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April 29, 2010

Mr. Jim Richenderfer
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BELL BEND NUCLEAR POWER PLANT
IFIM AND AQUATIC IMPACT STUDIES WORKPLAN
BNP-2010-103 Docket No. 52-039

References: 1) BNP-2009-073, T. L. Harpster (PPL Bell Bend, LLC) to Paula. B. Ballaron, Susquehanna River Basin Commission, "Bell Bend Nuclear Power Plant Application for Groundwater Withdrawal, Application for Surface Water Withdrawal, Application for Consumptive Water Use", dated May 13, 2009.

2) BNP-2009-309, T. L. Harpster (PPL Bell Bend, LLC) to Paula. B. Ballaron, Susquehanna River Basin Commission, "Bell Bend Nuclear Power Plant Supplemental Information for Application for Surface Water Withdrawal, Application for Consumptive Water Use", dated October 9, 2009.

3) Michael G. Brownell, Susquehanna River Basin Commission, to T.L. Harpster, PPL Bell Bend, LLC, "Notice of Application Review for the PPL Bell Bend, LLC", dated March 1, 2010.

In a March 1, 2010 letter to PPL Bell Bend LLC (PPL), the Susquehanna River Basin Commission (Commission) provided detailed comments on the above referenced application and amendment for the proposed Bell Bend Nuclear Power Plant (BBNPP). This letter provides a response to the comments raised by the Commission in its March 1 letter with respect to the performance of certain aquatic impact studies to address the information needs of the Commission.

This letter transmits the following documents for Commission consideration:

- "Study Plan to Assess the Potential Effects of the Bell Bend Project on Aquatic Resources and Downstream Users" (Enclosure 1).
- PPL response to issues related to intake impingement and entrainment (Enclosure 2).
- PPL response to questions regarding the BBNPP intake and discharge locations (Enclosure 3).

These documents were developed in response to aquatic impact issues raised by the Commission under 18 CFR §806.23(b)(2), 18 CFR §806.14(a)(3)(i), 18 CFR §806.14(a)(3)(iii), 18 CFR §806.14(b)(1)(iv), 18 CFR §806.14(b)(v)(C), and Parts I.D.7 and V.J. of the Commission's Comprehensive Plan.

1The attached study plan (Enclosure 1) proposes certain studies to be undertaken during 2010 to comprehensively evaluate the potential effects that BBNPP's operations might have upon aquatic biota and water quality in the river, namely:

- The potential reduction of suitable aquatic habitat,
- The potential incremental impairment of river water quality below known AMD discharges from Nescopeck Creek,
- Potential impacts due to the thermal discharge from the BBNPP to the river,
- Potential water quality impacts to shallow water areas inhabited by smallmouth bass, and
- Potential impacts to downstream water users.

Enclosure 2 responds to the Commission's request for PPL to clarify certain tabular data contained in the report entitled "Impingement and Entrainment Sampling for the Proposed Bell Bend Nuclear Power Plant at the SSES Circulating Water Supply System Intake Structure, Luzerne County, Pennsylvania, May 2009", and to provide additional information, studies, and monitoring plans as may be necessary to ensure that BBNPP intake designs are adequately protective of the local aquatic community. It is PPL's intent to fully comply with the Track I design and monitoring requirements of 40 CFR §125.80.

Enclosure 3 provides a summary siting analysis of the proposed BBNPP intake and discharge structure locations. PPL has thoroughly evaluated locations for the BBNPP intake and discharge structures along the North Branch of the Susquehanna River and does not believe that a different location would be of value, either in terms of minimizing potential thermal or other environmental impacts, or from a technical or economic perspective.

In-river evaporation is not addressed in this transmittal because it is specifically requested in the March 1 application response letter as part of an analysis of alternative heat dissipation methods.

As discussed at the April 13, 2010 project status meeting with the resource agencies, it is PPL's understanding that the Commission desires an agency meeting to comprehensively review and discuss the Enclosure 1 study plan. PPL would request that such meeting be held as soon as possible so the plan can be finalized on a cooperative and expedited basis and so field work can be initiated and completed in 2010, in accordance with the proposed study schedule.

Should the Commission have any questions regarding the attached, please contact Bradley A. Wise, Environmental Permitting Supervisor, at 610-774-6508. We look forward to resolving all outstanding matters pertaining to the applications with the Commission.

Sincerely,

Terry L. Harpster

TLH/dw

cc: (w/ Enclosures)

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Enclosure 1

Study Plan to Assess the Potential Effects of the Bell Bend Project on Aquatic Resources and Downstream Users

Study Plan to Assess the Potential Effects of the Bell Bend Project on Aquatic Resources and Downstream Users

Prepared for

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APRIL 2010

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ABBREVIATIONS

Abbreviation	Meaning
°F or °C	Degrees Fahrenheit or Celsius (water temperature)
7Q10	Seven-day, consecutive low flow with a ten-year return frequency.
ACOE	U.S. Army Corps of Engineers
ADCP	Acoustic Doppler Current Profiler, instrument to measure velocity at varying depths
ADF	Average Daily Flow computed on an annual basis
AMD	Acid Mine Drainage
BBNPP	Bell Bend Nuclear Power Plant
BBNPP ER	Bell Bend Nuclear Power Plant Environmental Report submitted to the Nuclear Regulatory Commission
cfs	Cubic feet per second; 1 cfs = 0.646 mgd
COLA	Combined Construction and Operating License Application
CORMIX	Cornell Mixing Zone Expert System, mixing zone model
DO	Dissolved oxygen
EFDC	Environmental Fluid Dynamics Code, 3-D hydrodynamic and water quality model
EMA	Eastern Middle Anthracite Fields
ERM	Environmental Resources Management, Inc.
GEMSS®	Generalized Environmental Modeling System for Surfacewater, 3-D hydrodynamic and water quality model
HSC	Habitat Suitability Curve, index used to indicate fish preferences for microhabitat variables (e.g., water velocity, depth, substrate/cover);expressed on a scale of 0 (least suitable) to 1 (optimum)
IFIM	Instream Flow Incremental Methodology, habitat-based methodology to estimate available aquatic habitat under changing flow conditions; based on the premise that stream-dwelling organisms prefer a certain range of microhabitats (velocity,depth,and substrate/cover)
mgd	Million gallons per day; 1 mgd = 1.55 cfs
NPDES	National Pollutant Discharge Elimination System
NRC	Nuclear Regulatory Commission
PADEP	Pennsylvania Department of Environmental Protection
PFBC	Pennsylvania Fish & Boat Commission
PHABSIM	Physical Habitat Simulation, model integrates outputs of hydraulic model(s) and species micro-habitat preferences (depth, velocity, and substrate/cover)
PLS	Professional Land Surveyor
PPL Bell Bend	PPL Bell Bend, LLC; sponsor of the BBNPP project
RHABSIM	Customized version of PHABSIM
Sonde	Device that measures DO, temperature, pH and conductivity; French for "probe"
SRAFRC	Susquehanna River Anadromous Fish Restoration Committee
SRBC	Susquehanna River Basin Commission
SSES	Susquehanna Steam Electric Station
TMDL	Total Maximum Daily Load
TRPA	Thomas R. Payne & Associates
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
WUA	Weighted Usable Area, an index of available habitat

EXECUTIVE SUMMARY

In October 2008, PPL Bell Bend, LLC (PPL Bell Bend) applied to the U.S. Nuclear Regulatory Commission (NRC) for a combined license to construct and operate the Bell Bend Nuclear Power Plant (BBNPP). The BBNPP will be a single-unit plant with an electrical output of approximately 1,600 megawatts, located adjacent to the Susquehanna Steam Electric Station (SSES) in Salem Township, Luzerne County, Pennsylvania. PPL Bell Bend expects to receive the requested NRC license in 2013, to begin construction in 2013, and to begin operation in the 2018-2020 timeframe.

On May 13, 2009, PPL Bell Bend applied to the Susquehanna River Basin Commission (SRBC or Commission) for approval of water use at the proposed BBNPP. A supplement to the application was filed with the SRBC on October 9, 2009.

PPL Bell Bend seeks approval from the SRBC for a maximum peak-day surface water withdrawal of up to 44 million gallons per day (mgd) and for a maximum peak-day consumptive use of 31 mgd[1]. During plant operation, all water except the potable water supply will be withdrawn from the Susquehanna River. Evaporation from the two main cooling towers will comprise most of the consumptive use. The actual amount of water to be withdrawn from the river and used consumptively will vary from day to day, and seasonally, depending upon BBNPP operations and ambient meteorological conditions.

The BBNPP river intake will be located approximately 300 ft downstream of the existing SSES river intake. Water not consumed will be returned to the river via a submerged discharge diffuser to be located approximately 680 ft downstream of the BBNPP river intake and approximately 380 ft downstream from the existing SSES discharge diffuser. The river is pooled in this reach so that the relative locations of the SSES and BBNPP intakes and discharges will have no significant effect on river depths or velocities.

The peak day consumptive use and the peak day surface (river) water withdrawal amounts for which approval is sought were determined based on very conservative assumptions, in order to ensure that the daily consumptive use amounts (as will be determined by appropriate monitoring) will never exceed the approved amounts. The amounts applied for include allowance for monitoring inaccuracy within the limit allowed by the SRBC.

At a meeting in July 2009, the SRBC noted that the cumulative consumptive water use in the Middle Susquehanna Subbasin which is neither mitigated by upstream compensation nor subject to a passby flow exceeds 10 percent of the seven-day ten-year low flow (7Q10). Accordingly, the SRBC expressed concern for the additional consumptive use at the BBNPP and requested that PPL Bell Bend perform an instream flow study to determine the potential effects that BBNPP's consumptive use might have on the aquatic resources of the river. PPL Bell Bend

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[1] In this study plan, million gallons per day (mgd) will be used as the unit of water usage and cubic feet per second (cfs) will be used as the unit of river flow. (1 mgd = 1.55 cfs).

understands that if the results of the study were to indicate significant impairment of aquatic resources, the SRBC could require a "passby flow" at the BBNPP, or require PPL Bell Bend to provide upstream consumptive use make-up water, in whole or in part. If the BBNPP were to be subject to a passby flow, consumptive use of water would be precluded whenever river flow (e.g., measured at the Wilkes-Barre gage) is equal to or less than the imposed passby flow.

This study, as detailed herein, will provide sufficient information to allow the SRBC and cooperating agencies to determine whether a passby flow or other mitigation to protect aquatic resources is needed at the BBNPP. PPL Bell Bend intends to complete the necessary field studies during 2010 and to have a draft report available for review by the SRBC and the cooperating agencies by the first quarter of 2011.

In November 2009, PPL Bell Bend submitted a proposed study plan to the SRBC and cooperating agencies for review and comment. At a meeting in January 2010, the SRBC and several of the cooperating resource agencies requested PPL Bell Bend to submit an expanded study plan to comprehensively address four specific potential adverse effects that BBNPP's operations might have upon aquatic biota and water quality in the river, namely:

- the potential reduction of suitable aquatic habitat,
- the potential incremental impairment of river water quality below known AMD discharges from Nescopeck Creek,
- potential impacts due to the thermal discharge from the BBNPP to the river ; and,
- potential water quality impacts to shallow water areas inhabited by smallmouth bass.

By letter to PPL Bell Bend dated March 1, 2010, the SRBC provided detailed comments on PPL Bell Bend's application and requested further information. Three additional "in-stream issues" were raised by the SRBC in this letter, namely:

- potential impacts to downstream water users;
- potential fish impingement and entrainment at the BBNPP intake; and,
- BBNPP intake and discharge locations.

This study plan includes a proposed approach to evaluate the potential effects of the BBNPP upon downstream water users. Potential fish impingement/entrainment and intake/discharge locations are addressed in the transmittal letter and Enclosures 2 and 3 of that letter. In-river evaporation is not addressed in this study plan because it is specifically requested in the application response letter as part of an analysis of alternative heat dissipation methods. Therefore, this study plan addresses a total of five potential effects.

The overall approach to study each of the five potential effects is summarized below; separate sections of this study plan present details of proposed work, analysis, and presentation of results pertaining to each potential effect.

- ***Potential reduction of suitable aquatic habitat***

This phase of the study will involve field work and analysis to conduct an "IFIM" study for the aquatic species and life stages known to be present or observed in the vicinity of the BBNPP site. For purposes of this study, several species of special concern have been identified and will be evaluated more intensively than the other species. The species of special concern are: the American shad, which has been targeted for restoration to the upper Susquehanna River; the smallmouth bass, which has been a subject of intensive investigation due to its young being afflicted by a bacterium; and, the green floater and yellow lampmussels, which are both considered imperiled in Pennsylvania.

All aquatic species will be evaluated using habitat use-based guilds (i.e., grouping species showing similar depth-velocity preferences). This approach allows the flow needs of the entire biotic community to be assessed. All species and their life stages known to be present in the vicinity of the BBNPP site have been assigned to one of the four following habitat-based guilds according to depth and velocity preferences:

- Shallow-slow: (<2 ft, <1 ft/sec);
- Shallow-fast (<2 ft, >1 ft/sec);
- Deep-slow (>2 ft, <1 ft/sec); and,
- Deep-fast (>2 ft, >1 ft/sec).

The text indicates the assignment of species to these four habitat-based guilds and the months or seasons in which the various life stages occur for all species of interest.

The objective of this portion of the study will be to estimate the potential effect of BBNPP consumptive use on change in weighted usable habitat (expressed as a fraction or percentage change and as absolute values) for each selected habitat guild and species of special concern in the absence of a passby flow and with selected alternative passby flows. The benefits of alternative degrees of consumptive use makeup will also be evaluated.

The study reach for evaluating the aquatic habitat impacts will be the river from Little Wapwallopen Creek upstream from SSES/BBNPP to approximately one mile downstream from Nescopeck Creek. Field studies will be performed to assess habitat at approximately 17 transects in four mesohabitat types. In order to calibrate IFIM models, attempts will be made to conduct field work in 2010 at three target river flows, namely 2,000 cfs, 5,000 cfs and 10,000 cfs. Field work at these flows would allow PHABSIM extrapolation to 800 cfs on the low side and up to 25,000 cfs. However, suitable flow conditions cannot be guaranteed, and alternate hydraulic modeling may be necessary to estimate depths and velocities to flows as low as the 7Q10.

- ***Potential incremental impairment of river water quality below known AMD discharges from Nescopeck Creek***

This phase of the study will determine whether and to what extent reduced dilutive capacity due to BBNPP consumptive use might affect river water quality downstream from Nescopeck Creek. Analysis will be undertaken using a combination of field data collection, mass balance calculations and, if warranted, numerical modeling. The study reach will be from Nescopeck Creek as far downstream as an AMD plume from discharge from Nescopeck Creek can be detected by a survey of temperature, conductivity and pH.

- ***Potential impacts due to the thermal discharge from the BBNPP to the river***

The thermal plume at BBNPP had been evaluated earlier, in the report "Susquehanna River Thermal Plume and Dilution Modeling." The BBNPP plume had been modeled at five different ambient conditions, both in isolation and in combination with the SSES plume, using the CORMIX and GEMSS® models. This modeling indicated maximum water surface temperature excesses (rises) of considerably less than 1°F. In this study, additional modeling will be performed to determine the extent of the plume under a wider range of ambient flow and temperature conditions, including the 7Q10 flow.

The potential effect of the thermal discharge on DO relates to reduced DO saturation concentrations at higher temperatures. This effect will be quantified. The anticipated study reach will be limited to the pool in which the SSES and BBNPP intake and discharge structures are located. This study reach is consistent with the results of the prior study, which indicated that the thermal effect is limited to the pool. However, should the modeling indicate that thermal effects extend downstream of the pool, the study reach will be extended accordingly.

- ***Potential water quality impacts to shallow water areas inhabited by smallmouth bass***

Concern for temperature and DO relates to the bacterial disease *(Flavobacterium columnare)* in smallmouth bass found in the Susquehanna River. The resulting infection may be exacerbated by low nighttime DO conditions during summer (Chaplin *et al.* 2009). A total of three representative shallow water areas have been selected for study. Depths and substrate in these areas will be mapped. Depth, temperature and DO will be sampled and analyzed to determine the effect of reduced flows. Visual observations of smallmouth bass spawning during low flows will also be made. These observations would be supplemented by electroshocking surveys.

- ***Potential impacts to downstream water users***

The potential adverse effects of the BBNPP on downstream water users (primarily holders of NPDES or SRBC withdrawal permits) are:

  - Reduced quantity for withdrawal or for meeting discharge assimilation requirements;
  - Reduced levels in wells adjacent to the river ; and,

- Reduced water quality due to less dilution of AMD-impaired flow from Nescopeck Creek.

Water users located along the river between the BBNPP and Danville will be contacted to determine any potential negative effect that might result from river flow reduction due to consumptive use at the BBNPP.

1. INTRODUCTION

PPL Bell Bend, LLC (PPL Bell Bend) proposes to construct and operate the Bell Bend Nuclear Power Plant (BBNPP), to be located adjacent to and southwest of the Susquehanna Steam Electric Station (SSES) in Salem Township, Luzerne County, Pennsylvania (Figure 1-1). To this end, PPL Bell Bend has applied to the Susquehanna River Basin Commission (SRBC or Commission) for approval to withdraw water from the Susquehanna River at the BBNPP and to use some of the withdrawn water consumptively. The studies proposed to be conducted in accordance with this study plan will support PPL Bell Bend's application to the SRBC, as explained below.

