highest for most stations during May and July.

Post-EPU Metric comparison to Pre-EPU

A comparison of pre- and post-EPU electrofishing metric values allows for inspection of potential differences that may have been a result of the increase in temperature from the EPU. Figure 6-17 through Figure 6-20 provide box plots of the four metrics selected to describe the fish community. The metrics include square root transformed CPUE, Total Richness, Total RIS, and Shannon Diversity. pre- and post-EPU metric values for the four metrics were generally comparable for most stations and months. For CPUE the observed values during post-EPU monitoring were comparable to pre-EPU at all electrofishing stations with all post-EPU values within the range of the pre-EPU values. For total species, Stations 189, 190, 165, and 187 values observed post-EPU were greater than or equal to pre-EPU monitoring. For Station 161 during September of the post-EPU monitoring the total of five species was less than pre-EPU observations with six species being the lowest number collected during pre-EPU monitoring. Similarly,12 species were collected post-EPU at Station 217, the lowest number total species at this station was 13 species during pre-EPU monitoring. For Total RIS, Stations 189, 190, 165, and 187 values observed post-EPU were greater than or equal to pre-EPU monitoring. Two Stations, 161 and 189, had one monthly post-EPU value less than pre-EPU monitoring. For both of the stations the post-EPU value was slightly less (one species) compared to pre-EPU observations. Shannon Diversity values during post-EPU monitoring were generally within the range of pre-EPU observations with a few exceptions at Stations 190 (thermally influenced) and

Stations 165 and 187 (non-thermally influenced). Overall, the metrics values for each month of monitoring during post-EPU were comparable to pre-EPU observations indicating that the fish community relative abundance, richness and composition has not measurably changed with the EPU.

6.3.3 Seine Results 2016

Four metrics were calculated to provide a description of the fish community among stations and across monthly collections in Conowingo Pond from May to September 2016. Table 6-30 through Table 6-33 provide the metric values for each station and Figure 6-21 through Figure 6-24 provide box plots which graphically illustrate the monthly metric values among stations. Catch per unit effort (no./five seine hauls) was generally similar among stations during each month with lowest CPUE of one fish observed at Station 220 in May and the highest CPUE of 359 fish observed at Station 214 in July. Total species richness ranged from one species at Stations 208 and 220 to seven species at Stations 208 and 220. RIS richness ranged from zero species at Stations 208, 220, and 221 to four species collected at Stations 208 and 220. Shannon Diversity values ranged from 0.0 at Stations 208, 220, and 221 to 1.55 at Station 208. For each metric the observed values were variable with no consistent seasonal pattern observed.

Post-EPU Metric Comparison to Pre-EPU

A comparison of pre- and post-EPU seine metric values allows for inspection of potential differences that may have been a result of the increase in water temperature from the EPU. Figure 6-21 through Figure 6-24 provide box plots of four metrics selected to describe the fish community. The metrics include square root transformed CPUE, Total Richness, Total RIS, and Shannon Diversity. Pre- and post-EPU metric values for the four metrics were generally comparable for most stations and months. For CPUE the observed values during post-EPU monitoring were comparable to pre-EPU at most seine stations with the exception of Stations 220 and 208 (non-thermal). For total species, Stations 214 and 215 values observed post-EPU were greater than or equal to pre-EPU monitoring. For Stations 208, 220 and 221 a few monthly post-EPU observations were less than pre-EPU with the difference being one species. For Total RIS, the values observed at Stations 214 and 215 during post-EPU monitoring were greater than or equal to pre-EPU monitoring. For Stations 208, 220 and 221 a few monthly post-EPU observations were less than pre-EPU with the difference being one species. Shannon Diversity values during post-EPU monitoring were generally within the range of pre-EPU observations with a few exceptions. At Stations 208, 220, and 221 a few observations during post-EPU monitoring were less than pre-EPU observations. Overall, the metrics values for each month of monitoring post-EPU are comparable to pre-EPU observations indicating that the fish community relative abundance, richness and composition has not measurably changed with the EPU.

6.3.4 Discussion

The community metrics and CPUE provide a description of the fish community both spatially (station) and temporally (month) within Conowingo Pond. The electrofishing results illustrate variation in the data across stations and months. The metrics indicate that fewer fish species were present at Station 161 during July through September. Fishes likely avoided this area because of the elevated water temperatures resulting from the PBAPS thermal discharge. Station 161 is the station closest to PBAPS and experienced the highest water temperatures observed at the electrofishing stations. Patterns of avoidance were not readily apparent from the monthly metric values for most of the other thermally affected electrofishing stations. One exception was Station 189 where species richness was lower indicating avoidance in September. However, species richness at Station 189 was comparable to observations during pre-EPU monitoring at this station. Patterns of avoidance were not readily apparent for the monthly metrics at the thermally affected seine stations.

For both electrofishing and seining collections the metrics values were useful in evaluating differences in the fish community and relative abundance of common species across locations and months of collection. Fish tended to avoid stations that experienced the highest water temperatures during the summer months. This was most clearly evident at electrofishing Station 161 from July through in September where six to eight fewer species were collected as compared to May or June.

6.3.5 Conclusions

- A diverse fish community of 34 species was observed in Conowingo Pond during 2016; Characteristics of the fish community were similar between pre-EPU and post-EPU observations;
- CPUE among species, and between stations, was variable due to differences in year class strength, habitat preferences, and other environmental variables;
- Avoidance was observed at electrofishing Station 161 at high water temperatures from July through September –;
- Avoidance was not observed at the seine stations.

Table 6-26. CPUE of fish by month for electrofishing collection locations in Conowingo Pond, May through September 2016.

	Station					
Month	161	189	190	217	165	187
May	646	147	326	304	202	218
June	65	92	186	157	88	120
July	146	302	870	526	229	170
August	169	317	1229	529	310	3129
September	691	249	292	625	291	218
Mean	343	221	581	428	224	771

Table 6-27. Total RIS by month for electrofishing collection locations in Conowingo Pond, May through September 2016.

	Station					
Month	161	189	190	217	165	187
May	7	8	8	7	8	8
June	5	6	5	6	5	8
July	4	8	8	7	6	7
August	5	5	6	7	5	8
September	3	4	6	7	7	7
Mean	4.8	6.2	6.6	6.8	6.2	7.6

Table 6-28. Total Species by month for electrofishing collection locations in Conowingo Pond, May through September 2016.

	Station					
Month	161	189	190	217	165	187
May	13	17	15	13	14	19
June	10	11	9	12	9	16
July	7	16	15	15	15	16
August	7	11	13	13	10	12
September	5	8	12	13	16	15
Mean	8.4	12.6	12.8	13.2	12.8	15.6

Table 6-29. Shannon Diversity by month for electrofishing collection locations in Conowingo Pond, May through September 2016.

	Station					
Month	161	189	190	217	165	187
May	1.71	2.35	1.83	1.74	1.86	2.55
June	1.70	1.96	1.74	1.38	1.65	1.83
July	1.22	2.16	1.44	1.48	2.19	2.48
August	1.43	1.43	0.61	1.18	1.61	0.71
September	0.39	1.63	1.79	1.32	1.81	1.59
Mean	1.29	1.90	1.48	1.42	1.82	1.83

Table 6-30. CPUE of fish by month for seine collection locations in Conowingo Pond, May through September 2016.

	Station				
Month	214	215	208	220	221
May	171	21	2	1	156
June	17	2	8	12	17
July	359	117	3	107	23
August	36	36	56	130	23
September	137	31	74	140	10
Mean	144	41.4	28.6	78	45.8

Table 6-31. Total RIS by month for seine collection locations in Conowingo Pond, May through September 2016.

	Station				
Month	214	215	208	220	221
May	2	1	0	0	1
June	2	1	3	3	1
July	1	3	1	3	1
August	2	2	4	3	2
September	2	3	1	4	0
Mean	1.8	2	1.8	2.6	1

Table 6-32. Total Species by month for seine collection locations in Conowingo Pond, May through September 2016.

	Station				
Month	214	215	208	220	221
May	6	2	1	1	2
June	3	2	5	4	2
July	6	5	2	7	3
August	2	3	7	6	3
September	4	4	5	6	1
Mean	4.2	3.2	4	4.8	2.2

Table 6-33. Shannon Diversity by month for seine collection locations in Conowingo Pond, May through September 2016.

	Station				
Month	214	215	208	220	221
May	1.1	0.2	0.0	0.0	0.0
June	0.8	0.7	1.6	1.1	0.4
July	1.2	1.0	0.6	1.1	0.9
August	0.6	1.0	1.0	1.0	0.9
September	1.0	0.8	0.5	1.0	0.0
Mean	0.9	0.7	0.7	0.8	0.4

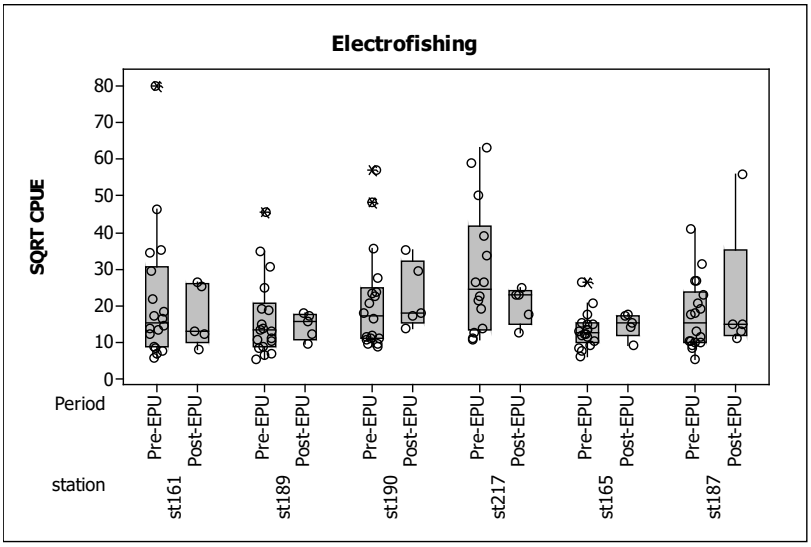


Figure 6-17. Box plot of square root transformed CPUE (no./0.5hr) for all electrofishing stations, May to September, pre-EPU (2010-2013) and post-EPU (2016).

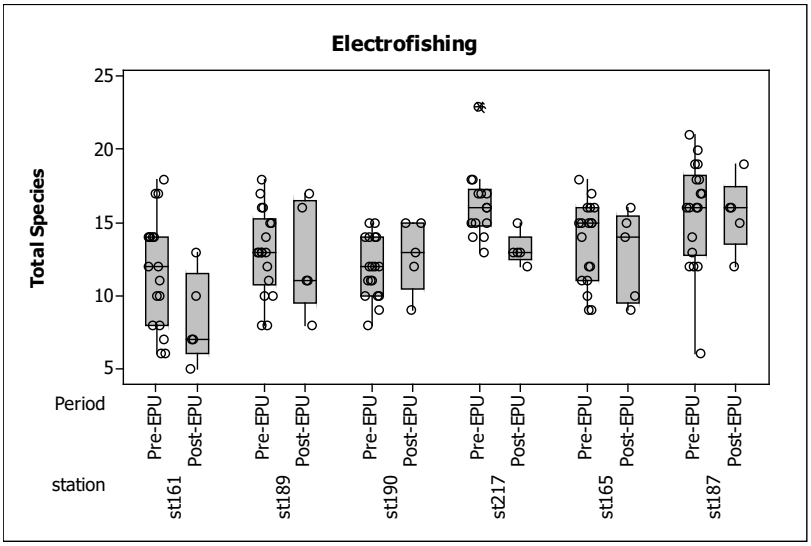


Figure 6-18. Box plot of total species for all electrofishing stations, May to September, pre-EPU (2010-2013) and post-EPU (2016).

(boxes = interquartile range containing 50% of the values, the line across the box = median value, vertical lines extending from the box = highest and lowest values, circle = metric value, and asterisk = outlier)

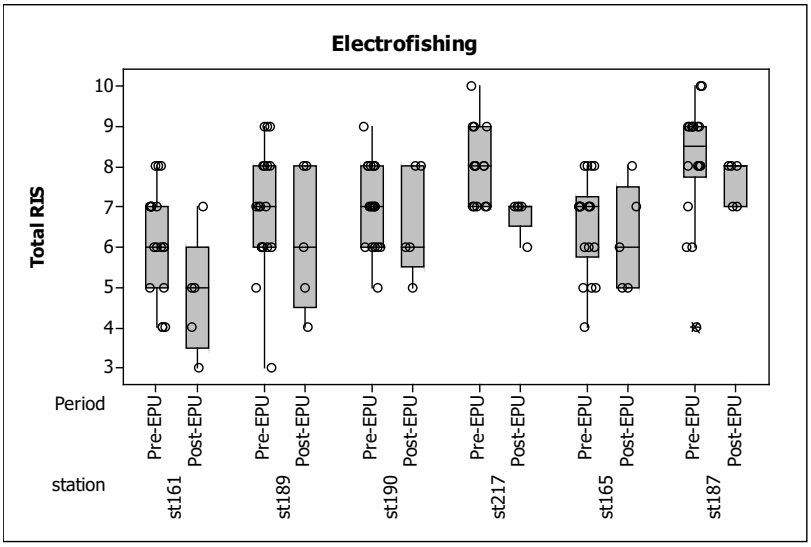


Figure 6-19. Box plot of total RIS for all electrofishing stations, May to September, pre-EPU (2010-2013) and post-EPU (2016).

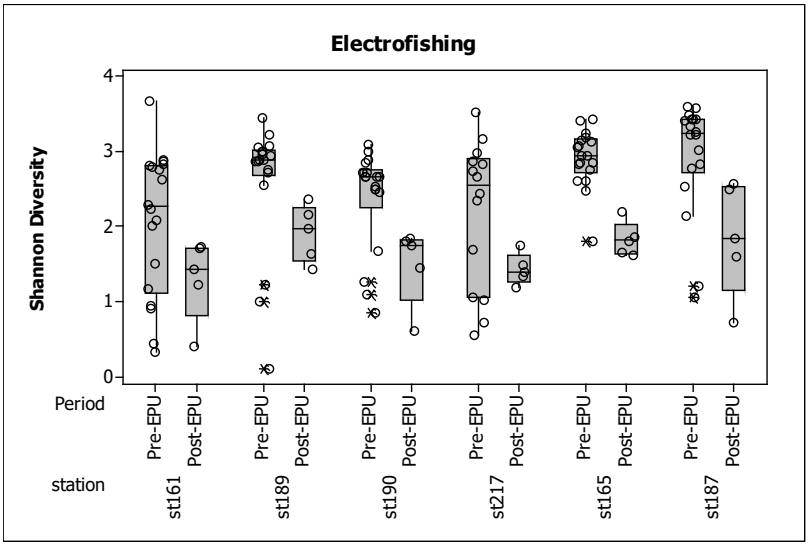


Figure 6-20. Box plot of Shannon Diversity for all electrofishing stations, May to September, pre-EPU (2010-2013) and post-EPU (2016).

(boxes = interquartile range containing 50% of the values, the line across the box = median value, vertical lines extending from the box = highest and lowest values, circle = metric value, and asterisk = outlier)

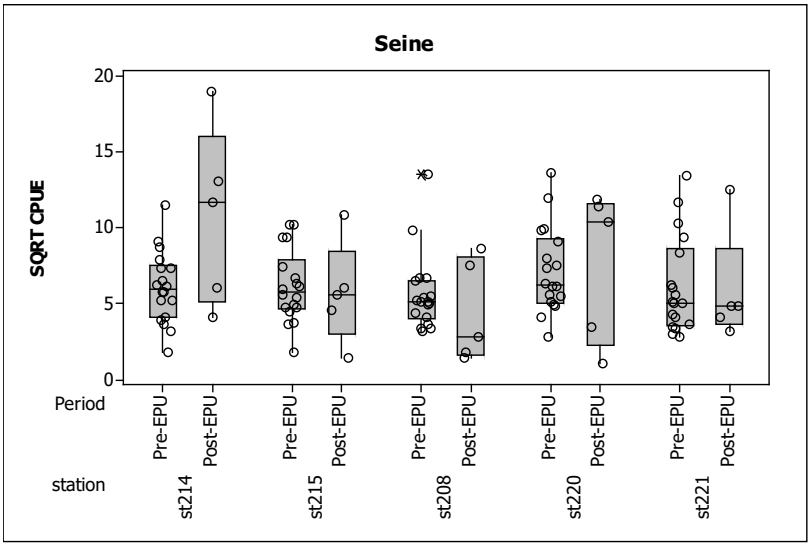


Figure 6-21. Box plot of CPUE for all seine stations, May to September, pre-EPU (2010-2013) and post-EPU (2016).

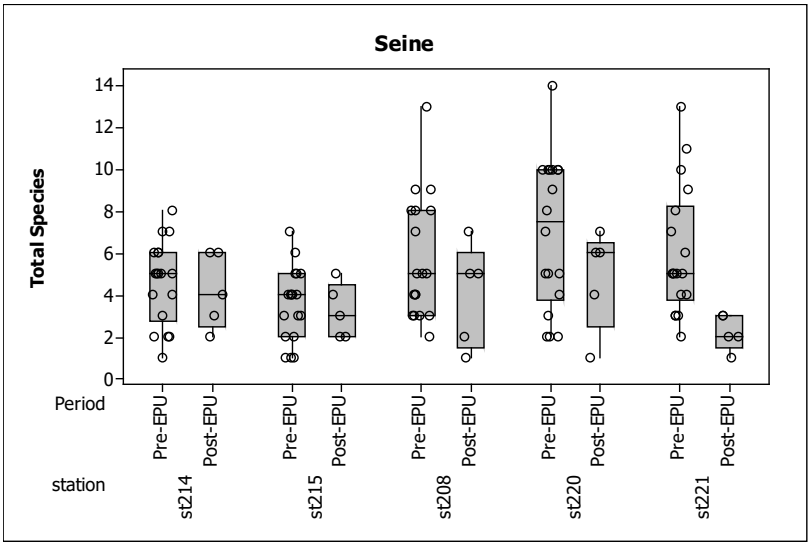


Figure 6-22. Box plot of total species for all seine stations, May to September, pre-EPU (2010-2013) and post-EPU (2016).

(boxes = interquartile range containing 50% of the values, the line across the box = median value, vertical lines extending from the box = highest and lowest values, circle = metric value, and asterisk = outlier)

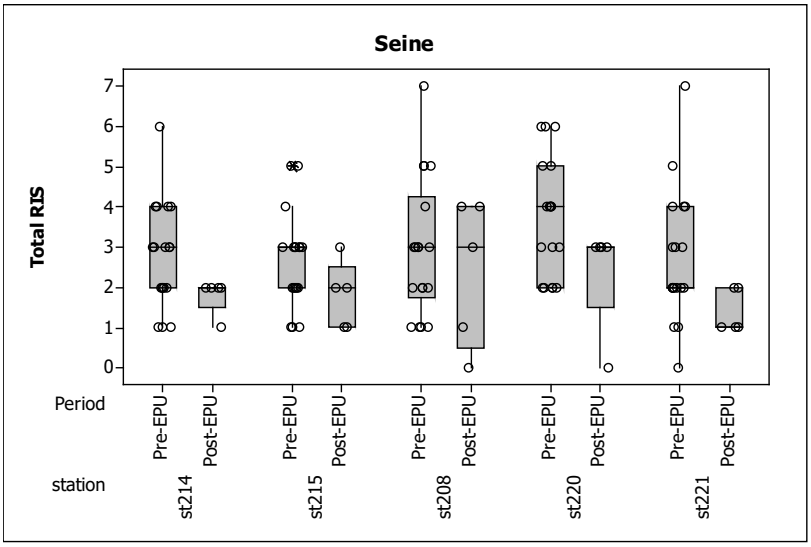


Figure 6-23. Box plot of total RIS for all seine stations, May to September, pre-EPU (2010-2013) and post-EPU (2016).

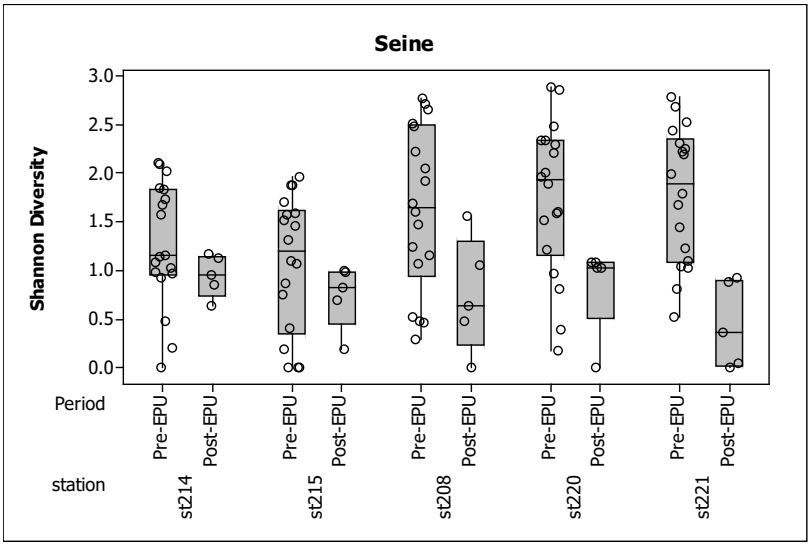


Figure 6-24. Box plot of Shannon Diversity for all seine stations, May to September, pre-EPU (2010-2013) and post-EPU (2016).

(boxes = interquartile range containing 50% of the values, the line across the box = median value, vertical lines extending from the box = highest and lowest values, circle = metric value, and asterisk = outlier)

6.3.6 Length-Frequency Distribution

Length-frequency distributions of fish populations can provide an indication of rates of reproduction, recruitment, growth, and mortality of the age groups present. The length distributions and their changes over time can help in understanding population variations and identifying problems such as year-class failures or low recruitment, slow growth, or excessive

annual mortality (Anderson and Neumann 1996). The presence of small-sized fish represents successful spawning and subsequent survival and multimodal distribution is indicative of several age classes. Only fish collected during May through September were included in this analysis. Stations were grouped into thermal and non-thermal stations as described previously.

Bluegill

The length frequencies of Bluegill collected at the thermal and non-thermal stations exhibit similar multimodal distributions during pre- and post-EPU monitoring with a preponderance of the fish smaller than 60 mm (Figure 6-25). During each period the number of small individuals (<60 mm) collected at the thermal stations was high, suggesting spawning activity in areas affected by the thermal plume. The annual mode of small (<70-mm) Bluegill for the pre- and post-EPU monitoring was within the 45 to 60-mm intervals for both the thermal and non-thermal locations. Additionally, other modes were present, indicating multiple age classes were present at both thermal and non-thermal stations during both periods. The overall similarity of the length frequency distributions indicates substantially similar successful reproduction, recruitment and growth of Bluegill in and near the thermally affected and non-thermally affected habitats represented by the sampling stations during both pre- and post-EPU monitoring.

Bluntnose Minnow

Although the sample sizes were small, comparisons of the length frequencies of Bluntnose Minnow between the thermal and non-thermal stations during both pre- and post-EPU monitoring exhibited similar multimodal distributions (Figure 6-26). Each mode roughly corresponds to a separate age group. Smaller (<50 mm) Bluntnose Minnow were collected in similar numbers at the thermal stations and the non-thermal stations during both pre- and post-EPU monitoring. The presence of fish <50 mm suggests spawning activity in the thermally and non-thermally affected areas.

Channel Catfish

Comparisons of the length frequencies of Channel Catfish between the thermal and non-thermal stations exhibit similar multimodal distributions for the both the pre- and post-EPU monitoring (Figure 6-27). Each mode roughly corresponds to a separate age group. Like the other species, small (<100 mm) Channel Catfish were collected at the thermal stations suggesting spawning activity in the thermally affected areas during both periods.

Gizzard Shad

Comparisons of the length frequencies of Gizzard Shad between the pre- and post-EPU monitoring exhibited similar distributions with a preponderance of the fish being smaller than 100 mm; few adult fish were collected (Figure 6-28). Gizzard Shad was collected in greater numbers at the thermal stations than the non-thermal stations, including large numbers of individuals less than 100 mm, suggesting spawning activity near the thermally affected areas.

Largemouth Bass

Size structure of Largemouth Bass was similar between pre- and post-EPU monitoring (Figure 6-29). Smaller fish (<100 mm) were collected in similar numbers at both thermally and non-thermally influenced locations during both periods. Most individuals were between 120 and 240 mm in length with few fish greater than 300 mm being collected during either period.

Chesapeake Logperch

A similar size structure was observed between pre- and post-EPU monitoring (Figure 6-30). Most fish were between 50-75 mm in total length. During both periods smaller fish (<60 mm) were collected at both thermally and non-thermally influenced locations suggesting spawning activity near the collection stations. The mean length and length range were similar between pre- and post-EPU monitoring (Table 6-34).

Smallmouth Bass

Length frequencies of Smallmouth Bass at the thermal and non-thermal stations during both pre- and post-EPU monitoring exhibited similar multimodal distributions (Figure 6-31). Each mode roughly corresponds to a separate age group. During both periods smaller fish (<100 mm) were collected at both thermally and non-thermally influenced locations suggesting spawning activity near the collection stations. Greater numbers of Smallmouth Bass greater than 250 mm were collected during post-EPU at both thermally influence and non-thermally influenced locations compared to pre-EPU monitoring. The average size of Smallmouth Bass was greater during post-EPU monitoring (Table 6-34).

Spotfin Shiner

Comparisons of the length frequencies of Spotfin Shiner between the thermal and non-thermal stations exhibit similar multimodal distributions for the both the pre- and post-EPU monitoring (Figure 6-32). Similar multimodal distributions suggest the presence of multiple age classes and spawning activity. The average size of Spotfin Shiner was similar between both periods (Table 6-34).

Walleye

A similar size structure was observed between pre- and post-EPU monitoring (Figure 6-33). Most fish were between 150-300 mm in total length. Few fish were collected during post-EPU monitoring within the thermally influenced locations. The mean length and length range were similar between pre- and post-EPU monitoring (Table 6-34).

White Crappie

A figure of length distributions for White Crappie was not generated, as only 28 individuals were collected and measured during pre-EPU monitoring and only one individual was collected during post-EPU monitoring. Due to the extremely small numbers of White Crappie that were collected

from all stations, comparisons of the length frequencies between the two periods would not have been meaningful.

White Sucker

A figure of length distributions for White Sucker was not generated, as only 18 individuals were collected and measured during pre-EPU monitoring and only one individual was collected during post-EPU monitoring. Due to the extremely small numbers of White Sucker that were collected from all stations, comparisons of the length frequencies of between the thermal and non-thermal stations would not have been meaningful.

Discussion and Conclusions

For the RIS that were evaluated multimodal length distributions indicated multiple age classes present at both the thermal and non-thermal stations during both pre- and post-EPU monitoring. Differences in length frequency distributions between pre- and post-EPU monitoring are not directly attributable to changes in the thermal plume from the EPU. Differences in length frequency distributions among species are likely due to habitat differences between stations. For most RIS, small individuals (young-of-the-year) were collected at the thermal stations, suggesting reproduction by the species near the collection location. Comparison of length frequency distributions did not indicate distorted distributions (e.g., absence of young-of-the-year or presence of only one year-class), and for most species many age-classes were present including young individuals and several age classes of mature fish. This analysis indicates that the RIS were able to reproduce, grow, and be recruited to the fish community within Conowingo Pond after the EPU was implemented. No measurable change to the length frequency distribution of fish was observed that is attributable to the EPU.

Table 6-34. Descriptive statistics for total length of RIS collected in Conowingo Pond.

Data obtained using seine and electrofisher for sample stations that were surveyed during both pre-EPU (2010-2013) and post-EPU (2016) monitoring for non-thermal and thermally influenced locations, May through September.

		Pre-EPU				Post-EPU			
Taxon	Location	Mean	Minimum	Maximum	Total Number	Mean	Minimum	Maximum	Total Number
Bluegill	Nonthermal	99	21	220	626	119	21	201	115
Bluegill	Thermal	92	11	250	1150	103	11	219	406
Bluntnose minnow	Nonthermal	58	31	91	239	62	38	91	36
Bluntnose minnow	Thermal	58	22	90	316	59	38	84	27
Channel catfish	Nonthermal	174	41	535	765	194	45	413	142
Channel catfish	Thermal	166	31	611	1294	225	41	496	210
Gizzard shad	Nonthermal	101	21	398	304	102	37	372	82
Gizzard shad	Thermal	93	19	400	494	98	7	340	107
Largemouth bass	Nonthermal	229	45	453	36	154	91	225	22
Largemouth bass	Thermal	204	52	465	168	206	66	475	82
Logperch	Nonthermal	74	40	99	121	66	44	105	36
Logperch	Thermal	71	32	112	144	63	44	102	24
Smallmouth bass	Nonthermal	174	41	508	384	187	12	490	316
Smallmouth bass	Thermal	150	32	494	551	206	34	471	428
Spotfin shiner	Nonthermal	69	11	106	298	74	36	104	47
Spotfin shiner	Thermal	66	22	108	549	72	31	108	149
Walleye	Nonthermal	216	122	470	70	182	114	424	32
Walleye	Thermal	293	97	635	67	292	222	470	4
White crappie	Nonthermal	158	131	195	4	155	155	155	1
White crappie	Thermal	136	47	263	24	*	*	*	0
White sucker	Nonthermal	136	50	260	12	*	*	*	0
White sucker	Thermal	151	96	232	6	271	271	271	1

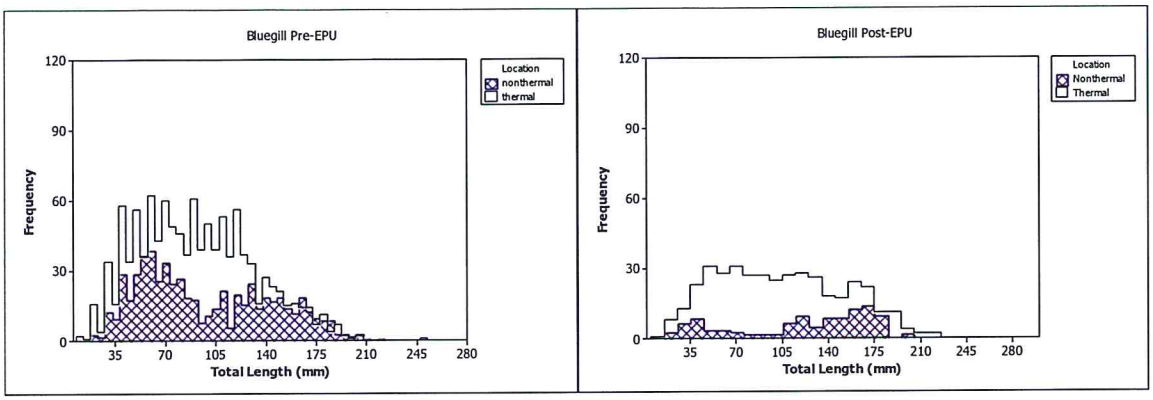


Figure 6-25. Length-frequency distribution of Bluegill collected in Conowingo Pond using seine and electrofisher for sample stations that were surveyed during both pre-EPU (2010-2013) and post-EPU (2016) monitoring for non-thermal and thermally influenced locations.

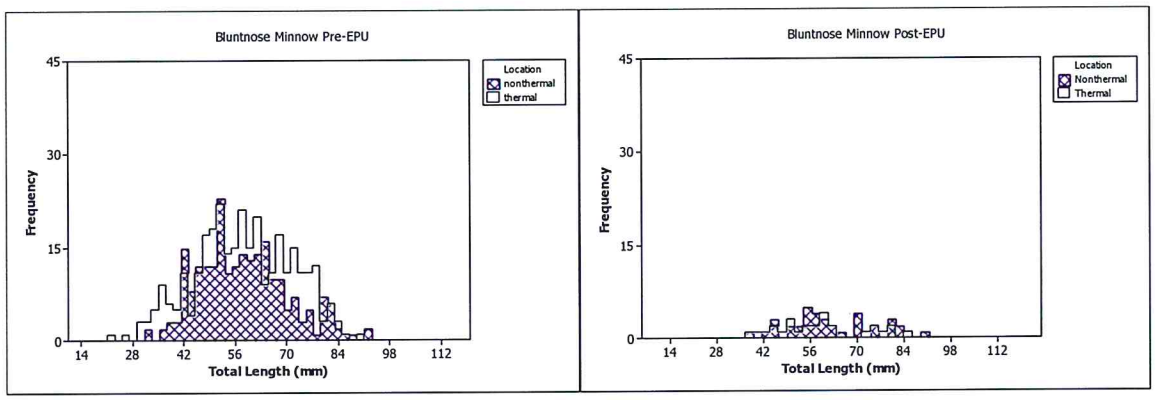


Figure 6-26. Length-frequency distribution of Bluntnose Minnow collected in Conowingo Pond using seine and electrofisher for sample stations that were surveyed during both pre-EPU (2010-2013) and post-EPU (2016) monitoring for non-thermal and thermally influenced locations.

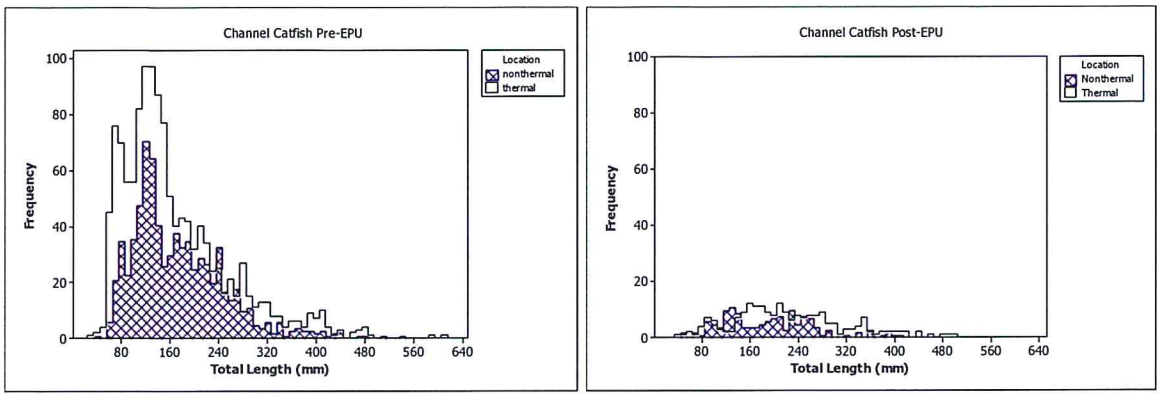


Figure 6-27. Length-frequency distribution of Channel Catfish collected in Conowingo Pond using seine and electrofisher for sample stations that were surveyed during both pre-EPU (2010-2013) and post-EPU (2016) monitoring for non-thermal and thermally influenced locations.

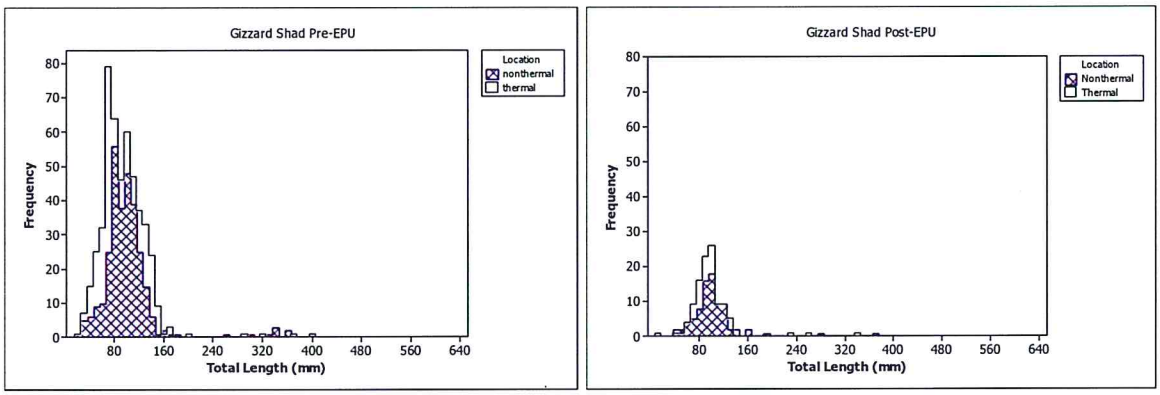


Figure 6-28. Length-frequency distribution of Gizzard Shad collected in Conowingo Pond using seine and electrofisher for sample stations that were surveyed during both pre-EPU (2010-2013) and post-EPU (2016) monitoring for non-thermal and thermally influenced locations.

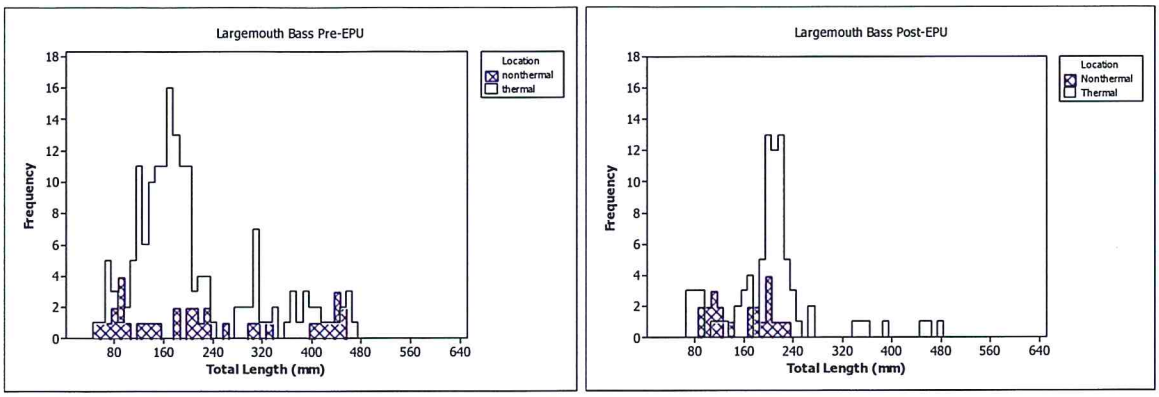


Figure 6-29. Length-frequency distribution of Largemouth Bass collected in Conowingo Pond using seine and electrofisher for sample stations that were surveyed during both pre-EPU (2010-2013) and post-EPU (2016) monitoring for non-thermal and thermally influenced locations.

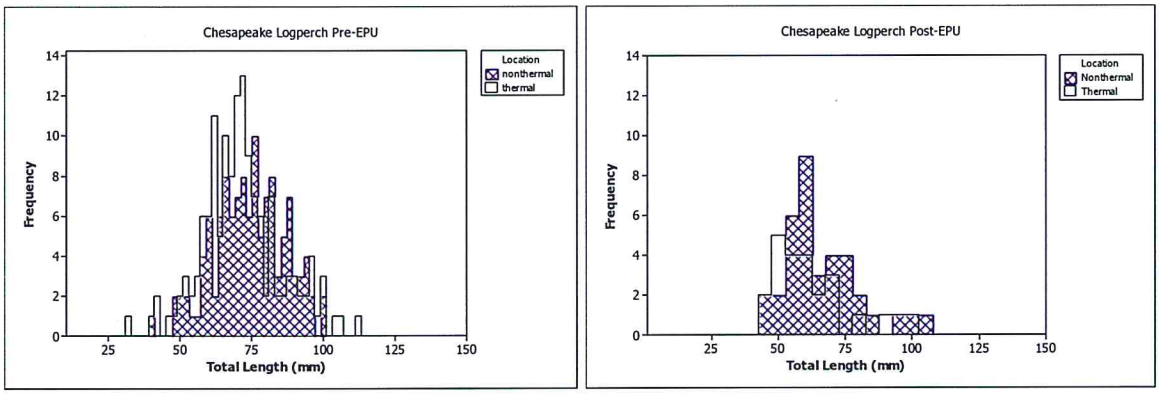


Figure 6-30. Length-frequency distribution of Chesapeake Logperch collected in Conowingo Pond using seine and electrofisher for sample stations that were surveyed during both pre-EPU (2010-2013) and post-EPU (2016) monitoring for non-thermal and thermally influenced locations.

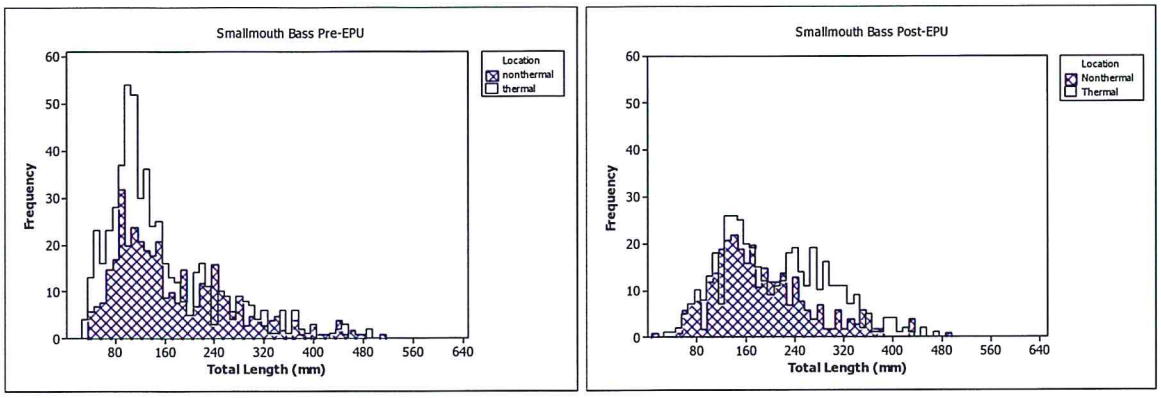


Figure 6-31. Length-frequency distribution of Smallmouth Bass collected in Conowingo Pond using seine and electrofisher for sample stations that were surveyed during both pre-EPU (2010-2013) and post-EPU (2016) monitoring for non-thermal and thermally influenced locations.

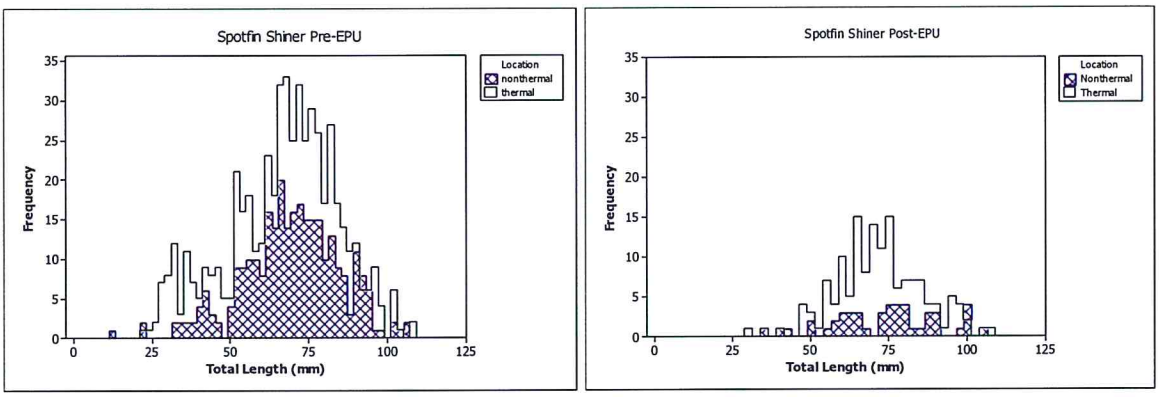


Figure 6-32. Length-frequency distribution of Spotfin Shiner collected in Conowingo Pond using seine and electrofisher for sample stations that were surveyed during both pre-EPU (2010-2013) and post-EPU (2016) monitoring for non-thermal and thermally influenced locations.

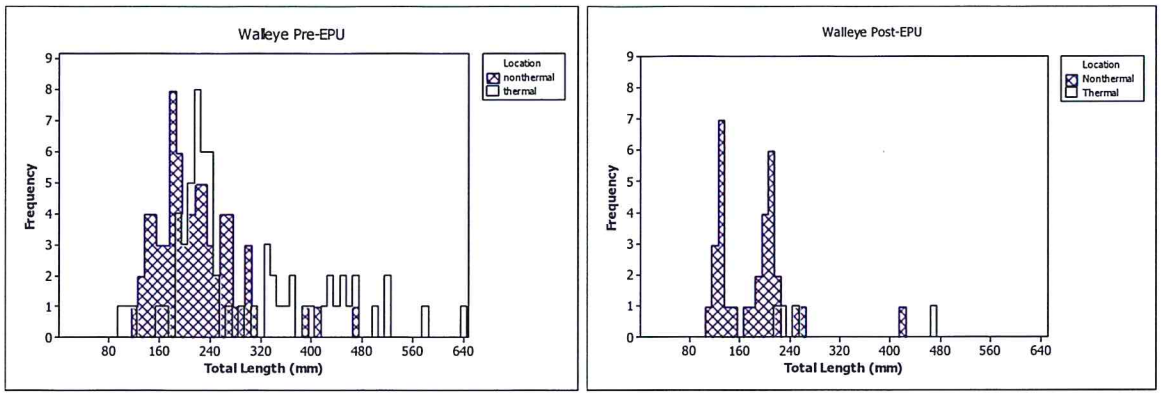


Figure 6-33. Length-frequency distribution of Walleye collected in Conowingo Pond using seine and electrofisher for sample stations that were surveyed during both pre-EPU (2010-2013) and post-EPU (2016) monitoring for non-thermal and thermally influenced locations.

6.3.7 Fish Condition

Relative weight (W_r) is an index of condition or well-being for a fish. Relative weight and other condition assessments are commonly employed by fisheries personnel for evaluating fish populations and communities. This is a standard, widely accepted and used method for assessing fish body condition. Relative weight was calculated following Murphy and Willis (1996).

Relative weight is one indicator of overall fish condition and describes the relative plumpness of an individual fish. Plump fish may be indicators of favorable environmental conditions (e.g., habitat conditions, ample prey availability); whereas, thin fish may indicate less favorable environmental conditions. A relative weight of 100 for an individual fish would indicate that the weight is equal to the average weight of a fish with the identical length for the larger population that was used to develop the standard weight equation.

Relative weights were calculated for Bluegill, Smallmouth Bass, Largemouth Bass, and Channel Catfish collected from the electrofishing stations during May through September for pre-EPU (2010-2013) and post-EPU (2016). A total of six stations were assessed (non-thermal: Stations 187 and 165; thermal: Station 161, 189, 190, and 217). Weight measurements were not taken for these four species collected using a seine because most were smaller, young individuals. These four RIS were selected for analysis because sufficient numbers of individuals and weight measurements were taken to enable valid comparisons of individuals collected at both thermal and non-thermal stations during pre- and post-EPU monitoring.

The purpose of this analysis is to determine whether W_r was different between the pre- and post-EPU monitoring periods. Conceptually, fishes living in elevated water temperatures may be affected by insufficient food availability, physiological stress associated with elevated temperatures, higher metabolic demands, and therefore, poorer body condition indicated by low W_r values. Obvious erroneous W_r values were excluded from the analysis as determined by the range of species-specific length-weight values provided in Carlander (1969 and 1977).

Relative weights were calculated for a total of 805 Bluegill with mean W_r of 103 (Table 6-35). Mean Wr was generally higher for most stations during post-EPU monitoring as compared to pre-EPU monitoring for both thermal and non-thermal stations. Mean W_r ranged from 85 at Station 189 (post-EPU) to 131 at Station 161 (post-EPU). The distribution of W_r among the sample stations was similar for non-thermal and thermal stations with post-EPU values generally higher than pre-EPU monitoring (Figure 6-34). The mean W_r was near or above 100 for most sample stations. Relative weights were calculated for a total of 176 Largemouth Bass with an overall mean W_r of 108 (Table 6-36). Mean W_r ranged from 98 at Stations 189 (pre-EPU) and 217 (post-EPU) to 119 at Station 161 (post-EPU). The distribution of W_r among the sample stations was comparable for thermal and non-thermal stations during pre- and post-EPU periods, with mean W_r above 97 for all stations (Figure 6-35). Note that W_r was calculated for few individuals at stations 165, 187, and 161.

Relative weights calculated for a total of 1,931 Channel Catfish resulted in an overall mean W_r of 112 (Table 6-37). Mean W_r ranged from 107 at Station 189 (pre-EPU) to 126 at Station 189 (post-EPU). The distribution of W_r among the sample stations was similar for non-thermal and thermal stations with median and mean W_r above 100 for all stations. Figure 6-36 provides a box plot which illustrates the spread of the Wr values for each station during pre- and post-EPU monitoring.

Relative weights calculated for 757 Smallmouth Bass resulted in a mean W_r of 99 (Table 6-38). Mean W_r ranged from 92 at Station 217 (pre-EPU) to 104 at Stations 190 and 187 (post-EPU). The distribution of W_r among the sample stations in reference to W_r of 100 was comparable with most stations having mean and median W_r near 100. Figure 6-37 provides a box plot which illustrates the spread of the Wr values for each station during pre- and post-EPU monitoring. For most stations Wr values tended to be slightly higher during post-EPU period.

Discussion and Conclusions

Relative weights for all four species (i.e., Bluegill, Smallmouth Bass, Largemouth Bass, and Channel Catfish) were similar between non-thermal and thermal stations during pre- and post-EPU monitoring. Although mean and median W_r values showed some variation among the stations, the relative weight observations did not indicate low W_r values for the near-field or far-field thermal stations during pre- or post-EPU monitoring. Differences in W_r were likely due to seasonality, reproductive status (pre- or post-spawn), length frequency distribution of individuals at a station, and differences between the sexes. The observations for these four species indicate no detrimental effect of the thermal plume on fish condition as measured by relative weight. Fish condition of these four species was similar between the pre- and post-EPU monitoring.

Table 6-35. Descriptive statistics for Bluegill relative weight by station for individuals collected during pre-EPU and post-EPU monitoring, May through September.

		Relative Weight (Wr)			
Station	Period	Mean	Standard Error	Median	Total Number
st161	Pre-EPU	101	3.4	94	92
st161	Post-EPU	131	2.7	128	80
st189	Pre-EPU	97	3.2	94	99
st189	Post-EPU	85	3.2	82	53
st190	Pre-EPU	88	3.2	81	91
st190	Post-EPU	107	3.1	109	56
st217	Pre-EPU	108	3.3	105	94
st217	Post-EPU	108	2.9	105	23
st165	Pre-EPU	97	2.6	99	106
st165	Post-EPU	107	1.8	106	44
st187	Pre-EPU	102	4.2	100	41
st187	Post-EPU	126	2.8	127	26
Overall		103	1.1	104	805

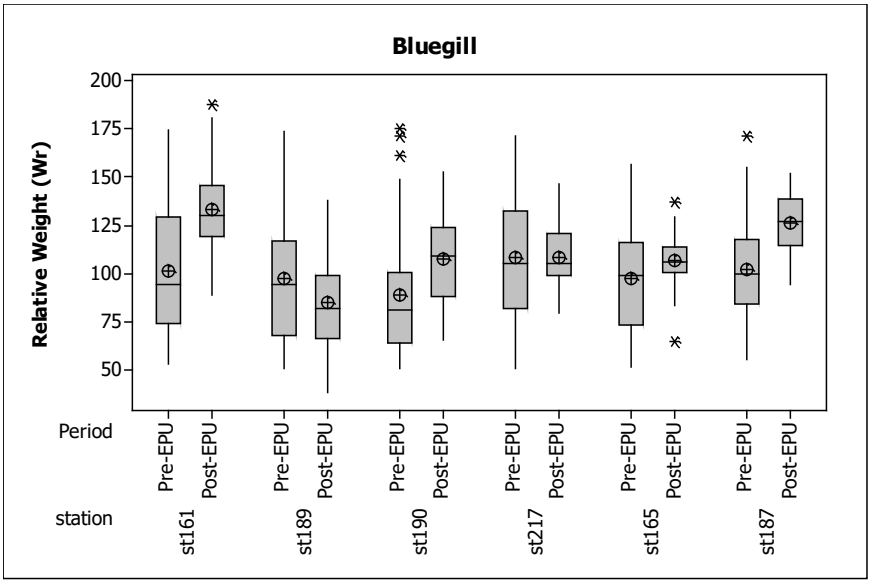


Figure 6-34. Box plot of Bluegill relative weight by station during pre-EPU and post-EPU monitoring, May through September.

(boxes = interquartile range containing 50% of the values, the line across the box = median value, circle = mean, and the vertical lines extending from the box = highest and lowest values, asterisk = outlier)

Table 6-36. Descriptive statistics for Largemouth Bass relative weight by station for individuals collected during pre-EPU and post-EPU monitoring, May through September.

		Relative Weight (Wr)			
Station	Period	Mean	Standard Error	Median	Total Number
st161	Pre-EPU	*	*	*	0
st161	Post-EPU	114	3.1	113	3
st189	Pre-EPU	98	4.1	97	17
st189	Post-EPU	117	8.9	107	22
st190	Pre-EPU	116	5.7	125	13
st190	Post-EPU	103	7.5	104	17
st217	Pre-EPU	111	2.6	110	57
st217	Post-EPU	98	2.2	94	27
st165	Pre-EPU	100	*	100	1
st165	Post-EPU	101	14.5	88	4
st187	Pre-EPU	99	10.3	100	7
st187	Post-EPU	119	14.2	105	8
Overall		108	1.9	104	176

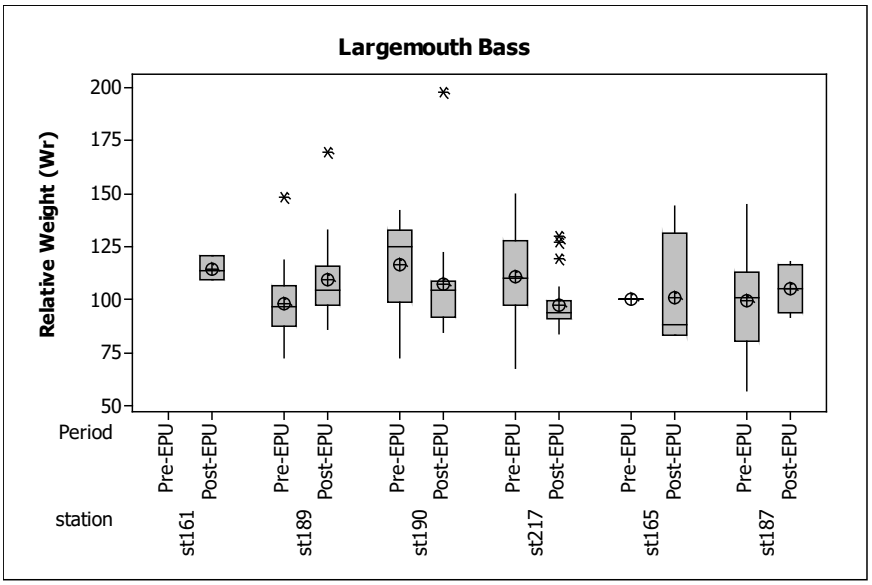


Figure 6-35. Box plot of Largemouth Bass relative weight by station during pre-EPU and post-EPU monitoring, May through September.

(boxes = interquartile range containing 50% of the values, the line across the box = median value, circle = mean, and the vertical lines extending from the box = highest and lowest values, asterisk = outlier)

Table 6-37. Descriptive statistics for Channel Catfish relative weight by station for individuals collected during pre-EPU and post-EPU monitoring, May through September.

		Relative Weight (Wr)			
Station	Period	Mean	Standard Error	Median	Total Number
st161	Pre-EPU	112	2.1	109	236
st161	Post-EPU	116	4.4	109	25
st189	Pre-EPU	107	1.8	106	251
st189	Post-EPU	126	5.8	119	34
st190	Pre-EPU	110	1.9	103	287
st190	Post-EPU	115	4.7	104	58
st217	Pre-EPU	118	2.1	118	204
st217	Post-EPU	116	3.9	109	74
st165	Pre-EPU	111	1.9	103	345
st165	Post-EPU	118	2.7	115	80
st187	Pre-EPU	112	1.9	109	279
st187	Post-EPU	115	2.4	111	58
Overall		112	0.7	108	1931

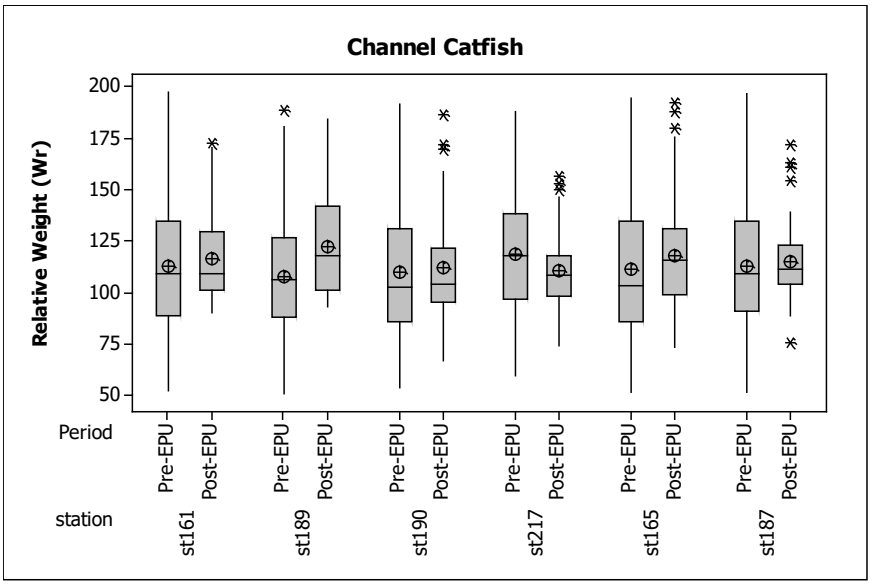


Figure 6-36. Box plot of Channel Catfish relative weight by station during pre-EPU and post-EPU monitoring, May through September.

Table 6-38. Descriptive statistics for Smallmouth Bass relative weight by station for individuals collected during pre-EPU and post-EPU monitoring, May through September.

		Relative Weight (Wr)			
Station	Period	Mean	Standard Error	Median	Total Number
st161	Pre-EPU	98	1.8	96	86
st161	Post-EPU	99	4.3	94	28
st189	Pre-EPU	97	4.4	92	11
st189	Post-EPU	97	2.9	95	33
st190	Pre-EPU	87	4.7	87	21
st190	Post-EPU	104	1.8	102	101
st217	Pre-EPU	92	2.8	89	27
st217	Post-EPU	95	1.5	93	123
st165	Pre-EPU	99	2.1	94	78
st165	Post-EPU	99	1.5	97	121
st187	Pre-EPU	98	2.1	97	56
st187	Post-EPU	104	2.5	100	72
Overall		99	0.7	96	757

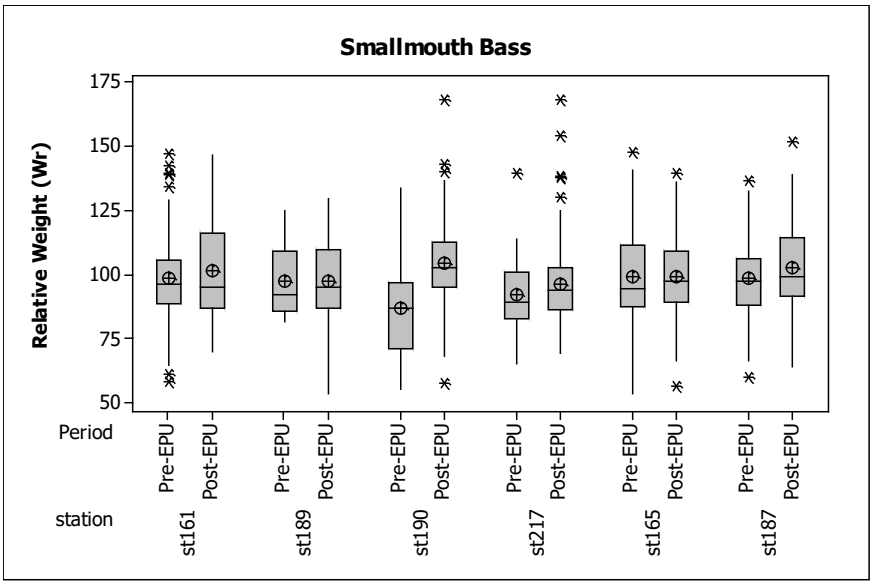


Figure 6-37. Box plot of Smallmouth Bass relative weight by station during pre-EPU and post-EPU monitoring, May through September.