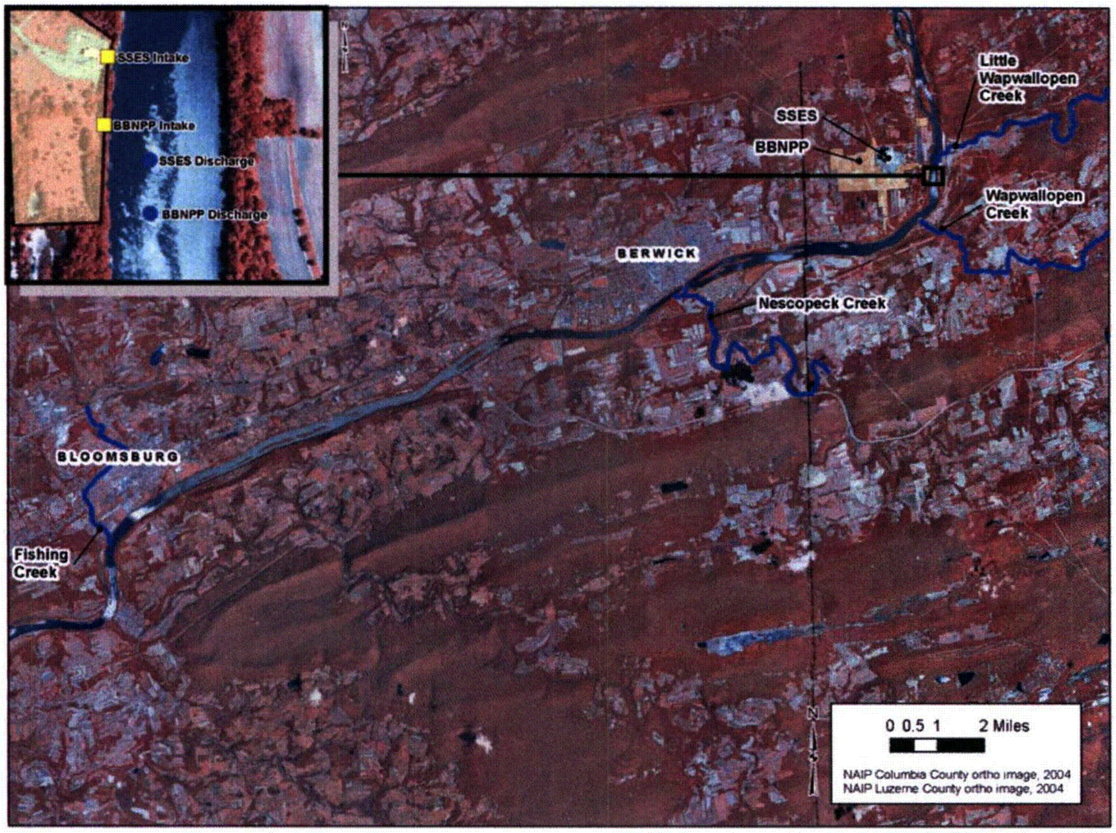

Figure 1-1 Study area

In October 2008, PPL Bell Bend applied to the U.S. Nuclear Regulatory Commission (NRC) for a combined license (COLA) to construct and operate the BBNPP. PPL Bell Bend expects to receive the requested license in 2013, to begin construction in 2013, and to begin operation in the 2018-2020 timeframe. The COLA may be viewed on-line at:

http://www.nrc.gov/reactors/new-reactors/col/bell-bend.html

1.1. BACKGROUND

On May 13, 2009, PPL Bell Bend applied to the SRBC for approval of a maximum peak-day withdrawal from the Susquehanna River of up to 44 million gallons per day (mgd) and for a maximum peak-day consumptive water use of 31 mgd. In its application, PPL Bell Bend proposed to comply with the Commission's consumptive use regulation by providing "in-lieu" payment to the Commission, pending the study of potential sources of consumptive use make-up water. PPL Bell Bend supplemented its application on October 9, 2009.

At a meeting in July 2009, the SRBC noted its concern over "in-lieu" payment as a compliance measure, and also that the cumulative consumptive water use in the Middle Susquehanna Subbasin which is neither mitigated by upstream compensation nor subject to a passby flow exceeds 10 percent of the seven-day ten-year low flow (7Q10). Accordingly, the SRBC requested that PPL Bell Bend perform an instream flow study to determine the potential effects that BBNPP's consumptive use might have on the aquatic resources of the river. Subsequently, in a letter dated March 1, 2010, the SRBC requested additional information about BBNPP including information about the potential effect BBNPP might have on downstream water users. PPL Bell Bend understands that if the results of the study were to indicate significant impairment or impact, SRBC could require either a "passby flow" at the BBNPP, or require PPL Bell Bend to provide upstream consumptive use make-up water, in whole or in part. If the BBNPP were to be subject to a passby flow, consumptive use of water would be precluded whenever river flow (e.g., measured at the Wilkes-Barre gage) is equal to or less than the imposed passby flow.

The studies to be conducted in accordance with this study plan will provide sufficient information to permit an SRBC decision in this matter.

1.2. BELL BEND PROJECT DESCRIPTION

The BBNPP will be a single-unit, nuclear power plant with an evolutionary pressurized water reactor. The plant's expected rated power will be 4,590 megawatts (thermal) and its expected electrical output will be approximately 1,600 megawatts. Refueling outages are expected on 18-month cycles, to alternate between spring and fall, and normally will last for 11 to 16 days. Every 10 years the outage will be expanded for an in-service inspection and turbine/generator overhaul. These expanded outages are expected to last up to 32 days.

During operation of the plant, all water except potable water supply will be withdrawn from the Susquehanna River. The BBNPP river intake will be located approximately 300 ft downstream of the existing SSES river intake. The amount of water to be withdrawn from the river and used consumptively will vary depending upon the BBNPP's operations and ambient meteorological conditions.

Water withdrawn from the river but not consumed will be returned to the river via a submerged discharge diffuser to be located approximately 680 ft downstream of the BBNPP intake and approximately 380 ft downstream from the existing SSES discharge diffuser. The fact that the river is pooled at the location of the existing SSES and proposed BBNPP intakes and discharges means that the relative locations of the SSES and BBNPP intakes and discharges will have no significant effect on river depths or velocities. The pool extends from about one mile upstream to three miles downstream of the BBNPP intake structure.

Most of the consumptive water use at BBNPP will be evaporation from the two main cooling towers. These two towers are assumed for purposes of this study to be natural draft, counter-flow cooling towers; they will remove heat from the circulating water after it passes through the plant's steam condenser. Other consumptive uses include:

- Main cooling tower drift
- Essential Service Water Emergency Makeup System (ESWEMS) cooling tower evaporation and drift. (There will be four ESWEMS cooling towers, all mechanical draft; during normal operation, only two towers are expected to be in service.)
- ESWEMS retention pond evaporation
- Water Retention Basin evaporation
- Power plant consumptive use
- In-stream evaporation associated with heat rejected in the cooling tower blowdown

The BBNPP consumptive use will be monitored as the difference between metered river water withdrawal and metered plant discharge (primarily cooling tower blowdown), in accordance with a water monitoring plan to be developed by PPL Bell Bend, and approved by the SRBC. The total monitored consumptive use is not expected to exceed 31 mgd on a peak-day basis. This amount allows for each of the above expected consumptive water uses and includes an allowance for monitoring inaccuracy within the limit allowed by the SRBC (5 percent). The inaccuracy for this purpose was conservatively assumed to occur unfavorably in both directions, i.e., monitoring of the river water withdrawal 5 percent too high and monitoring of the plant discharge or blowdown 5 percent too low. The consumptive use will also vary substantially on a seasonal basis as further discussed below (see Section 5).

1.3. REGULATORY FRAMEWORK

The following comprise the SRBC's regulatory framework relevant to this study:

Susquehanna River Basin Compact (1970)

> The Compact among the Federal Government and the three basin states established the SRBC and granted to the Commission broad authority regarding the water resources of the basin including the authority to review and approve any project within a signatory state determined to have a significant effect on water resource within another signatory state. The Compact requires that the Commission develop a Comprehensive Plan and

prevents agencies of the Federal government from exercising their powers in substantial conflict with the Comprehensive Plan.

Code of Federal Regulations, Title 18, Part 806 as amended, effective January 15, 2009.

Part 806 (Review and Approval of Projects) establishes standards and prescribes the review process for applications and approvals of withdrawals from groundwater and surface water. Section 806.22 establishes standards for the consumptive use of water and requirements to mitigate consumptive use, and allows the Commission to determine what manner of consumptive use mitigation is acceptable. Section 806.30 establishes standards for monitoring and reporting water withdrawal and use.

Comprehensive Plan for the Water Resources of the Susquehanna River Basin (2008)

The Comprehensive Plan sets forth overall objectives, strategies and activities in the "priority management areas" of: Water Supply; Water Quality; Flooding; Ecosystems; Chesapeake Bay; and Coordination, Cooperation and Public Information. With respect to the Chesapeake Bay, the Comprehensive Plan calls for the identification of minimum freshwater inflows needed to restore and maintain the Bay's ecological health and for the Commission to develop and implement plans to address such flow requirements. Also, the Comprehensive Plan includes "Consumptive Use Mitigation" as an "area of special interest."

Consumptive Use Mitigation Plan (SRBC, 2008)

The Consumptive Use Mitigation Plan (CUMP) quantifies the consumptive use in the basin and sets forth specific goals, strategies and projects to mitigate the consumptive use by providing stored water supplies from which water can be released to augment river flow to compensate for (make up) consumptive use during critical low flow periods. The CUMP adopts a strategy focused on providing flow augmentation during the months of August through October, as best meets the needs of freshwater inflow to the Chesapeake Bay, in lieu of the prior strategy to compensate for consumptive use during sub-7Q10 low flow conditions.

"Guidelines for Using and Determining Passby Flows and Conservation Releases for Surface-Water and Ground-Water Withdrawal Approvals" (Policy No. 2003-01, SRBC, 2002)

The guidelines call for "passby flows" of certain amounts during specified conditions. A passby flow is the minimum flow that must be left in a stream; removal of water must cease if the flow falls below the specified passby flow. Projects whose consumptive use is less than 10 percent of the 7Q10 flow are considered to be "minimum" and not subject to passby flow. If a passby flow is required, the passby flow shall be determined based upon the classification and quality of the stream, and may be determined by a study. When a passby flow is warranted, the minimum passby flow shall be the 7Q10. For warmwater streams of unimpaired quality, the nominal passby flow shall be 20 percent of the Average Daily Flow (ADF). The guidelines do not discuss consideration of cumulative consumptive use as a basis for a passby flow requirement; SRBC cited cumulative consumptive use (not mitigated by upstream releases) in the Middle Susquehanna Subbasin as basis for requiring an Instream Flow Study at the BBNPP in order to determine the potential need for a passby flow.

2. *STUDY OBJECTIVES*

The studies to be conducted in accordance with this plan will provide sufficient information to permit the SRBC to determine whether a passby flow is needed at BBNPP. An "Instream Flow Study" for this purpose was first requested by the SRBC at a meeting with PPL Bell Bend on July 8, 2009. PPL Bell Bend and its consultants thereupon began preparation of a proposed study plan. In a meeting on January 26, 2010 among representatives of PPL Bell Bend, the SRBC and cooperating resource agencies, the parties reached agreement on four specific study objectives.

Subsequently, in a letter to PPL Bell Bend dated March 1, 2010, the SRBC requested additional information regarding PPL Bell Bend's applications for surface water withdrawal and consumptive water use. As a result of this letter, a fifth study objective was added to this study plan.

The objectives of this study are:

- To establish incremental relationships between aquatic habitat and river flows for the selected species and life stages in the study area to compare aquatic habitat available at a range of Susquehanna River flows with and without BBNPP consumptive use, a passby flow, and potential consumptive use makeup (Section 6);
- To assess the effects of potentially reduced river flow due to BBNPP consumptive use on the dilutive capacity of the river relative to acid mine drainage (AMD) from the Nescopeck Creek (Section 7);
- To expand the prior assessment of the effects of the BBNPP discharge on river water temperature and dissolved oxygen (Section 8);
- To assess the magnitude of the impact reduced river flow and stage due to BBNPP consumptive use on dissolved oxygen (DO) and temperature in backwater areas particularly habitable by smallmouth bass (Section 9);
- To assess the effect of potentially reduced river flows, stage or water quality due to BBNPP operation on downstream water withdrawers and dischargers (Section 10);

PPL Bell Bend intends to complete the necessary field studies during 2010 and to have a draft report available for review by SRBC and the cooperating agencies by the first quarter of 2011.

3. *RELEVANT DATA AND PRIOR STUDIES*

This section of the study plan summarizes relevant and readily available hydrologic, water quality and fisheries data. Important excerpts of cited reports are presented in Appendix A. Relevant data sources and reports are outlined in Table 3-1.

Table 3-1 Summary of Relevant Prior Studies and Data

Source	Reports and Data
Ecology III	Currently conducts quarterly water quality sampling at five sites; measures daily temperature and water surface elevation; performs electrofishing and seining. Macroinvertebrate, mussel, and impingement/entrainment investigations were also conducted. Annual reports are available beginning in 1971 with occasional special studies (e.g., thermal plume surveys) published separately. Reports include summary of water quality parameters (pH, DO, temperature, alkalinity, conductance, hardness, TDS, nutrients and metals).
EPA	Published two TMDL's (Susquehanna River and Nescopeck Creek) which summarize water quality data (pH, alkalinity and metals: aluminum, iron and manganese). Primary source of data are the sampling done in support of TMDL's (AMD-related TMDL for both Susquehanna River reach upstream of the BBNPP and Nescopeck Creek, and PCB-related TMDL for the Susquehanna River).
PPL Bell Bend	Published the BBNPP Environmental Report which is not a primary source, but contains a summary of available water quality parameters (pH, DO, temperature, alkalinity, conductance, hardness, TDS, nutrients and metals). Primary source of data are two SSES sampling locations used since 1968 and additional sampling performed during 2008.
USGS	Measures stage and discharge on various streams and the Susquehanna River itself. Several water quality parameters (pH, nutrients, metals, minerals, hydrocarbons and TDS) measured at USGS station near Hunlock Creek and Danville.

3.1. *HYDROLOGY*

This section presents background information on flows in the Susquehanna River and in tributaries of importance to this study.

3.1.1. *USGS Gaging Sites and Records*

The USGS gaging sites of importance to this study are shown in Table 3-2, below.

Table 3-2 USGS gaging sites

Location	USGS No.	Drainage Area (sq mi)	Period of Record
Susquehanna River at Wilkes-Barre	01536500	9,960	Daily discharge, 4/1899-present
Susquehanna River at Danville	01540500	11,220	Daily discharge, 4/1905-present
Nescopeck Creek at Nescopeck	01538600	171	Periodic measurements since 1949

The Wilkes-Barre river gage is the nearest river gage upstream from the study reach. The next gage on the river downstream from Wilkes-Barre is located at Danville. It is not anticipated that the study reach will extend to Danville except for evaluation of potential effects to water users and dischargers.

The drainage area at SSES/BBNPP is 2.8% greater than at the Wilkes-Barre gage. Wapwallopen Creek at Wapwallopen is the only active gage on a stream entering the river between the Wilkes-Barre gage and SSES/BBNPP; the Wapwallopen Creek gage has a drainage area of only 43.8 sq miles. Flow as measured and recorded at the Wilkes-Barre gage will be considered to represent the flow in the study area upstream from Nescopeck Creek. Recorded daily river flows at Wilkes-Barre for the period April 1899 (beginning of record) through March 2010 will be used to evaluate the occurrence of the potential impacts of BBNPP consumptive water use[2]. Table 3-3 presents selected statistics of the daily river flow at Wilkes-Barre from April 1899 through March 2010.

Table 3-3 Selected daily flow statistics at Wilkes-Barre, April 1899 - March 2010

	Daily flow (cfs)			
Month/season[3]	Minimum	Median	Average (mean)	Maximum
Jan	1,010	9,100	14,500	210,000
Feb	1,060	8,800	14,900	179,000
Mar	2,100	22,100	30,400	229,000
Apr	5,210	24,000	31,000	206,000
May	2,000	12,000	16,300	206,000
Jun	1,350	5,775	9,400	329,000
Jul	787	3,480	5,600	142,000
Aug	716	2,440	4,200	95,300
Sep	532	2,290	4,600	244,000
Oct	658	3,360	7,200	151,000
Nov	627	7,540	11,500	123,000
Dec	860	10,200	14,500	184,000
Annual	532	7,400	13,700	329,000
Jan-Mar	1,010	12,100	20,100	229,000
Apr-Jun	1,350	13,000	18,900	329,000
Jul-Sep	532	2,670	4,800	244,000
Aug-Oct[4]	532	2,570	5,400	244,000
Oct-Dec	627	6,720	11,100	184,000

River flow downstream from Nescopeck Creek will be increased by measured or simulated inflow from Nescopeck Creek. The USGS takes intermittent readings at the Nescopeck site. The drainage area at the site includes essentially all of the drainage area of Nescopeck Creek. The USGS has taken 137 stage-flow readings at the site since 1949 and continues to take several readings per year. This dataset will be used to attempt to develop an estimating procedure for flows in the Nescopeck Creek relative to Susquehanna River flows. Also, the flow at this site will be measured each time field work is being performed for this study. Flow in the river between Nescopeck Creek and Fishing Creek will be assumed to be the sum of the Wilkes-Barre flow and the Nescopeck flow.

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[2] SRBC has requested that daily river flows for the entire period of record be used for this study. (Pers. communication with A. Dehoff.)

[3] Other "seasons" (e.g., May-June) may be appropriate for evaluation of potential habitat loss for certain species-life stage combinations.

[4] August-October was selected to coincide with the required consumptive use mitigation period indicated in SRBC's "Consumptive Use Mitigation Plan."

The reduction in water levels at the Wilkes-Barre and Danville gages for hypothetical consumptive use of 31 mgd (48 cfs) at selected low flows are presented in Table 3-4.

Table 3-4 Reduction in river stage for hypothetical consumptive use of 31 mgd

	Wilkes-Barre		Danville	
Ambient flow	Flow (cfs)	Stage reduction (ft)	Flow (cfs)	Stage reduction (ft)
7Q10	820[5]	0.049	948[6]	0.021
10% ADF	1,345	0.038	1,550	0.016
15% ADF	2,018	0.029	2,333	0.016
20% ADF	2,6903	0.029	3,1107	0.014

These stage reductions are presented only to give an idea of the general magnitude of the expected stage reduction due to the proposed consumptive use at the BBNPP. They do not necessarily represent comparable stage reduction in the study reach.

3.1.2. Upstream Low Flow Regulation

There are numerous reservoirs in the Susquehanna River watershed upstream from the BBNPP, most of which probably regulate low flows to some extent although low flow regulation is not a purpose. However, only two reservoirs are known to have significant effect. These reservoirs, are Cowanesque Lake and Whitney Point Lake which are each federal, multipurpose reservoirs operated by the U.S. Army Corps of Engineers (ACOE).

Cowanesque Lake is located on the Cowanesque River in Tioga County, Pennsylvania. Cowanesque has approximately 25,000 acre-ft of water supply storage sponsored by PPL Susquehanna, LLC and PPL Montour, LLC and Exelon through the SRBC that is dedicated to consumptive use mitigation for SSES; the Montour Steam Electric Station and the Three Mile Island Nuclear Generating Station. Cowanesque storage has been available for consumptive use mitigation since the early 1990's, and mitigation releases have been made occasionally. In accordance with an Operations Manual, upon notice by the SRBC, the ACOE will release water during sub-7Q10 low flow events for those three generating facilities in amounts up to approximately 40 cfs, including an allowance for flow reduced in transit. Presently, the SRBC and the ACOE are evaluating the possibility of modifying operation of Cowanesque to conform to the SRBC's Consumptive Use Mitigation Plan, which places highest priority on the availability of consumptive use mitigation in August, September and October.

Whitney Point Lake is located on the Otselic River in Broome County, New York. In 2009, the Whitney Point Lake Section 1135 Modification Project became effective. (Section 1135 of the federal Water Resources Development Act allows the ACOE to modify their projects to restore and enhance environmental quality.) The Whitney Point modification allows releases of up to 100 cfs from 8,500 acre-ft of conservation storage for periodic augmentation of low flow conditions downstream.

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[5] Source: SRBC "Consumptive Use Mitigation Plan" (2008)

[6] Danville Q7-10 estimated from Wilkes-Barre Q7-10 in proportion to ratio of respective ADFs

[7] Danville ADF determined from daily record 2/9/196 through 2/8/2010 is 15,530 cfs

Depending on the scale of habitat and water quality impacts identified in this study, PPL Bell Bend may include a sensitivity analysis of the effect of Cowanesque and Whitney Point releases that pass SSES and BBNPP during low flow conditions.

3.1.3. Nescopeck Creek

The Nescopeck Creek drains 171 square miles, as measured at USGS gage No. 01538600. The period of record for this gage includes periodic measurements from 1949-50, 1982-87, 1989-91, and 1995 to present, a total of 137 measurements. Other gages on the Nescopeck and Little Nescopeck include USGS No. 01538500 Nescopeck Creek near St. Johns, PA (49 square miles), daily measurements from 1919 to 1926; and, USGS No. 01538510 Little Nescopeck Creek near Freeland, PA daily measurements from 1973 to 1979 and 1995 to 1998.

The discharge at the mouth of the Nescopeck includes AMD from multiple sources. Jeddo Tunnel, the largest AMD contributor, discharges to the Little Nescopeck Creek which flows into the Nescopeck Creek. The Jeddo Tunnel system drains deep anthracite mines in watersheds adjacent to the Little Nescopeck. Although the mines are no longer active, Jeddo Tunnel system continues to drain these abandoned mine workings. Because of the diversion of these flows into its watershed, yields from the Nescopeck may vary as compared to the yields from other watersheds draining to the Susquehanna River. The water balance for the Jeddo Tunnel has been quantified in Ballaron (1999). Other AMD discharges in the Nescopeck Creek watershed are from Black Creek, which receives AMD directly from the Gowen mine, and other small creeks.

3.1.4. Downstream Withdrawals

Table 3-5 lists entities that withdraw water from the Susquehanna River below the location of the BBNPP down to Danville, located about eight miles above the confluence of the Susquehanna River with the West Branch. With the exception of Danville, withdrawals are from groundwater wells adjacent to the Susquehanna River.

Table 3-5 Downstream water withdrawals

Facility/Location	Type	Design flow (mgd)	Distance downstream of the BBNPP intake (mi)
PA-American Water Company (serves Berwick and Nescopeck)	Water supply - wells	4.6	6.5
Mifflin Township Water Authority	Water supply - wells[8]	0.223 (typ.) 0.432 (max.)	11
Catawissa Borough Municipal Authority	Water supply - wells[9]	0.12 (avg.) 0.2 (max.)	22
Danville Municipal Authority	Water supply	2 (avg.)	30

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[8] within ¼ mi of river

[9] wells ½ mi upstream along Catawissa Creek, surface intake – not usually used – on Catawissa Creek

3.2. *WATER QUALITY*

This section of the study plan describes the water quality of the Susquehanna River in the vicinity of the BBNPP and the water quality of the Nescopeck Creek.

3.2.1. ***Susquehanna River Water Quality***

Susquehanna River water quality has been monitored at the Susquehanna SES Environmental Laboratory from 1971 through the present, with modifications to the program over the years. Table 3-6 summarizes the sampling periods, frequency, locations and programs. Additional information on the programs and parameter lists can be found in Appendix A.

Table 3-6 Ecology III Susquehanna River water quality monitoring program

Year	Sample period	Sample frequency	Sample locations	Programs
1971	Aug-Dec	Twice a month	6-9 locations Falls, PA to Berwick, PA	
1972	Apr-Dec	Daily	SSES	Various analyses
		Monthly	SSES	Diurnal
		Semimonthly	Falls to Berwick	River Run
		Quarterly	SSES to Columbia	Extended River Run
1973	Jan-Dec	Daily	SSES	Various analyses
		Monthly	SSES	Diurnal
		Semimonthly	Falls to Berwick	River Run
		Quarterly	SSES to Columbia	Extended River Run
1974	Jan-Dec	Semi-weekly	SSES, Bell Bend	Various analyses
		Mar, May, Jul, Sep	SSES	Diurnal
		Feb, May, Jul, Sep, Dec	Falls to Berwick	River Run
1975	Jan-Dec	Weekly (Jan-Feb)	SSES, SSES-A[10]	Various analyses
		Weekly (Mar-Dec)	SSES-A	Various analyses
		Apr, May, Jun, Jul, Aug, Sep	SSES-A	Diurnal
1976	Mar, Oct-Dec	Semimonthly	SSES-A	Various analyses
	Apr-Jun	Semiweekly		
	Jul-Sep	Weekly		
1977	Apr-Sep	Semiweekly	SSES-A	Various analyses
	Jan-Mar, Oct-Dec	Semimonthly		
1978-1985	Apr-Sep	Semiweekly	SSES**, Bell Bend	Various analyses
	Jan-Mar, Oct-Dec	Weekly		
1986-2004	Apr-Sep	Weekly	SSES, Bell Bend, Bell Bend I	Various analyses
	Jan-Mar, Oct-Dec	Semimonthly		
2005-present		Quarterly	SSES, Bell Bend	Various analyses
1974-present	Constant monitor for river level and river temperature			

Ecology III has measured water temperatures 1620 ft upstream of the SSES intake structure on the west bank of the Susquehanna River daily since 1974 (Ecology III, Inc. 2008). A maximum

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[10] Same sampling location from 1975 to present. SSES-A was renamed SSES.

water temperature of 86.5 F was recorded on 15 Aug 1988 and on 4 Aug 2007. A minimum water temperature of 32.0 F was recorded numerous times in January. Other statistical summaries, for example, monthly mean and maximum temperatures, can be developed from this daily record.

The Susquehanna River adjacent to the BBNPP is designated as a Warm Water Fishery (WWF). Specific water quality criteria (Pa. Code, Chapter 93. Water Quality Standards, § 93.7. Specific water quality criteria) for DO and pH are as follows:

> "DO2 (applicable to WWF): Minimum daily average 5.0 mg/l; minimum 4.0 mg/l."

> "pH (applicable to WWF): range between 6.0 and 9.0 inclusive"

Pennsylvania provides the following criteria for temperature (Pa. Code, Chapter 93. Water Quality Standards, § 93.7. Specific water quality criteria):

> "Maximum temperatures in the receiving water body resulting from heated waste sources are regulated under Chapters 92, 96 and other sources where temperature limits are necessary to protect designated and existing uses. Additionally, these wastes may not result in a change by more than 2°F during a 1-hour period."

Table 3-7 summarizes the temperature limits by "critical use period" applicable to Warm Water Fishery streams. These values represent the maximum allowable water temperatures at an unspecified distance downstream of the discharge where fully-mixed conditions occur.

Table 3-7 Temperature limits applicable to Warm Water Fishery streams

Source: Pa Code, Chapter 93, § 93.7

Critical Use Period:	Temperature (°F)
January 1-31	40
February 1-29	40
March 1-31	46
April 1-15	52
April 16-30	58
May 1-15	64
May 16-31	72
June 1-15	80
June 16-30	84
July 1-31	87
August 1-15	87
August 16-30	87
September 1-15	84
September 16-30	78
October 1-15	72
October 16-31	66
November 1-15	58
November 16-30	50
December 1-31	42

A search of USGS records for recent dissolved oxygen measurements in Susquehanna River shows that Hunlock Creek (USGS No. 01537700) is the nearest water quality station upstream of SSES and that Danville (USGS No. 01540500) is the nearest water quality station downstream of SSES. There were 76 samples taken at Danville and 15 samples at Hunlock Creek since January 2001. DO values for all samples were within the range of 7 mg/l to 15 mg/l. The DO values were consistently above the applicable DO criterion (DO2). The pH values ranged from 6.4 to 8.9. The pH values were consistently within the required standard.

The water quality of the Susquehanna River upstream of the BBNPP has also been studied as part of two TMDL's. The first TMDL study (PADEP 1999; USEPA, 1999) focused on polychlorinated biphenyls (PCBs). The second TMDL (PADEP 2009; USEPA 2009) focused on mine drainage-affected segments for metals (iron, aluminum and manganese), pH, and alkalinity. These Susquehanna River TMDL studies provide measured water quality parameters (pH, alkalinity and metals: iron, aluminum and manganese).

3.2.2. Nescopeck Creek Water Quality

The Eastern Middle Anthracite (EMA) Field, one of the four anthracite fields in Pennsylvania, extends across parts of Carbon, Columbia, Luzerne and Schuylkill counties. The Nescopeck Creek is the major contributor of AMD from the EMA Field to the Susquehanna River. The Nescopeck Creek receives AMD from Black Creek and Little Nescopeck Creek as seen in Figure 3-1.

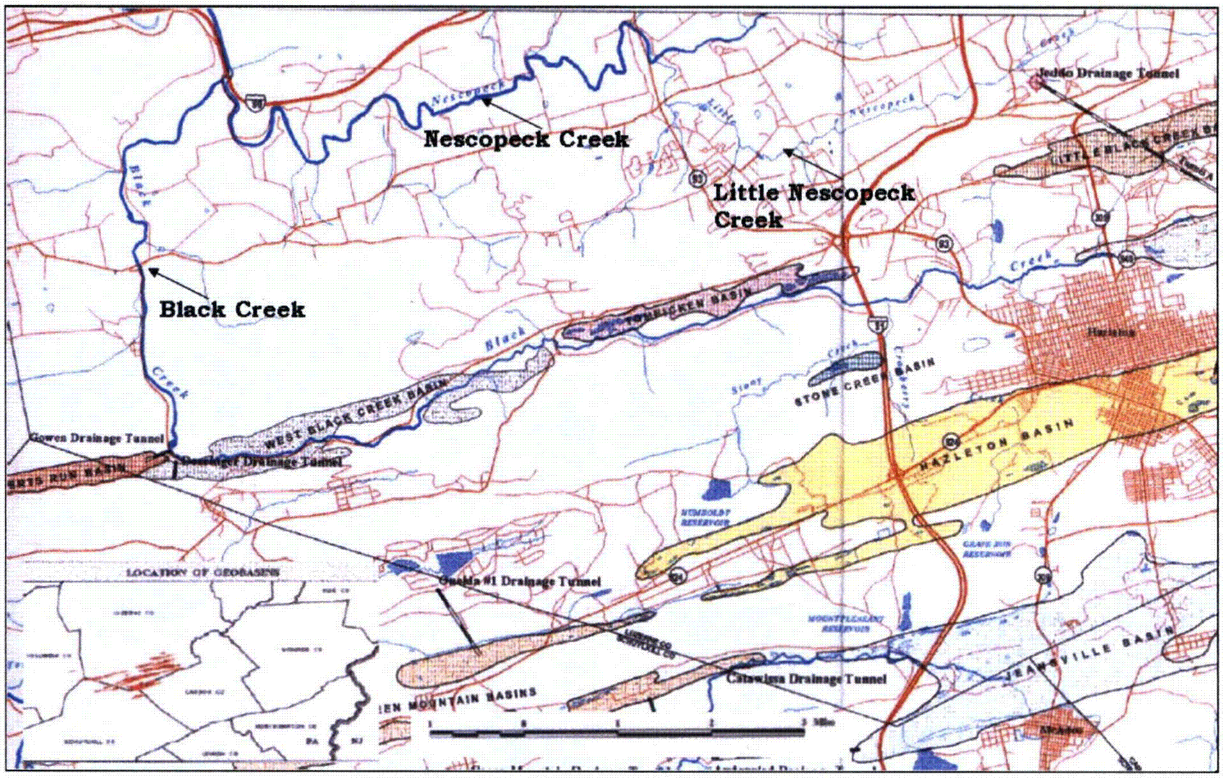

Figure 3-1 Nescopeck Creek AMD sources

Source Hollowell (1999)

The Little Nescopeck Creek, a tributary to Nescopeck Creek, is severely impacted by AMD from the Jeddo Tunnel. The Jeddo Tunnel drains deep anthracite mines in a watershed adjacent to the Little Nescopeck. Although the mines are no longer active, the tunnel system continues to drain the abandoned mine workings. Because flows in the Little Nescopeck Creek and consequently the Nescopeck Creek are augmented by Jeddo Tunnel flows, the water quality and water quantity are unlike those of the more pristine watersheds draining to the Susquehanna River near the BBNPP.

A search of USGS records for dissolved oxygen and pH measurements in Nescopeck Creek revealed the following. Only one station in Nescopeck Creek (USGS No. 01538600) contained recent measurements. A total of 67 samples are available since January 2001. The DO values ranged from 6 mg/l to 15 mg/l exceeding the DO2 criteria. The pH values, however, ranged from 4.7 to 6.5. Out of all the samples, pH was only within the water quality criterion 9 times.

The water quality of the Nescopeck Creek has been studied as part of a TMDL (PADEP 2005; USEPA, 2006). The Nescopeck Creek TMDL provides measured water quality parameters (pH, alkalinity and metals: iron, aluminum and manganese).

3.2.3. *SSES and BBNPP Thermal Discharges*

The existing SSES and the proposed BBNPP thermal plumes result from the discharge of cooling tower blowdown to the Susquehanna River. The temperature of the blowdown typically exceeds the temperature of the Susquehanna River. The differential is typically highest in seasons other than summer.

The existing SSES intake and discharge structures are located as shown in Figure 1-1, with the intake upstream of the discharge. The BBNPP intake and discharge structures will each be downstream of their corresponding SSES structures so that the upstream to downstream sequence is SSES intake, BBNPP intake, SSES discharge, and BBNPP discharge.

Preliminary modeling for the SSES thermal plume was performed for the 1972 Environmental Report (Pennsylvania Power and Light Company 1972) and the plume's size and configuration has been measured in a total of five surveys in 1986, 1987 and 2008 (Jacobsen 1987; Jacobsen 2009). The surveys were scheduled such that plumes were measured during the fall, winter, and spring seasons (one survey each season, documented in the 1987 report) and in the summer season (two surveys documented in the 2009 report). The surveys consisted of about 25 vertical temperature profiles taken near the SSES discharge structure. About 400 temperature measurements were made during each survey. Susquehanna River flow, stage, temperature and SSES blowdown rate and temperature were recorded during the surveys. Obtaining an accurate ambient temperature was somewhat problematic, especially for the summer surveys due to the natural increase in upstream water temperatures over the one or two hours it took to complete these surveys.

The results of the surveys were presented as the projection onto the water surface of the 0.5°F temperature rise isotherm wherever it occurred in the water column. The 0.5°F temperature rise isotherm was generally the largest rise measured, except for a small 1°F plume observed during one of the summer surveys. The reports concluded that the thermal plumes were "relatively small" (Jacobsen 1987) and "very limited even during low river flow conditions" (Jacobsen 2009).

For the proposed BBNPP, extensive modeling was performed for the BBNPP ER to estimate the size and configuration of the BBNPP thermal plume and the combined BBNPP and SSES thermal plume. The results are published in ERM (2008). The modeling used CORMIX for the near-field calculation of thermal plume size and configuration for the individual discharges, and used GEMSS for a far-field calculation of the combined thermal plume. Both CORMIX and GEMSS compute the transfer of heat from the water surface to the atmosphere by the processes governing surface heat exchange: incident and reflected and long-wave radiation and back radiation, evaporation, and conduction. The modeling was verified by comparing model output to the Jacobsen observations.

There were five cases simulated with the near- and far-field models, as shown in Table 3-8. The temperature rise ("excess temperature") in all cases was based on the cooling tower blowdown temperature provided by the BBNPP engineer and did not include any temperature reduction due to retention ponds or loss in transit. These cases used winter and summer extreme temperature rises in combination with winter and summer mean and low Susquehanna River flows. For these cases winter was represented by January and summer by August. For each of these five cases, two thermal plumes were simulated: the plume due to combined SSES and BBNPP discharges and the thermal plume for the BBNPP discharge alone. For the latter simulation, the SSES discharge was assumed to be in operation, but the temperature rise from the SSES was included in the ambient temperature. This method of isolating the BBNPP thermal plume correctly includes the dynamics of the overlapping plumes.

Table 3-8 BBNPP ER thermal plume scenarios

Parameter Description	Scenario 1 Summer mean flow (August)	Scenario 2 Summer low flow (August)	Scenario 3 Winter mean flow (January)	Scenario 4 Winter low flow (January)	Scenario 5 Annual mean flow (January)
Susq. River flow, cfs	4,473	1,246	12,482	2,848	12,800
Water surface elevation, ft	487.5	486.0	489.8	486.8	489.8
Susq. River Temperature, °F	86.5	86.5	32.0	32.0	32.0
		SSES			
Temperature rise, °F	12.5	12.5	31.0	31.0	31.0
Intake rate, gpm	42,300	42,300	42,300	42,300	42,300
Discharge rate, gpm	11,200	11,200	11,200	11,200	11,200
		BBNPP			
Temperature rise, °F	3.5	3.5	33.8	33.8	33.8
Intake rate, gpm	34,458	34,458	34,458	34,458	34,458
Discharge rate, gpm	11,172	11,172	11,172	11,172	11,172

Thermal plume dimensions are commonly presented as surface and bottom areas. As an example, Table 3-9 shows these areas for Scenario 2 for the combined SSES and BBNPP thermal plumes and for the BBNPP thermal plume separately but with SSES operating, as described earlier.

Table 3-9 Surface and bottom areas for Scenario 2, Summer low flow

		Plume area, acres			
		SSES and BBNPP		BBNPP	
Lower temperature rise bound, °F	Upper temperature rise bound, °F	Surface	Bottom	Surface	Bottom
0.5	1	4.94	0.47	0.00	0.23
1	1.5	0.00	0.38	0.00	0.14
1.5	2	0.00	0.29	0.00	0.10
2	2.5	0.00	0.23	0.00	0.04
2.5	3	0.00	0.19	0.00	0.01
3	3.5	0.00	0.03	0.00	0.00

Figure 3-2 and Figure 3-3 show the combined SSES and BBNPP thermal plume at the surface and bottom, respectively. Figure 3-4 and Figure 3-5 show the thermal plume attributable only to the BBNPP discharge, i.e., the temperature increase at the surface and bottom, respectively, from the BBNPP cooling tower blowdown.