(boxes = interquartile range containing 50% of the values, the line across the box = median value, circle = mean, and the vertical lines extending from the box = highest and lowest values, asterisk = outlier)

External Anomalies (DELTs)

During the course of field processing fish were examined for external anomalies or DELTs. The term DELTs refers to deformities, erosions, lesions, and tumors. This examination is a visual assessment completed with the naked eye that is commonly used during fisheries investigations to document the external condition of captured fish. Types of external anomalies that were determined during the course of study included deformities, eroded fins, lesions, tumors, anchor worm, black spot, leeches, and fungal infections. See PADEP protocol provided in the Study Plan (Appendix 11.1).

The occurrence of DELTs was tabulated for both non-thermally influenced and thermally influenced stations during post-EPU monitoring. The incidence of DELTs in the Conowingo Pond fish community was low during the post-EPU monitoring. DELTs were observed on 21 individuals of six species with 15 individual observed at thermal stations and six observed at non-thermal stations. The most commonly observed DELTs were eroded fins and lesions. The highest incidence of DELTs for a species was 12 Smallmouth Bass observed with DELTs; a proportion of 1.6% of the Smallmouth Bass examined during 2016.

Overall, 5,324 fish collected with electrofisher were examined with 0.40% of all individuals with DELTs. The incidence of DELTs was similar, given the number of sampling locations and fish collected, for those stations closest to the end of the PBAPS discharge canal as compared to the non-thermal monitoring locations. No DELTs were observed on fish collected with seine.

During the 4 years of pre-EPU field investigations DELTs were observed on 103 individuals of 18 species. The highest incidence of DELTs for any species or year occurred in 2013 with 10 Smallmouth Bass observed with DELTs; a proportion of 1.2% of the Smallmouth Bass examined during the year. The occurrence of DELTs was low and comparable between the pre-EPU and post-EPU monitoring.

The low proportion of fishes with DELTs during recent monitoring indicates an aquatic environment where stressful water quality conditions are minimal or such that conditions did not result in significant occurrence of DELTs. It is important to note that we do not know for certain where fishes lived prior to being collected at individual stations, thus, the thermal history is assumed to be that of the collection station. The occurrence of DELTs in Conowingo Pond is comparable or lower than other monitoring locations within the Susquehanna River, in particular, for Smallmouth Bass where higher disease rates have been observed for young of year fish at several upstream monitoring locations in the vicinity of Harrisburg, PA. Typical background occurrence of DELTs for Age 1 or older Smallmouth Bass and other fish species in the Susquehanna River is approximately 1-2% (G. Smith PAFBC, personal communication).

Table 6-39. Total number of each species with DELTs for all sample locations in Conowingo Pond, May through September 2016.

Species [1]	Total number of DELTs		Total Individuals of Species Processed	Total DELTs	Percent of species with DELTs
	Thermal Stations	Non-thermal Stations			
Bluegill	3		1296	3	0.23
Channel catfish	2	1	387	3	0.78
Flathead catfish	1		38	1	2.63
Largemouth bass	1		104	1	0.96
Smallmouth bass	7	5	749	12	1.60
White sucker	1		1	1	100
Total	15	6		21	

[1] *All fish collected during electrofishing; no external anomalies observed for fish collected with seine*

Table 6-40. Types of external anomalies observed by species for fish collected in Conowingo Pond, May through September 2016.

Species	Deformities	Eroded fins	Emaciated	Fungal infection	Leech	Open sore	Open Sore/Tumor	Trematode	Tumor	Total
Bluegill	1					2				3
Channel catfish					1	1	1			3
Flathead catfish									1	1
Largemouth bass			1							1
Smallmouth bass	1	5	3	1		1		1		12
White sucker						1				1
Total	2	5	4	1	1	5	1	1	1	21

6.3.8 Relative Abundance and Retrospective Analysis of RIS

Knowledge of the abundance of fish populations is an important component in management of fisheries. The most common indices of relative abundance are computed from catch per unit effort (CPUE) data for samples from a fish population. A common application in fisheries management is using CPUE to evaluate temporal patterns in relative abundance. Here, relative abundance is illustrated with time series plots for select RIS in Conowingo Pond.

Temporal patterns in CPUE are illustrated for both seine and electrofishing gears. A long-term data set for select RIS is available for the Pond for the period 1966 to 2016. This period covers fish collections at many locations throughout Conowingo Pond prior to operation of PBAPS (1966-1973) and after PBAPS became operational (1974-2016). Electrofishing surveys were not initiated until 1974, thus no pre-operational relative abundance data for this sampling gear are available. The data set for 1993 includes only October sampling and the 1996 data set includes multiple samples each month. This data set includes several time intervals associated with prior PBAPS 316(a) demonstration studies (PECO 1975, and 1979; Normandeau Associates 1997-2000a; Normandeau and ERM 2014).

Relative abundance data provided in each figure includes fish collections throughout the entire Conowingo Pond. Sampling station locations varied throughout the course of these studies within the Pond, thus not all stations sampled previously are the same as the present study. However, the long-term data set still provides useful information regarding abundance trends and although station locations differed over time, the collections occurred in similar habitats. The data reflect collections that occurred from June-October for 1974 through 2013 and May-September for 2016. CPUE data were square root transformed to decrease the effects of single year extreme CPUE values.

Seine

Relative abundance data from all stations surveyed in the Pond using a seine are provided for Bluegill, Smallmouth Bass, Spotfin Shiner, Bluntnose Minnow, and Chesapeake Logperch. This subset of RIS represents species that are more commonly collected using a seine. CPUE values during 2016 were within or above the historical range for all species (Figure 6-38 through Figure 6-42). CPUE for Bluegill, Smallmouth Bass, and Spotfin Shiner during 2016 was comparable to pre-EPU observations. For Bluntnose Minnow and Chesapeake Logperch the post-EPU CPUE was lower than the pre-EPU observations but within the range of historic values. No long-term temporal trends in CPUE were observed for these species. Short-term trends were observed for Spotfin Shiner and Bluntnose Minnow. Bluntnose Minnow CPUE was lower during 2016 as compared to 2010-2013 and the 1990's, but higher than most values during 1960-1970s. Spotfin Shiner CPUE was lower in 2016 and 2010-2013 as compared to historic collections which varied widely from year to year and over the short-term relative abundance appears to be declining in the Pond. Chesapeake Logperch relative abundance was higher during the 1996-2016 period compared to prior years.

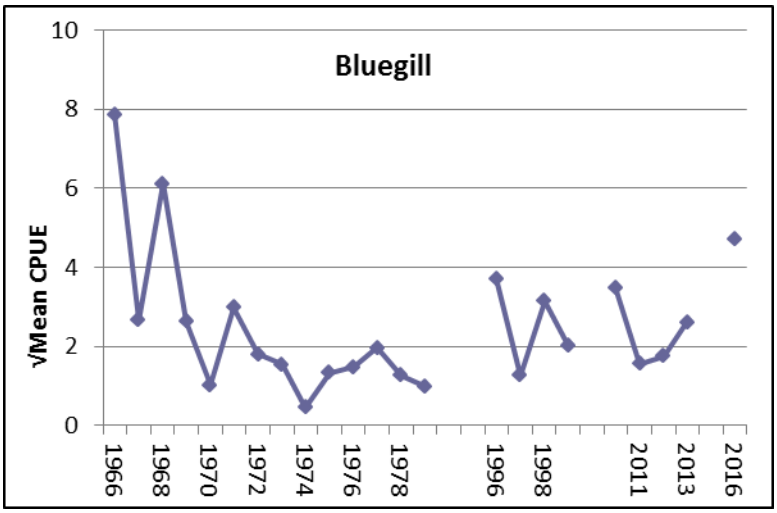


Figure 6-38. Square root transformed mean CPUE for Bluegill collected using a seine in Conowingo Pond, June-October 1966-2013 and May-September 2016.

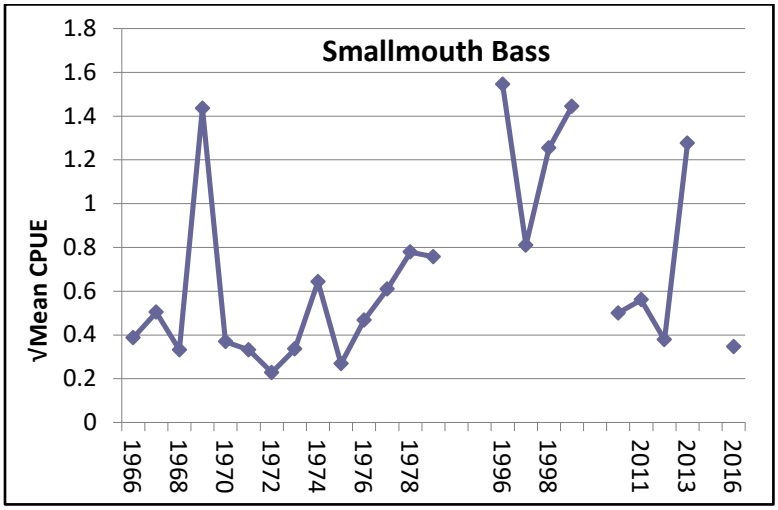


Figure 6-39. Square root transformed mean CPUE for Smallmouth Bass collected using a seine in Conowingo Pond, June-October 1966-2013 and May-September 2016.

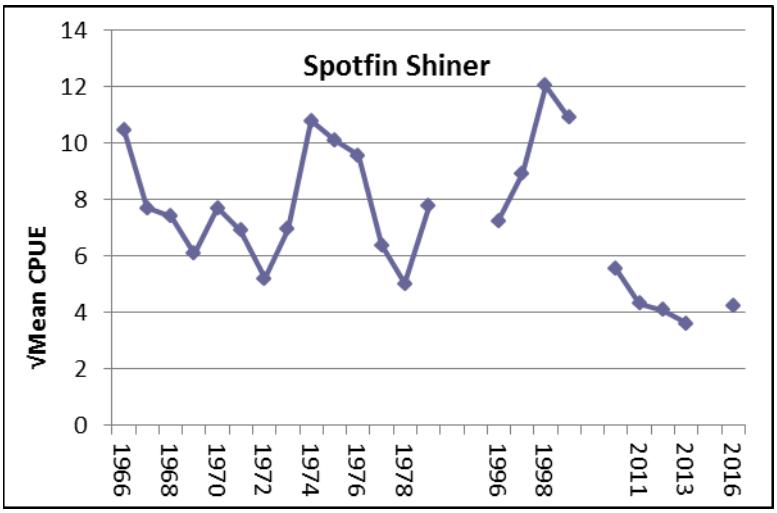


Figure 6-40. Square root transformed mean CPUE for Spotfin Shiner collected using a seine in Conowingo Pond, June-October 1966-2013 and May-September 2016.

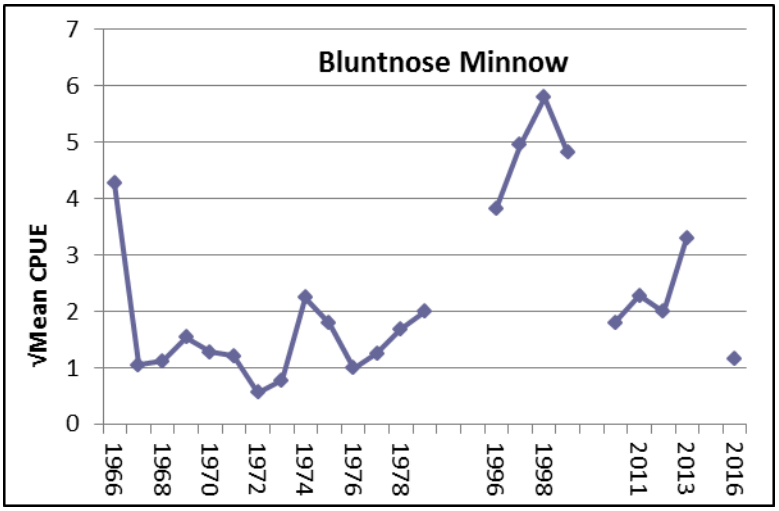


Figure 6-41. Square root transformed mean CPUE for Bluntnose Minnow collected using a seine in Conowingo Pond, June-October 1966-2013 and May-September 2016.

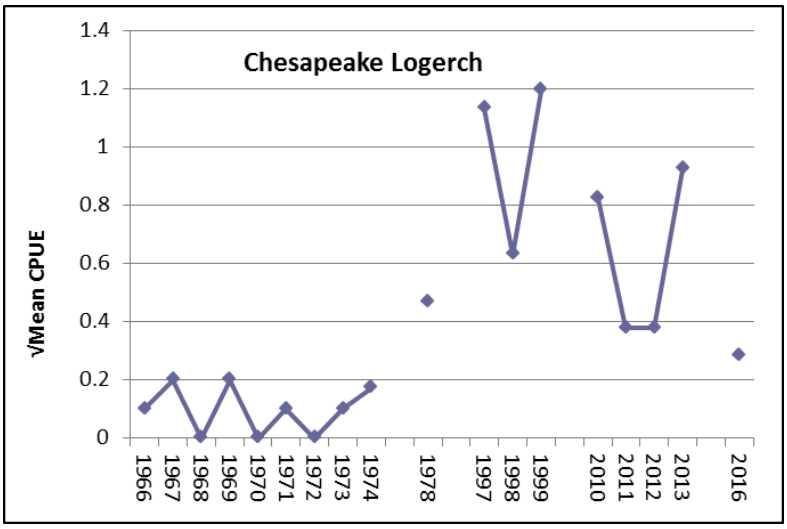


Figure 6-42. Square root transformed mean CPUE for Chesapeake Logperch collected using a seine in Conowingo Pond, June-October 1966-2013 and May-September 2016.

Electrofishing

Relative abundance data from all stations surveyed in the Pond using boat electrofisher are provided for Bluegill, Smallmouth Bass, Gizzard Shad, White Crappie, Channel Catfish, Walleye, and Chesapeake Logperch. Figure 6-43 through Figure 6-49 compare the annual mean CPUE for each species during the period of available electrofishing data from 1975-2016. This subset of RIS represent species that are commonly collected using a boat electrofisher in the Pond.

CPUE values during 2016 were within or above the pre-EPU observations for most species. Gizzard Shad relative abundance was comparable to pre-EPU and much higher than historic

observations. White Crappie relative abundance was comparable to pre-EPU but lower than previous years. Smallmouth Bass and Channel Catfish CPUE was comparable to pre-EPU values and within the historic range of observations. Bluegill relative abundance was comparable to pre-EPU and much higher than historic observations. Long-term trends for White Crappie and Gizzard Shad were evident. White Crappie relative abundance showed a long-term decline over time and Gizzard Shad relative abundance indicated a long-term increase over time. CPUE of Chesapeake Logperch in 2016 was within the range observed pre-EPU and higher than the historic values. Walleye CPUE was slightly lower in 2016 than pre-EPU observations but within the range of historic values.

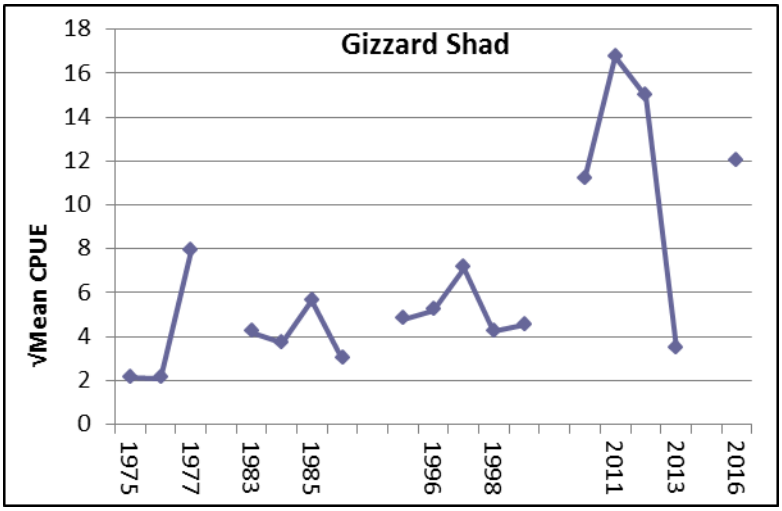


Figure 6-43. Square root transformed mean CPUE(no/0.5hr) for Gizzard Shad collected using a boat electrofisher in Conowingo Pond, June-October 1975-2013 and May-September 2016.

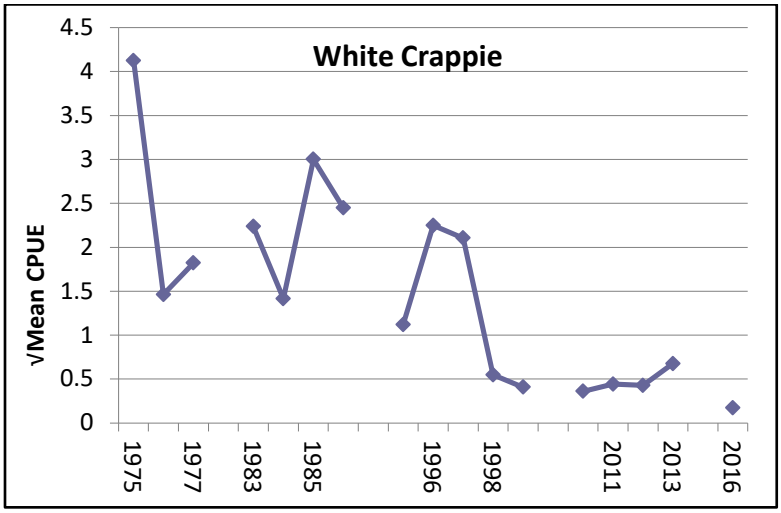


Figure 6-44. Square root transformed mean CPUE(no/0.5hr) for White Crappie collected using a boat electrofisher in Conowingo Pond, June-October 1975-2013 and May-September 2016.

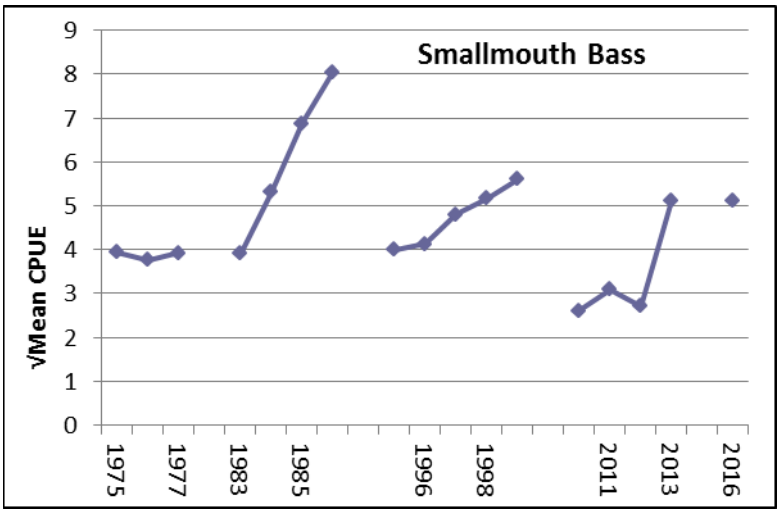


Figure 6-45. Square root transformed mean CPUE(no/0.5hr) for Smallmouth Bass collected using a boat electrofisher in Conowingo Pond, June-October 1975-2013 and May-September 2016.

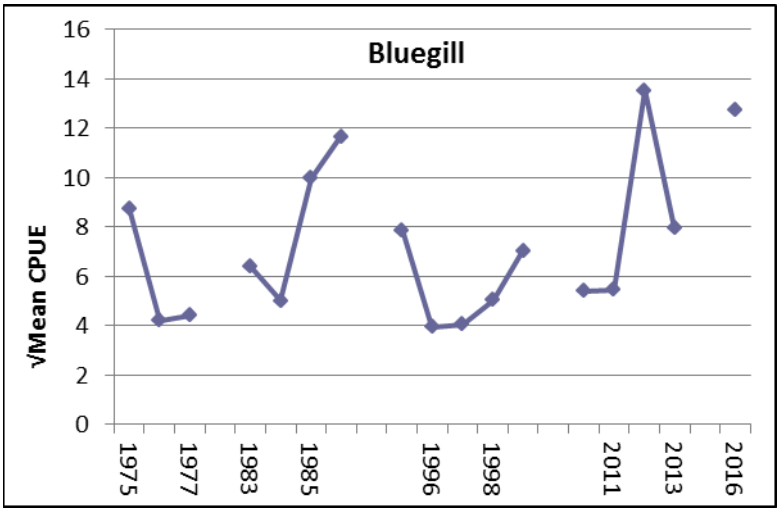


Figure 6-46. Square root transformed mean CPUE(no/0.5hr) for Bluegill collected using a boat electrofisher in Conowingo Pond, June-October 1975-2013 and May-September 2016.

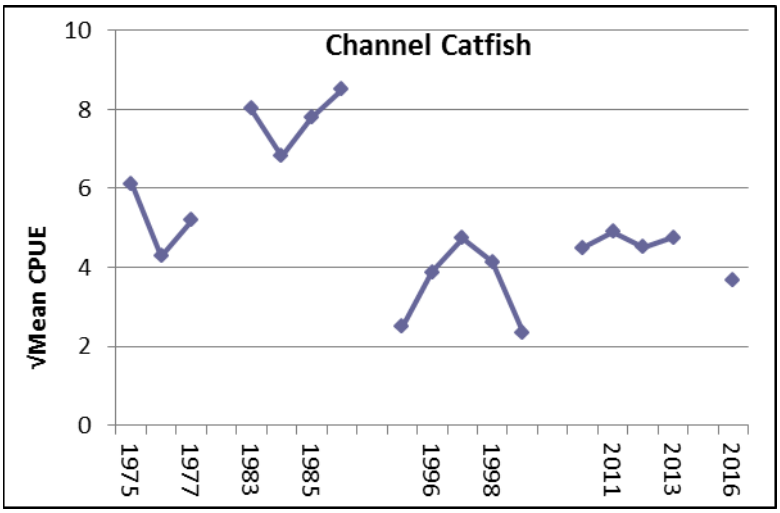


Figure 6-47. Square root transformed mean CPUE(no/0.5hr) for Channel Catfish collected using a boat electrofisher in Conowingo Pond, June-October 1975-2013 and May-September 2016.

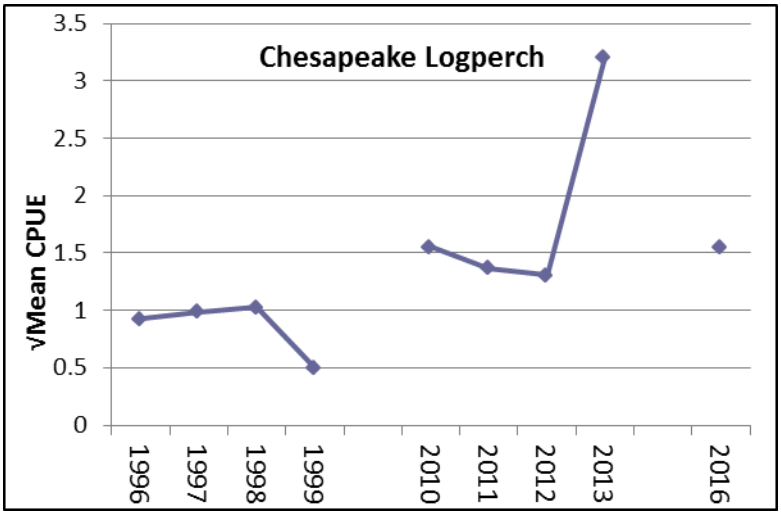


Figure 6-48. Square root transformed mean CPUE(no/0.5hr) for Chesapeake Logperch collected using a boat electrofisher in Conowingo Pond, June-October 1996-2013 and May-September 2016.

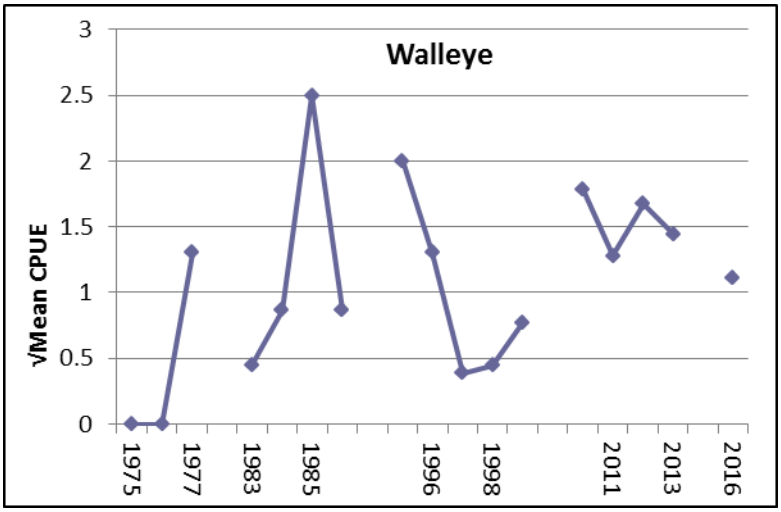


Figure 6-49. Square root transformed mean CPUE(no/0.5hr) for Walleye collected using a boat electrofisher in Conowingo Pond, June-October 1975-2013 and May-September 2016.

Discussion and Conclusions

Temporal differences in CPUE were evident for several species and reflect variations in the fish community associated with year-class strength and changes in species composition. CPUE during 2016 was comparable to pre-EPU study observations and within the range of historic observations for all species except White Crappie. Long-term trends in electrofishing CPUE were observed for Gizzard Shad and White Crappie. No long-term trends in the seine collections were evident for the selected RIS.

Many confounding factors affect fish population dynamics in Conowingo Pond, including changes in water quality, year-to-year differences in river flow, species introductions, and immigration from Conowingo East Fish Lift and emigration through the Holtwood Fish Lift. Fish populations are not static and differences in relative abundance reflect these changes. Many environmental factors including floods, droughts, and water quality changes (e.g. phosphorous loading from upper basin) can affect relative abundance.

Based on the comparison of relative abundance results of this study and the available historic data we can conclude:

- Relative abundance of the RIS was comparable to pre-EPU observations,
- Relative abundance of most RIS in 2016 was within their historic ranges,
- Considerable variation in relative abundance occurred over the available data period,
- Variable year-class strength for some species resulted in a wide range of relative abundance, and
- Changes in fish populations were within normal ranges and the result of naturally variable environmental conditions.

7 Juvenile American Shad Migration

This section of the report addresses PADEP draft NPDES permit comments related to the potential effect of the post-EPU PBAPS thermal discharge on migratory fishes. In particular, PADEP raised a question regarding the potential for PBAPS's thermal plume to block migration of juvenile American Shad in Conowingo Pond.

7.1 Analysis

Under the previously licensed thermal power conditions (prior to EPU) the design plant discharge temperature increase above ambient intake temperature (ΔT) was approximately 22°F without cooling towers in operation. However, during the Pre-EPU Demonstration Study (Normandeau and ERM 2014) temperature monitoring determined that the ΔT was less than 22°F and averaged 19.4°F during July and August; the months with warmest ambient water temperature. The post-EPU temperature monitoring completed in 2016 indicated that the increase in PBAPS discharge temperature did not exceed 3°F which corresponded well with the expected (based on engineering specifications) maximum increase in the ΔT of 3°F. Thus during 2016 monitoring period (May 1 through September 30) the observed maximum post-EPU ΔT was 22.4°F (19.4°F + 3°F). The modelling analyses provided herein use the maximum design ΔT of 25.0°F (22°F + 3°F) which is higher than the observed conditions and provides an additional conservative margin of +2.6°F.

Evidence of absence of impedance to emigration of juvenile American Shad in Conowingo Pond was gathered from two sources: (1) field sampling, and (2) a 3-D time varying hydrodynamic model.

There is no reported reproduction of American Shad in Conowingo Pond. Most juvenile American Shad use Conowingo Pond as an emigration corridor during their seaward journey. These juveniles originate from Pennsylvania Fish and Boat Commission stocking of chemically marked hatchery-reared fry during late May and June upstream of the hydroelectric dams on the Susquehanna River. Historically, three fixed locations had been monitored for juvenile American Shad during the fall months which may be used as indices for the time of entry of the juveniles into Conowingo Pond, residency duration of juveniles within Conowingo Pond, and exit of the juveniles out of Conowingo Pond. The monitoring locations were: sampling at the Holtwood Hydroelectric Dam inner forebay by lift net (entry), PBAPS outer screens (duration of residency), and Conowingo Dam cooling water strainers (exit time). The entry of juvenile American Shad into Conowingo Pond generally occurs in October and November at water temperatures between 50 to 65°F (10.0°C-18.3°C) with peak emigration generally occurring between 50 to 55.4°F (10.0 -13.0°C) coincident with a fall freshet typically in late October to mid-November. Table 7-1 summarizes the number of juvenile American Shad collected at the three monitoring locations between 2005 and 2009.

Historically, water temperatures of 50 to 60° F (10.0-15.6°C), as measured at Holtwood Hydroelectric Dam, occurred 25% of the time in October and 23% in November. At these

ambient water temperatures, with the designed rise in temperature of 25°F (13.9 °C), the temperature of the PBAPS effluent at the point of discharge structure would be 75.0°F (23.9 °C) and 85.0°F (29.5°C), respectively. At an ambient water temperature of 65° F, the water temperature of the discharge at the point of entry into Conowingo Pond is predicted to be 90 °F. Allowing for rapid dissipation via the "jet" type discharge, the actual temperature will be less than 90°F. However, results of the 3-D time varying hydrodynamic model more accurately quantify the size and temperature of the plume because it takes into account the effects of other factors including river flow and operation of the MRPSF.

The emigration period for juvenile American Shad through Conowingo Pond is October and November. The analyses provided herein focus on water temperatures and the configuration of the PBAPS thermal plume during these months. The long-term data set for daily water temperatures and flows at Holtwood Hydroelectric Dam were used to determine near worst case conditions for combined low flows and high temperatures during juvenile American Shad emigration. Two modelling scenarios were selected: ambient temperatures of 65 °F and river flows of 10,000 cfs and ambient temperatures of 55° F and river flows of 15,000 cfs. The joint probability occurrence of these river flows and water temperatures ranged from 1.65 to 14.66% (Table 7-2). We modeled these hydrological conditions and integrated the model results with the reported avoidance temperature of juvenile American Shad to delineate the potential areas of avoidance. For this analysis water temperature greater than 86°F was assumed to be an impedance to juvenile shad emigration. Experimental studies (Moss 1970; Marcy et al.1976) have reported that juvenile American Shad avoid water temperatures above 86°F.

We used a time-varying 3-D hydro-thermal model (Generalized Environmental Modeling System for Surface waters or GEMSS® to identify (a) PBAPS plume size and configuration and (b) areas in Conowingo Pond exceeding 86°F during the migration period in the fall months.

Figure 7-1 and Figure 7-2 show the thermal plume dispersion at river flows of 10,000 cfs and 15,000 cfs with ambient water temperatures of 65 and 55°F, respectively at four depths (surface, 5ft, 10ft, and 15ft). No area above 86.0ºF exists during the month of November. In October at ambient water temperature of 65°F only a small narrow area exists at the surface along the western shore. Subsurface temperatures are all less than 86°F. Virtually the entire pond is available for downstream migrating juveniles. These model results suggest an absence of impedance to emigration of juvenile American Shad in Conowingo Pond.

7.2 Summary and Conclusions

A 3-D time varying hydrodynamic model was used to predict the areas in Conowingo Pond during October and November at two hydrological conditions: ambient temperatures of 55° F and 65°F and river flows of 10,000 cfs and 15,000 cfs; the EPU maximum rise in water temperature was assumed to be 25°F with no cooling towers operating. The joint probability occurrences of these hydrological events in October and November ranged from 1.65 to 14.66%. Modeling results indicated that only a very small, narrow area hugging the west shoreline downstream of the PBAPS discharge structure contains surface water temperature > 86°F (assumed an impedance to juvenile shad emigration) at an ambient temperature of 65°F;

at ambient water temperatures of ≤ 61.0 °F no area of 86.0 °F exists. Virtually the entire Conowingo Pond is available for juvenile American Shad emigration. Therefore, there is no potential for thermal blockage. This is supported to a large extent by the collection of emigrating juvenile American Shad at cooling water strainers at Conowingo Dam (7 mi downstream of PBAPS).

Table 7-1. Juvenile American Shad Outmigration Data for Holtwood Lift Net, PBAPS travelling screens, and Conowingo Dam Strainer, September 11 through December 12, 2004 through 2009.

Date	Holtwood Lift Net [a]	PBAPS Fall Sampling [b]	Conowingo Dam Strainer Sampling [c]	Date	Holtwood Lift Net [a]	PBAPS Fall Sampling [b]	Conowingo Dam Strainer Sampling [c]
Sept. 11	0	0	0	Nov. 11	0	1	
				Nov. 12	0	1	0
Oct. 12	0	0	0	Nov. 13	0	1	
Oct. 13	0	3	0	Nov. 14	0	0	
Oct. 14	0		0	Nov. 15	0	0	0
Oct. 15	0	0	0	Nov. 16	0	0	
Oct. 16	0			Nov. 17	0	0	
Oct. 17	0			Nov. 18	0	0	
Oct. 18	0	0	0	Nov. 19	0	2	0
Oct. 19	0	1		Nov. 20	0	6	0
Oct. 20	0	2	0	Nov. 21	0	8	
Oct. 21	0	1	5	Nov. 22	0	0	0
Oct. 22	0	0	0	Nov. 23	0	0	
Oct. 23	0	7		Nov. 24	0	1	0
Oct. 24	8	46	5	Nov. 25	0	0	
Oct. 25	2	15	0	Nov. 26	0	1	2
Oct. 26	0	23	4	Nov. 27	0	2	
Oct. 27	0	25		Nov. 28	0	1	0
Oct. 28	181	7	7	Nov. 29	0	0	
Oct. 29	0	1	1	Nov. 30	0	0	
Oct. 30	0	0		Dec. 1	0	1	
Oct. 31	17	20	7	Dec. 2	0	0	
Nov. 1	0	26	0	Dec. 3	0	1	
Nov. 2	0	3	2	Dec. 4	0		0
Nov. 3	0	9		Dec. 5	0	2	0
Nov. 4	0	7		Dec. 6	0	0	
Nov. 5	0	12	0	Dec. 7	0		
Nov. 6	0			Dec. 8	0	11	
Nov. 7	0	8	1	Dec. 9	0		
Nov. 8	0	2	1	Dec. 10		5	
Nov. 9	1	1	1	Dec. 11	0		
Nov. 10	0	1	1	Dec. 12	0		

	Holtwood Lift Net	PBAPS Fall Sampling	Conowingo Dam Strainer Sampling
Overall Total	209	264	37

[a] Am. Shad collected by Lift Net in 2005, 2006, and 2008

[b] Am. Shad collected at PBAPS in 2005, 2006, 2007, 2008, and 2009

[c] Am. Shad collected in Conowingo Strainers in 2005, 2006, 2007, and 2008

Peak outmigration water temperature range: 10.0°C to 13.0°C

Table 7-2. Joint probability occurrence (%) of average daily water temperature and river flows measured at Holtwood Dam in October and November, 1956-2012. October –November are emigration periods of juvenile American Shad in lower Susquehanna River.

River Flow (cfs)	Water Temperature (°F)								
	46-50	**51-55**	**56-60**	**61-65**	**66-70**	**71-75**	**76-80**	**>80**	**Total**
	October*								
0-9,999		2.26	7.64	14.66	12.65	5.19	1.10	0.31	43.80
10,000-14,999		1.71	4.58	7.45	2.93	0.92	0.06	0	17.65
15,000-19,999	0.24	1.10	3.85	2.69	1.16	0.49	0.06	0	9.59
20,000-24,999	0.06	1.34	2.50	2.02	0.73	0.18	0	0	6.84
	November*								
0-9,999	3.44	6.93	4.07	1.65	0.45	0	0	0	17.37
10,000-14,999	3.31	5.22	0.83	0.51	0	0	0	0	12.21
15,000-19,999	2.93	2.99	0.57	0.25	0	0	0	0	9.16
20,000-24,999	3.05	1.97	0.89	0.25	0	0	0	0	9.80

**Emigration period for juvenile American Shad in the lower Susquehanna River*

Note: shaded cells referred to in the text

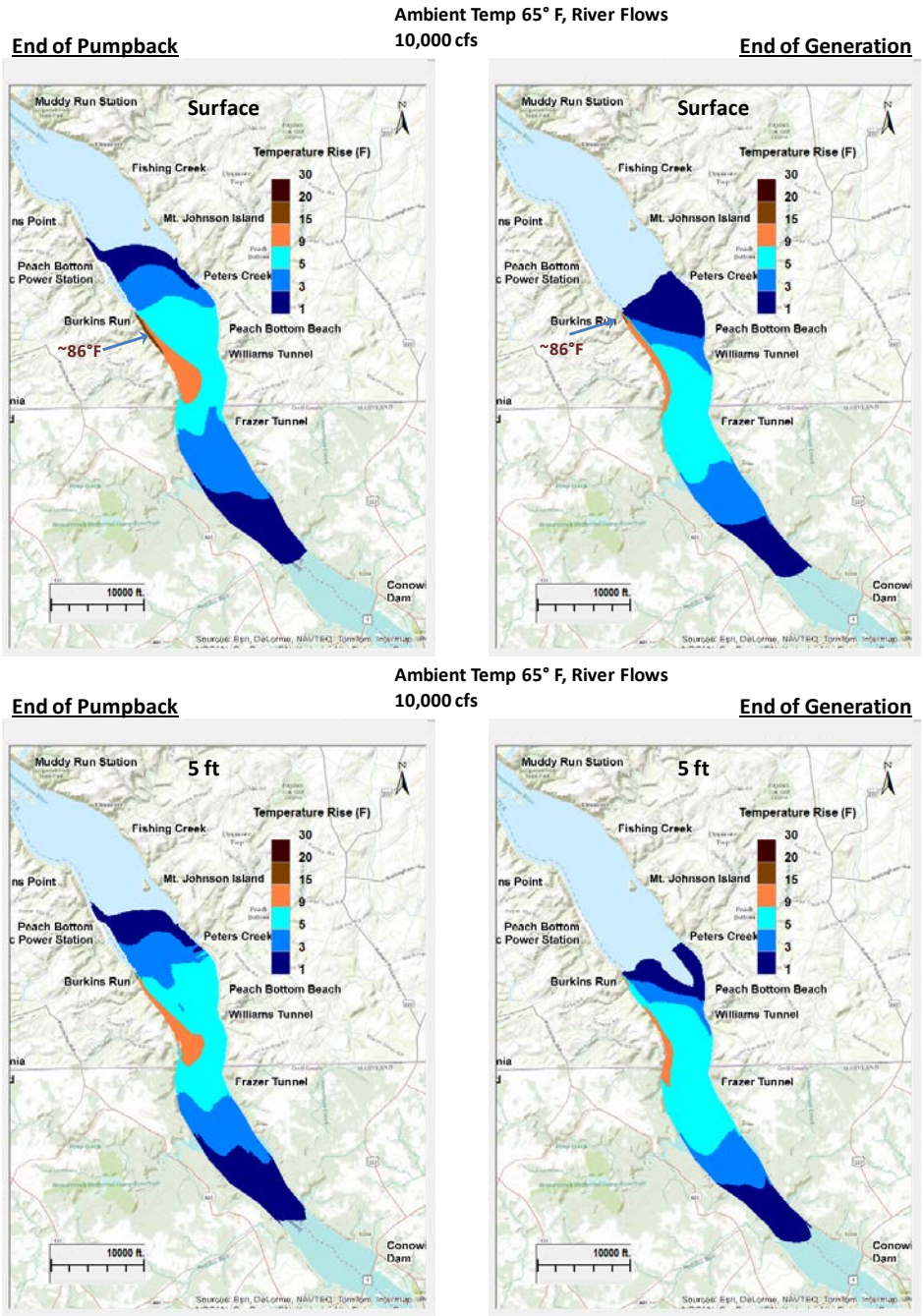
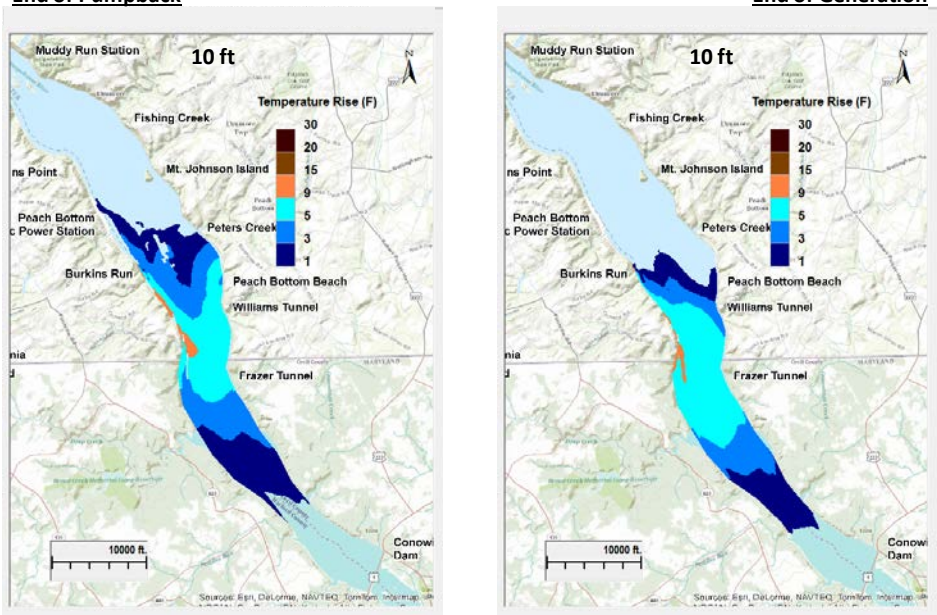


Figure 7-1. Predicted thermal plume at surface, 5ft, 10ft, and 15ft during MRPSF pumping

(left panel) and generation (right panel) at river flow of 10,000 cfs and water temperature 65° F (representing the month of October). MRPSS pumping (28,000 cfs) continuously for 12h followed by generation (28,000 cfs) for 12h. Peach Bottom operating under EPU conditions resulting in temperature rise (color coded) above the ambient temperature of 65° F.

Ambient Temp 65° F, River Flows 10,000 cfs

End of Pumpback **End of Generation**



Ambient Temp 65° F, River Flows 10,000 cfs

End of Pumpback **End of Generation**

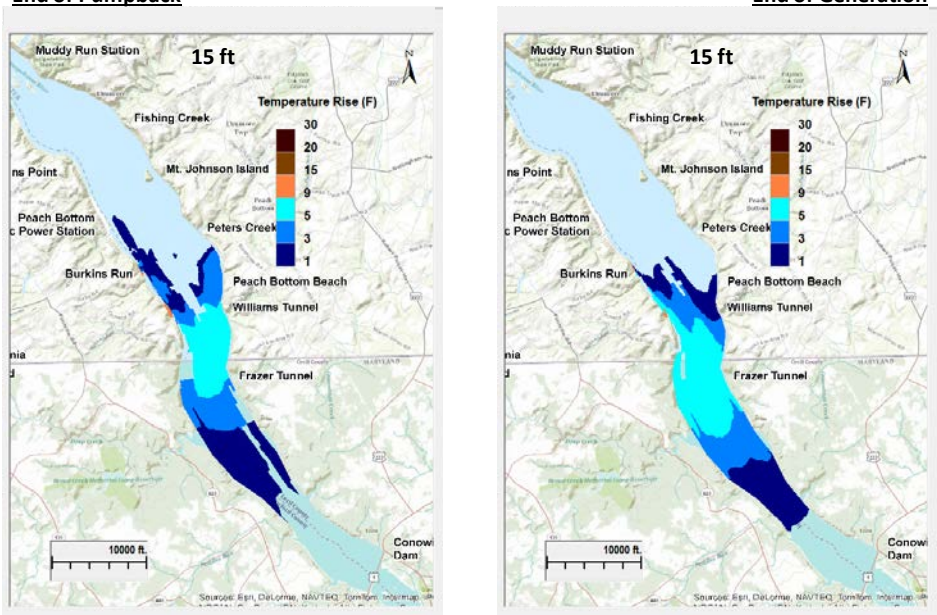


Figure 7-1. Continued.

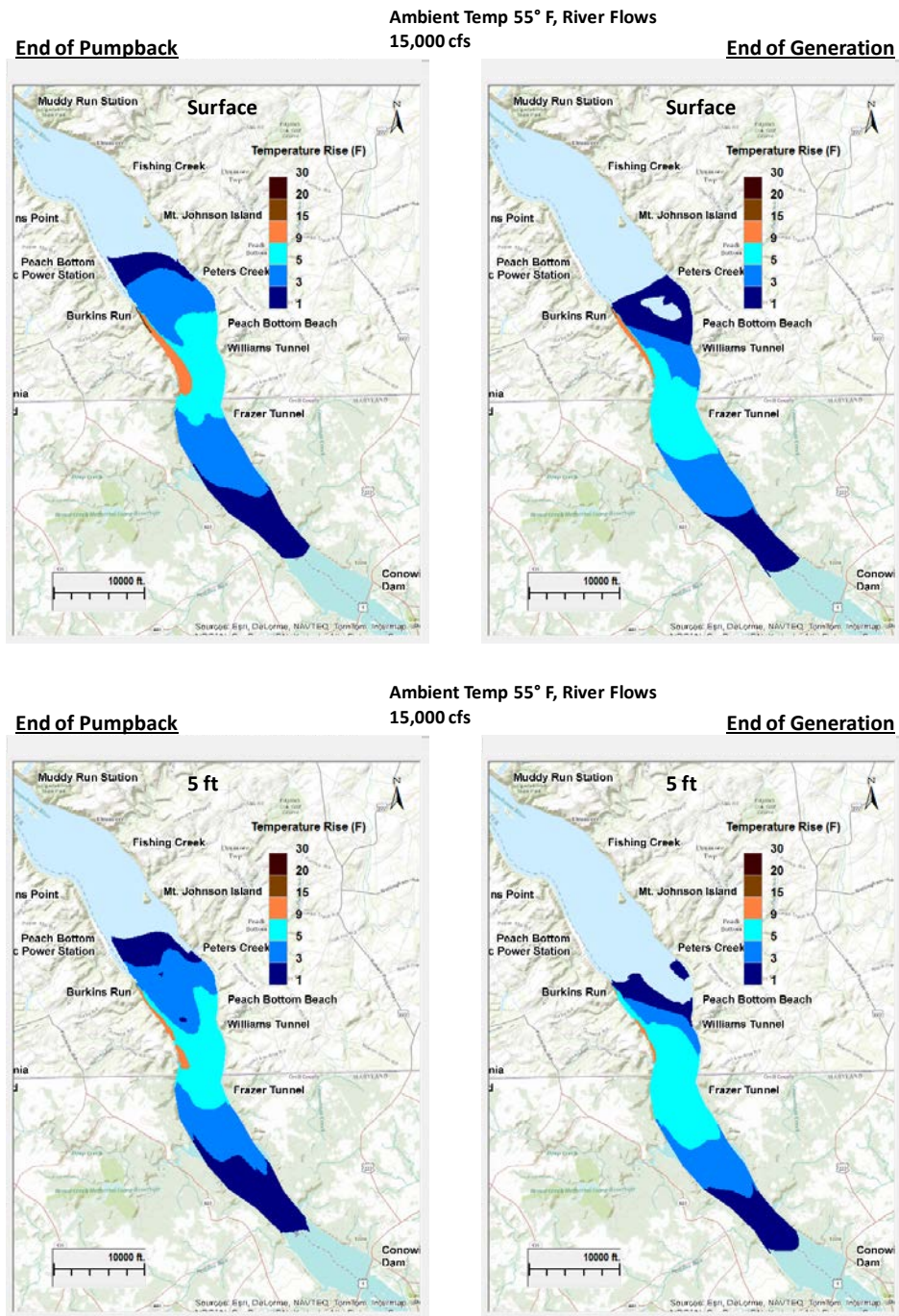
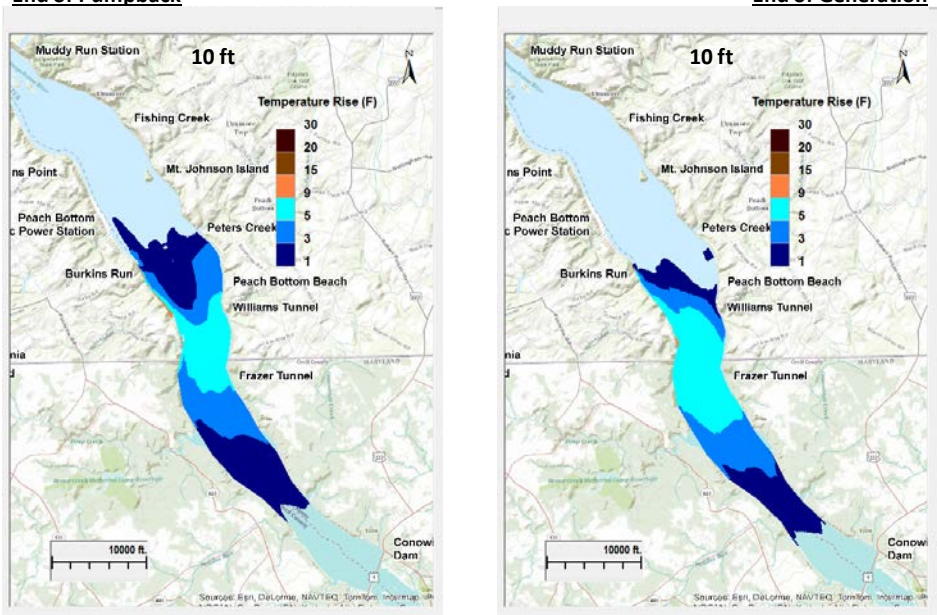


Figure 7-2. Predicted thermal plume at surface, 5ft, 10ft, and 15ft during MRPSF pumping

(left panel) and generation (right panel) at river flow of 15,000 cfs and water temperature 55° F (representing the month of November). MRPSS pumping (28,000 cfs) continuously for 12h followed by generation (28,000 cfs) for 12h. Peach Bottom operating under EPU conditions resulting in temperature rise (color coded) above the ambient temperature of 55°F.

Ambient Temp 55° F, River Flows 15,000 cfs

End of Pumpback **End of Generation**



Ambient Temp 55° F, River Flows 15,000 cfs

End of Pumpback **End of Generation**

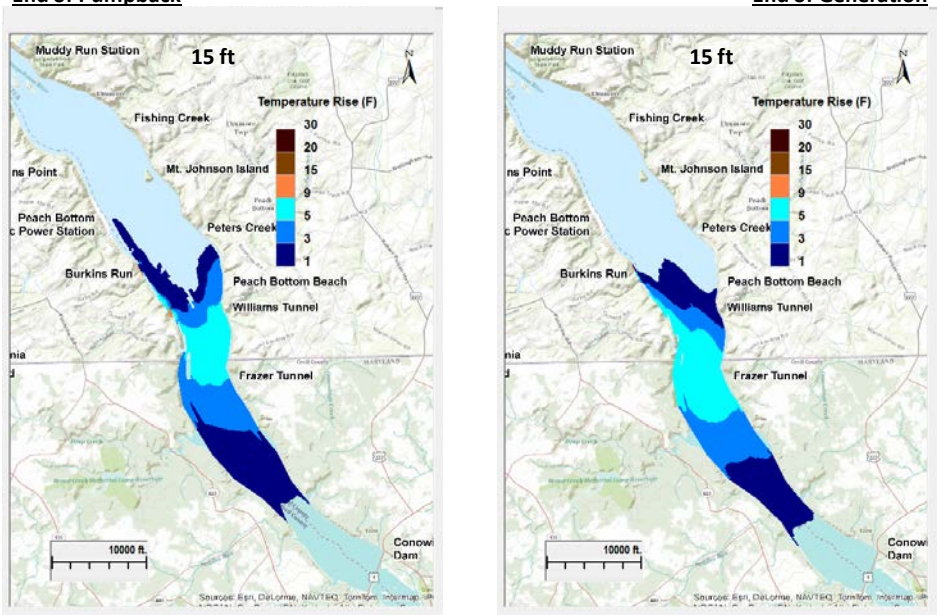


Figure 7-2. Continued

8 Gizzard Shad Seasonal Distribution

This section of the report addresses United States Fish and Wildlife Service (USFWS) comments related to the seasonal distribution of Gizzard Shad in Conowingo Pond relative to the PBAPS thermal plume. The USFWS raised a question about whether the thermal plume may provide a winter refuge for Gizzard Shad which, otherwise, may not survive extreme cold temperatures during the winter. Exelon agreed to provide a compilation of information from previous studies related to Gizzard Shad seasonal distribution in Conowingo Pond relative to the thermal plume. This compilation of data available from previous studies includes information related to winter water temperatures in the pond, Gizzard Shad distribution, and winter survival.

8.1 Analysis

Gizzard shad, native to eastern North America (Jenkins and Burkhead 1993), was inadvertently introduced into Conowingo Creek, a tributary to Conowingo Pond in May 1972 during an American Shad transport from the Conowingo Dam West Fish Lift. Successful reproduction ensued the same year and the species dispersed into the Muddy Run Reservoir and Muddy Run Recreation Lake. A chronology of Gizzard Shad population expansion in Conowingo Pond is provided in Appendix 10.2. Gizzard Shad are present in much of the Pennsylvania portion of the Susquehanna River including some upstream reservoirs (Stauffer et al. 2016) which are most likely subject to extreme winter conditions and do not receive heated effluent from power plants.

Gizzard Shad are reported to become disoriented at cold water temperatures and may suffer high mortality at water temperatures below 3.3 °C (38.0 °F) with mortality being size selective such that larger sized Gizzard Shad have a higher survival than smaller individuals (Bodola 1965; Jester and Jensen 1972; Adams et al. 1985; Fetzer et al. 2011; Michaletz 2010). Natural winter “die offs” of Gizzard Shad, particularly young Gizzard Shad have been reported from water bodies with and without thermal discharge. Depending upon the severity and duration of winters, a natural winter “die off” of Gizzard Shad, particularly young-of-the year, has been reported from water bodies with or without thermal discharges including Conowingo Pond. However, a complete “kill” has not been reported or inferred. Presumably an unknown number of older fish survive over winters as evident by capture of adults the following spring in water bodies unaffected by thermal discharge. Bodola (1965) reported winter “die off” of Gizzard Shad in multiple years from Lake Erie, PA, Jester and Jensen (1972) from Elephant Butte Lake, NM, and Fetzer *et al*. (2011) from Oneida Lake, NY.

In Conowingo Pond, the Gizzard Shad seems to tolerate temperatures < 2.2 °C (< 36.0 °F) and does not appear to need a “thermal refuge” to sustain its population. The average water temperature in December 1972 (first winter month exposure) the year Gizzard Shad were inadvertently introduced into Conowingo Pond (PBAPS was not operating), was 37.8 °F (3.2 °C). In January and February 1973 the average temperatures were 1.9 °C (35.5 °F) and 1.3 °C (34.3 °F), respectively. These temperatures were measured at Holtwood Dam, 7 miles upstream of PBAPS. From a historical perspective, the long term (1956-2007) average incoming water

temperatures (as measured at the upstream Holtwood Dam, 1956-2007) in December, January, and February, respectively are: 3.1 °C (37.6 °F), 1.5 °C (34.7 °F), 1.5 °C (34.7 °F), similar to those experienced in December 1972, and January-February 1973.

The complete shutdown of PBAPS (i.e., no thermal refuge) between 1987 and 1989 did not seem to affect the Gizzard Shad population in Conowingo Pond; the population survived the winters despite the absence of PBAPS thermal discharge. The incoming average water temperatures (°F) in December – February (1987-1989) were:

Month	1987	1988	1989
December	39.3	36.2	33.5
January	34.8	32.5	34.2
February	34.0	33.1	36.3

The tolerance of Gizzard Shad to low water temperatures was also corroborated by recent electrofishing sampling of non-thermally affected areas at Mt. Johnson Island (Station 164) and the East Shore (Station 165) in Conowingo Pond in January 2013. Some 22 Gizzard Shad were collected at Mt. Johnson Island and 21 on the East Shore (water temperature of 2.0 °C or 35.6 °F compared to 20 specimens each collected at the two locations in the thermal discharge (Stations 189 and 190). Therefore, the lower temperature tolerance of Gizzard Shad appears to be < 2.2 °C (< 36.0 °F).

During the fall large numbers of Gizzard Shad have been observed emigrating from Conowingo Pond downstream past Conowingo Dam. The annual migration (fish lift introductions) of Gizzard Shad from the lower Susquehanna River (up to 1 million Gizzard Shad) likely contributes substantially to the total population of this species in the Pond, and these fish do not benefit from overwintering in the Pond within the extent of the PBAPS thermal plume.

8.2 Summary and Conclusions

The Gizzard Shad population expanded rapidly after being inadvertently introduced into Conowingo Creek, a tributary to Conowingo Pond in May 1972. PBAPS was not operating then. The average water temperatures in subsequent January and February 1973 were 1.9 °C (35.5 °F) and 1.3 °C (34.3 °F), respectively. Again, when PBAPS was completely shut down (no thermal discharge) for two years (between 1987 and 1989) the Gizzard Shad population appeared to survive extreme winter conditions (water temperature between 32.5 and 36.3 °F). Gizzard Shad population experienced extreme winter temperatures in subsequent years and colonized other upstream areas. The population is thriving in areas unaffected by thermal discharges in the Susquehanna River and elsewhere. Conowingo Pond is an open system and recruits Gizzard Shad from both downstream and upstream sources. Gizzard shad are distributed throughout Conowingo Pond and each year upwards of 1 million adult Gizzard Shad

are introduced into Conowingo Pond from the Conowingo Dam East Fish Lift. A “thermal refuge” is not necessary for propagation and sustenance of the Gizzard Shad population in Conowingo Pond.

9 Conclusions

9.1.1 Temperature

An important component of the pre-EPU 316(a) Demonstration Study was modeling temperatures and temperature increases for extreme low flow and high temperature conditions using the post-EPU thermal discharge rate. In 2016, Susquehanna River flows and temperatures were very close to the flow and temperature values used to predict worst case biological impacts post-EPU. Because direct measurement was completed of net temperature increases from the EPU and reductions that occur when the cooling towers operate, the summer of 2016 was ideal for verifying the model and observing overall physical and biological impacts.

Model verification was undertaken in two steps, validation of assumptions and comparison of model results to observations. Modeling performed for the pre-EPU 316(a) Demonstration Study, and subsequently used in the biological evaluation, assumed a value of the temperature increase from the intake to the head of canal and a specific level of cooling tower performance. Based on measurements obtained in 2016, these two modeling assumptions were validated. The average temperature increase from the intake to the head of canal was 22.1°F, which was 0.3°F less than the assumed post-EPU condenser temperature rise of 22.4°F. Furthermore, each cooling tower provided about a third more cooling than expected (2.2°F instead of 1.6°F).

Model results showed very good agreement with observations. Agreement was tested by comparing temperature observations against model results at the warmest, most biologically sensitive monitoring stations, as identified in the pre-EPU 316(a) Demonstration Study. The observations were hourly, allowing between 400 and 1700 observations for comparisons to model results. Because the model was run for a single set of extreme Susquehanna River flows and temperatures, it was sufficient for the observations to be bounded by the model's estimate of maximum temperatures. Only 0.05% of observations exceeded this upper bound; which constitutes satisfactory model verification.