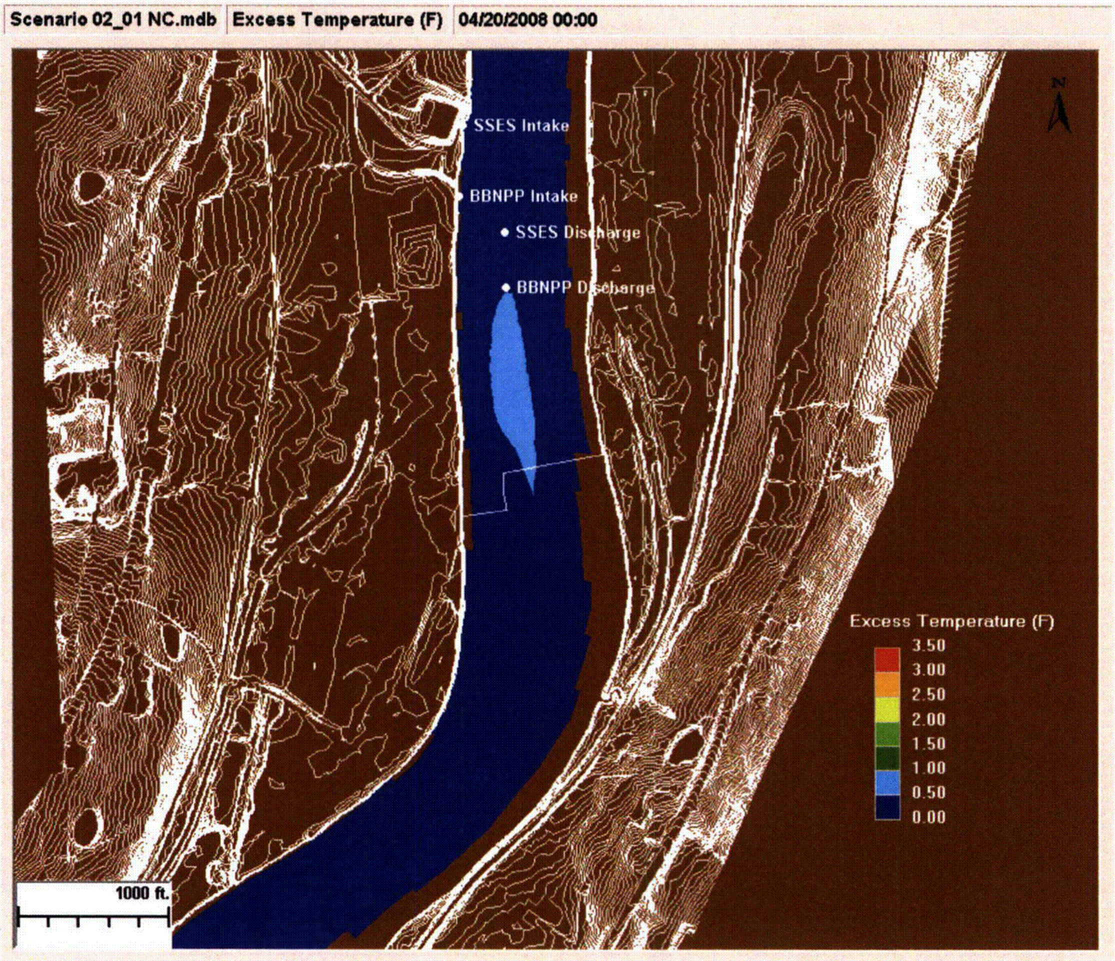

Figure 3-2 Surface excess temperature for combined BBNPP/SSES thermal plume

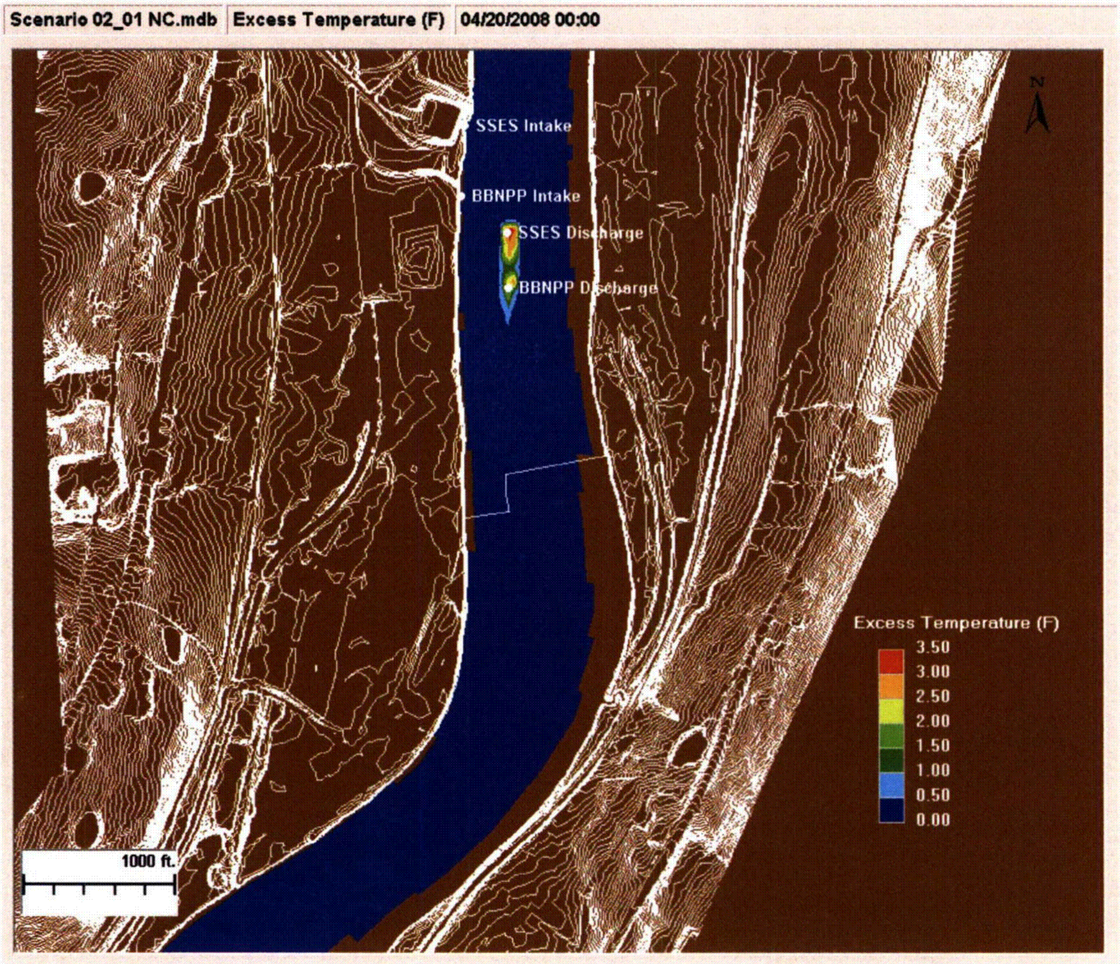

Figure 3-3 Bottom excess temperature for combined BBNPP/SSES thermal plume

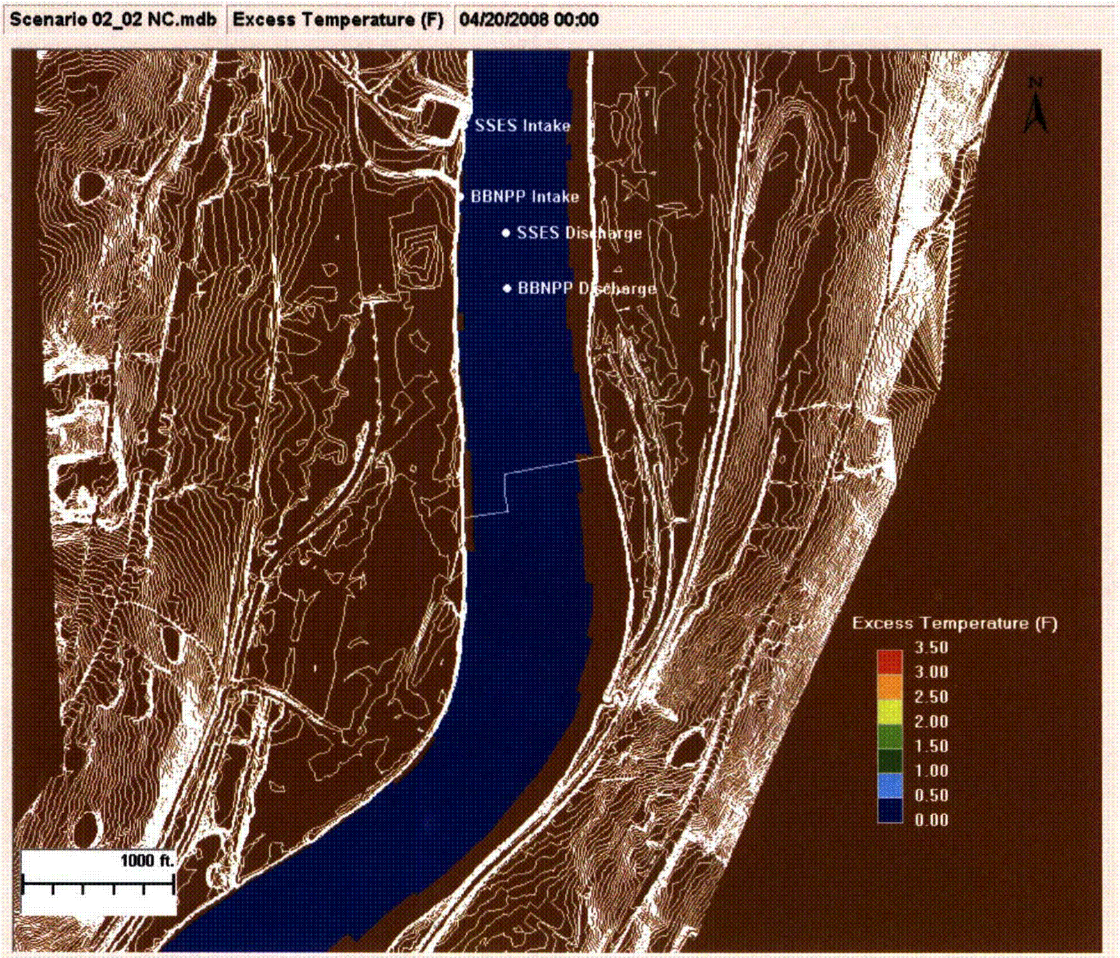

Figure 3-4 Surface excess temperature for the BBNPP thermal plume

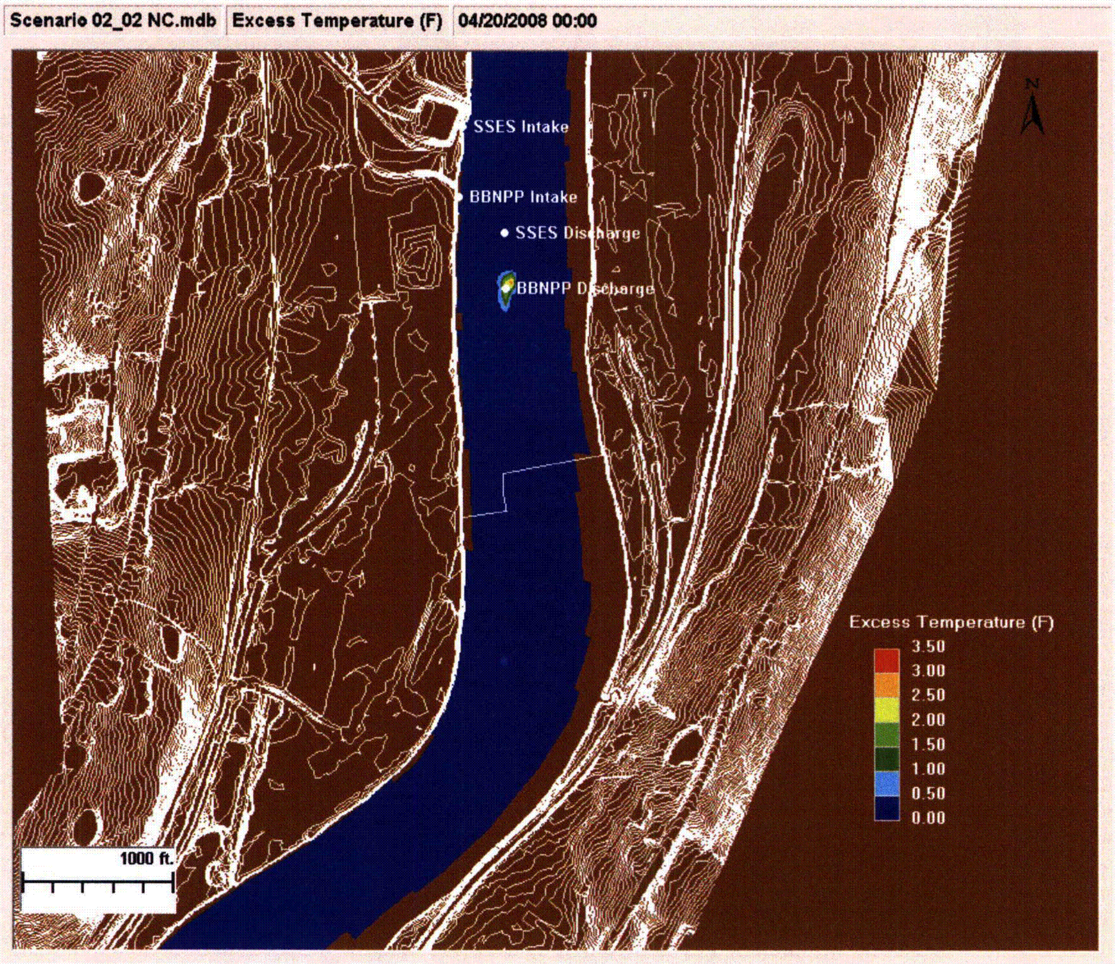

Figure 3-5 Bottom excess temperature for the BBNPP thermal plume

3.2.4. Downstream Discharges

Table 3-10 lists downstream water discharges, all of which are publicly-owned treatment works. As such they depend somewhat on the Susquehanna River flow to dilute treated water.

Table 3-10 Downstream water dischargers

Facility/Location	Type	Design flow (mgd)	Distance downstream of the SSES intake (mi)
Nescopeck Borough	POTW	0.11	6.5
Berwick Area Joint Sewer Authority	POTW	3.7	6.5
Briar Creek	POTW (discharges to East Branch of Briar Creek)	(unknown)	9.5
Bloomsburg Town Municipal Authority	POTW	4.29	18
Catawissa Borough Sewage Treatment Plant	POTW[11]	0.2	22
Danville Municipal Authority	POTW	3.62	30

3.2.5. Time-of-Travel Studies

Sutron Corporation (1985) conducted comprehensive dye dispersion studies in 1984. Velocities, depths, and dye concentrations were obtained at three Susquehanna River flows: 1,950 cfs (characterized as low flow), 15,400 cfs (medium), and 46,550 cfs (high flow). Dye was injected into the SSES blowdown and concentrations were measured at stations along 11 longitudinal transects from SSES to the Danville Bridge and at the Danville Water Works intake. There were six transects between SSES and the Nescopeck Creek.

The dye concentration data were used to develop time-of-travel estimates for the three Susquehanna River flows and to calibrate a dispersion model that computes time-of-travel estimates for a range of Susquehanna River flows. These time-of-travel estimates were based on the time that the peak dye concentrations passed each transect. The times of arrival of the leading and trailing edges of the dye were also noted. For the present study, these data will be used to calibrate the alternate hydraulic model (Section 6.5).

3.3. FISHERIES

Susquehanna River fishes have been monitored at the Susquehanna SES Environmental Laboratory from 1971 through the present, with modifications to the program over the years. Table 3-11 summarizes the sampling periods and frequency, sampling locations, and programs.

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[11] discharge to Catawissa Creek

Table 3-11 Ecology III Susquehanna River fish monitoring program

Year	Sample period	Sample frequency	Sample locations	Programs
1971	Jul-Dec	Biweekly	25 locations Shickshinny-Berwick	Seining
1972	Jun-Dec	Monthly	11 sites Shickshinny-Berwick	Seining
	May-Dec	Monthly	14 zones near SSES and 4 locations Falls-Millersburg	Electrofishing
1973	Apr-Nov	Monthly	11 locations Shickshinny-Berwick	Seining
	Jan-Nov	Monthly	5 locations Falls to Nescopeck	Electrofishing
1974	Apr-Dec	Monthly	SSES East, West	Seining
			Bell Bend East, West	
	Apr-Dec	Monthly	SSES East, West	Electrofishing
			Bell Bend East, West	
1975	May-Sep	Monthly	SSES East, West	Seining
			Bell Bend East, West	
	Jan-Dec	Monthly	SSES East, West	Electrofishing
			Bell Bend East, West	
1976	Apr-Nov	Monthly	SSES East, West	Seining
			Bell Bend East, West	
1976-1977	Mar-Nov	Monthly	SSES East, West	Electrofishing
			Bell Bend East, West	
1977-1985	Apr-Oct	Monthly	SSES East, West	Seining
			Bell Bend East, West	
1978-1985	Mar-Dec	Monthly	SSES East, West	Electrofishing
			Bell Bend East, West	
1986-present	Jun, Aug, Oct		SSES East, West	Seining
			Bell Bend East, West	
	Apr or May Jun, Jul, Aug, Oct		SSES East, West	Electrofishing
			Bell Bend East, West	
1972-1984	Larval Fish Program			
1976-present	Before-After-Control-Indicator (BACI) analyses			

3.3.1. Fish Community

Extensive surveys of the riverine fish community in the vicinity of the proposed BBNPP have been conducted since the 1970s. The most recent surveys of the fish community were conducted from 2004 through 2007 (Ecology III reports). Sampling was performed both upstream and downstream of SSES. Both boat electrofishing and seining were used to collect fish. Sampling details are described in the Ecology III report (2008) submitted to the NRC as part of the BBNPP ER. Appendix B of that report presents the species composition determined by seine and electrofishing collections.