9.1.2 Fish and benthic macroinvertebrate communities

Water temperatures observed during 2016 at the biological monitoring locations were comparable to pre-EPU observations with the exception of late August through September period, which was warmer. Dissolved oxygen monitoring was completed within and outside of the PBAPS thermal plume to evaluate DO concentrations that may affect available fish habitat or cause blockage to fish migration past PBAPS. DO concentrations were protective of the aquatic community with sufficiently high DO to maintain fish habitat and allow for migration past PBAPS.

Surveys of the benthic macroinvertebrate community indicated similar species composition to pre-EPU monitoring; the community was characterized by tolerant taxa, in particular, Oligochaeta, Chironomidae, *Gammarus*, Gastropods, and *Corbicula* which were abundant at most stations. IBI scores and metrics indicated that the benthic community was similar to pre-

EPU observations for most months of monitoring. IBI scores and metrics were higher in July and August at the nearfield stations (214 and 215) during the post-EPU monitoring. In contrast, post-EPU scores were lower at Stations 214 and 215 in September due to lower flows and higher ambient temperatures during this month. The areas with measurable effects from the thermal plume were along the west shoreline at Stations 214 and 215 as was the case during pre-EPU monitoring.

A diverse warmwater fish community represented by 34 species was observed during the 2016 monitoring. Fish composition and relative abundance was similar between the thermal and non-thermal stations. Observations of the fish community as characterized by the selected metrics indicated similar composition to the pre-EPU period. Avoidance of the highest water temperature was observed at the nearfield electrofishing station (161) from July through September. The pattern of avoidance was comparable to pre-EPU observations with the exception of September where avoidance was not observed during pre-EPU monitoring. The avoidance and measurable reduction in the fish diversity was observed along the west shoreline and was limited to periods with high water temperatures and low flows. Avoidance was not observed at the seine stations (214 and 215) that experience the highest water temperatures. Observations of fish health (external anomalies) and fish condition (relative weight) indicated minimal differences between the thermally influenced and non-thermal locations. Fish health and condition were comparable to the Pre-EPU Demonstration Study with no measurable influence from the EPU identified. The length-frequency distribution of the representative important species was comparable to Pre-EPU observations and relative abundance of most RIS was within their historic ranges.

9.1.3 Overall

Post-EPU monitoring occurred during a period of low Susquehanna River flows coincident with high water temperatures. These conditions provided an ideal opportunity to evaluate the impact of the EPU on Conowingo Pond during extreme conditions. The monitoring results showed that cooling tower operation effectively mitigates the additional heat discharge by the EPU. This conclusion is based on the fact that observed water temperatures at the nearfield stations in 2016 for extreme low flow and water high temperature conditions were less than the modeled temperatures presented in the pre-EPU 316(a) Demonstration Study.

The measurable spatial and temporal effects of the PBAPS thermal plume on the biota of Conowingo Pond were similar to those observed during the pre-EPU monitoring. Temporal patterns of fish avoidance and decline in benthos diversity were apparent, related to high water temperatures and were also similar to those observed during the pre-EPU monitoring.

Periods of high temperatures occurred from July through September with measurable effects on the fish community as observed at Station 161 similar to pre-EPU results. The measurable loss in benthic community diversity was most evident during September at Stations 214 and 215 due to higher temperatures and lower flows during this month. The stations with measurable impacts are the same areas of the Pond where similar observations were made during pre-EPU

monitoring. These impacts are along the west shore at stations within approximately 0.6 mile of the PBAPS discharge canal.

Both the fish and benthic macroinvertebrate community composition and relative abundance were similar to pre-EPU monitoring. Indices used to describe the community structure of the biological community indicated that thermally influenced and non-thermally influenced stations were similar during pre-EPU and post-EPU monitoring. Overall, a balanced indigenous community exists in Conowingo Pond with the EPU.

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11 Appendices

11.1 PBAPS Post-EPU Study Plan

11.2 Chronology of Gizzard Shad Population Expansion

APPENDIX 11.1

STUDY PLAN

STUDY PLAN FOR POST-EPU THERMAL AND BIOLOGICAL MONITORING

PEACH BOTTOM ATOMIC POWER STATION

Prepared for:

Exelon Generation®

Prepared by: Normandeau Associates, Inc. and ERM, Inc.

Revision 3, April 2016

Introduction

This study plan outlines the details for performing biological and thermal monitoring following Extended Power Uprates (EPU) for Peach Bottom Atomic Power Station (PBAPS) Unit Nos. 2 and 3. This biological and thermal study supports the monitoring requirements of fish and macroinvertebrate communities set forth in Part C of PBAPS's NPDES Permit No. PA0009733. Section 1 of this study plan addresses the biological and thermal monitoring discussed above. Section 2 of this study plan addresses a review of potential impacts to American Shad migration as a result of the EPUs for PBAPS Unit Nos. 2 and 3. This review of American Shad migration is being performed based on PADEP's disposition of NPDES permit comments during the review period of the draft NPDES Permit. Section 3 of this study plan addresses USFWS comments related to distribution of Gizzard Shad in Conowingo Pond relative to PBAPS's thermal plume.

Section 1

Thermal Plume Monitoring

Objective: Monitor water temperatures in Conowingo Pond to compare to 2010-2013 NPDES thermal study results regarding the characteristics of the plume after implementation of the EPU.

Monitoring Period: May 1 through September 30, 2016.

Monitoring Locations: Thermal monitoring locations will include: cooling water intake outer screen structure; head of discharge canal; end of discharge canal; and at Transects 200, 300 and 400 in Conowingo Pond, specifically stations 201, 203, 205, 301 303, 401 and 403 (Figure 1). At the Transect stations, the temperature monitors will be installed at the surface (at approximately 1 foot depth) and at approximately 10 feet depth below surface, and bottom at each station. At the other referenced monitoring locations a single monitor will be installed at approximately mid-depth to characterize water temperature. In addition, temperature monitors will be installed at the biological collection locations, specifically stations 221, 208, 214, 215, 189, 190, 216, and 217 (Figure 2). At the biological stations, a single temperature monitor will be installed on the bottom. Table 1 provides a summary of the proposed temperature monitoring locations and monitor depths.

Table 1. Water temperature monitor location and monitor depth.

Monitor Location	**Monitor Depth**			
	Water Surface	**10ft Below Surface**	**Mid-Depth**	**Bottom**
Intake Screen			X	
Head of Canal			X	
End of Canal			X	
201, 203, 205, 301, 303, 401, 403	X	X		X
221, 208, 214, 215, 189, 190, 216, 217				X

Monitoring Method: Water temperatures will be recorded hourly using temperature data loggers that are accurate to approximately 0.36 °F in the range of 32 to 122 °F.

Deliverables: A spreadsheet providing raw water temperature data will be created along with a list of collected daily average, minimum and maximum temperatures. Temperature reporting will include tables or figures that provide the duration and frequency of high temperatures. Temperature changes due to cooling tower operations will be recorded and evaluated. A comparison of daily average, minimum, and maximum temperatures during the transition period (i.e., turning on a cooling tower) to values obtained from the thermal model will be prepared. The comparison will consider that the forcing conditions (meteorology, river flows and plant operations) during 2016 will be different than the ones used in the thermal model. Analysis to compare the post-EPU temperatures with the predictive model will be completed to verify the model.

This monitoring plan includes a sufficient number of monitoring stations and frequency of data collection such that the temporary loss of data from one or more thermistors will not interfere with the proposed analysis. Furthermore, because data will be recovered approximately monthly, gaps due to malfunctioning or displaced thermistors will not exceed one month. Any loss of data will be noted in the report.

Dissolved Oxygen Monitoring

Objective: Monitor dissolved oxygen in Conowingo Pond in shallow shoreline areas along west shoreline downstream of the PBAPS discharge canal. In particular,

monitoring will focus on periods of low-flow and high water temperature which could result in low dissolved oxygen concentrations.

Monitoring Period: June 1 through September 30, 2016.

Monitoring Locations: Dissolved oxygen monitoring will be completed at biological stations 208, 215 and 189. A single monitoring device will be installed toward the bottom of the water column at each location. Monitors will be installed in water with depth less than 10 ft.

Monitoring Method: Dissolved oxygen concentrations will be recorded hourly using a Hydrolab water quality multiprobe or equivalent data logger.

Deliverables: A spreadsheet providing raw dissolved oxygen data will be created along with a list of collected daily average, minimum, and maximum dissolved oxygen concentrations.

Biological Monitoring

Objective: Monitor biological community in Conowingo Pond to determine characteristics of the fish and benthic macroinvertebrate communities after implementation of the EPU. Collection locations for fish and benthic macroinvertebrates are provided in Figure 3.

Monitoring Period: May 1 through September 30, 2016

Sampling Procedure: Fish sampling will generally employ the same field sampling protocols that were used during the 2010 through 2013 studies (Normandeau and ERM 2014). Collected fish will be identified to species (or genus for those too small to identify to species in the field), counted, measured, and examined for disease, external parasites, lesions, tumors (DELTs) and anomalies. Fish DELTs and anomalies will be recorded using the acronyms provided in PADEP Field Data Sheet for Tissue Sampling (Attachment 1). Live fish will be released back to the Pond except for those retained to confirm identifications or retained as voucher or reference specimens. Large numbers of collected fishes will be subsampled (maximum of 50 specimens per species) for individual length measurement.

Seine

A seine measuring 10 ft by 4 ft with ¼-inch mesh will be used once monthly at each station. Most sites able to be sampled effectively with this gear are small beaches less than 100 ft long. To standardize results for each site, five hauls will be conducted at each sampling station. This sampling with fine mesh seines is intended to capture the young of many species and those fishes having a relatively small size as adults that frequent shallow, shore zone habitat.

Data recorded at each station for each collection will include weather, date, time, Secchi disc transparency, air and surface water temperatures, dissolved oxygen, and estimated water depth.

Electrofishing

Fish will be collected at night using boat electrofishing equipment employing pulsed direct current to minimize fish injury. The boat-mounted shocker will be maneuvered slowly through the stations as close to shore as practicable. Each sample will consist of approximately 30 minutes of shocking. Stunned fish will be netted and placed in an on-board live well for subsequent processing except for large specimens (e.g., common carp and quillback) which will not be brought on-board, but will be counted and recorded. Boat electrofishing will collect larger fish that frequent the shallow, shore zone habitats that are not effectively sampled with seines.

Data recorded at each station for each collection will include weather, date, time, air and surface water temperatures, dissolved oxygen, specific conductance, and estimated water depth.

Benthic Macroinvertebrates

Collections will occur within littoral benthic habitats and samples processed following the PADEP Multi-habitat Stream Assessment Protocol (PADEP 2008). A habitat assessment will be completed during each benthic macroinvertebrate collection following PADEP habitat assessment protocol (PADEP 2013).

Monitoring Locations:

Electrofishing:

Upstream of thermal plume: 187 and 165
Downstream of thermal plume: 161, 189, 190, and 217

Seining:

Upstream of thermal plume: 220, 221, and 208
Downstream of thermal plume: 214 and 215

Benthic Macroinvertebrates:

Upstream of thermal plume: 208, 220, and 221
Downstream of thermal plume: 189, 214, 215, and 216

Figure 3 provides a spatial representation of the monitoring locations.

Monitoring Interval: Perform monthly fish and benthic macroinvertebrate collections at each station.

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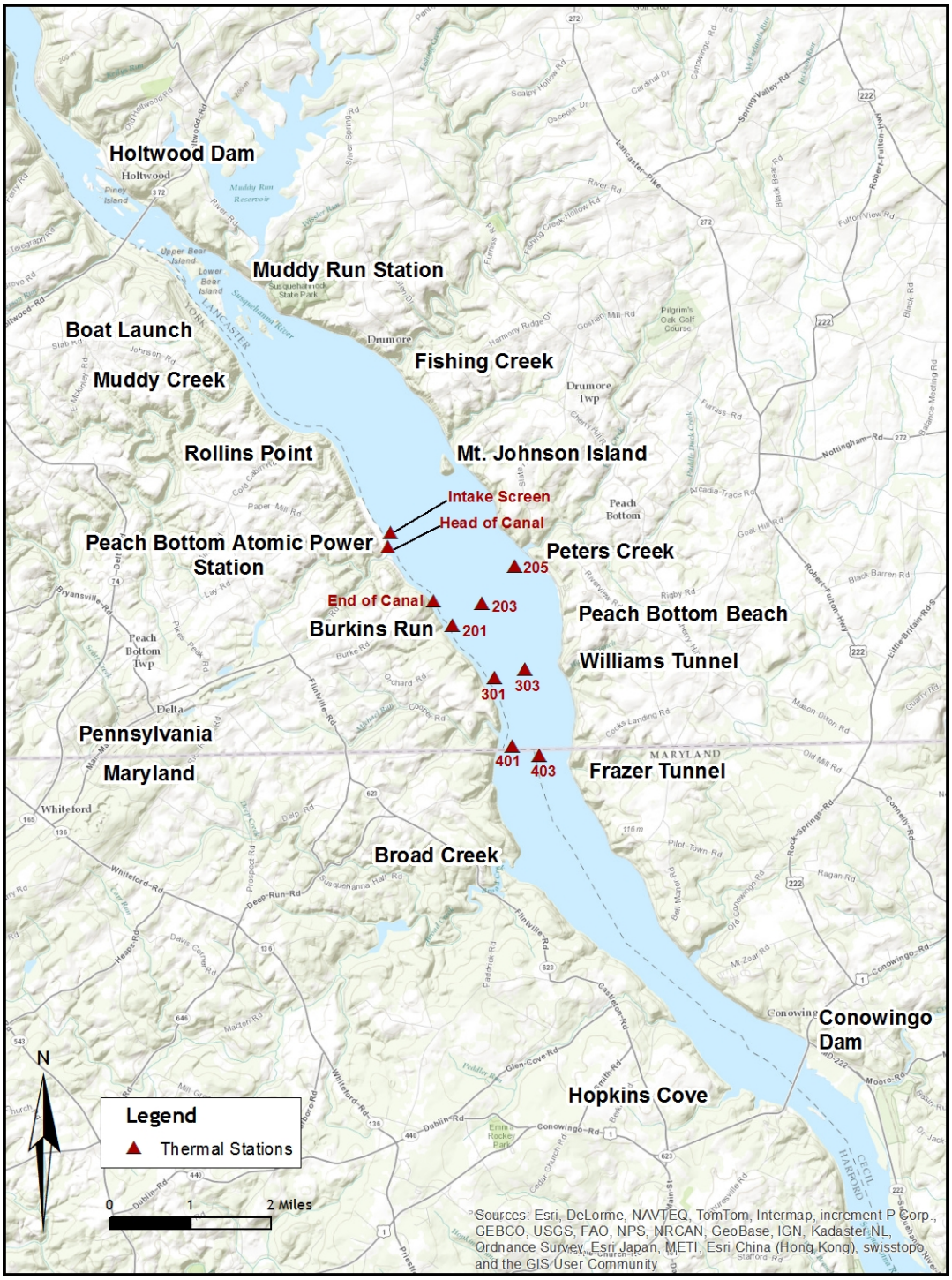


Figure 1. Proposed temperature monitoring transects and locations in Conowingo Pond.

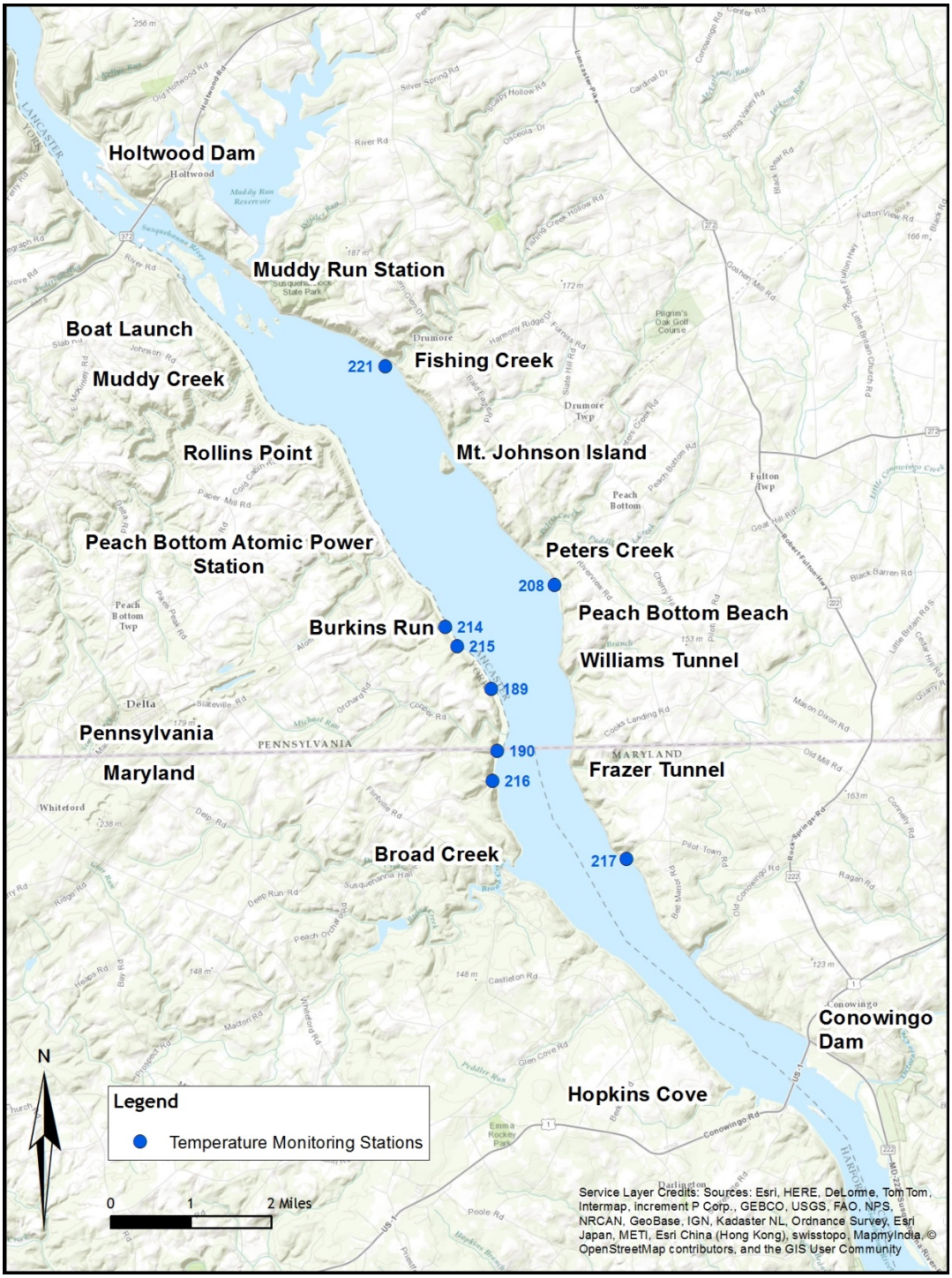


Figure 2. Proposed temperature monitoring locations that coincide with biological collection locations in Conowingo Pond.

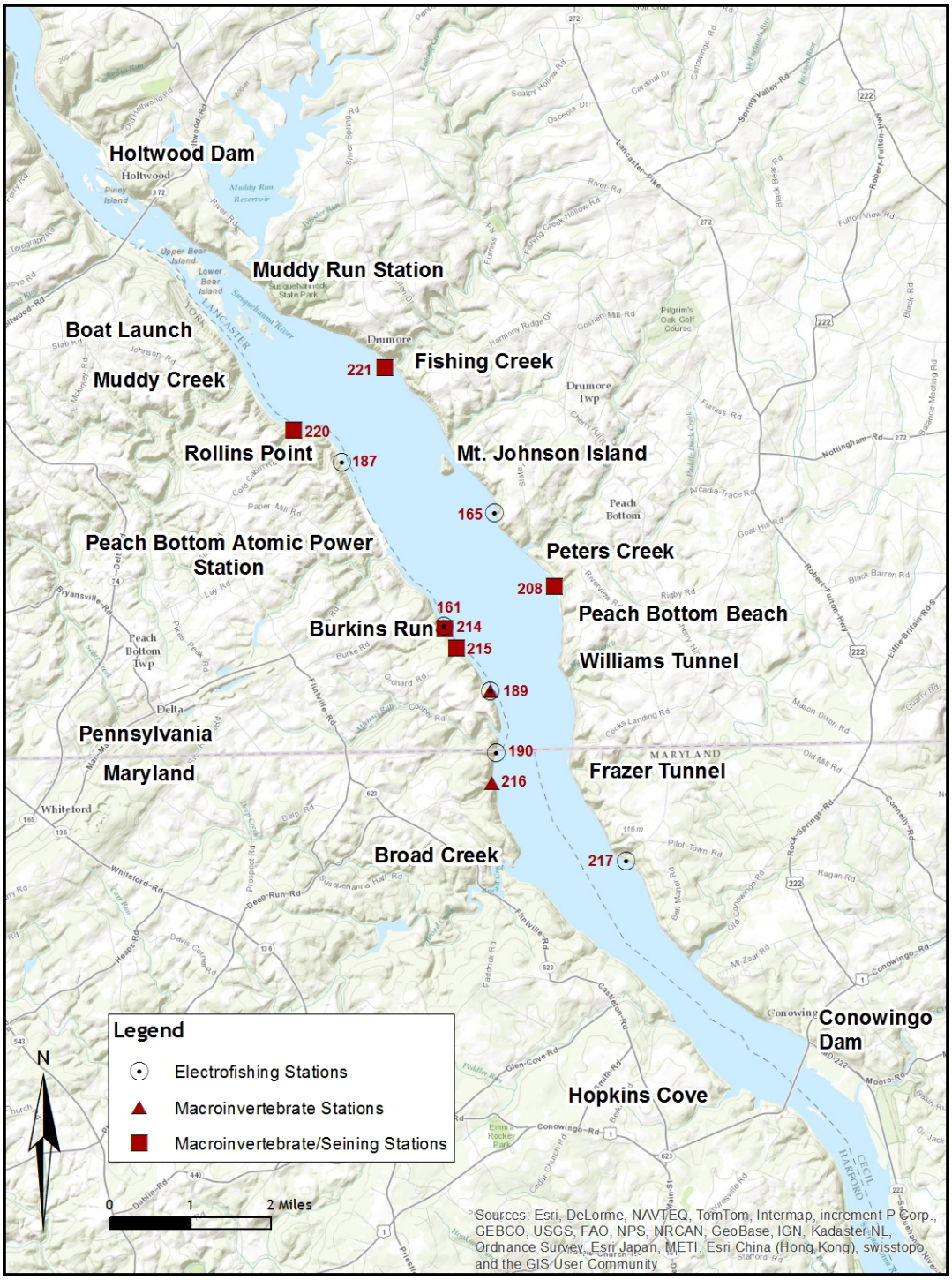


Figure 3. Proposed biological collection locations in Conowingo Pond.

Section 2

American Shad Study

Objective: To address draft NPDES permit comments related to the potential effect of the PBAPS thermal discharge on American Shad during post-EPU conditions on Unit Nos. 2 and 3.

Exelon Deliverable: A desktop study that will use existing information and current scientific understanding of American Shad in Conowingo Pond to address the draft NPDES permit comments. This will be accomplished through use of the existing hydrothermal model and existing model outputs that characterize the thermal plume for several low-flow and high water temperature scenarios. The existing model output for these scenarios will then be evaluated to determine the potential for PBAPS's thermal plume to block migration of American Shad in the Conowingo Pond.

Section 3

Gizzard Shad Seasonal Distribution

Objective: To address USFWS April 2016 comments related to seasonal distribution of Gizzard Shad in Conowingo Pond relative to the PBAPS thermal plume.

Exelon Deliverable: Provide a compilation of information related to Gizzard Shad seasonal distribution in Conowingo Pond relative to the PBAPS thermal plume. This information will be obtained from existing reports, primarily the Final Report for the Thermal Study to Support a 316 (a) Demonstration at Peach Bottom Atomic Power Station, March 2013.

Deliverables: After completion of monitoring a report will be submitted to PADEP. This report will include all three sections of the Study Plan. Section 1 will include data tables, analysis of the data, and comparison with pre-EPU biological and thermal monitoring data. The report will be submitted to PADEP for review by February 3, 2017. This monitoring plan includes a sufficient number of monitoring stations and frequency of data collection such that a minor interruption of data collection due to weather or other impacts will not interfere with proposed analysis.

Raw data files for biological monitoring will be submitted to PADEP in a database format such that for each observation a single independent row of biological data is provided and non-biological data is linked to the biological data through a common identifier.

ATTACHMENT 1

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL PROTECTION
BUREAU OF WATER STANDARDS AND FACILITY REGULATION

GENERAL INSTRUCTIONS FOR FIELD DATA SHEET TISSUE SAMPLING

STATION NUMBER: Enter WQN Station Number, WQF Station Number or Survey Station Number as appropriate. Leave blank if none of these apply.

NOTE: If WQN Number is entered, then Waterbody Name, Location, County and Municipality can be left blank.

DATE, COLLECTOR, AGENCY and COLLECTOR NUMBER: Must be completed.

NEW STATIONS: If a WQF station number has not previously been assigned, Quad. Name, Quad. Number, either Lat/Long or inches-N/inches-W and RMI (to nearest 0.1 mile) must be entered (for STORET input).

TISSUE TYPE: Standard samples are:

1. Skin-on, scaled fillets for gamefish, panfish and rough fish.
2. Skinless fillets for catfish and bullheads.

SAMPLE: A normal sample is a composite of 10 fillets from 5 fish. For large fish, 5 fillets can be used.

75 PERCENT RULE: The individual fish in each composite should be as close to the same size as possible. A general guideline is that the length of the smallest individual in the composite should be no less than 75 percent of the length of the largest individual.

Fish Health:					
Black grub	**Bg**	Trematode	**Tr**	Frayed fins	**Ff**
Deformities	**De**	Tumor	**Tu**	Eroded fins	**Ef**
Eroded skin	**Es**	White cysts	**Wc**	Eroded gills	**Eg**
Fungal infection	**Fi**	Emaciated	**Em**	Frayed gills	**Fg**
Leeches	**Le**	Cloudy eye	**Ce**	Clubbed gills	**Cg**
Melanistic area	**Ma**	Exophthalmic eye	**Ee**	Spotted Gills	**Sg**
Open sore	**Os**	Hemorrhagic eye	**He**	Cyst on gills	**Cg**
Raised red sore	**Rr**	Missing eye	**Me**		
Life History:					
Gravid	**G**	Post spawn	**Ps**	Milting male	**Mm**

ATTACHMENT 1

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL PROTECTION
BUREAU OF WATER STANDARDS AND FACILITY REGULATION

FIELD DATA SHEET TISSUE SAMPLING

Station # _____ Waterbody _____ Date & Time _____

Location _____

_____

County _____ Municipality _____

Collector _____ Agency _____ Coll.# _____

COMPLETE FOR NEW STATIONS

Quad. Name _____ Quad.# _____

Lat. (inches N) _____ Long. (inches W) _____ RMI _____

Method:
- ☐ Electrofishing
- ☐ Rotenone
- ☐ Seine
- ☐ Angling
- ☐ Gill Net
- ☐ Other (specify)

Tissue Type:
- ☐ Whole Fish
- ☐ Skin-on Fillet – Scaled
- ☐ Skinless Fillet
- ☐ Skin-on Fillet – Not Scaled
- ☐ Other (specify):

SPECIES	TL (inches)	WT (lbs. oz.)	Fish Health & Life History*
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			

*Use Fish Health & Life History Codes (if needed)

Comments: (water/weather conditions, man-hours expended, problems, etc.)

_____

_____

_____

_____

_____

APPENDIX 11.2

CHRONOLOGY OF GIZZARD SHAD POPULATION EXPANSION

Chronology of Gizzard Shad Population Expansion

Gizzard shad, native to eastern North America, was inadvertently introduced (100+ specimens) into Conowingo Creek, a tributary to Conowingo Pond, in May 1972 during an American Shad transport from the Conowingo Dam West Fish Lift. The introduction of Gizzard Shad and its subsequent population explosion in Conowingo Pond occurred prior to the operation of Peach Bottom Atomic Power Station (PBAPS) Unit 2 in July 1974 and Unit 3 in December 1974. At present, Gizzard Shad has successfully colonized new habitats in the Susquehanna River (upstream of York Haven Dam) with or without a thermal plume.

The spawning success of Gizzard Shad in 1972 was demonstrated by capture of its larvae the same year (Figure 1). Prior to 1972, no larval Gizzard Shad were collected but beginning in 1972 catch of larval Gizzard Shad became routine with high densities thereafter. Although the Tropical Storm Agnes in June 1972 had a catastrophic effect on most of the fish community of Conowingo Pond, Gizzard Shad appeared to be quite resilient with continued expansion.

Trawl samples (Figure 2) in Conowingo Pond demonstrated a similar pattern indicating that the Gizzard Shad population was successfully established in the Pond in a relatively short time and became self-sustaining.

Although the Muddy Run Reservoir is not affected by thermal discharge Gizzard Shad successfully colonized this additional habitat since 1972. Block net samples in the Muddy Run Reservoir coves (Figure 3) show Gizzard Shad population continued to grow since 1972. Subsequently, a population developed rapidly and spread to the nearby Muddy Run Recreation Lake (unaffected by thermal discharge). This population experiences same extreme winter temperatures as the population in Conowingo Pond. A large number of young Gizzard Shad is observed emigrating from Muddy Run Reservoir in the fall which may contribute to the Conowingo Pond population.

Gizzard Shad population in Conowingo Pond as noted elsewhere seems resilient despite severe winters, extreme hydrological/meteorological events (e.g., hurricanes, storms, etc.) with only a small start-up (100+ fish) population needed for its explosive population growth.