Based upon the surveys, the fish community in the vicinity of the BBNPP can be characterized as an assemblage of warmwater species. Spotfin shiner, spottail shiner, bluntnose minnow, and white sucker are most common. Other relatively abundant species present are smallmouth bass, walleye, quillback, northern hog sucker, shorthead redhorse, and rock bass. Recreationally important species include smallmouth bass, muskellunge, northern pike, channel catfish, walleye, yellow perch, bluegill, and redbreast sunfish. All these species are year-round residents of the Susquehanna River in the vicinity of the BBNPP site; no migratory fish species have been collected during the seining or electrofishing surveys.

No commercial fishing occurs in the Susquehanna River in the vicinity of the BBNPP.

3.3.2. American shad

Efforts to restore American shad to the upper Susquehanna River have been ongoing for decades. These efforts have included installation of fishways at the four hydroelectric dams on the lower river, and stocking of hatchery reared fry and fingerlings at different locations within the watershed, including the area near Berwick and in the New York portions of the Susquehanna River basin. However, due to downstream obstructions, adult American shad migrating upstream do not presently have access to this reach of the river for spawning and production of a future progeny.

Upstream migration of adults occurs from mid-April to early June on the lower Susquehanna River. Should downstream obstructions be removed in the future, upstream-migrating adult shad would be expected to reach the BBNPP from early May to mid June depending upon the prevailing water temperature. However, many shad may find downstream river areas suitable for spawning and may not reach the area near the BBNPP.

In the lower Susquehanna River, juvenile American shad emigration occurs primarily in October and November. In the future, their emigration past the BBNPP would most likely occur in late July through late September. Juveniles produced from Connecticut River adult shad transplanted in 1981 were captured in fishing gear near the BBNPP in late September (Ecology III, 1981).

3.3.3. American eel

American eel is a catadromous species that spawns in the Sargasso Sea in late winter through spring; all American eel on the Atlantic Coast come from a single spawning population in the Sargasso Sea. After spawning, the spawners die and the resulting larvae and elvers (young eels 2-5 inches long) travel on ocean currents along the coast and eventually enter brackish and freshwater tributaries where they reside for 7 to 25 years, until they reach maturity. In the Susquehanna River, the upstream migration of elvers, as indexed by catches below Conowingo Dam, occur each year in late spring. Mature eels emigrate in late summer and fall and return to the Sargasso Sea to spawn.

American eel has been targeted for restoration to the Susquehanna River. As part of the restoration efforts, young eels captured at Conowingo Dam are being transported to various upstream tributaries. However, none have been observed near the proposed BBNPP site or have been captured at the SSES intake.

3.4. *MACROINVERTEBRATES AND MUSSEL SPECIES*

The relative abundance and species composition of macroinvertebrates were studied from 1980 to 1994 by Ecology III (Annual Reports issued each year) at three locations (one upstream and two downstream of the SSES) to assess the potential effects of the operation of the SSES. This program was conducted over a wide range of hydrological conditions and provided both a long term pre-operational (1980-1982) and post-operational (1983-1994) data set for isolating power plant-related effects. The analysis of these data sets did not detect an adverse effect of SSES operations on the macroinvertebrate community; upstream and downstream macroinvertebrate communities showed similarities (Ecology III 1995). However, both spatial and temporal variations, independent of power station operations, were noted in the density and biomass of common taxonomic groups (ephemeropterans and trichopterans). The presence of these groups of fish food organisms was considered to be indicative of good water quality conditions (Ecology III 1995).

The most recent sampling of benthic macroinvertebrates occurred in summer of 2007-2008 (Ecology III 2008); benthic macroinvertebrates were collected from two locations, one station upstream and one downstream of SSES. Two replicates samples were collected at each of the stations from the river bottom using a 1.75-ft^2 (0.163-m^2) dome suction sampler.

Results from this sampling were compared to those obtained in early years; no substantial differences were reported (Ecology III 2008). Appendix B provides a listing of benthic organisms collected in 2007-2008. Data on the macroinvertebrate community established from this sampling were used to select the taxonomic groups for evaluating the effects of the BBNPP consumptive use.

The macroinvertebrate community present in the Susquehanna River is diverse and characteristic of a large river system (Ecology III 2008). Three groups were dominant at the two sampled stations: Ephemeroptera (mayflies), Coleoptera (beetles), and Mollusca (snails and clams). A total of 18 EPT (Ephemeroptera, Plecoptera, Trichoptera) taxa was collected which comprised 19.1% of the benthic community. A total of 30 taxa were collected near the BBNPP site of which four taxa (mayfly, *Anthopotamus;* beetle, *Stenelmis;* midges, *Chironomous* spp; and, fingernail clams, *Musculium)* contributed over 80% of the total number of 1,486 organisms collected. Many taxa were present in relatively low proportions (less than 2%). The macroinvertebrate community was similar between sampled locations.

A qualitative mussel survey was performed during fall 2007 to determine the community composition of mussels inhabiting the Susquehanna River upstream and downstream of the proposed BBNPP intake and discharge structures (NAI 2008). At the time of the survey, the exact locations of the proposed intake/discharge structures were unknown, thus the survey effort focused on the approximate locations which are in the vicinity of the SSES intake and discharge structures. Surveys were completed by wading and viewing the river bottom with and without the aid of a transparent-bottom bucket.

The Asiatic clam (*Corbicula fluminea*) is the only known nuisance species to occur in the Susquehanna River in the vicinity of the BBNPP site. It was not present in the macroinvertebrate collections taken in 1994 (Ecology III, 1995), which were the most recent until the sampling performed in 2007. But it has successfully established a population in this section of the river over the past few years. In the macroinvertebrate samples collected in 2007, Asiatic clam numerically accounted for nearly 7% of the macroinvertebrates collected in the vicinity of the BBNPP site.

No other nuisance species are known to be present in the Susquehanna River in the vicinity of BBNPP site. However, zebra mussel (*Driessena polymorpha*) was recently confirmed in the Susquehanna River upstream of Great Bend, approximately 65 mi (105 km) upriver of the BBNPP site, during fall 2007 by PADEP. Previously, zebra mussels were discovered in Cowanesque Lake, Tioga County, Pennsylvania during the summer of 2007. The lake is located approximately 170 river mi (274 km) upstream from the BBNPP site. The zebra mussel was also confirmed to be present in the main stem Susquehanna River in Goodyear Lake, which is located in New York. Goodyear Lake is the first major impoundment on the main stem Susquehanna River and is located approximately 240 river mo (386 km) up-river of the BBNPP site. More recently in 2009, presence of zebra mussel was confirmed by Normandeau Associates in the lower Susquehanna River in the Conowingo Reservoir.

It is probable that the spread of zebra mussels will continue and that sometime in the future they will be present in the river near BBNPP. PPL in collaboration with Kings College (Dr. Bryan Mangan, personal communication) periodically monitors the presence of zebra mussel and Asiatic clams in areas upstream and downstream of the BBNPP site. When Asiatic clams were found near the SSES intake area appropriate treatment has been applied.

4. DELINEATION OF STUDY REACHES

Study reaches have been delineated based on available data for each of the potential impact areas addressed in this study plan. These initial study reaches are presented in Figure 4-1 and discussed below. Appendix C provides selected photos of aquatic habitat at river flows between approximately 3,400 cfs and 7,000 cfs in September and November 2009, respectively,

Final reach selection will depend on additional data collection. If a potential effect is determined during the study to extend beyond or into areas not included in the initially-proposed study reach, the study reach will be extended accordingly.

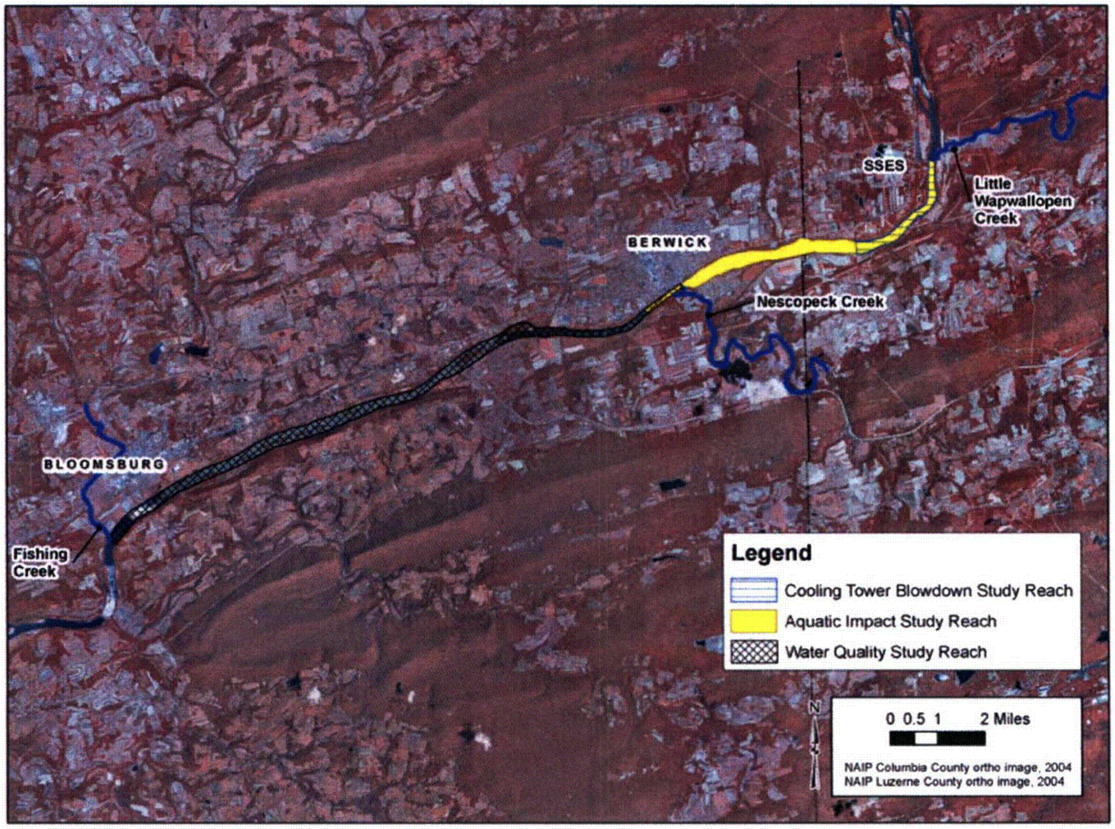

Figure 4-1 Initial study reach delineation

The study reach for assessing the effects on <u>aquatic habitat</u> is expected to extend from Little Wapwallopen Creek to approximately one mile downstream of Nescopeck Creek. The extent of this study reach is based on an initial field survey of habitat types. Field observations made to date indicate that this approximately seven mile reach provides a reasonable representation of habitat characteristics farther downstream. Furthermore, the river area immediately below the plant is expected to be the area of greatest flow impact. Tributary flows would be expected to lessen impacts farther downstream. Required mitigation, if any, would therefore be expected to be driven by habitat conditions and impacts defined for the selected aquatic habitat study reach.

For assessing the effects of BBNPP consumptive water use on river water quality due to the AMD-influenced Nescopeck Creek, a study reach extending from the mouth of the Nescopeck Creek to the mouth of the Fishing Creek in Bloomsburg is proposed based on a preliminary assessment of the likely extent of discernable effects. When the results of the AMD field surveys are analyzed, the study reach may be extended or shortened if the data indicate.

For assessing the temperature effects of the BBNPP cooling tower blowdown, the initial study reach is the pool into which the BBNPP discharges its blowdown. Prior thermal studies for the BBNPP indicate that the thermal plume essentially remains within the pool. This study reach may be extended farther downstream depending on the results of the additional simulations that will be executed during the course of this study.

The study area for evaluating the potential effect of BBNPP consumptive water use on DO conditions in smallmouth bass habitat will consist of three representative backwater and three main channel areas located within the study reach proposed for the aquatic habitat study. The backwater areas are areas assumed to be potentially susceptible to exposure to low nighttime DO and high daytime temperature during the summer when young smallmouth bass may be most vulnerable to low DO conditions (<4.0 mg/l). These areas will be continuously monitored using a system similar to that used by the USGS in its study of smallmouth bass affliction by a bacterium. Additional or alternative areas may be selected based on initial 2010 field work.

The initial study reach for downstream user impacts extends to Danville (not indicated in Figure 4-1). This reach may be modified should 2010 studies reveal potential impacts to additional downstream users.

All proposed changes to the initial study reach delineations will be coordinated with the SRBC, and cooperating agencies as appropriate.

5. *BELL BEND CONSUMPTIVE USE*

5.1. ALTERNATIVE CONSUMPTIVE USE TO BE EVALUATED

For purposes of this study, two alternative "levels" of BBNPP consumptive use will be evaluated. The greater alternative level ("A") is based on the maximum (peak-day) consumptive use for which PPL Bell Bend applied to SRBC. The lesser alternative level ("B") is based on the expected maximum monthly average BBNPP consumptive use determined as described below. Each alternative will vary during the year, by month, in proportion to the variation of the maximum monthly averages experienced at SSES. Table 5-1 shows the resulting alternative monthly and seasonal average values of BBNPP consumptive use to be assumed in the study.

Table 5-1 Alternative consumptive use to be evaluated

Month/season	Experienced maximum monthly consumptive use at SSES as percentage of peak month (1987-2009)[12]	A Maximum daily consumptive use applied for with SRBC, adjusted (mgd)[13]	B Representative expected maximum average BBNPP consumptive use (mgd)[14]
Year	83% (12-mo avg)	26	21
Jan	73%	23	18
Feb	74%	23	19
Mar	67%	21	17
Apr	76%	23	19
May	85%	26	21
Jun	86%	26	21
Jul	100%	31	25
Aug	100%	31	25
Sep	96%	30	24
Oct	89%	28	22
Nov	75%	23	19
Dec	73%	23	18
Jan-Mar	72% (3-mo avg)	23	18
Apr-Jun	82% (3-mo avg)	25	20
Jul-Sep	98% (3-mo avg)	30	25
Aug-Oct	95% (3-mo avg)	30	24
Oct-Dec	79% (3-mo avg)	25	19

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[12] Percentages rounded to nearest percent. Maximum monthly monitored consumptive use at SSES 1987-2009 occurred July 2000.

[13] The amounts in this column are the product of the maximum (peak day) consumptive use applied for with SRBC (48 cfs) and the respective SSES percentages in the column to the left, rounded to nearest cfs. These amounts are extremely conservative and include sufficient allowance for in-river evaporation due to the thermal discharge.

[14] The amounts in this column are the product of the maximum monthly consumptive use at BBNPP simulated from long-term Wilkes-Barre meteorological data (24.8 mgd in July 1955) and the respective SSES percentages in the second column to the left, rounded to nearest mgd. These amounts are conservative and include sufficient allowance for in-river evaporation due to the thermal discharge.

PPL Bell Bend expects to derive refined monthly and seasonal estimates of consumptive use in response to SRBC's March 1, 2010 letter. If such values appear to differ sufficiently from the above to potentially make a difference in this study and are available in timely fashion, then the above values will be replaced with the refined values.

The variation in maximum average SSES consumptive uses for each month of the year, as determined from records for SSES since 1987, represent typical variation of consumptive use throughout the year based on actual nuclear power plant operation. The month-to-month variation of these values (shown as percentages in the table above) was used to determine the "A" and "B" monthly consumptive uses.

5.2. PASS-BY FLOW AND CONSUMPTIVE USE MAKE-UP ALTERNATIVES

This study will include analysis of the benefits of different levels of passby flows and different levels of consumptive use makeup. Selected alternative passby flows up to 20% ADF may be analyzed; passby flows will be assumed to be in place year-round. Selected alternative consumptive use makeup scenarios may be analyzed up to 100% makeup. Application of assumed consumptive use makeup does not presume knowledge or assurance of any particular source of makeup. The number and range of passby and consumptive use makeup alternatives to be evaluated will depend on the scale of impacts defined in initial study analyses. Also, depending on the scale of habitat and water quality impacts identified in this study, PPL Bell Bend may include a sensitivity analysis of the effect of Cowanesque and Whitney Point releases that pass SSES and BBNPP during low flow conditions.

6. *AQUATIC HABITAT MODELING USING IFIM*

6.1. *OVERVIEW OF INSTREAM FLOW INCREMENTAL METHODOLOGY*

The Instream Flow Incremental Methodology (IFIM), developed by the U.S. Fish and Wildlife Service, is commonly used to determine the effects of water management practices on aquatic habitat within a specific reach of a stream. IFIM is based on the premise that stream-dwelling organisms prefer a certain range of depths, velocities, substrates, and cover types, depending on the species and life stage, and that the availability of these preferred habitat conditions varies with stream flow. This method is designed to quantify potential physical habitat available for each species and life stage of interest at various levels of stream discharge, using a series of computer programs, namely Physical Habitat Simulation or PHABSIM (Bovee 1982).

A natural stream contains a complex mosaic of physical features. One area, such as a riffle, may be shallow and fast-moving over a substrate of cobble and gravel and no cover while another area, such as a pool, may be deep and slow-moving over a substrate of silt, with a large root wad along the shore (Bovee 2004). One species life stage may find the riffle desirable while another species may prefer the pool; a third species may not prefer either. These different habitat types (e.g., pools, riffles, runs, and glides) are known as mesohabitats.

A fish species or life stage prefers a particular mesohabitat type because its microhabitat characteristics of depth, velocity, substrate, and cover are generally within its preferred range. Preferred velocity, depth, and substrate/cover for selected target species and life stages are expressed in an IFIM analysis in the form of habitat suitability curves in which the optimum range of a particular microhabitat variable is assigned a weighting factor of 1, and the least suitable range a weighting factor of 0. The weighting factors on the Y-axis (0 to 1) are used as input to each value on the X-axis in a series of programs within the Physical Habitat Simulation Model (PHABSIM) model.

PHABSIM is a one-dimensional computational method, comprised of a suite of programs used in an IFIM analysis. PHABSIM consists of three components: (1) channel structure; (2) hydraulic simulation; and, (3) habitat suitability criteria. Channel structure includes all fixed-channel features that generally do not change with discharge. These include channel cross-sectional geometry, substrate composition and distribution, and structural cover. Hydraulic variables are those that change with discharge, such as water surface elevations, depth velocities, wetted perimeter, and channel surface area.

In PHABSIM, habitat mapping through field studies is used to characterize and categorize the types of habitats (e.g., pools, runs, and riffles) in a river. Habitat mapping quantifies the amount and distribution of each habitat type. Results of habitat mapping are used in PHABSIM to select and weight each transect in proportion to the occurrence of that habitat type in the study reach.

Field measurements of microhabitat variables (depth, velocity, substrate, and cover) are collected at numerous points across the channel and at a number of locations along the length of the river.

These locations represent all the different habitat types found in the reach of river being studied. Hydraulic measurements are taken at each location at low to high flow conditions of interest. Once calibrated to the flows measured in the field, PHABSIM can predict habitat availability at flows other than those measured. The output of the habitat simulation is Weighted Usable Area (WUA) for a range of simulated stream discharges (Figure 6-1).

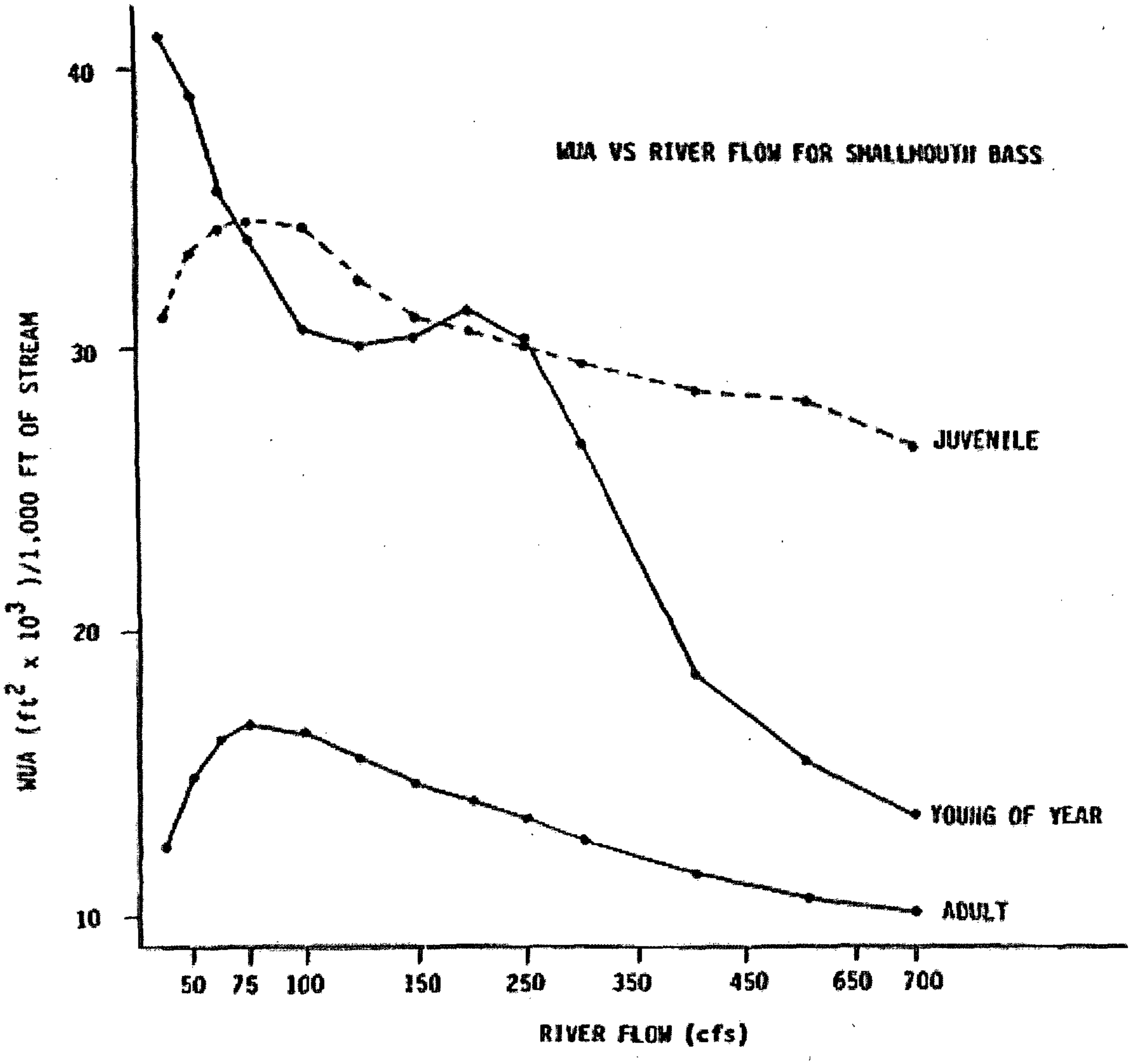

Figure 6-1 Example relationship between aquatic habitat expressed as Weighted Usable Area (WUA) over a range of river flows

Source: RMC (1992)

There are several methods to analyze the impact of flow alterations on aquatic habitat. These include habitat duration curves (see example reproduced in Figure 6-2 from Bovee 1982) in various time steps (monthly, weekly, annual, etc.), and habitat impact analysis, using the difference in WUA between any two flow schemes at a given river flow (Denslinger *et al.* 1988), among others. Water managers or regulatory agencies can then use this data analysis to determine whether the level of impact is "acceptable", and/or whether mitigation is required.

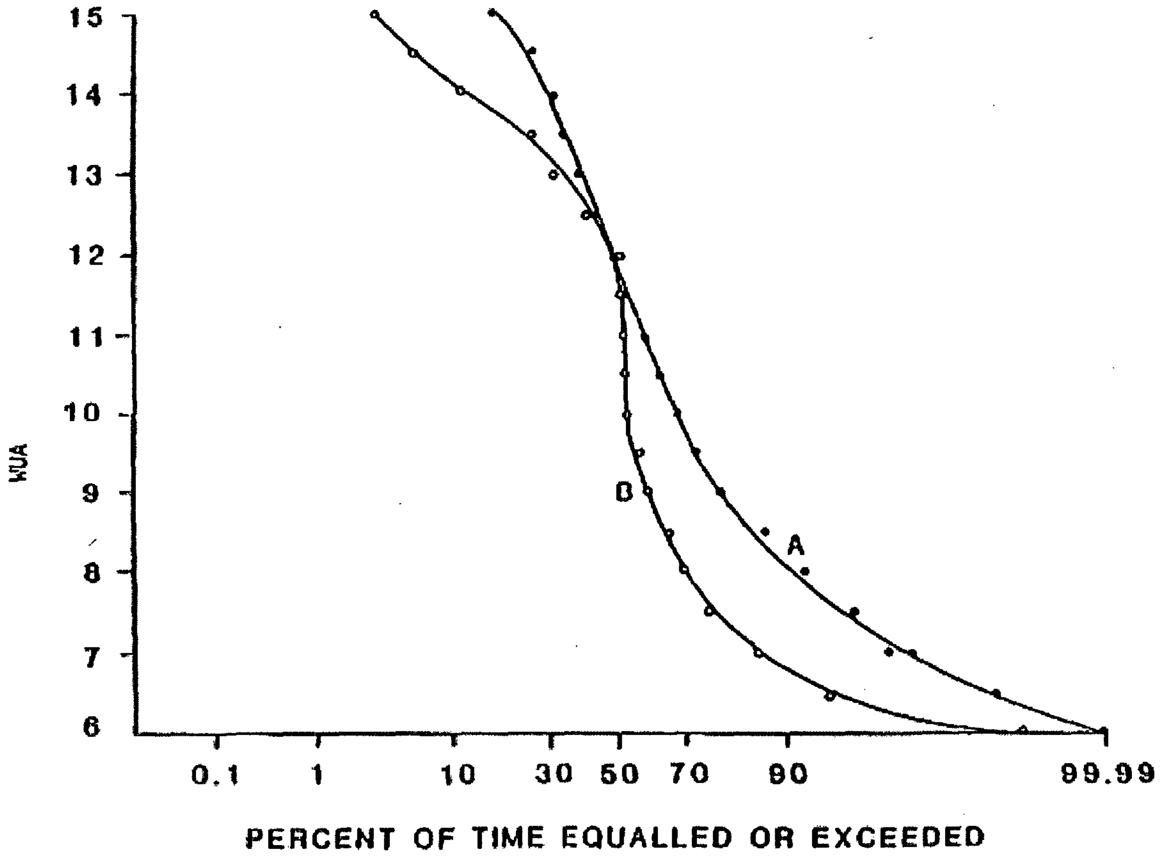

Figure 6-2 Example comparison of habitat expressed as Weighted Usable Area (WUA) duration curves for two flow schemes ("A" and "B")

Source: Bovee (1982)

A schematic of the sequence for the application of IFIM methodology is given in Figure 6-3.

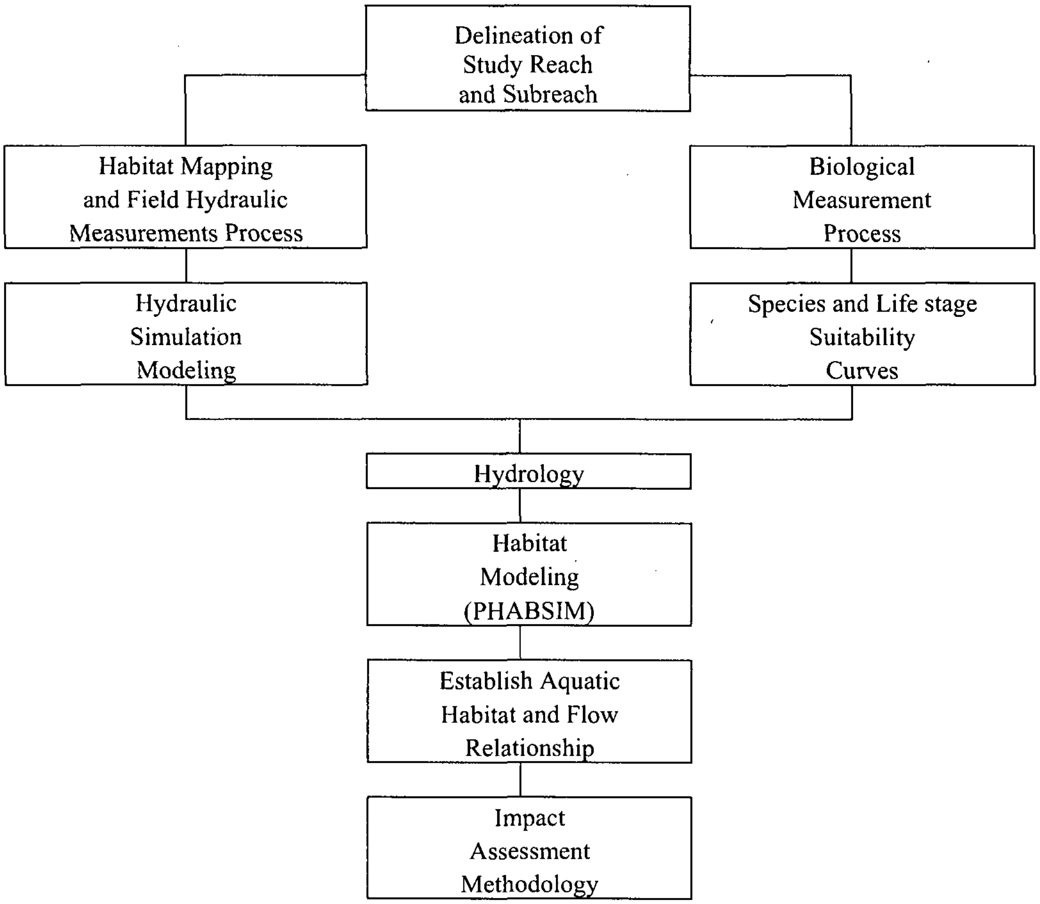

Figure 6-3 Generalized IFIM sequence

Modeling of impacts for the aquatic habitat study reach will follow the generalized IFIM procedure described above. This generalized IFIM procedure will use the mesohabitat mapping method for transect placement and WUA estimation and the PHABSIM hydraulic models that were used in the work described in SRBC Publication 191 (Denslinger, et al. 1998). The specific steps are described below.

6.2. Evaluation Species, Life Stages, and Habitat Suitability Curves

This study will develop incremental relationships between aquatic habitat and river flow for species of special concern (American shad, smallmouth bass, yellow lampmussel, and green floater) and for habitat-based species guilds. These relationships will be used to compare aquatic habitat available at a range of Susquehanna River flows with and without the BBNPP consumptive use, and under the assumption of different levels of consumptive use make-up and passby flow.

6.2.1. Use of Habitat-Based Guilds

The PHABSIM component of the IFIM provides a widely used tool for explicitly analyzing habitat availability for fishes and other biota as a function of flow regimes through the use of species-specific habitat suitability criteria or curve (HSC). To facilitate decision making, such analyses are typically conducted only for a limited suite of evaluation species and life stages. Thus, the selection of appropriate HSC of the targeted species and life stages is typically an important determinant of the results of IFIM studies (Aadland 1993; Bowen *et al.* 1998). However, in species-rich communities typically inhabiting warmwater streams, decision making using species-specific models is more difficult (Bowen *et al.* 1998).

One method for reducing the complexity of habitat requirements for a species-rich community and to overcome the above limitation is to aggregate species into habitat "guilds" (defined as a group of species that exploit the same class of environmental resources in a similar way).

Several IFIM studies (*e.g.*, Bowen *et al.* 1998; Normandeau Associates 2000; Progress Energy 2004; DTA 2005) have utilized the habitat-based guilds approach to show variation in aquatic habitat of organisms as a function of flow. Normandeau (2000) utilized this approach for the warm-water fish community inhabiting the Clarion River, PA, with the concurrence of the Pennsylvania Fish & Boat Commission.

Leonard and Orth (1988) and Aadland (1993) identified four primary habitat-use guilds as follows into which each species and life stage can be classified:

- Shallow-fast habitat (< 2 ft depth, > 1 ft/sec velocity) guild;
- Shallow-slow (< 2 ft depth, < 1 ft/sec) guild;
- Deep-fast (> 2 ft depth, > 1 ft/sec) ; and,
- Deep-slow (> 2 ft depth, < 1 ft/sec).

The first step in implementing the habitat-based guild approach is to assemble a complete list of species collected in the study area. For the present study, this was accomplished from a long-term sampling program performed by Ecology III, which documents the species composition and abundance of fishes (from1971 to present) and macroinvertebrates (1980 to 1994; 2007 and 2008) in the vicinity of the BBNPP. In this study, macroinvertebrates are categorized into the following ecological functional feeding groups: predator, collector/gatherer, filterer/collector, scraper, and shredder. Appendix B provides a list of species collected in the area of the proposed BBNPP. Table 6-1 shows the seasonal occurrence of species/taxa that comprised ≥ 0.5% of the catch; also shown in this table are the macroinvertebrate feeding functional groups.

Table 6-1 Seasonal occurrence of species taxa

Source: Ecology III (2008): Blue shaded rectangles represent the season occurrence of species/ taxa that comprised ≥ 0.5% of catch near the proposed BBNPP intake downriver to the Berwick-Nescopeck Bridge.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
American shad												
Spawning							■	■	■			
Juvenile							■	■	■			
Adults					■	■						
Gizzard shad												
Spawning						■	■					
Larval						■	■					
Juvenile	■	■	■	■	■	■	■	■	■	■	■	■
Adults	■	■	■	■	■	■	■	■	■	■	■	■
Brown trout[15]												
Spawning												
Larval												
Juvenile												
Adults	■	■	■	■							■	■
Muskellunge												
Spawning				■	■							
Larval				■	■	■						
Juvenile	■	■	■	■	■	■	■	■	■	■	■	■
Adults	■	■	■	■	■	■	■	■	■	■	■	■
Common carp												
Spawning					■	■						
Larval					■	■	■					
Juvenile	■	■	■	■	■	■	■	■	■	■	■	■
Adults	■	■	■	■	■	■	■	■	■	■	■	■
River chub												
Spawning					■	■						
Larval					■	■						
Juvenile	■	■	■	■	■	■	■	■	■	■	■	■
Adults	■	■	■	■	■	■	■	■	■	■	■	■

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[15] Presence results from tributary stream stocking by various groups.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Fall fish												
Spawning												
Larval												
Juvenile												
Adults												
Longnose dace												
Spawning												
Larval												
Juvenile												
Adults												
Blacknose dace												
Spawning												
Larval												
Juvenile												
Adults												
Quillback												
Spawning												
Larval												
Juvenile												
Adults												
White sucker												
Spawning												
Larval												
Juvenile												
Adults												
Northern hogsucker												
Spawning												
Larval												
Juvenile												
Adults												
Shorthead redhorse												
Spawning												
Larval												
Juvenile												
Adults												

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Yellow bullhead												
Spawning					■	■						
Larval					■	■	■					
Juvenile												
Adults												
Channel catfish												
Spawning					■	■						
Larval					■	■	■					
Juvenile								■	■	■	■	■
Adults	■	■	■	■	■	■	■	■	■	■	■	■
Spotfin shiner												
Spawning					■	■	■					
Larval						■	■	■	■			
Juvenile										■	■	■
Adults	■	■	■	■	■	■	■	■	■	■	■	■
Spottail shiner												
Spawning					■	■	■					
Larval						■	■	■				
Juvenile	■	■	■	■	■	■	■	■	■	■	■	■
Adults	■	■	■	■	■	■	■	■	■	■	■	■
Bluntnose minnow												
Spawning					■	■						
Larval					■	■	■					
Juvenile	■	■	■	■	■	■	■	■	■	■	■	■
Adults	■	■	■	■	■	■	■	■	■	■	■	■
Green sunfish												
Spawning					■	■						
Larval					■	■	■					
Juvenile	■	■	■	■	■	■	■	■	■	■	■	■
Adults	■	■	■	■	■	■	■	■	■	■	■	■
Pumpkinseed												
Spawning					■	■						
Larval					■	■	■					
Juvenile	■	■	■	■	■	■	■	■	■	■	■	■
Adults	■	■	■	■	■	■	■	■	■	■	■	■

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Bluegill												
Spawning					■	■						
Larval					■	■	■					
Juvenile	■	■	■	■	■	■	■	■	■	■	■	■
Adults	■	■	■	■	■	■	■	■	■	■	■	■
Smallmouth bass[16]												
Spawning					■	■						
Larval						■	■					
Juvenile								■	■	■	■	■
Adults	■	■	■	■	■	■	■	■	■	■	■	■
Tessellated darter												
Spawning					■	■						
Larval					■	■						
Juvenile	■	■	■	■	■	■	■	■	■	■	■	■
Adults	■	■	■	■	■	■	■	■	■	■	■	■
Walleye												
Spawning			■	■								
Larval				■	■	■	■					
Juvenile								■	■	■	■	■
Adults	■	■	■	■	■	■	■	■	■	■	■	■

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[16] Species of special concern.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Yellow lampmussel[17]												
Spawning/larval			■	■	■							
Adults	■	■	■	■	■	■	■	■	■	■	■	■
Green floater[18]												
Spawning/larval			■	■	■							
Adults	■	■	■	■	■	■	■	■	■	■	■	■
Eastern elliptio												
Spawning/larval							■	■	■			
Adults	■	■	■	■	■	■	■	■	■	■	■	■
Fingernail clams												
Spawning/larval	■	■	■	■	■	■	■	■	■	■	■	■
Adults	■	■	■	■	■	■	■	■	■	■	■	■
Macroinvertebrates[19]												
Predator	■	■	■	■	■	■	■	■	■	■	■	■
Collector/gatherer	■	■	■	■	■	■	■	■	■	■	■	■
Filterer/collector	■	■	■	■	■	■	■	■	■	■	■	■
Scraper	■	■	■	■	■	■	■	■	■	■	■	■
Shredder	■	■	■	■	■	■	■	■	■	■	■	■

Table 6-2 shows assignments of the listed species and their life stages to the four primary habitat guilds. The following sources of literature were used to make these assignments for the Bell Bend flow assessment study: Aadland (1993); Bowen *et al.* (1998); Normandeau (2000); Entrix (2004 for Progress Energy); and, DTA (2005).