Installation of fishways, first at Conowingo (1972, and 1991; Figure 4 and 5) then later at Holtwood and Safe Harbor in 1997, and at York Haven in 2000; Figure 6) at all the dams on the Susquehanna River in combination with its presence over 200 miles of the Susquehanna River (unaffected by thermal discharges) including the Muddy Run Reservoir assures a consistent supply of Gizzard Shad spawning stock for upstream and downstream dispersal (Figures 4-6); the system is basically open. Presently, fishes can and do volitionally move upstream to areas above York Haven Hydroelectric Dam (RM 56).

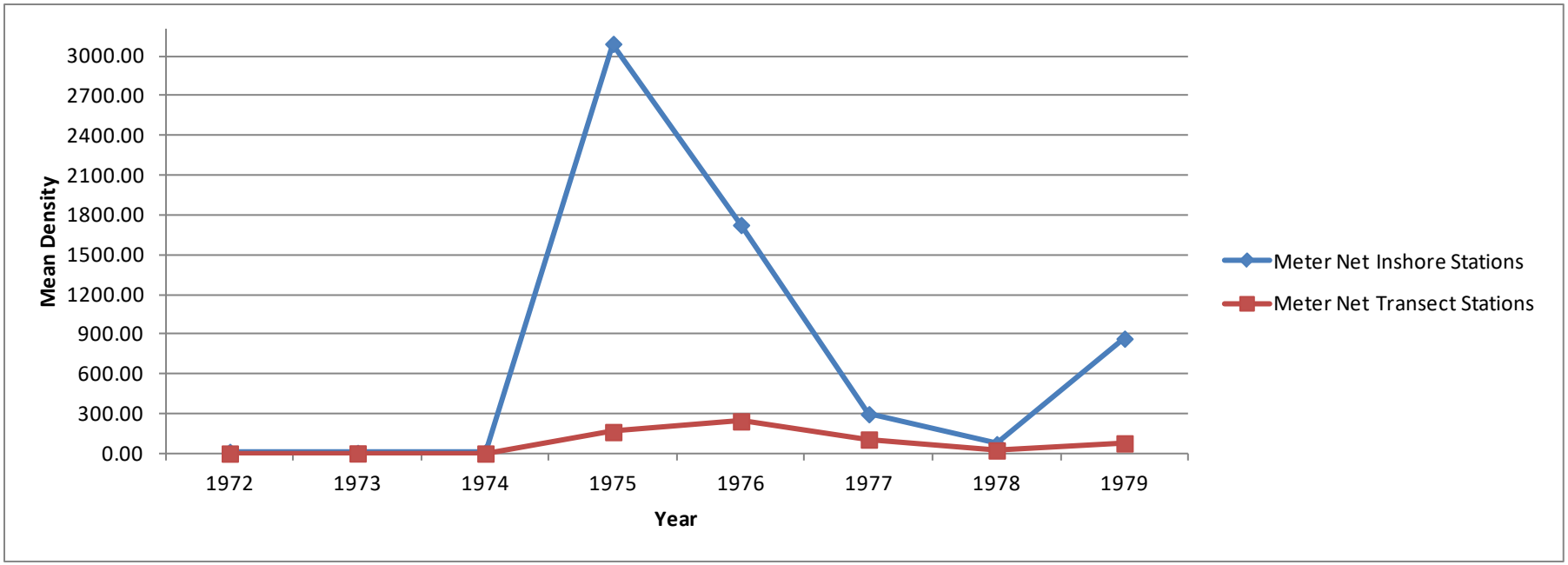


Figure 1. Reproductive success of Gizzard Shad indexed by catch of larval gizzard shad (number of larvae ≤ 25 mm per 1000 m^3) at inshore stations (creeks and coves) and in the main Conowingo Pond (Transect stations), 1972-1979. Densities of larval Gizzard Shad in 1972-1974 at inshore stations < 13.5 per 1000 m^3 could not be shown on the same vertical scale. Data source: RMC-Ecological Division (1979).

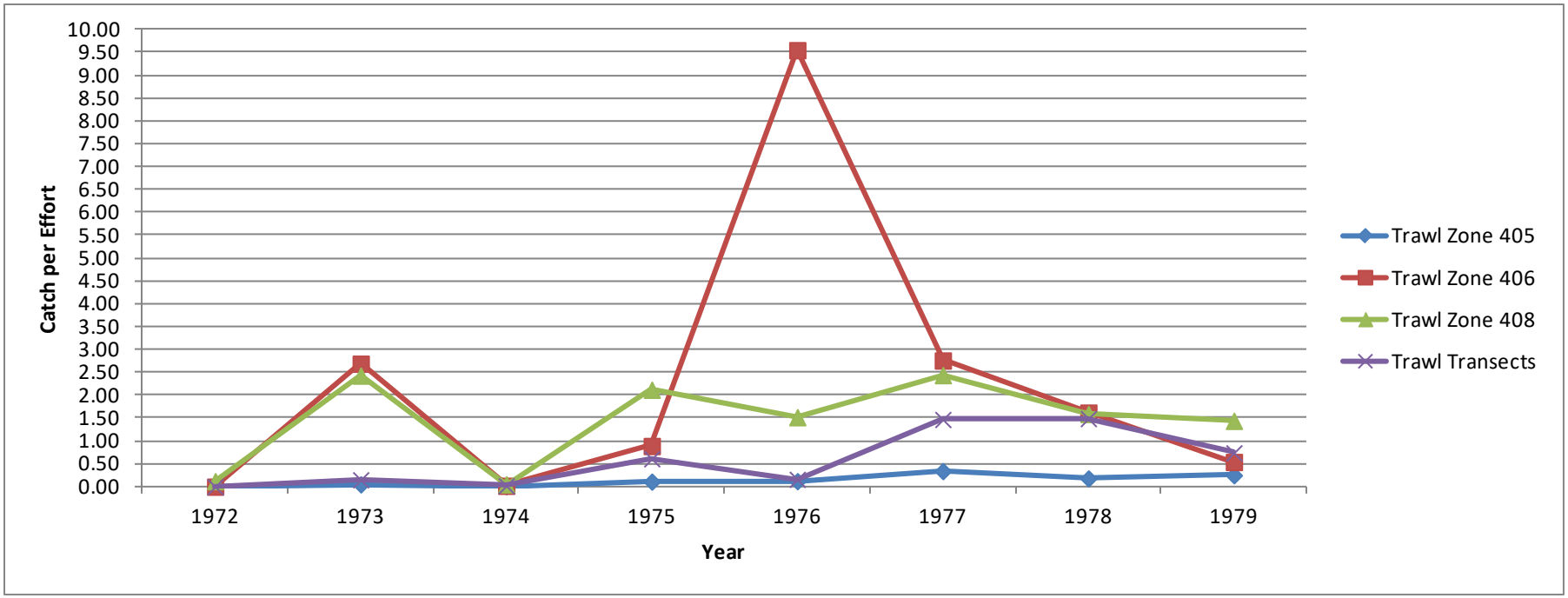
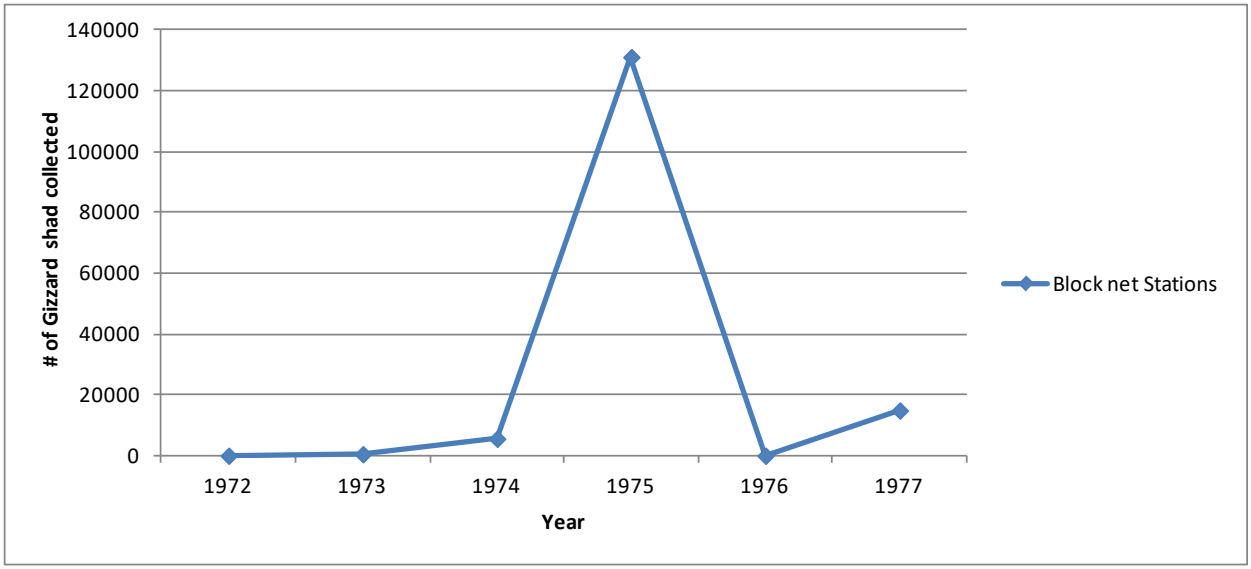


Figure 2. Catch per effort (number per 10 min trawl haul) of Gizzard Shad in Conowingo Pond, 1972-1979.

A



B

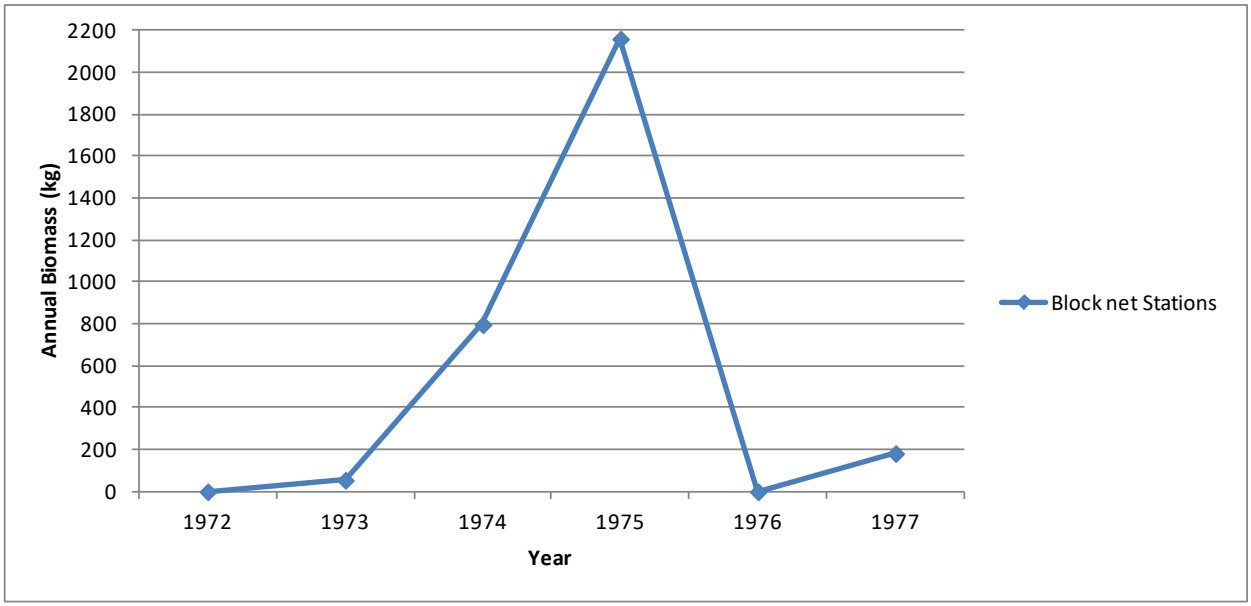


Figure 3. **Number (A) and biomass (kg per ha, B) of Gizzard Shad collected by block net in the Muddy Run Reservoir, 1972-1978. Source: RMC-Ecological Division (1979).**

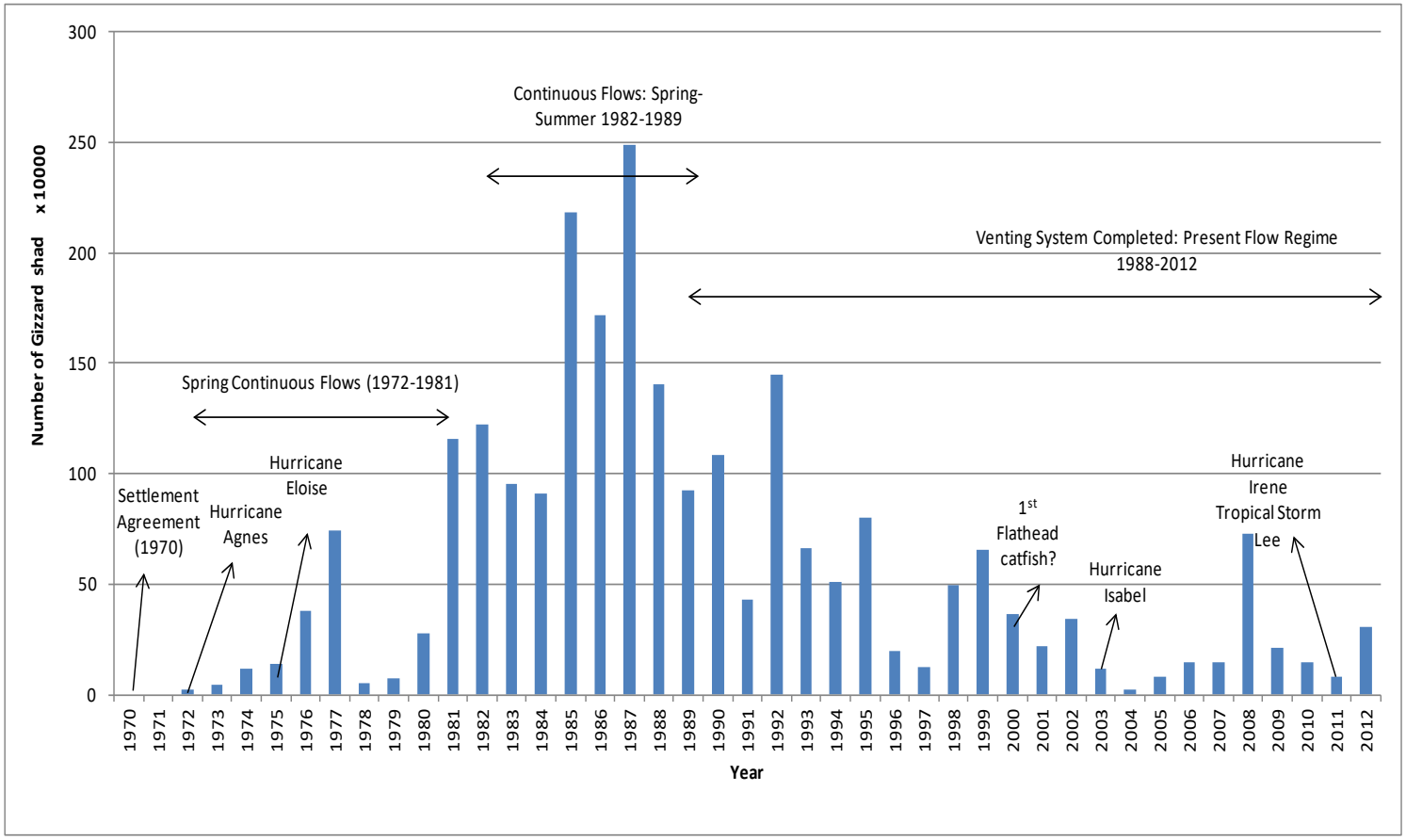


Figure 4. Passage counts of Gizzard Shad at the Conowingo West Fish Lift (1972-2012).

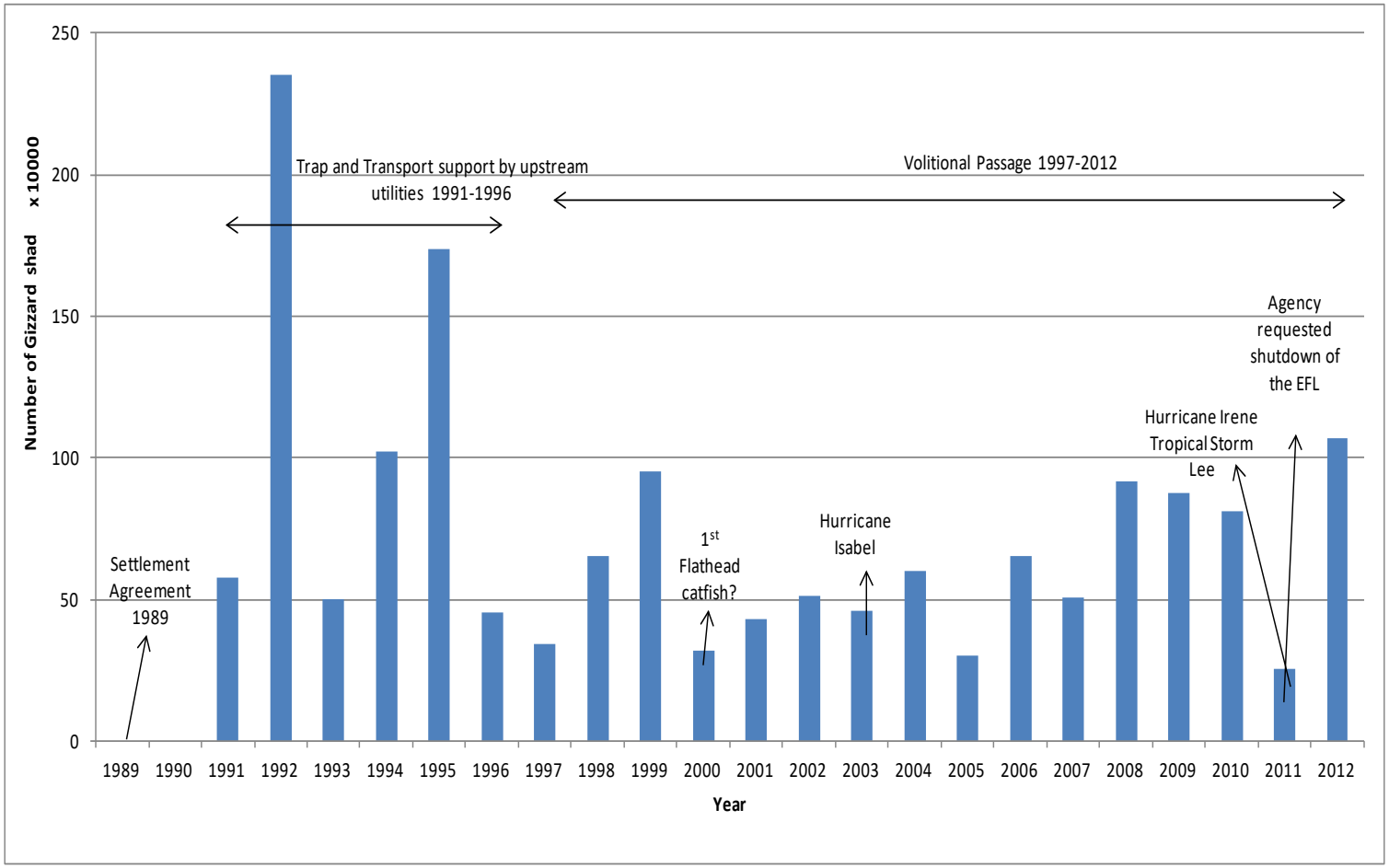


Figure 5. Passage counts of Gizzard Shad at the Conowingo East Fish Lift (1991-2012).

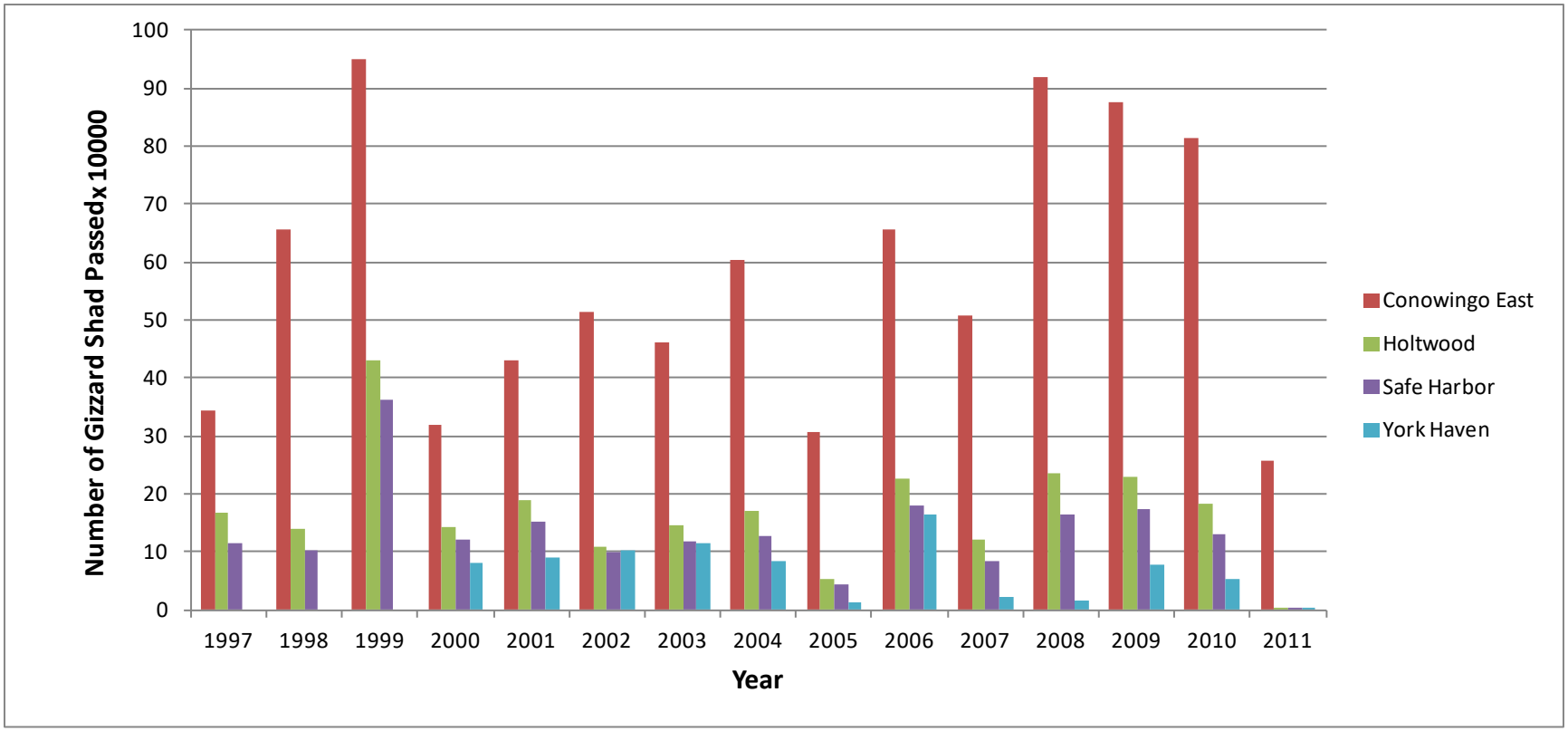


Figure 6. **Passage counts of Gizzard Shad at the four fishways showing rapid colonization of upstream areas, 1997-2011. Voluntary passage at Conowingo EFL, Holtwood and Safe Harbor commenced in 1997; and York Haven in 2000.**

The following sources/reports were reviewed to prepare the response and conclusions that a "thermal refuge" is not necessary for propagation and sustenance of Gizzard Shad and the population is thriving in areas unaffected by thermal discharges.

- Pre-operational report (1966-1973) and the initial 316(a) report (1977) describing the baseline water quality, benthic and zooplankton, fish composition, ecology, distribution, and abundance of fishes in the Pond and surrounding waters. The 316(a) report and a supplement compared the pre-operational and post-operational data on the studied parameters and provided thermal tolerances (temperature preference, avoidance, heat and cold shock) of approximately 27 species.
- Semi-annual post-operational reports (prepared as part of PBAPS as part of U.S. Nuclear Regulatory Commission Technical Specifications requirements relative to the operation of the station. These reports compared changes, if any, in the above mentioned parameters.
- Annual reports prepared relative to the operation of the Three Mile Island Nuclear Station (approximately 49 miles upstream of PBAPS) during forced shutdown, and subsequent start-up. These reports show presence of Gizzard Shad in the 1990s before the fishways were installed at Holtwood, Safe Harbor dams (1997) or York Haven Dam (2000).
- Sampling in Conowingo Pond relative to operation of Peach Bottom Atomic Power Station: (1) meter net samples (1969-1977) to signify spawning success, time, temperature, and areas, and (2) trawling (1967-1980, 1996-1999), seining, trap netting, electroshocking to indicate survival and successful establishment of Gizzard Shad population in the Pond and exposures to a wide array of environmental changes, and (3) responses to natural catastrophic events such as Tropical Storm Agnes in 1972 and Hurricane Eloise in 1975.
- Sampling in Muddy Run Pumped Storage Reservoir (1970-1977) as part of licensing of the Muddy Run Pumped Storage Station: block net sampling and meter net sampling (1970-1977) to demonstrate successful establishment of Gizzard Shad population in 1972 and the potential for recruitment to Conowingo Pond, particularly during voluntary fall emigration;
- Annual Conowingo West Lift Fish (1972-present) and East Fish Lift (1991-present) operation reports. These reports provide (1) fish passage counts, (2) temporal changes in relative abundance and expansion of Gizzard Shad population before (1972-1996) and after (1997-present) voluntary passage at the EFL along with events deemed notable since 1972, (3) annual recruitment of Gizzard Shad into Conowingo Pond, and (3) potential factors contributing to the species expansion;
- Holtwood, Safe Harbor Fish Lift Counts (1997-present), and York Haven Fish Ladder (2000-present) provide an estimate of the number of Gizzard Shad that may continue upstream migration into non-thermally affected areas with potential for downstream recruitment; and range expansion.

CCN 17-56

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

MAY 03 2017

Patrick D. Navin
Plant Manager
Exelon Generation Company LLC
1848 Lay Road
Delta, PA 17314-9032

Re: Response to Final Report for Post-EPU Thermal and Biological Monitoring and Notice of Planned Measurement Uncertainty Recapture Uprate
Peach Bottom Atomic Power Station (PBAPS)
NPDES Permit No. PA0009733
Peach Bottom Township, York County

Dear Mr. Navin:

This letter is in reference to the final report for Post-EPU Thermal and Biological Monitoring and notice of Planned Measurement Uncertainty Recapture Uprate recently submitted by Exelon Generation Company LLC (Exelon) to support compliance with the existing permit requirements developed under Section 316(a) of the Clean Water Act (CWA). The Department of Environmental Protection (DEP) has reviewed these documents and would like to provide the following comments:

Final Report for Post-EPU Thermal and Biological Monitoring

In accordance with Part C.I of the above-referenced NPDES permit reissued in 2014, a study plan was developed to perform one-year biological and thermal monitoring[1] in order to evaluate the impact on the fish and macroinvertebrate populations in the Susquehanna River as a result of thermal component of the discharge from the above-referenced facility following implementation of the extended power uprate (EPU) which was completed in 2016. The study was also determined to be necessary to compare post-EPU conditions with predictions, such as the characteristics of the plume, made in the previous monitoring study performed during the period from 2010 through 2013 (i.e., demonstration study; *finalized in 2013*). A review of the submitted final report for 2016 Post-EPU Thermal and Biological Monitoring revealed that Exelon has adequately implemented the monitoring plan through this one-year study and has addressed all of the components of this study in the final report. DEP has therefore determined that Exelon has achieved compliance with the existing permits requirements and continuation of CWA Section 316(a) thermal variance is still warranted for the current NPDES permit term.

DEP appreciates Exelon's efforts to collect extensive physical and biological data to support the monitoring requirements. While continuation of the thermal variance is warranted for the

[1] Temperature monitoring from May 1 through September 30 of 2016, Dissolved Oxygen monitoring from July 1 through August 31 of 2016, Biological monitoring May 1 through September 30 of 2016.

remainder of current permit cycle, DEP strongly recommends that Exelon consider operation of the cooling tower(s) until the end of September of each year. No cooling towers were operated in September 2016 as it was not required by the permit. For many of the downstream monitoring stations, several year-to-year analyses in the final report show that daily average water temperatures in September 2016 were warmer than temperatures measured in September of previous years. Furthermore, temperature differences from the intake to the downstream monitoring station 214 in September were mostly higher than those calculated for any of the months within the 2016 monitoring period. For macroinvertebrate community, Exelon concluded, along with other findings, that a temporary impact, in terms of lower IBI scores, was observed at two (2) downstream monitoring stations in September. All of above-mentioned items were identified during the monitoring period presumably due to the unusual ambient river conditions observed in September 2016 that were repeatedly mentioned in the final report (i.e., very low-flow with high ambient water temperatures). However, the final report indicates that the average temperature rise from the intake to the head of discharge canal in September 2016 was higher than previously predicted in the demonstration study (i.e., 22.5°F v. 22.4°F; Table 3-5 of the final report). As a result, higher water temperatures were observed at the downstream monitoring stations not only because of unusual river conditions occurred in September but possibly because of additional thermal load potentially generated from the facility. In order to protect the aquatic community, the operation of the cooling tower(s) may be necessary during any of naturally-occurring high temperature periods to additionally "balance" the thermal load generated from PBAPS. Exelon observed during the monitoring period that the per tower discharge canal cooling was higher than previously expected in the demonstration study (i.e., 2.2°F v. 1.6°F); therefore, using the cooling tower(s) additionally in September will further mitigate potential impacts on the fish and macroinvertebrate populations in the Susquehanna River as a result of thermal component of the discharge.

This final report as well as any relevant information provided by Exelon will be considered in developing appropriate permit requirements for the subsequent NPDES permit renewal.