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[17] Species of special concern.

[18] Species of special concern.

[19] Source for categorizing into functional feeding groups: PADEP.

Table 6-2 Species and habitat guild assignments

Sources: Aadland (1993); Bowen et al. (1998); Normandeau (2000); Entrix (2004; for Progress Energy); DTA (2005). A = Adult, J = Juvenile, S = Spawning.

	Habitat Guild			
Species	Shallow-slow (< 2 ft, < 1 ft/s)	Shallow-fast (< 2 ft, > 1 ft/s)	Deep-slow (> 2 ft, < 1 ft/s)	Deep-fast (> 2 ft, > 1 ft/s)
American eel	J		J, A	
American shad[20]				A, J, S
Gizzard shad	A, J		A, J, S	
Cisco[21]				A, J
Rainbow trout[22]		S		A, J
Brown trout[23]		S		A, J
Northern pike			A, S, J	A, S, J
Muskellunge			A, S, J	
Chain pickerel			A, S, J	
Tiger muskie			A, S, J	
Central stoneroller	S, A, J	A, J, S		
Common carp	J, S		A, J, S	
Cutlips minnow			J	A, S
River chub		S, A, J		
Golden shiner	J, S		A	
Comely shiner	J, S	S, A		
Common shiner	J, S	S, A		
Spottail shiner	A, J	S	A, J	
Swallowtail shiner			A, J	S
Spotfin shiner	A, J	S	A, J	
Bluntnose minnow	A, J, S			
Blacknose dace		S, J, A		
Longnose dace	A, J, S			
Creek chub	A	S	A, J	
Fallfish	A	S	A, J	

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[20] Species of special concern. American shad not present now; juveniles produced from transplanted adults from Connecticut River in 1981 were captured in electrofishing samples by Ecology III.

[21] Likely escapees from Harvey's Lake.

[22] Stocked rainbow trout washed downstream.

[23] Stocked brown trout washed downstream.

	Habitat Guild			
Species	**Shallow-slow (< 2 ft, < 1 ft/s)**	**Shallow-fast (< 2 ft, > 1 ft/s)**	**Deep-slow (> 2 ft, < 1 ft/s)**	**Deep-fast (> 2 ft, > 1 ft/s)**
Quillback		S	A	S, J
White sucker		S	J	A
Northern hogsucker		S	S	A, J
Shorthead redhorse	J	S	A	A
White catfish			A, J, S	
Yellow bullhead			A, J, S	
Brown bullhead			A, S, J	
Channel catfish			A, S, J	
Margined madtom		A, S, J		
Banded killfish	A, S, J			
Striped bass X white bass hybrid				A, J
Rock bass	J, S		A, J, S	
Redbreast sunfish	J, S		A, J, S	
Green sunfish	J, S		A, J, S	
Pumpkinseed	J, S		A, J, S	
Bluegill	J, S		A, J, S	
Smallmouth bass[24]	S, J		A	
Largemouth bass	J, S		A, J, S	
White crappie	A, J, S		A, J	
Black crappie			A, J, S	
Tessellated darter	A, J	S	A	
Banded darter	J	S, A		
Yellow perch			A, J, S	
Shield darter	J	S, A		
Walleye			A, J, S	
Mottled sculpin	A, J		A, J	
Macroinvertebrates[25]				
Predator				
Agnetina		✓		✓
Neoperla		✓		✓
Tricladida	✓		✓	
Collector/gatherer				

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[24] Species of special concern.

[25] Source for categorizing into functional feeding groups: PADEP.

	Habitat Guild			
Species	Shallow-slow (< 2 ft, < 1 ft/s)	Shallow-fast (< 2 ft, > 1 ft/s)	Deep-slow (> 2 ft, < 1 ft/s)	Deep-fast (> 2 ft, > 1 ft/s)
Caenis	✓		✓	
Tricorythodes	✓		✓	
Chironimidae	✓		✓	
Filterer/collector				
Musculium	✓	✓	✓	✓
Cheumatopsyche		✓		✓
Corbicula	✓	✓	✓	✓
Scraper				
Physa	✓		✓	
Stenelmis		✓		✓
Stennema		✓		✓
Protoptila		✓		✓
Shredder				
Lepidostoma	✓	✓	✓	✓
Mussels[26]				
Yellow lampmussel[27]	✓	✓	✓	✓
Green floater[28]	✓	✓	✓	✓
Eastern elliptio	✓	✓	✓	✓
Fingernail clams	✓	✓	✓	✓

Although all the species either known to occur or expected to occur in the study area are listed in Table 6-1 and Table 6-2, the following species are of special concern. The effects of consumptive use will be assessed for each of these individually.

These are:

- American shad: though not currently present in the area, they are targeted for restoration to the upper Susquehanna River; juveniles of Connecticut River adult shad transplanted in the area were captured during electrofishing;
- Smallmouth bass: young smallmouth bass have been recently reported to have succumbed to bacterial affliction (*Flavobacterium columnare*); low nighttime DO and elevated water temperature were suspected to predispose stressed fish to bacterial infection (Chaplin *et al.* 2009); and,

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[26] Species of special concern.

[27] Species of special concern.

[28] Species of special concern.

- Green floater and yellow lampmussels: species are imperiled in Pennsylvania.

As has been the practice in virtually all the recent IFIM studies involving flow assessment for warm-water aquatic communities (RMC 1992; Normandeau Associates 2000; Progress Energy 2004; DTA 2005; Payne Associates and Louis Berger 2007) literature-based habitat suitability indices are proposed for use in the Bell Bend flow study. These indices are shown in Appendix D. With each successive IFIM study much practical and professional experience has been gained in usage of these indices. Consequently, many of these indices have been modified since the 1980s; modification of habitat suitability indices is done in close consultation with the resource agencies. As an example, smallmouth bass habitat suitability curves were modified in consultation with resource agencies for an IFIM study conducted by RMC (1992) in Pigeon River, NC because additional information had become available since the initial suitability curves were published by Edwards *et al.* (1983) for this species.

Table 6-3 provides literature sources used for habitat suitability curves for species of special concern and for each habitat-based guild for the Bell Bend study. However, these curves may be modified based upon: (a) consultation and recommendation of the resource agencies, and (b) field sampling (electrofishing) of the four primary habitat-guilds (Table 6-2). The electrofishing effort is discussed further in Section 9.1.

Table 6-3 Sources of habitat suitability curves

Sources for species of special concern and habitat-based guilds; see footnotes for their usage in IFIM studies.

Species of Special Concern	
American shad	
Adult	Stier and Crance (1985)
Spawning	Stier and Crance (1985)
Juvenile	Ross *et al.* (1993); observations from Susquehanna River during sampling
Fry	Stier and Crance (1985)
Smallmouth bass[29]	
Adult	RMC (1987, 1992); Angermeir (1987); Ross *et al.* (1987); Todd and Rabeni (1989); North Carolina Dept. of Water Resources
Spawning	RMC (1987, 1992); North Carolina Dept. of Water Resources
Juvenile	RMC (1987, 1992); North Carolina Dept. of Water Resources; USFWS File #A0051
Fry	RMC (1987, 1992); North Carolina Dept. of Water Resources

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[29] Original habitat suitability curves for smallmouth bass (Edwards et al. 1983; FWS/OBS-82/10.36) were modified in consultation with NCDWR for IFIM study in Pigeon River, NC (RMC 1992).

Yellow lampmussel	Normandeau (2008); Normandeau numerous surveys
Green floater	Normandeau (2008); Normandeau numerous surveys
Habitat-based guilds[30]	
Shallow-slow (< 2 ft, < 1 ft/sec)	Leonard and Orth (1988); Aadland (1993); Normandeau (2000); DTA (2005)
Shallow-fast (< 2 ft, > 1 ft/sec)	Aadland (1993); Normandeau (2000); DTA (2005)
Deep-slow (> 2 ft, < 1 ft/sec)	Aadland (1993); Normandeau (2000); DTA (2005)
Deep-fast (> 2 ft, > 1 ft/sec)	Aadland (1993); Normandeau (2000); DTA (2005)

6.3. HABITAT REPRESENTATION AND TRANSECT SELECTION

Development of a relationship between suitable aquatic habitat and river flow for selected species and life stages within the IFIM/PHABSIM framework depends on the measurement or estimation of physical habitat parameters (depth, velocity, substrate/cover) within the study reach. Generally, the lateral and longitudinal distribution of the values of these parameters at given river flows are determined at points along transect lines across the stream channel, positioned to account for spatial and flow-related variability. A variety of hydraulic modeling techniques can be used to estimate water depth and velocity as a function of river flow; substrate and cover values are generally fixed at a given point. With physical habitat thus characterized for a range of river flows, the suitability of the habitat (for a particular species and life stage) at each point is scaled from zero to one, usually by multiplying together the corresponding suitability values for depth, velocity, and substrate from the appropriate HSC curves. These point estimates of suitability are then used to weight the physical area of the study represented by each point, and the weighted areas are accumulated for the entire study reach to produce the index of useable habitat (WUA) as a function of river flow for each species and life stage.

The physical area represented by each transect point depends on the design of the PHABSIM study. On smaller streams, it may be possible to place transects and points in such proximity that the entire physical study reach is covered by rectangular "cells" centered on each point, such that the physical parameters of depth, velocity, substrate, and cover are relatively uniform throughout the cell, and the total physical area of all cells equals the area of the entire study reach, or at least a "representative reach" within the study area. On larger and more complex waterways, this approach is impractical. This study will use the mesohabitat typing, or habitat mapping, approach originally described by Morhardt *et al.* (1983) and summarized by Bovee *et al.* (1998). In this design, mesohabitats (broadly defined habitat generalizations) are mapped over the entire study reach, such that each area of the waterway is characterized by a general habitat type, and the total length and proportion of the study reach assigned to each mesohabitat type is determined.

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[30] Habitat-based guilds developed by Leonard and Orth (1988) and Aadland (1993); utilized in IFIM studies by Normandeau Associates (2000); DTA (2005); Progress Energy (2003)

Physical habitat parameters (river flow dependent depth and velocity, substrate, and cover) representative of each mesohabitat type are measured or modeled at one or more transects placed within the mesohabitat area. The exact number and placement of transects depends on the lateral and longitudinal variability of physical habitat within a mesohabitat type for the study reach, as well as practical issues such as accessibility. Generally, the total number of transects will be distributed among mesohabitat types in proportion to the area of the study reach assigned to each mesohabitat. The physical area represented by each transect point is then determined by both the lateral distribution of points on a transect, and the length or proportion of the study reach that each transect is presumed to represent.

An initial boat-based site visit in early September 2009, when the prevailing river flow was approximately 3,400 cfs, provided information for the classification of the major mesohabitat types within the study area. Figure 6-4 shows the four major mesohabitat types found: pool, run-glide, riffle, and narrow channel. The four mesohabitats are described in Table 6-4. Transects will be strategically placed in each mesohabitat type to both represent the proportion of each habitat type in the study area, and to reflect the variability within the habitat type.

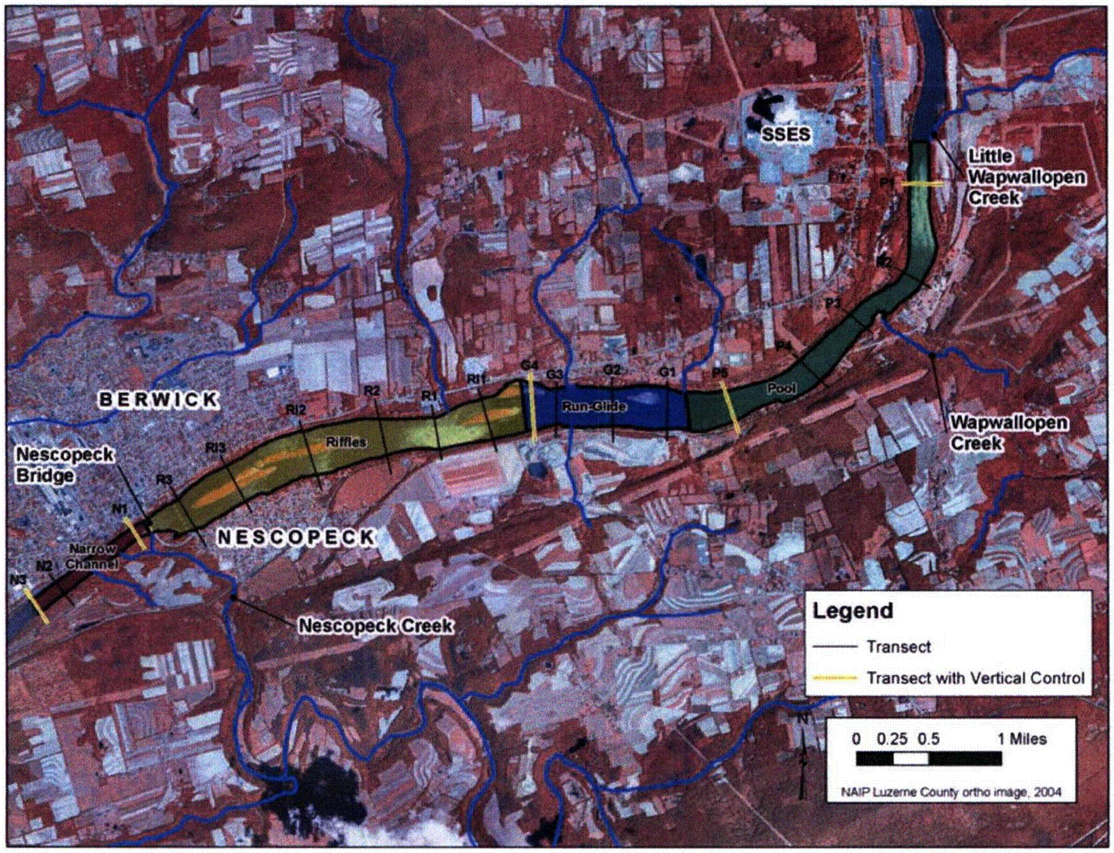

Figure 6-4 The four major mesohabitat types in the aquatic habitat study reach

Table 6-4 Mesohabitat types for the Susquehanna River near the BBNPP

Mesohabitat Type	Description
Pool	Deep, slow water with turbulent flow (if present) only near the head. Retains standing water as discharge approaches zero.
Run/Glide	Shallow, fast water with smooth or laminar flow and little or no exposed substrates. Common in tailouts of deeper pools or interspersed with runs. Also referred to as flatwater or smooth run.
Riffle	Shallow with gravel, cobble, or boulder hydraulic control, fast water with turbulent flow. Possible exposed substrate, usually boulder.
Narrow Channel	Deep, fast water with turbulent flow and infrequent exposure of bedrock, boulders, or coarse substrate.

Figure 6-4 also shows an initial placement of habitat transects, based on available information from the site visit, existing streambed profiles (ERM 2008; Sutron Corp. 1985), and aerial photography (Pennsylvania Spatial Data Access website; Google Earth). Five transects (P1 to P5) are placed within the "pool" habitat type, to reflect variation in channel width and curvature. Four transects (G1 to G4) are placed within the "run/glide" habitat type, including one to represent the island and back channel at the lower end of that section. In the "riffle" habitat type, three transects (R1 to R3) are placed in the single-channel areas, again reflecting variation in stream width and depth, and another three (RI1 to RI3) are placed to represent the split-channel areas created by islands. A final two transects (N1, N2) are placed in the "narrow channel" area downstream of Nescopeck Creek. These 17 proposed transects should be adequate to characterize the physical habitat variability found within the study reach (Payne *et al.* 2004). The final number and exact placement of these transects are subject to revision as additional information on channel morphology, substrates, and flow patterns becomes available from early on-site reconnaissance, bathymetric survey data (see the section on "Alternate Hydraulic Model" later in this study plan), and multi-dimensional modeling of the entire study reach.

The habitat transects placed within each mesohabitat type define locations where microhabitat variables (depth, velocity, substrate, and cover) will be measured or estimated. The total distance by length of each mesohabitat type will determine the amount of river channel to be represented by each transect. Any proposed changes to transect locations will be discussed with the SRBC and cooperating agencies for concurrence prior to planned field measurements.

6.4. PHABSIM HYDRAULIC MODEL

This section of the study plan describes the application and use of the PHABSIM hydraulic model for the IFIM assessment.

6.4.1. Hydraulic Data Collection

Field data collection and data recording will generally follow the guidelines established in the field techniques manuals (Trihey and Wegner 1981; Milhous *et al.* 1984; Bovee 1997). Additional useful quality control checks from previous applications of the simulation models will be included.

Implementation of PHABSIM, IFIM's aquatic habitat assessment component, requires velocity and depth measurements at three flow rates to establish stage-discharge curves at each of the habitat transects. The measurements need to be taken at a range of Susquehanna River flows that encompass the flows of interest. The limit of reliable extrapolation is 40% of the lowest of the three flow measurements and 250% of the highest flow measured (Payne and Bremm 2003). As an example, to obtain reliable depth and velocity estimates for a low flow value of 800 cfs, measurements at Susquehanna River flows no higher than 2,000 cfs would be required.

Data collection will target flows of approximately 2000 cfs, 5000 cfs, and 10,000 cfs. These targets will permit data extrapolation to flows as low as 7Q10, and as high as approximately 25,000 cfs. Based on historical flows at Wilkes-Barre, the highest target flow will likely only occur in the spring, while the lowest flow at or near 2000 cfs is likely to occur in the August to September period. In any event, field measurements will be scheduled at the earliest available opportunity.