Notice of Planned Measurement Uncertainty Recapture Uprate

As per reporting requirements set forth in Part A.III.C.2.b of the above-referenced NPDES permit reissued in 2014, Exelon has indicated via a letter dated February 17, 2017 that additional thermal loading is expected as a result of a Measurement Uncertainty Recapture (MUR) uprate of PBAPS Units 2 and 3. The MUR uprate, in which the license amendment is scheduled to be submitted to the NRC by the end of February 2017 according to the February 17, 2017 letter, will increase the station's licensed power level from 3951 MWth (megawatt thermal) to 4016 MWth. It is expected that this change will ultimately result in a plant intake to discharge temperature (Δt) increase of up to 0.4°F over current conditions[2] and the net temperature increase at the near field temperature stations downstream of the plant would range from 0.02°F and 0.06°F over the EPU model. Based on the given information, DEP has determined that the MUR uprate is not expected to significantly

[2] The February 17, 2017 letter documented that the net increase projected for MUR will be only 0.1 °F as the actual maximum net temperature under EPU conditions was determined to be 22.1 °F as opposed to 22.4 °F which is the value predicted during the Section 316(a) demonstration study.

contribute to additional thermal impacts on the Susquehanna River. Consequently, no NPDES permit amendment is required at this time. However, because the expected Δt value was determined solely based on assumptions determined through the application of EPU model, DEP requests that temperature monitoring be conducted following implementation of the uprate to validate such assumptions. Given that the uprate is scheduled for April, 2018 according to the February 17, 2017 letter, DEP is requesting that Exelon to submit the one-year monitoring data with the subsequent NPDES permit renewal application which is due by April, 2019.

Section 316(a) Thermal Variance Request

Pursuant to 40 CFR §122.21(l)(6), a request for a variance under CWA Section 316(a) for the thermal component of the discharge must be filed with a timely NPDES permit renewal application. If such request will be submitted with the NPDES permit renewal application, please contact DEP to discuss any additional information that may be necessary for DEP to evaluate continuation of CWA Section 316(a) thermal variance for PBAPS during the subsequent NPDES permit renewal application review process.

If you have any questions, please contact me at 717.705.4795 or mbebenek@pa.gov.

Sincerely,

Maria D. Bebenek, P.E.
Environmental Program Manager
Clean Water Program

cc: Brian Trulear, U.S. Environmental Protection Agency
Sheila Eyler, U.S. Fish and Wildlife Service
Mark A. Hartle, PA Fish & Boat Commission
Susan Gray, Maryland Department of Natural Resources
Joseph Brozonis, PE, Exelon Generation Company, LLC
Kristen Schlauderaff, PA DEP
Kristen Bardell, PA DEP
Curtis Sullivan, PA DEP

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Exelon Generation

August 18, 2017

Maria D. Bebenek, P.E.
Environmental Program Manager
Clean Water Program, PA DEP
909 Elmerton Ave.
Harrisburg, PA 17110

Subject: PBAPS Cooling Tower Operation and Measurement Uncertainty Recapture Uprate Thermal Monitoring

Dear Ms. Bebenek,

We are writing to communicate our response to a letter from PA DEP dated May 3, 2017 and pursuant conversation on "08/18/17" related to Post-EPU Thermal and Biological Monitoring and Notice of Planned Measurement Uncertainty Recapture Uprate. You will find our response to the two topics outlined below, as discussed on our call.

PBAPS Cooling Tower Operation (Post-EPU)

Based upon data from the Post-EPU Thermal Monitoring study performed in 2016, PA DEP has strongly recommended Exelon consider continued operation of the PBAPS Cooling Towers until the end of September to mitigate the thermal impact to the Susquehanna River, especially during period of elevated temperatures and low-flow River conditions. Exelon agrees with the DEP's observation of the unusual environmental conditions in September of 2016, and understands the additional benefits of running towers under these conditions. Going forward Peach Bottom has decided to operate Cooling Towers on a conditional temperature basis until the end of September, although we understand the current NPDES Permit requirements, PA0009733, will remain unchanged for this permit cycle. Exelon has developed the following average intake temperature basis conditions for cooling tower operation from the end of August through September 30th (all based on 48 hour averages):

1. One tower will operate continuously through September 30, if temperature is equal to or greater than 81 F. If temperature lowers to 81F the one remaining operational tower may be secured.

2. A second tower will continue operation or commence operation within 48 hours of average intake temperatures being equal to or greater than 83F. When intake temperature is less than 83F, operation of the second cooling tower will cease.

3. A third cooling tower will operate conditionally in accordance with the language in the current NPDES Permit.

Operation of the cooling towers in this manner will "balance" the thermal load generated from PBAPS and mitigate potential impacts on the fish and macroinvertebrate populations in the Susquehanna River. Should we not be able to meet these guidelines during the September period due to operational or equipment challenges, Peach Bottom will provide courtesy notifications and pursue the plan to restore availability.

Measurement Uncertainty Recapture Uprate Thermal Monitoring

Measurement Uncertainty Recapture (MUR) Uprate is scheduled to commence in December of 2017. We have developed a monitoring plan as discussed which can be found attached to this letter. Once the uprate has been implemented, PBAPS will commence the attached plan over the course of one year. The data will be compiled and submitted with the NPDES Permit renewal application in April 2019 to support continuation of our thermal variance.

Should you have any questions on either of these matters, please contact Samantha Rice (717-456-4526), Environmental Specialist in training, or Ben Neufeld, Environmental Supervisor (717-456-4809)

Sincerely,

Matthew J. Herr, Plant Manager
Peach Bottom Atomic Power Station

Attachment:

SCOPE OF SERVICES

The following scope of work provides detail regarding temperature monitoring during 2017 and 2018 associated with the MUR Uprate for Exelon's Peach Bottom Atomic Power Station (PBAPS). This work is a continuation of aspects of temperature monitoring completed during 2010 through 2013 and again during 2016. Normandeau's understanding is that PADEP is requesting this monitoring to validate the assumptions of the increase in ΔT of up to 0.4 °F associated with the MUR Uprate. As per our previous efforts associated with temperature monitoring at PBAPS, Normandeau will sub-contract ERM to complete aspects of this scope of work. The scope of work is outlined below.

- Install equipment and monitor water temperature from December 1, 2017 through November 30, 2018
- Monitor water temperature at biological stations 208, 214, 215, 189, 190 (a subset of the Post-EPU monitoring stations)
- Monitor water temperature at temperature transects 201, 203, 205, 301, 303 (a subset of Post-EPU monitoring stations)
- Monitor water temperature at the PBAPS intake screen, head of the discharge canal, and end of the discharge canal
- Monthly download of water temperature loggers for all stations
- Complete data processing and analysis
- Complete short report detailing methods and results of the Post-MUR temperature monitoring and comparison to the assumptions of the MUR Uprate

ASSUMPTIONS: Normandeau assumptions regarding this proposal are as follows:

1. Normandeau will deploy equipment (except for temperature monitors) that was used during previous 316(a) monitoring studies at PBAPS.
2. Cost includes purchase of new temperature monitors.
3. Monthly downloads of temperature loggers will be completed starting in January 2018.
4. One round of comments and revisions based on consolidated Exelon comments for the report.
5. Cost does not include presentation or meeting with PADEP or Exelon.

SCHEDULE

Monitoring equipment will be deployed prior to December 1, 2017. Monitoring equipment will be retrieved after November 30, 2018. The report will be completed prior to January 31, 2019.

1D.101
2H.103

Exelon Generation.

December 15, 2016

Mr. Archie Gleason
General Manager - Exelon Hydro
Conowingo Hydroelectric Station
2569 Shures Landing Road
Darlington, Maryland 21034

Subject: Peach Bottom Atomic Power Station
2016 Results for the Water Temperature Monitoring Plan of Conowingo Pond

Dear Mr. Gleason,

Please find attached the Peach Bottom Atomic Power Station (PBAPS) 2016 Results for the Water Temperature Monitoring Plan (Monitoring Plan) of Conowingo Pond (Attachment 1) as required by FERC Order Modifying and Approving Non-Project Use of Project Lands and Waters, 152 FERC ¶ 62,142, Project No. 405-113, issued on September 2, 2015. The Monitoring Plan is to verify that operating the cooling towers under the Pennsylvania Department of Environmental Protection's (PA DEP) NPDES permit requirements adequately reduces discharge temperatures during warm weather months and that the thermal plume disseminates locally, as predicted by the extensive modeling studies previously performed and that PBAPS continuously monitors and records effluent temperatures at the plant discharge. This is the first of five (5) annual reports for years 2016 through 2020 required to be submitted to Conowingo and ultimately FERC as part of the Water Temperature Monitoring Plan for Conowingo Pond (Attachment 2). The annual report also includes the results from PBAPS's thermal mitigation measures described in its Final Plan for Study or Mitigation to Address Impact of Water Withdrawals to Migratory Fish (Final Plan), as required by FERC Order Modifying and Approving Thermal Mitigation Measures, 156 FERC ¶ 62,109, Project No. 405-116, issued on August 8, 2016. Based on the 2016 results under this Monitoring Plan which includes 2016 specific thermal and biological monitoring performed under the Study Plan for Post-EPU Thermal and Biological Monitoring (Revision 3, reflecting updates described in the Final Plan), PBAPS's thermal plume disseminates locally and there is adequate protection of the fish and benthic community.

As explained in the Final Plan, the results of the 2016 Thermal Study including Dissolved Oxygen monitoring, Fish Community monitoring, Benthic Macroinvertebrate Community monitoring, and a Migratory Species review are being incorporated into a final report scheduled for submittal to PA DEP on February 3, 2017.

If there are questions or additional information is required, please contact Joseph Brozonis P.E., Sr. Environmental Chemist, at (717)-456-3795.

Sincerely,

Patrick D. Navin
Plant Manager
Peach Bottom Atomic Power Station

Attachments

1 - Peach Bottom Atomic Power Station (PBAPS) 2016 Results for the Water Temperature Monitoring Plan of Conowingo Pond

2 - Water Temperature Monitoring Plan for Conowingo Pond and Final Plan for Study or Mitigation to Address Impact of Water Withdrawals to Migratory Fish

CCN 16-110

Attachment 1

Peach Bottom Atomic Power Station

Summary of 2016 Results of the Water Temperature Monitoring Plan for Conowingo Pond

Background

On March 1, 2016, Exelon Generation filed Peach Bottom Atomic Power Station's (PBAPS) Water Temperature Monitoring Plan with FERC, in accordance with the requirements of the September 2, 2015 FERC Order Modifying and Approving Non-Project Use of Project Lands and Waters, 152 FERC ¶ 62,142, Project No. 405-113. The FERC Order mandates that Exelon Generation, as the Project licensee, require that PBAPS develop and implement a water temperature monitoring plan (the "Monitoring Plan"). The Monitoring Plan must verify that operating under the Pennsylvania Department of Environmental Protection's ("PA DEP") cooling tower operating guidelines adequately reduces discharge temperatures and that the thermal plume disseminates locally, as predicted by the extensive modeling studies. The Monitoring Plan must be implemented for five upstream and five downstream fish migration seasons and must include (1) measures to be implemented if anticipated discharge temperatures are exceeded or if any adverse impacts to migrating fish are observed and (2) a schedule for implementing the plan and reporting results. Exelon Generation as the Project licensee is to file the Monitoring Plan no later than March 1, 2016 and the first of the five annual reports by December 31, 2016.That Monitoring Plan is based, in part, on PBAPS "Study Plan for Post-EPU Thermal and Biological Monitoring," Revision 3, April 2016 (the "Thermal Study").

On April 8, 2016, the Commission issued an order approving the Monitoring Plan (attached). In its order, FERC noted that "data collected from the implementation of Peach Bottom's plan, when compared to fish passage data, should adequately fulfill the intent of the requirement" to monitor impact on migratory fish.

On July 20, 2016, Exelon Generation filed thermal mitigation measures described in the Final Plan for Study or Mitigation to Address Impact of Water Withdrawals to Migratory Fish (Final Plan). On August 8, 2016, FERC approved the Final Plan in its Order Modifying and Approving Thermal Mitigation Measures, 156 FERC ¶ 62,109, Project No. 405-116. In the August 8 Order, FERC modified the Final Plan to require reporting of the results of PBAPS's mitigation measures concurrently with the results of the Monitoring Plan, by December 15 annually. As noted above, FERC's September 2, 2015 Order required submission of the results of the Monitoring Plan by December 31, annually. Accordingly, Exelon Generation submits the results of the Monitoring Plan and its mitigation measures by December 31, 2016.

Introduction

The Water Temperature Monitoring Plan identifies Existing and Ongoing Monitoring requirements detailed in PBAPS's NPDES Permit No. PA 0009733. This scope includes continuous discharge temperature monitoring and recording and monthly reporting to PA DEP. The NPDES permit also establishes the conditions for operation of the cooling towers which reduces plant discharge temperatures during warm weather months. A maximum discharge temperature action level is also included in the NPDES permit. If the action level is reached, PBAPS must implement its established procedure to reduce temperature below the action level. Actions to reduce the temperature include decreasing power and/or starting another cooling tower, if available.

The Water Temperature Monitoring Plan identifies additional 2016 thermal and biological monitoring scope as defined in the Study Plan for Post-EPU Thermal and Biological Monitoring.

The study plan required temperature monitoring at multiple locations and at multiple depths in the Conowingo Pond. Additional temperature monitors were installed at various biological collection locations to monitor temperatures at various depths in the Conowingo Pond. Water temperatures were recorded hourly from May 1 through September 30, 2016. This monitoring period exceeds the period during which PBAPS must use its cooling towers (June 15 through August 31). The plan requires data collected during this monitoring period to be reviewed and evaluated to determine whether the data supports the conclusions of the extensive pre-EPU studies with respect to the discharge temperatures and the expected thermal conditions.

The study plan also requires a review of the potential impact of the EPUs on American shad through a desktop study using existing information and current scientific understanding of American shad in the Conowingo Pond. PBAPS will use the existing hydrothermal model and model outputs that characterize the thermal plume for several low-flow and high water temperature scenarios and evaluate the scenarios to determine the potential for the post-EPU thermal plume to block migration of American shad in the Conowingo Pond.

The PBAPS NPDES permit and monitoring plan also encompasses PBAPS studies for entrainment and impingement to evaluate actions under the new 316(b) regulation issued by the U.S. Environmental Protection Agency.

2016 Water Temperature Monitoring Plan Update

Daily Temperature Monitoring and Cooling Tower Operation

Continuous discharge temperature monitoring and recording and monthly reporting to PA DEP has occurred throughout 2016 to date without exception. Cooling tower operation was performed in accordance with NPDES permit requirements which are based on a June 15th through August 31st time frame for the first cooling tower and the remaining cooling towers were operated in accordance with the river temperatures requirements set forth in the NPDES permit. No exceptions to cooling tower operational requirements occurred. The maximum discharge temperature action level was not

reached during 2016; therefore, no additional actions were required for further temperature reduction. No evidence of stressed fish was observed during biological sampling detailed later in this report, or by station personnel during other periods of the year.

2016 Temperature and Biological Monitoring

Please note results of the 2016 Thermal Study which encompasses the following 2016 Dissolved Oxygen Monitoring, Fish Community Monitoring, Benthic Macroinvertebrate Community Monitoring, and Migratory Species Review section are being finalized and the final report is required to be submitted to PA DEP on February 3, 2017.

Based on initial data analysis the temperature monitoring program for the post-EPU study supported both the biological assessment and an evaluation of cooling tower effectiveness within the discharge canal and in the thermal plume. Within the canal, monitors measuring hourly temperatures were deployed that allow direct measurement of temperature changes from intake to the head-of-the-canal and from the head of the canal to end-of-the-canal. Data recovery for the discharge canal stations was complete (100%) for the May 1 through September 30 period. Preliminary analysis show that the cooling towers performed as expected when compared to 2011, 2012, and 2013 (one-, two- and three-towers, respectively).

In Conowingo Pond, the temperature monitoring program supports a direct assessment of temperature changes during cooling tower operation, including validation of a three-dimensional hydrothermal model used to anticipate these changes and to develop the cooling tower operating sequence that was made part of the NPDES permit. For this assessment use was made of monitors located directly within the thermal plume, especially those immediately downstream of the PBAPS discharge. Data recovery for these stations was complete (100%). The observed changes in temperatures were within the expected ranges predicted by the hydrothermal model.

Continuous water temperature monitoring was completed at a total of eight biological stations including all of the benthic macroinvertebrate and seining collection stations, and four of the six electrofishing stations (no monitoring at Stations 165 and 187). Monitoring was performed *in situ* using Onset HOBO® Pro v2 Water Temperature Data Loggers. The loggers recorded water temperature every hour and were located in shallow shoreline locations (<5 ft water depth) on the river bottom where complete mixing of the water column occurs

Data recovery was approximately 99% for the entire monitoring period for all eight monitoring locations. Ambient water temperatures measured in Conowingo Pond over the course of the 2016 study period (May 1 to September 30) followed a typical seasonal pattern for the Susquehanna River with warmest temperatures observed during July and August. Water temperature during late-August through September was elevated from the typical seasonal pattern with extraordinarily warm and dry conditions during September. Water temperature measured at the thermally influenced biological stations followed the same pattern as the ambient water temperatures and was similar to Pre-EPU

temperatures with exception of late-August through September. During late-August through September water temperatures were substantially warmer compared to Pre-EPU monitoring years.

2016 Dissolved Oxygen Monitoring

Aquatic life in Pennsylvania freshwater waterbodies is protected from adverse impacts associated with low dissolved oxygen (DO) by dissolved oxygen criteria which are found in PA Code Chapter 93.7. For warm water fisheries (WWF) the PA Code criteria is 7-day average of 5.5 mg/L and instantaneous minimum of 5.0 mg/L. These criteria were developed to be protective of all life stages of warm water fishes. To determine whether sufficient DO was present within these areas to be protective of aquatic life hourly DO concentrations were measured in the shallow shoreline areas of Conowingo Pond along the west shoreline downstream of the PBAPS discharge canal at Stations 215 and 189 and upstream of the PBAPS discharge canal on the east shoreline at Station 208.

Monitoring was completed at each location from June 1 through September 30, 2016 with a total number of 7,397 measurements obtained. The 7-day average DO measured at the three monitoring locations was not less than 5.5 mg/L during the study period. DO concentrations were similar among the three stations over the course of the monitoring period. Preliminary analysis indicates that DO concentrations were not restrictive to aquatic organism movement or use of shallow shoreline areas within the Pond. Final DO analysis is being completed and the final report will be submitted to PA DEP on February 3, 2017.

2016 Fish Community Monitoring

The fish community was sampled on a monthly basis from May 1 through September 30, 2016 to evaluate characteristics of the fish and benthic macroinvertebrate communities after implementation of the EPUs. Fish surveys were completed using a boat electrofisher and seine at various locations upstream and within the PBAPS thermal plume. Collected fish were identified to species, counted, measured, and examined for external anomalies. Several indices were calculated including catch per unit effort (CPUE) and species richness in order to characterize the community observed among the sampling stations. A total of 14,568 individuals representing 31 species was collected during the sampling efforts. Several species were commonly collected at all locations and represented a large percentage of the overall catch including bluegill (37%), gizzard shad (30%), green sunfish (6%), smallmouth bass (5%), spotfin shiner (5%), comely shiner (3%), and channel catfish (3%). Electrofishing collection yielded 12,879 individuals representing 31 species and the seine effort collected 1,689 individuals and 17 species.

CPUE and species richness were generally comparable among collection locations and months. However, fish avoidance of the highest water temperatures was observed at the monitoring locations closest to the end of the discharge canal, particularly seine station 214 and electrofishing station 161. A similar pattern of avoidance of the highest water temperatures was observed during Pre-EPU monitoring that occurred from 2010-2013. Fewer species were collected while electrofishing at station

161 during July, August, and September indicating that several fish species avoided this sample reach. Avoidance at station 161 was also observed during Pre-EPU sampling during July and August but avoidance was not observed in Sept during Pre-EPU monitoring. Similarly, fewer fish species were collected with seine in August at station 214 indicating fish avoidance at this location. A similar pattern of avoidance was observed during Pre-EPU monitoring. The incidence of external anomalies was low within and outside of the thermal plume with < 0.2% of fish observed with external anomalies. Overall, fish species composition, distribution, and relative abundance was comparable to Pre-EPU monitoring effort. No thermally stressed fish were observed during the monitoring program. A diverse, productive, and balanced indigenous fish community continues to be maintained in Conowingo Pond.

2016 Benthic Macroinvertebrate Community Monitoring

The benthic macroinvertebrate community was sampled at seven stations both upstream and within the PBAPS thermal plume on a monthly basis from May through September for a total of 35 collection events. The monitoring was completed in order to evaluate characteristics of the benthic community after implementation of the EPU for both units. Collections were completed with a kicknet following the PADEP multi-habitat protocol. A large proportion of the benthic macroinvertebrate community was comprised of Chironomidae, oligochaetes, *Corbicula, Gammarus and Caenis.* Few EPT taxa were collected at either the thermally influenced or non-thermally influenced collection locations. IBI scores were generally low with scores ranging between 11.5 and 49.4. Lower IBI scores were observed during September at the nearfield locations (stations 214 and 215) coincident with the prolonged exposure to the highest water temperatures. The lowest IBI scores in 2016 for both stations were recorded in September and were comparable to observations at these stations under Pre-EPU conditions during July and August. During the other collection months IBI scores at Stations 214 and 215 were comparable to the IBI scores observed at the other monitoring locations, both within and outside of the thermal plume.

2016 Migratory Species Review

A review of the potential impact of the EPUs on American shad through a desktop study using existing information and current scientific understanding of American shad in the Conowingo Pond is in progress. This desktop study will be forwarded to PA DEP as part of the post-EPU study report which is scheduled for completion on February 3, 2017.

316b Entrainment

Peach Bottom Atomic Power Station began collecting entrainment data to comply with 316b requirements in 2012 at the discharge location. In 2016 additional data was collected to supplement the 2012 data. During 2016 entrainment samples were collected at three locations; intake, discharge, and discharge berm. From 24 March to 27 September a total of 331 samples were collected among the three stations and all 331 samples have been processed and all organisms identified.

Preliminary data suggest that the dominant species collected were gizzard shad and percids, particularly darters. Over the entire sampling period (24 March to 27 September) the intake sample location saw the

least amount of ichthyoplankton collected whereas the discharge and discharge berm locations saw 50% more organisms collected during the same time frame. Early data suggest that spawning and larval production in the intake ponds and discharge basin is supplementing naturally entrained ichthyoplankton from Conowingo Pond.

316b Impingement Mortality

An Impingement Mortality study plan is being developed and will be planned for implementation after evaluation of entrainment study results. Final 316b impingement and entrainment results along with the Best Technology Available determination will be forwarded to PA DEP as part of the NPDES Permit Application in 2019.

Attachment 2

PEACH BOTTOM ATOMIC POWER STATION
WATER TEMPERATURE MONITORING PLAN FOR CONOWINGO POND

Background

NPDES Permit: On September 22, 2014, the Pennsylvania Department of Environmental Protection ("PA DEP") issued a new National Pollutant Discharge Elimination System ("NPDES") permit to Peach Bottom Atomic Power Station ("PBAPS") for the period October 1, 2014 through September 30, 2019. The NPDES permit established new thermal requirements for PBAPS's implementation of Extended Power Uprates ("EPU") to Units 2 and 3. In support of its permit request, PBAPS conducted extensive biological and thermal studies of the Conowingo Pond spanning a four year period. The extensive studies included modeling of the predicted thermal and biological impacts of the increased heat load due to the increase in the megawatt output from the EPUs and the thermal reduction of the cooling towers was obtained through actual cooling tower operations. The NPDES permit granted a 316(a) thermal variance which requires operation of the cooling towers for the combined operation of Units 2 and 3 under certain conditions during the period June 15 through August 31 of each year. The NPDES permit further requires that PBAPS submit to PA DEP for approval a written biological and thermal monitoring plan. The biological and thermal monitoring plan must assess the impact of the EPUs (post-EPU operation) on fish and macroinvertebrate populations. Any modifications or amendments to the monitoring plan required by the PA DEP must be submitted or implemented (as applicable) within thirty days, unless PA DEP approves a different implementation schedule.

In addition to the studies sponsored by PBAPS, as referenced above, studies conducted by other generators near PBAPS address the impact of PBAPS operations on migratory fish, including an August 2012 "Final Study Report Muddy Run Project Effects on Migratory Fishes: Interactions with the PBAPS Thermal Plume RSP 3.6" (the "August 2012 study") and a July 2013 "Analysis for the Maryland Department of Natural Resources' Question of the Effects of Peach Bottom Power Station Uprate on Migratory Fishes" (the "July 2013 study"). The August 2012 study evaluated the potential interactive effects of the PBAPS thermal plume upstream dispersal on the migration of adult and juvenile American shad and American eel. That study concluded that the thermal plume from PBAPS would not present any significant barrier to the migration of these species. Likewise, the 2013 study evaluated the potential impacts of the EPUs on upstream and downstream migratory adult and juvenile American shad and American eel. The 2013 study concluded that the post-EPU thermal plume would have a negligible, if any, adverse effect on the upstream or downstream migration. Nonetheless, in response to comments submitted by the U.S. Fish and Wildlife Service ("FWS"), PA DEP required PBAPS to consider the actual impact of post-EPU operation on migratory fish when developing the biological and thermal monitoring plan required by the NPDES permit.

FERC Order: On September 2, 2015, the Federal Energy Regulatory Commission ("FERC") issued an Order Modifying and Approving Non-Project Use of Project Lands and Water. This FERC Order authorizes Exelon Generation Company, LLC as the licensee for the Conowingo Hydroelectric Project (the "Project") to allow PBAPS to withdraw and consumptively use water from Conowingo Pond at levels commensurate with the withdrawal and consumptive use levels authorized by the Susquehanna River Basin Commission, subject to the conditions set forth in the FERC Order. Specifically, the FERC Order mandates that Exelon Generation, as the Project licensee, require that PBAPS develop and implement a water temperature monitoring plan (the "Monitoring Plan"). The Monitoring Plan must verify that operating under the PA DEP cooling tower operating guidelines adequately reduces discharge temperatures and that the thermal plume disseminates locally, as predicted by the extensive modeling studies referenced above. The Monitoring Plan must be implemented for five upstream and five downstream fish migration seasons and must include (1) measures to be implemented if anticipated discharge temperatures are exceeded or if any adverse impacts to migrating fish are observed and (2) a schedule for implementing the plan and reporting results. Exelon Generation as the Project licensee is to file the Monitoring Plan no later than March 1, 2016 and the first of the five annual reports by December 31, 2016.

FERC Letter: On January 20, 2016, FERC issued a letter in response to Exelon Generation's self-disclosure of PBAPS's deviations from the FERC limits for water use. The letter included consideration of comments submitted by FWS in response to Exelon Generation's application seeking to increase the water use limits, and advised Exelon Generation to "consult with the FWS and National Marine Fisheries Service to develop a study or mitigation that specifically addresses impacts of water withdrawals at Peach Bottom to migratory Susquehanna River fish populations in the project reservoir" and to "include a component to monitor for entrained and impinged fish at Peach Bottom's water intake structure." Exelon Generation is to file a study outline or proposed mitigation measures on or before April 19, 2016 and a final plan, including record of consultation, on or before July 20, 2016. The final plan is to be approved by FERC prior to implementation.

Description of Monitoring Plan

The following information summarizes the Monitoring Plan PBAPS intends to implement to comply with the NPDES requirements and the September 2, 2015 FERC Order. PBAPS recognizes that the consultation with FWS and the Marine Service described in FERC's January 20, 2016 letter may result in modifications or adjustments to this Monitoring Plan. In January 2016, PBAPS representatives initiated contact with FWS and Marine Service. Subsequently, in late February 2016, PBAPS sent FWS and Marine Service a letter enclosing a packet of studies already conducted and to be conducted, including the details of the PBAPS's post-EPU thermal and biological monitoring study scheduled to start in 2016. PBAPS requested that FWS and

Marine Service review the provided documentation and contact the Company representatives to schedule a meeting to begin the consultation process. Exelon Generation will report on the status of any modifications or adjustments to the Monitoring Plan in its April 19, 2016 and July 20, 2016 submissions to FERC.

Existing and Ongoing Monitoring: Under the current NPDES permit, PBAPS continuously monitors and records effluent temperatures at the discharge canal. Average daily discharge temperatures are recorded and reported monthly to the PA DEP. The NPDES permit establishes the conditions for operation of the cooling towers. A maximum discharge temperature action level is also included in the NPDES permit. If the action level is reached or exceeded, PBAPS must implement its established procedure to reduce temperature below the action level. Actions to reduce the temperature include decreasing power and/or starting another cooling tower, if available. This continuous monitoring and reporting will continue throughout the five year reporting period established by the FERC Order.

Additional Monitoring Scope for 2016: In addition to the continuous monitoring and recording described above, PBAPS will conduct additional thermal and biological monitoring at various Conowingo Pond locations. The details of this additional monitoring are provided in the "Study Plan for Post-EPU Thermal and Biological Monitoring," Revision 1, July 2015 (attached). In addition to the continuous temperature monitoring at the discharge canal, PBAPS will install monitors at multiple locations and at multiple depths in the Conowingo Pond. Additional temperature monitors will be installed at various biological collection locations to monitor temperatures at the bottom of the Conowingo Pond. Water temperatures will be recorded hourly from May 1 through September 30, 2016. This monitoring period exceeds the period during which PBAPS must use its cooling towers (June 15 through August 31). The data collected during this monitoring period will be reviewed and evaluated to determine whether the data supports the conclusions of the extensive pre-EPU studies with respect to the discharge temperatures and the expected thermal conditions.

Biological monitoring of the fish community will be conducted May 1 through September 30, 2016 to evaluate characteristics of the fish and benthic macroinvertebrate communities after implementation of the EPUs. Monitoring methods include electrofishing, seining, and benthic macroinvertebrate sampling at various locations upstream and downstream from the thermal plume. Fish sampling will generally employ the same field sampling protocols that were used during the 2010 through 2013 studies. Collected fish will be identified by species (or genus for those too small to identify by species in the field), counted, measured, and examined for disease, external parasites, lesions, tumors (DELTs), and anomalies. Fish DELTs and anomalies will be recorded using the acronyms provided in PA DEP Field Data Sheet for Tissue Sampling. Live fish will be released back to the Pond except for those retained to confirm identifications or retained as voucher or reference specimens. Large numbers of collected fishes will be subsampled for individual length measurement.

Dissolved oxygen will be measured from July 1 through August 31, 2016 at two of the biological monitoring stations.

To address the potential impact of the EPUs on American shad, PBAPS will conduct a desktop study using existing information and current scientific understanding of American shad in the Conowingo Pond. PBAPS will use the existing hydrothermal model and model outputs that characterize the thermal plume for several low-flow and high water temperature scenarios and evaluate the scenarios to determine the potential for the post-EPU thermal plume to block migration of American shad in the Conowingo Pond.

The environmental study includes evaluation studies for entrainment and impingement to evaluate actions for the new 316(b) regulation issued by the U.S. Environmental Protection Agency.

The "Additional Monitoring" scope described above will be implemented during calendar year 2016. The discharge canal temperature monitoring will be continuous for at least the next five years and is key to understanding the thermal changes to the Conowingo Pond. The results of the additional monitoring completed in 2016 will be evaluated by PBAPS, and its environmental consulting company will confirm if the results of monitoring during actual EPU conditions are bounded within the results of the 2010-2013 NPDES thermal study results regarding the characteristics of the plume after implementation of the EPUs. Following this evaluation, PBAPS will determine if additional biological and temperature sampling will be required in the Conowingo Pond. Regardless, continuous monitoring of the discharge canal temperatures will remain in place and will be reported to the Project for the remaining four years.

Corrective Actions

As explained above, PBAPS monitors the thermal discharges to ensure the temperatures remain below the cooling tower instantaneous limits. If the instantaneous limits are approached, PBAPS procedures require PBAPS to either decrease power or use a cooling tower, if available. Although PBAPS does not anticipate exceeding the instantaneous limits with use of all three cooling towers, its procedures include immediate corrective actions to decrease the temperatures and to timely report an unanticipated exceedance of the instantaneous limits.

PBAPS procedures include monitoring of aquatic life. If PBAPS observes or learns of any adverse impacts to migrating fish, PBAPS procedures require it to promptly respond to any indication of potential environmental harm to determine the cause and implement corrective actions.

Schedule for Implementation and Reporting

The Additional Monitoring described in this Monitoring Plan will begin in May 2016. PBAPS will provide the Monitoring Plan to the Project and will submit an annual report summarizing the results of its Monitoring Plan, including any required corrective actions, to the Project on or before December 15 of each calendar year from 2016 through 2020.

December 26, 2017

Ms. Kimberly Bose, Secretary
Federal Energy Regulatory
Commission 888 First Street, NE
Washington, DC 20428

Re: 2017 Results for the Water Temperature Monitoring Plan for Conowingo Pond
By Order Modifying and Approving Non-Project Use of Project Lands and Waters
(Order 152 FERC ¶ 62,142, issued September 2, 2015)
Conowingo Hydroelectric Project No. 405-113

Dear Secretary:

Exelon Generation Company, LLC, owner and operator of the Conowingo Hydroelectric Project, hereby submits the 2017 Results for the Water Temperature Monitoring Plan for Conowingo Pond. This report is the second of five annual reports submitted in accordance with the requirements of the FERC Order Modifying and Approving Non-Project Use of Project Lands and Waters, 152 FERC ¶ 62,142, dated September 2, 2015, and the Peach Bottom Atomic Power Station Water Temperature Monitoring Plan for Conowingo Pond, approved on August 8, 2016 by order 156 FERC ¶ 62,109.

Please contact Reta White at (410) 457-2499 or reta.white@exeloncorp.com if you have further questions or concerns.

Respectfully submitted,

/s/ Edward Gleason
Edward Gleason
General Manager
Exelon Generation Company, LLC

Attachment (4 pages)

Exelon Generation

December 15, 2017

Mr. Archie Gleason
General Manager - Exelon Hydro
Conowingo Hydroelectric Station
2569 Shures Landing Road
Darlington, Maryland 21034

Subject: Peach Bottom Atomic Power Station
2017 Results for the Water Temperature Monitoring Plan of Conowingo Pond

Dear Mr. Gleason,

Please find the Peach Bottom Atomic Power Station (PBAPS) 2017 Results for the Water Temperature Monitoring Plan (Monitoring Plan) of Conowingo Pond (Attachment 1) as required by FERC Order Modifying and Approving Non-Project Use of Project Lands and Waters, 152 FERC ¶ 62,142, Project No. 405-113, issued on September 2, 2015. The Monitoring Plan is to verify that operating the cooling towers under the Pennsylvania Department of Environmental Protection's (PA DEP) NPDES permit requirements adequately reduces discharge temperatures during warm weather months and that the thermal plume disseminates locally, as predicted by the extensive modeling studies previously performed and that PBAPS continuously monitors and records effluent temperatures at the plant discharge. This is the second of five (5) annual reports for years 2016 through 2020 required to be submitted to Conowingo and ultimately FERC as part of the Water Temperature Monitoring Plan for Conowingo Pond (Attachment 2). Based on the 2016 results under this Monitoring Plan, which were described in Exelon Generation's filing of December 21, 2016, and the observations and data collected during 2017, PBAPS's thermal plume disseminates locally and there is adequate protection of the fish and benthic community.

If there are questions or additional information is required, please contact Ben Neufeld, Environmental Supervisor, at (717)-456-4809.

Sincerely,

Matthew J. Herr
Plant Manager
Peach Bottom Atomic Power Station

Attachments

1 - Peach Bottom Atomic Power Station (PBAPS) 2017 Results for the Water Temperature Monitoring Plan of Conowingo Pond

2 - Water Temperature Monitoring Plan for Conowingo Pond and Final Plan for Study or Mitigation to Address Impact of Water Withdrawals to Migratory Fish

CCN 17-108

Peach Bottom Atomic Power Station

Summary of 2017 Results for the Water Temperature Monitoring Plan for Conowingo Pond

Background

On March 1, 2016, Exelon Generation filed Peach Bottom Atomic Power Station's (PBAPS) Water Temperature Monitoring Plan with FERC, in accordance with the requirements of the September 2, 2015 FERC Order No. 405-116. The FERC Order mandates that Exelon Generation, as the Project licensee, require that PBAPS develop and implement a water temperature monitoring plan (the "Monitoring Plan"). The Monitoring Plan must verify that operating under the Pennsylvania Department of Environmental Protection's ("PA DEP") cooling tower operating guidelines adequately reduces discharge temperatures and that the thermal plume disseminates locally, as predicted by the extensive modeling studies. The Monitoring Plan must be implemented for five upstream and five downstream fish migration seasons and must include (1) measures to be implemented if anticipated discharge temperatures are exceeded or if any adverse impacts to migrating fish are observed and (2) a schedule for implementing the plan and reporting results. Exelon Generation as the Project licensee is to file the Monitoring Plan no later than March 1, 2016 and the first of the five annual reports by December 31, 2016.That Monitoring Plan is based, in part, on PBAPS "Study Plan for Post-EPU Thermal and Biological Monitoring," Revision 3, April 2016 (the "Thermal Study").

On April 8, 2016, the Commission issued an order approving the Monitoring Plan (attached). In its order, FERC noted that "data collected from the implementation of Peach Bottom's plan, when compared to fish passage data, should adequately fulfill the intent of the requirement" to monitor impact on migratory fish.

Introduction

The Water Temperature Monitoring Plan identifies Existing and Ongoing Monitoring requirements detailed in PBAPS's NPDES Permit No. PA 0009733. This scope includes continuous discharge temperature monitoring and recording and monthly reporting to PA DEP. The NPDES permit also establishes the conditions for operation of the cooling towers which reduces plant discharge temperatures during warm weather months. A maximum discharge temperature action level is also included in the NPDES permit. If the action level is reached, PBAPS must implement its established procedure to reduce temperature below the action level. Actions to reduce the temperature include decreasing power and/or starting another cooling tower, if available.

The PBAPS NPDES permit and monitoring plan also encompasses PBAPS studies for entrainment and impingement to evaluate actions under the new 316(b) regulation issued by the U.S. Environmental Protection Agency.

Daily Temperature Monitoring and Cooling Tower Operation

Continuous discharge temperature monitoring and recording and monthly reporting to PA DEP has occurred throughout 2017 to date without exception. Cooling tower operation was performed in accordance with NPDES permit requirements which are based on a June 15th through August 31st time frame for the first cooling tower and the remaining cooling towers were operated in accordance with the river temperatures requirements set forth in the NPDES permit. No exceptions to cooling tower operational requirements occurred. The maximum discharge temperature action level was not reached during 2017; therefore, no additional actions were required for further temperature reduction. No evidence of stressed fish was observed by station personnel during the year.

316b Impingement Mortality

Impingement latent mortality studies began on October 12, 2017. The study consists of 20 scheduled weeks from mid-October 2017 until October 2018. During the sample periods, sluice flow and screen wash water will be diverted into a sluice sampler to gently collect impinged fish and allow their removal and assessment of initial (Time=0 hours) and latent (Time=24 hours) survival. Sample periods consist of two adjacent dates, with data collected related to impingement abundance and mortality sampling.

Final 316b impingement and entrainment results along with recommendations for Best Technology Available determination will be forwarded to PA DEP as part of the NPDES Permit Application in 2019.

2016 Temperature and Biological Monitoring

Final results of the 2016 Thermal Study, Dissolved Oxygen Monitoring, Fish Community Monitoring, Benthic Macroinvertebrate Community Monitoring, and Migratory Species Review sections, which were referenced in the 2016 Report, were finalized and the final report was submitted to the PA DEP on February 3, 2017. There were no changes to the preliminary results referenced in the 2016 Report, a summary of which follows:

In Conowingo Pond, the temperature monitoring program supports a direct assessment of temperature changes during cooling tower operation, including validation of a three-dimensional hydrothermal model used to anticipate these changes and to develop the cooling tower operating sequence that was made part of the NPDES permit. For this assessment use was made of monitors located directly within the thermal plume, especially those immediately downstream of the PBAPS discharge. Data recovery for these

stations was complete (100%). The observed changes in temperatures were within the expected ranges predicted by the hydrothermal model.

Aquatic life in Pennsylvania freshwater waterbodies is protected from adverse impacts associated with low dissolved oxygen (DO) by dissolved oxygen criteria which are found in PA Code Chapter 93.7. For warm water fisheries (WWF) the PA Code criteria is 7-day average of 5.5 mg/L and instantaneous minimum of 5.0 mg/L. These criteria were developed to be protective of all life stages of warm water fishes. To determine whether sufficient DO was present within these areas to be protective of aquatic life hourly DO concentrations were measured in the shallow shoreline areas of Conowingo Pond along the west shoreline downstream of the PBAPS discharge canal at Stations 215 and 189 and upstream of the PBAPS discharge canal on the east shoreline at Station 208. DO concentrations were not restrictive to aquatic organism movement or use of shallow shoreline areas within the Pond.

Fish Community Monitoring: CPUE (catch per unit effort) and species richness were generally comparable among collection locations and months. However, fish avoidance of the highest water temperatures was observed at the monitoring locations closest to the end of the discharge canal, particularly seine station 214 and electrofishing station 161. A similar pattern of avoidance of the highest water temperatures was observed during Pre-EPU monitoring that occurred from 2010-2013. Fewer species were collected while electrofishing at station 161 during July, August, and September indicating that several fish species avoided this sample reach. Avoidance at station 161 was also observed during Pre-EPU sampling during July and August but avoidance was not observed in Sept during Pre-EPU monitoring. Similarly, fewer fish species were collected with seine in August at station 214 indicating fish avoidance at this location. A similar pattern of avoidance was observed during Pre-EPU monitoring. The incidence of external anomalies was low within and outside of the thermal plume with < 0.2% of fish observed with external anomalies. Overall, fish species composition, distribution, and relative abundance was comparable to Pre-EPU monitoring effort. No thermally stressed fish were observed during the monitoring program. A diverse, productive, and balanced indigenous fish community continues to be maintained in Conowingo Pond.

Benthic Macroinvertebrate Community Monitoring: The benthic macroinvertebrate community was sampled at seven stations both upstream and within the PBAPS thermal plume on a monthly basis from May through September for a total of 35 collection events. The monitoring was completed in order to evaluate characteristics of the benthic community after implementation of the EPU for both units. Collections were completed with a kicknet following the PADEP multi-habitat protocol. A large proportion of the benthic macroinvertebrate community was comprised of Chironomidae, oligochaetes, *Corbicula, Gammarus and Caenis*. Few EPT taxa were collected at either the thermally influenced or non-thermally influenced collection locations. IBI scores were generally low with scores ranging between 11.5 and 49.4. Lower IBI scores were observed during September at the nearfield locations (stations 214 and 215) coincident with the prolonged exposure to the highest water temperatures. The lowest IBI scores in 2016 for both stations were recorded in September and were comparable to observations at these stations under Pre-EPU conditions during July and August. During the other collection months IBI scores at Stations 214 and 215 were comparable to the IBI scores observed at the other monitoring locations, both within and outside of the thermal plume.

Exelon Generation.

Submitted electronically via FERC eFile.

December 18, 2018

Ms. Kimberly Bose, Secretary
Federal Energy Regulatory
Commission 888 First Street, NE
Washington, DC 20428

RE: 2018 Results for the Water Temperature Monitoring Plan for Conowingo Pond By Order Modifying and Approving Non-Project Use of Project Lands and Waters (Order 152 FERC ¶ 62,142, issued September 2, 2015)

Conowingo Hydroelectric Project No. 405-113

Dear Secretary:

Exelon Generation Company, LLC, owner and operator of the Conowingo Hydroelectric Project, hereby submits the 2018 Results for the Water Temperature Monitoring Plan for Conowingo Pond. This report is the third of five annual reports submitted in accordance with the requirements of the FERC Order Modifying and Approving Non-Project Use of Project Lands and Waters, 152 FERC ¶ 62,142, dated September 2, 2015, and the Peach Bottom Atomic Power Station Water Temperature Monitoring Plan for Conowingo Pond, approved on August 8, 2016 by order 156 FERC ¶ 62,109.

Please contact Reta White at (410) 457-2499 or reta.white@exeloncorp.com if you have further questions or concerns.

Respectfully submitted,

Joseph Dick,
General Manager
Exelon Generation Company, LLC

Attachment (4 pages)

Exelon Generation

December 15, 2018

Mr. Joseph Dick
General Manager - Exelon Hydro
Conowingo Hydroelectric Station
2569 Shures Landing Road
Darlington, Maryland 21034

Subject: Exelon Generation LLC
Peach Bottom Atomic Power Station
2018 Results for Water Temperature Monitoring Plan of Conowingo Pond

Dear Mr. Dick,

Attached is a summary of the Peach Bottom Atomic Power Station (PBAPS) 2018 Results for the Water Temperature Monitoring Plan (Monitoring Plan) of Conowingo Pond. The monitoring plan is required by Federal Energy Regulation Commission (FERC) Order Modifying and Approving Non-Project Use of Project Lands and Waters, 152 FERC ¶ 62,142, Project No. 405-113, issued on September 2, 2015. This is the third of five annual reports for years 2016 through 2020 required to be submitted to Conowingo and ultimately FERC as part of the Monitoring Plan for Conowingo Pond.

The Monitoring Plan verifies that operating the PBAPS cooling towers under the Pennsylvania Department of Environmental Protection's (PA DEP) NPDES permit requirements adequately reduces discharge temperatures during warm weather months, and that the thermal plume disseminates locally, as predicted by the extensive modeling studies previously performed. It also verifies that PBAPS continuously monitors and records effluent temperatures at the plant discharge. Based on the 2018 results under this Monitoring Plan, this criterion has been met, and there is adequate protection of the fish and benthic community.

If you have any questions, please contact Samantha Rice at (717) 456-4526.

Sincerely,

Matthew J. Herr
Plant Manager
Peach Bottom Atomic Power Station

Attachments
1 – Peach Bottom Atomic Power Station, Summary of 2018 Results for the Water Temperature Monitoring for Conowingo Pond

CCN 18-127

ATTACHMENT 1

PEACH BOTTOM ATOMIC POWER STATION
SUMMARY OF THE 2018 WATER TEMPERATURE MONITORING
FOR CONOWINGO POND

Background

On March 1, 2016, Exelon Generation filed Peach Bottom Atomic Power Station's (PBAPS) Water Temperature Monitoring Plan with FERC, in accordance with the requirements of the September 2, 2015, FERC Order 152 FERC ¶ 62,142, Project No. 405-113. The FERC Order mandates that Exelon Generation, as the Project licensee, require that PBAPS develop and implement a water temperature monitoring plan (the "Monitoring Plan"). The Monitoring Plan must verify that operating under the Pennsylvania Department of Environmental Protection's ("PA DEP") cooling tower operating guidelines adequately reduces discharge temperatures and that the thermal plume disseminates locally, as predicted by the extensive modeling studies. The Monitoring Plan must be implemented for five upstream and five downstream fish migration seasons and must include (1) measures to be implemented if anticipated discharge temperatures are exceeded, or if any adverse impacts to migrating fish are observed, and (2) a schedule for implementing the plan and reporting results.

Exelon Generation as the Project licensee filed the Monitoring Plan as required by March 1, 2016. The Monitoring Plan was based, in part, on the PBAPS "Study Plan for Post-EPU Thermal and Biological Monitoring," Revision 3, April 2016 (the "Thermal Study"). On April 8, 2016, FERC issued an order approving the Monitoring Plan (Attachment 2). In its order, FERC noted that "data collected from the implementation of Peach Bottom's plan, when compared to fish passage data, should adequately fulfill the intent of the requirement" to monitor the impact on migratory fish.

The first two of the five required annual reports were submitted to FERC in December of 2015 and 2016, respectively.

Introduction

The Water Temperature Monitoring Plan identifies Existing and Ongoing Monitoring requirements detailed in PBAPS's NPDES Permit No. PA 0009733. This scope includes continuous discharge temperature monitoring and recording and monthly reporting to PA DEP. The NPDES permit also establishes the conditions for operation of the cooling towers which reduces plant discharge temperatures during warm weather months. A maximum discharge temperature action level is also included in the NPDES permit. If the action level is reached, PBAPS must implement its established procedure to reduce temperature below the action level. Actions to reduce the temperature include decreasing power and/or starting another cooling tower, if available.

The PBAPS NPDES permit and monitoring plan also encompasses PBAPS studies for entrainment and impingement to evaluate actions under the Clean Water Act, Section 316(b), regulation issued by the U.S. Environmental Protection Agency.

2018 Daily Temperature Monitoring and Cooling Tower Operation

Continuous discharge temperature monitoring and recording and monthly reporting to PA DEP has occurred throughout 2018 to date without exception. Cooling tower operation was performed in accordance with NPDES permit requirements which are based on a June 15th through August 31st time frame for the first cooling tower, with the remaining cooling towers operated in accordance with the river temperatures requirements set forth in the NPDES permit. One exception to cooling tower operation occurred during 2018. On July 11-12,2018 there was a loss of electric power that resulted in the 'A' and 'C' cooling towers being declared inoperable for less than 5 hours. Proper notification was made to the PA DEP, and the cooling towers were returned to operable. The maximum discharge temperature action level was not reached during 2018; therefore, no additional actions were required for further temperature reduction. No evidence of stressed fish was observed by station personnel during the year.

2017-2018 316(b) Impingement Survival Study

A one-year impingement survival study was performed from October 2017 to October 2018. During the sample periods, sluice flow and screen wash water was diverted into a sluice sampler to gently collect impinged fish and allow for their removal and assessment of initial (Time=0 hours) and latent (Time=24 hours) survival. Sample periods consisted of two adjacent dates, with data collected related to impingement abundance and mortality sampling.

Final 316(b) impingement and entrainment results including recommendations for Best Technology Available determination will be forwarded to PA DEP as part of the NPDES Permit Renewal Application in 2019.

2018 post-MUR Temperature Monitoring

During 2018 a 12-month water temperature monitoring study was implemented in Conowingo Pond to evaluate the water temperature changes associated with a Measurement Uncertainty Recapture (MUR) power uprate at the PBAPS. The MUR uprate was anticipated to increase the PBAPS condenser discharge temperature a maximum of 0.4 °F. The temperature monitoring study was requested by PADEP to validate the assumption of a maximum 0.4 °F increase in the plant intake to discharge temperature (ΔT) following implementation of the MUR uprate.

The MUR uprate was implemented during mid-January 2018. However, due to boat ramp icing and river ice the installation of the temperature monitoring equipment was delayed until conditions improved on February 15th. Water temperature loggers were installed at 13 locations. Three loggers were installed onsite at PBAPS in the intake, at the head of the discharge canal, and at the end of the discharge canal. Ten temperature loggers were installed in Conowingo Pond within the thermal plume along shallow shoreline areas and at several buoy transects across Conowingo Pond. The water temperature loggers were set to continuously record water temperature on an hourly basis and data downloads occurred on a monthly basis.

Preliminary data have been evaluated through October 26, 2018. Data recovery varied substantially depending on the monitoring location and was hampered by environmental conditions. Due to the significant flood events that occurred during 2018 several of the buoy transects were lost and the temperature data were not recovered. Overall, data recovery varied from 46% to 100%. The lowest recovery rate occurred at one of the buoy transect locations where

the loggers and associated equipment were lost multiple times. Preliminary analyses indicated that the measured ΔT was within the predicted value of 0.4 °F. The average increase in ΔT was approximately 0.3 °F. Upon completion of the 12-month monitoring period a report will be completed that provides an analysis of the individual location monitoring data and the actual increases in water temperatures at these locations associated with the MUR uprate.

No adverse impacts to migrating fish were observed by biological field crews working in Conowingo Pond during 2018. While no biological monitoring was conducted in 2018, based on previous biological observations and the 2018 water temperature monitoring data, no adverse impacts are expected to migrating fish in Conowingo Pond.

FEDERAL ENERGY REGULATORY COMMISSION
Washington D.C. 20426

Office of Energy Projects

Project No. 405-113—Pennsylvania, Maryland
Conowingo Hydroelectric Project
Exelon Generation, LLC

February 23, 2018

Christopher Wilson, Director
Exelon Generation, LLC
101 Constitution Avenue NW
Suite 400 East
Washington, DC 20001

Subject: Water Temperature Monitoring Report – Article 409

Dear Mr. Wilson:

This letter acknowledges your 2017 Water Temperature Monitoring Report, filed with the Federal Energy Regulatory Commission (Commission) on December 26, 2017 pursuant to the Commission's September 2, 2015 Order Modifying and Approving Non-Project Use of Project Lands and Waters[1] and April 8, 2016 Order Approving Water Temperature Monitoring Plan[2] for the Conowingo Hydroelectric Project No. 405. The September 2, 2015 order requires you to monitor reservoir water temperatures associated with water returns from a non-project water withdrawal for five years. The monitoring is intended to ensure that any thermal plume from the return pipe is dissipated quickly, without impacting fish populations. In your 2016 report, filed with the Commission on December 21, 2016, you reported some slightly elevated water temperatures in late August through September.

You report that all observed temperatures were within the expected ranges, as predicted by your hydrothermal model. Your filing also includes associated fish sampling results. While the maximum discharge temperature action level was not reached in 2017, you observed similar avoidance patterns as in 2016, wherein fewer fish were observed near the end of the discharge canal. Your filing also notes that lower

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[1] 152 FERC ¶ 62,142.

[2] 155 FERC ¶ 62,021.

macroinvertebrate diversity appears to be correlated with persistent higher water temperatures near the discharge canal.

Review of your filing indicates that it fulfills the reporting requirements of the aforementioned orders. Based on the provided data, it appears that there may be some potential impacts to aquatic resources associated with the discharged thermal plume. Based on your first and second reports, it appears that any potential effects may be within the anticipated range; however, the full extent of any potential effects will hopefully be clarified by the subsequent three years of data collection.

Thank you for your cooperation. We look forward to your third report, **due December 31, 2018**. If you have any questions concerning this letter please contact me at (202) 502-8038 or alicia.burtner@ferc.gov.

Sincerely,

Alicia Burtner
Fish Biologist
Division of Hydropower Administration
and Compliance

ATTACHMENT A
LIST OF THE HISTORICAL STUDIES CONDUCTED AT THE PEACH BOTTOM ATOMIC POWER STATION

March 2019

1. 316(b) Demonstrations

Philadelphia Electric Company. 1977. 316(b) Demonstration for PBAPS Units No. 2 & 3 on Conowingo Pond. Materials prepared for the Environmental Protection Agency, June 1977.

Ichthyological Associates, Inc. 1977. Peach Bottom Atomic Power Station materials prepared for the EPA 316(b) demonstration for Peach Bottom Atomic Power Station Units No. 2 and 3 on Conowingo Pond, 103 pp.

URS Corporation. 2008. 316(b) Compliance report with source waterbody information, impingement mortality characterization study, and design and construction technology plan. Prepared for Exelon's Peach Bottom Atomic Power Station.

Normandeau Associates. 2016. Revised Scope of Work for Peach Bottom Atomic Power Station's Entrainment Abundance and Latent Impingement Mortality Characterization. Revision 2. Prepared for Exelon's Peach Bottom Atomic Power Station.

2. Pre-and Post-Operational Reports that Include Impingement and Entrainment Results

Robbins, Timothy W., and Dilip Mathur. 1974. Peach Bottom Atomic Power Station pre-operational report on the ecology of Conowingo Pond for Units No. 2 and 3. Ichthyological Associates, Inc., Drumore, Pa., prepared for Philadelphia Electric Company, xviii + 349 pp.

Robbins, Timothy W., and Dilip Mathur. 1974. Peach Bottom Atomic Power Station Post-operational Report No. 1 on the ecology of Conowingo Pond for Units No. 2 and 3. Ichthyological Associates, Inc., Drumore, Pa., prepared for Philadelphia Electric Company, xiii + 142 pp.

Robbins, Timothy W., and Dilip Mathur. 1975. Peach Bottom Atomic Power Station Post-operational Report No. 2 on the ecology of Conowingo Pond for Units No. 2 and 3. Ichthyological Associates, Inc., Drumore, Pa., prepared for Philadelphia Electric Company, xix + 192 pp.

Robbins, Timothy W., and Dilip Mathur. 1975. Peach Bottom Atomic Power Station Post-operational Report No. 3 on the ecology of Conowingo Pond for the period of July 1974-December 1974. Ichthyological Associates, Inc., Drumore, Pa., prepared for Philadelphia Electric Company, xxiv + 338 pp.

Robbins, Timothy W., and Dilip Mathur. 1975. Peach Bottom Atomic Power Station, Post-operational Report No. 4 on the ecology of Conowingo Pond for the period January 1975-June 1975. Ichthyological Associates, Inc., Drumore, Pa., prepared for Philadelphia Electric Company, xxiii + 322 pp.

Robbins, Timothy W., and Dilip Mathur. 1976. Peach Bottom Atomic Power Station Post-operational Report No. 5 on the ecology of Conowingo Pond for the period July 1975-December 1975. Ichthyological Associates, Inc., Drumore, Pa., prepared for Philadelphia Electric Company, xxiii + 501 pp.

Robbins, Timothy W., and Dilip Mathur. 1977. Peach Bottom Atomic Power Station Post-operational Report No. 6 on the ecology of Conowingo Pond for the period January 1976-June 1976. Ichthyological Associates, Inc., Drumore, Pa., prepared for Philadelphia Electric Company, xv + 191 pp.

Ichthyological Associates, Inc. 1977. Peach Bottom Atomic Power Station Post-operational Report No. 7 on the ecology of Conowingo Pond for the period July 1976-December 1976. Ichthyological Associates, Inc., Drumore, Pa., prepared for Philadelphia Electric Company, xxi + 313 pp.

Ichthyological Associates, Inc. 1977. Peach Bottom Atomic Power Station Post-operational Report No. 8 on the ecology of Conowingo Pond for the period January 1977-June 1977. Ichthyological Associates, Inc., Drumore, Pa., prepared for Philadelphia Electric Company, xi + 186 pp.

RMC Ecological Division. 1979. Peach Bottom Atomic Power Station, Post-operational Report No. 9 on the ecology of Conowingo Pond for the period of July 1977-December 1977. Prepared for Philadelphia Electric Company. Muddy Run Ecological Laboratory, Drumore, Pa. xiv + 245 pp.

3. Other Reports/Presentations/Papers

3.1. Impingement

Robbins, Timothy W., Pauline L. Heisey, and Paul G. Heisey. 1975. Environmental deviation report for impingement of fishes at the Peach Bottom Atomic Power Station Units No. 2 and 3 on 25-27 February 1975. Ichthyological Associates, Inc., Drumore, Pa., March 1975, prepared for Philadelphia Electric Company, 10 pp.

Mathur, Dilip, Paul C. Heisey, and Nancy C. Magnusson. 1976. Impingement of fishes at a nuclear power station on the lower Susquehanna River. A paper presented at the 106th Ann. Meeting Amer. Fish Soc., Dearborn, Michigan.

Mathur, Dilip, Paul C. Heisey, and Nancy C. Magnusson. 1976. Impingement of fishes at a nuclear power station on the lower Susquehanna River. A paper presented at the 32nd Ann. N. E. Fish and Wildlife Conf., Hershey, Pennsylvania.

Mathur, Dilip, Paul G. Heisey, and Nancy C. Magnusson. 1977. Impingement of fishes at Peach Bottom Atomic Power Station on Conowingo Pond, Pennsylvania. Trans. Amer. Fish. Soc. 106:258-267.

RMC Environmental Services Division. 1981. Report on impingement of gizzard shad at Peach Bottom Atomic Power Station, Units 2 and 3, December 1980-January 1981. Prepared for Philadelphia Electric Company. 7 pp.

Canberra/Radiation Management Corporation. 1984. Impingement of fishes at Peach Bottom Atomic Power Station, Units No. 2 and 3, during December 1983 and early January 1984. Prepared for Philadelphia Electric Company. 15 pp.

Heisey, P. G. 1987. Peach Bottom Atomic Power Station inner screens fish impingement. Letter report to D. Mathur, 8 January 1987. 2 pp.

RMC Environmental Services, Inc. 1994. Analysis of potential factors affecting the white crappie population in Conowingo Pond. Prepared for PECO Energy Company. 12 pp.

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