Although there is a good chance that observed Susquehanna River flows in the range needed for use of PHABSIM will occur in the next year, this study plan has a provision to accommodate the possibility that a suitable low flow event does not occur or cannot be measured in 2010. An alternate hydraulic modeling approach that is less dependent on capturing a low or high flow event is described in Section 6.5.

6.4.2. Velocity and Depth Measurements

Techniques for measuring discharge have evolved in recent years with the advent of Acoustic Doppler Current Profilers (ADCP's). The USGS has been using ADCP's in making stream flow measurements (depths and velocities) since 1985. Simply stated, ADCP's use sound energy to measure water velocity and depth and thereby compute stream flow. The use of ADCP's has increased steadily with manned boats used extensively on large rivers. With the addition of smaller units, tethered small boat platforms and improved software, ADCP's can be used to measure almost any size stream or channel.

Data acquisition will be made with a TRD Instruments Rio Grande ADCP. The ADCP can gather both depth and velocity information in user defined steps across a transect. The ADCP unit will be encased in an Ocean Science riverboat trimaran or mounted directly to the survey vessel and operated either direct cabled or with a radio modem. The operator views data in real-time through a connection between the ADCP and a laptop computer.

The ADCP only accurately measures to depths greater than approximately one foot. Edge cell measurements will be obtained by wading to complete the velocity and depth patterns in shallow areas for each transect, or in areas where the boat and ADCP cannot be successfully deployed. Electromagnetic Marsh-McBirney or mechanical Price AA flow meters, attached to top-set rods will be used for velocity measurements. Mean column velocity will be determined by a single measurement at six-tenths of the water depth in depths less than 2.5 feet, and derived from a two-tenths and eight-tenths measurement for depths between 2.5 feet and 4.0 feet. All three points (two-, six- and eight-tenths) will be measured where depths exceed 4.0 feet, or the velocity distribution in the water column is abnormal, and one or two points is not adequate to derive an accurate mean column water velocity. Depths in shallow areas will be measured with marked rods.

6.4.3. Split Channel Partitioning

Islands and split channels can be problematic utilizing transect based, 1-D modeling due to the partitioning of flow through multiple channels. At varying flow levels different proportions of the total flow may pass through a given channel depending on upstream and downstream hydraulic controls. For island study sites, discharge will be measured at all calibration flows in each channel. This allows for accurate flow allocation at the measured flows and the ability to compute flow splits at interpolated and extrapolated flows of interest. All island study site transect clusters will be surveyed to a common bench mark. In addition, control bottom profiles will be established in the event alternative modeling techniques should be necessary to determine flow split allocation.

6.4.4. Quality Control

To assure QA/QC of field data for the Bell Bend Project instream flow study, the following procedures and protocols will be used:

- Staff gauges will be established and continually monitored throughout the course of collecting data at each study site. Significant changes in gauge readings will be recorded, and if necessary, additional water surface elevation data will be taken.

- An independent benchmark will be established for each transect or set of transects. The benchmark will be an immovable tree, boulder, or other naturally occurring object that will not be subject to tampering, vandalism, or movement. Headpins and tailpins will consist of either rebar or spikes, depending on bank topography and substrate composition. Upon establishment of headpin and tailpin elevations, a level loop will be shot to check the auto-level for measurement accuracy. Allowable error tolerances on level loops will be set at 0.02 feet. This tolerance is also applicable to both headpin and tailpin measurements except where extenuating circumstances (pins under sloped banks, shots through dense foliage, etc.) explain discrepancies. All elevation surveying will be done using a Zeiss Ni 30 or Sokkia B-20 auto-level and telescoping Sokkia fiberglass stadia rods.

- Water surface elevations will be measured on both banks on each transect. If possible, on more complex and uneven transects such as riffles, water surface elevations will be measured at multiple locations across a transect. An attempt will be made to measure water surface elevations at each calibration flow at the same location (station or distance from pin) across each transect. Water-surface elevation measurements will be obtained by placing the bottom of the rod at the water surface until a meniscus formed at the base or selecting a stable area next to the water's edge.

- Pin elevations and water surface elevations will be calculated during field measurement and compared to previous measurements. Changes in stage since the previous flow measurement will be calculated. Patterns of stage change will be compared between transects and determined if reasonable. If any discrepancies are discovered, potential sources of error will be explored and noted. Calculated discharges will be compared between transects at the same flow to confirm accuracy.

- For areas where velocity measurements will be obtained by wading, high-quality current velocity meters will be used. Electromagnetic Marsh-McBirney meters will be calibrated prior to mobilization and monitored continually for errors or discrepancies during data collection. Mechanical Price AA meters will be inspected and spin tested daily. Pivot pins will be replaced if significant wear is noted and pin clearances adjusted if a meter fails to pass the calibration spin test. Meters will be continually monitored during the daily course of data collection to ensure that they function properly.

- Photographs will be taken of all transects at the three calibration flows. An attempt will be made to take each photograph from the same location at each of the three flows. These photographs provide a valuable record of the streamflow conditions (including velocity and depth), water surface levels, and channel configurations that can be used for confirmation during the hydraulic model calibration.

6.4.5. Hydraulic Model

PHABSIM was originally developed and maintained by the U.S. Fish and Wildlife Service Instream Flow Group (now U.S. Geological Service, Aquatic Systems and Technology Application Group, Fort Collins Science Center). PHABSIM calculates a habitat index (WUA) in part based on simulation of river depths and velocities from 1-D hydraulic models that represent the river by cross-sections. For 1-D applications in this study, the hydraulic and habitat index simulations will be derived from the computer program RHABSIM (Riverine Habitat Simulation). RHABSIM is software developed by Thomas R. Payne & Associates (TRPA) that implements the equivalent algorithms of PHABSIM. RHABSIM is an enhancement of many of the original PHABSIM model's component programs with greatly expanded input, output, graphic, error-checking, calibration, and interpretation capabilities. Although RHABSIM will be the specific form of the PHABSIM software used for the Bell Bend study, the terms as used in this study plan are interchangeable.

The ADCP uses its own proprietary software (WinRiverII, TRD Instruments) for velocity and depth data acquisition and playback. Because the ADCP collects water velocities and depths throughout the water column at relatively short intervals, it will be necessary to synthesize and condense the output into a form usable by PHABSIM software. For this task TRPA has developed an ADCP conversion program which allows a user to interactively view bottom profiles and velocity as a function of depth and establish stationing which can be directly entered into the hydraulic model module.

6.4.6. Stage-Discharge Calibration

Stage-discharge relationships for most 1-D transects are developed from measured discharge and water surface elevations using either an empirical log/log formula (IFG-4) or a channel conveyance method (MANSQ). Under these methods each transect is treated independently. The IFG-4 method requires a minimum of three sets of stage-discharge measurements and an estimate of stage-at-zero-flow (SZF) for each transect. The quality of the stage-discharge relationships will be evaluated by examination of mean error and slope output from the model. MANSQ only requires a single stage-discharge pair and utilizes Manning's equation to determine a stage-discharge relationship (Bovee and Milhous 1978). However, it is generally validated by additional stage-discharge measurements. In situations where irregular channel features occur on a cross section, for instance bars or terraces, MANSQ is often better at predicting higher stages than log/log. MANSQ is most often used on riffle or run transects and is not suitable for transects which have backwater effects from downstream controls, such as pools. It can also be useful as a test and verification of log/log relationships.

For transect(s) that cannot be adequately calibrated using the above techniques, a step-backwater (WSP) method will be employed. WSP requires a downstream hydraulic control and preferably an upstream control. WSP simulates water surfaces longitudinally along the stream channel using slope and roughness as calibration variables. All transects used to compute WSP stage-discharge must be linked to a common elevation and distances between cross sections must be known. Only a single stage-discharge pair is required, though multiple pairs assist in validating calibration.

Stage-discharge calibration of split channels can be made in two ways: 1) by combining the two channels, or 2) calibrating each channel as a separate component. Combining channels is accomplished either by averaging water surface elevations and bed elevations for both channels, or by raising or lowering elevations in one channel to match the second channel. This method is most effective when the difference in bed elevation and WSE between the two channels is relatively small, and flow partitioning is not necessary. It is also important that the resulting rating curve does not change the overall depth and velocity simulations at lower or higher flows for the individual channels.

6.4.7. Velocity Calibration

A one-dimensional model represents a stream by means of vertical slices (transects) across the channel. Depths are simulated with the rise and fall of a single, level (in most cases) water surface. The preferred method for simulating water velocities is the "one-flow" option. This technique uses a single set of measured velocities to predict individual cell velocities over a range of flows. Simulated velocities will be based on measured data and a relationship between a fixed roughness coefficient (Manning's n) and depth. In some cases roughness is modified for individual cells if substantial velocity errors are noted at simulation flows. Velocity Adjustment Factors (VAF's), the degree in which measured velocity and discharge is adjusted to simulate velocity and discharge, are an indication of the quality of hydraulic simulations. These are examined to detect any significant deviations and to determine if velocities remain consistent with stage and total discharge. VAF's in the range of 0.8 to 1.2 at the calibration (measured) flow are considered acceptable.

In instances where an adequate velocity simulation cannot be obtained, based on examination of VAF's or unrealistic simulated velocities, other methods may be employed. One technique termed the 'no velocity' or 'depth' method uses a single Manning's n value applied to all cell verticals to calculate velocities. In addition, limits can be placed on the maximum or minimum Manning's n. Other methods that may be employed include "variable roughness coefficients" and "velocity distribution factors" which allow for roughness to vary with depth and discharge.

6.5. ALTERNATE HYDRAULIC MODEL

Hydraulic modeling is essential to the application of the Instream Flow Incremental Methodology (IFIM) because water depths and velocities under varied flow conditions are important components of habitat suitability. As noted in Section 6.4, PHABSIM incorporates several techniques for determining water depths and velocities along each habitat transect over a range of stream flows. Each of these techniques is dependent on measurements at flow rates that envelope the range of flows of interest. Section 6.4.1 notes that there is a good chance that Susquehanna River flow rates that occur in 2010 will allow use of the hydraulic model component of PHABSIM, specifically the technique that estimates velocities by establishing a stage-discharge at each habitat transect. However, suitable flow events may not occur in 2010; in anticipation of that possibility, this study plan also proposes to simulate depths and velocities with a numerical, hydrodynamic model. This alternate hydraulic model will be calibrated to observations and will provide depths and velocities for the habitat analyses if these parameters cannot be measured over a suitable flow range. Use of the model will therefore increase the likelihood of being able to simulate accurately flows as low as the 7Q10 flow.

There are a number of advantages to an alternate hydraulic modeling effort. Because a hydrodynamic model uses bathymetric data throughout the study reach, it will be capable of providing depth and velocity information at any location in the study reach. This capability will help ensure that the selected habitat transects are representative of the entire study reach. To determine if the selected habitat transects are representative, a comparison of depths and velocities at locations within the study reach to depths and velocities at the selected habitat transects will be made.

The alternate modeling will also be used to address the effects of flow reduction on the distribution of AMD-influenced water from Nescopeck Creek in the Susquehanna River, if multi-dimensional modeling is required to address this concern (See Section 7).

6.5.1. Choice of Alternate Hydraulic Model

There are a number of numerical hydrodynamic models available for application to the physical habitat study reach. For this study, the requirements for the model are as follows:

- The model must be a fundamentally-based hydrodynamic and transport numerical calculation
- It must have a fate and transport capability to address the AMD-related issues;
- The model formulation should include a three-dimensional framework to represent longitudinal and lateral depths and vertical velocities;

- The model source code must be available to allow for application-specific modifications; and,
- The model must have a track record of riverine applications demonstrating successful application to pool, run-glide, and riffle reaches.

Two candidate models that meet all criteria are GEMSS® (Generalized Environmental Modeling System for Surfacewaters) and EFDC (Environmental Fluid Dynamics Code), each of which is a three-dimensional, time-varying finite difference model. GEMSS was used in the Susquehanna River pool to compute the distribution of heat from the BBNPP cooling tower blowdown and is described in ERM (2008). Both models have been applied to riverine cases, but EFDC has had more applications for river reaches with significant bottom slope. For this reason EFDC is preferred for application to the run-glide reach.

GEMSS has a comprehensive, GIS-enabled user interface and includes pre- and post-processors adept at analyzing field data and visualizing model results. The GEMSS user interface will be used for pre- and post-processing EFDC model input and output.

6.5.2. Data for the Alternate Hydraulic Model

Three-dimensional hydrodynamic and transport model applications require two types of data: (1) spatial data, primarily the water body shoreline and bathymetry, but also the locations, elevations, and configurations of man-made structures and (2) temporal data, that is, time-varying boundary condition data defining inflow rates and temperatures, inflow constituent concentrations, outflow rates, and meteorological data. The time-varying data can be used for either stochastic or deterministic simulations. For this study, the model will use steady-state values of the Susquehanna River, tributary, and BBNPP flows; temperatures; constituent concentrations; and, meteorological data.

For input to the model, the spatial data are typically encoded in two input files: the control and bathymetry files. The information in these files is geo-referenced. The temporal data are encoded in many files, each file representing a set of boundary conditions, for example, meteorological data for surface heat exchange and wind shear, or inflow rates for a tributary stream.

To provide the bathymetric data for the alternate hydraulic model, a vertically controlled bathymetric survey will be performed. The survey will be done by a bathymetric contractor, assisted by a Professional Land Surveyor (PLS). The vertical control will be provided at key transects; the beginning of the pool and the transitions between the pool, the run-glide and the riffle areas, and downstream at the end of the Nescopeck reach. The latter location will provide the downstream hydraulic control for the model to enable the calculation of the water surface. These locations are noted in Figure 6-4. The PLS will establish vertical control for each water level recorder, and the bathymetric contractor will provide depths measured from a boat and from the shore. The water level readings during the survey will then be used to convert water depths to elevations. Elevations are important because the model is based on absolute bathymetric and water surface elevations, not depths as in the stage-discharge relationships established independently for each transect in the PHABSIM approach described earlier.

The bathymetric survey will cover the pool from above the SSES intake. A second survey will be completed if the Nescopeck AMD survey indicates that modeling significantly below the Nescopeck confluence is required.

6.5.3. Alternate Hydraulic Model Application Procedure

The bathymetric data and shoreline will be used to build a geo-referenced, three-dimensional grid with a horizontal spatial resolution of sufficient detail to address the issues being modeled. Locations and dimensions of all natural and man-made features are then mapped onto this grid. These features include the BBNPP and SSES intake and discharge structures, bridge piers, islands and tributaries (e.g., the Nescopeck Creek confluence).

Following building of the spatial grid, the model will be tested for consistency, accuracy, and performance prior to calibration. The alternate hydraulic model will be calibrated with information from three sources:

- the Sutron (1985) report, which also presents the results of a time-of-travel dye study;
- the PHABSIM depth and velocity datasets; and,
- the depth and velocity dataset collected by the bathymetric contractor.

The model will be calibrated to generally accepted standards, which consist of primarily of graphical comparisons of time series of computed and observed data. The calibration procedure generally focuses on correctness of boundary conditions and their representation in the model and on adjustment of parameters such as bottom roughness.

6.6. HABITAT IMPACT ANALYSIS

Regardless of which hydraulic model is used to provide flow-related depth and velocity estimates to PHABSIM, the product of the habitat simulation will be a series of Weighted Usable Area (WUA) vs. river flow relationships for each guild or species and life stage to be considered. WUA is the building block upon which all other habitat analyses depend. Habitat vs. flow relationships are the quantitative estimates of the amount of suitable habitat available for each guild or species and life stage over the simulated range of natural river flows. WUA is usually expressed as square feet per 1000 feet of stream length.

This information will be synthesized to quantify and assess the impact of the requested consumptive use on suitable habitat availability. Since the absolute estimates of WUA can be expected to vary widely between species and life stages, the WUA vs. flow relationships will be "normalized," or scaled as a proportion of the maximum WUA value from each curve, so that habitat for all guilds, species, and life stages will be expressed on a comparable zero-to-one scale of normalized WUA (nWUA). This procedure casts all further discussion of habitat in terms of a proportion to the "best available" habitat over the simulated range of river flows. If the analysis indicates a need to reduce the complexity of dealing with multiple guilds and important individual species, several nWUA vs. flow relationships can be combined, using the procedure outlined in Denslinger, *et al.* (1998). This results in a Re-normalized Minimum Weighted Usable Area (RMWUA), which again puts all the WUA data on a comparable scale (zero to one), and also reflects the relative habitat availability for the most habitat-limited species or life stage in the combined group at each level of the river flow axis.

The first step in the analysis process will be to use the WUA (or nWUA or RMWUA) vs. flow relationships and the long-term hydrologic record for the Susquehanna River at the BBNPP site (represented by the Wilkes-Barre gage daily flow values, April 1899 through March 2010) to generate habitat time-series, and subsequently, habitat duration curves, for each species and life stage. These time-series will estimate, in a manner similar to the flow duration curves, the probability, or proportion of time, that a given level of habitat will be equaled or exceeded, with natural river flows, during the time frame under consideration (monthly, seasonally, annually). Similar curves will be developed based on the natural river flows adjusted to reflect the proposed consumptive use. Comparison of habitat duration curves for natural flows and adjusted flows will demonstrate the impact of the project on habitat availability. Depending on the impacts identified, passby flows ranging from 0% to 20% ADF, and consumptive use make-up ranging from 0% to 100% will be evaluated.

In discussing habitat impact analysis, SRBC Publication 191 (Denslinger, *et al.* 1998) defines "impact" as "the percentage difference between habitat available without the withdrawal and habitat available with the withdrawal in place." This approach speaks more directly to the question of how BBNPP consumptive use will affect available habitat at a range of river flows, and will allow consideration of whether the level of impact is acceptable or not. In this analysis, the change in habitat (WUA or RMWUA) resulting from the consumptive use will be expressed both as an area and as a percentage of available habitat, over a range of natural river flows.

"Change in habitat" for a given species, life stage, or combination, is essentially the difference, on the habitat axis, between two identical WUA vs. flow curves which are offset on the flow axis by an amount equal to the consumptive use. That is, for any given river flow entering the study reach, the habitat available in the presence of a consumptive use would be the same as the habitat provided by a lower un-impacted river flow. The absolute change in WUA due to the consumptive use is compared, as a percentage, to the level of WUA that would be provided at the natural river flow (Figure 6-5).

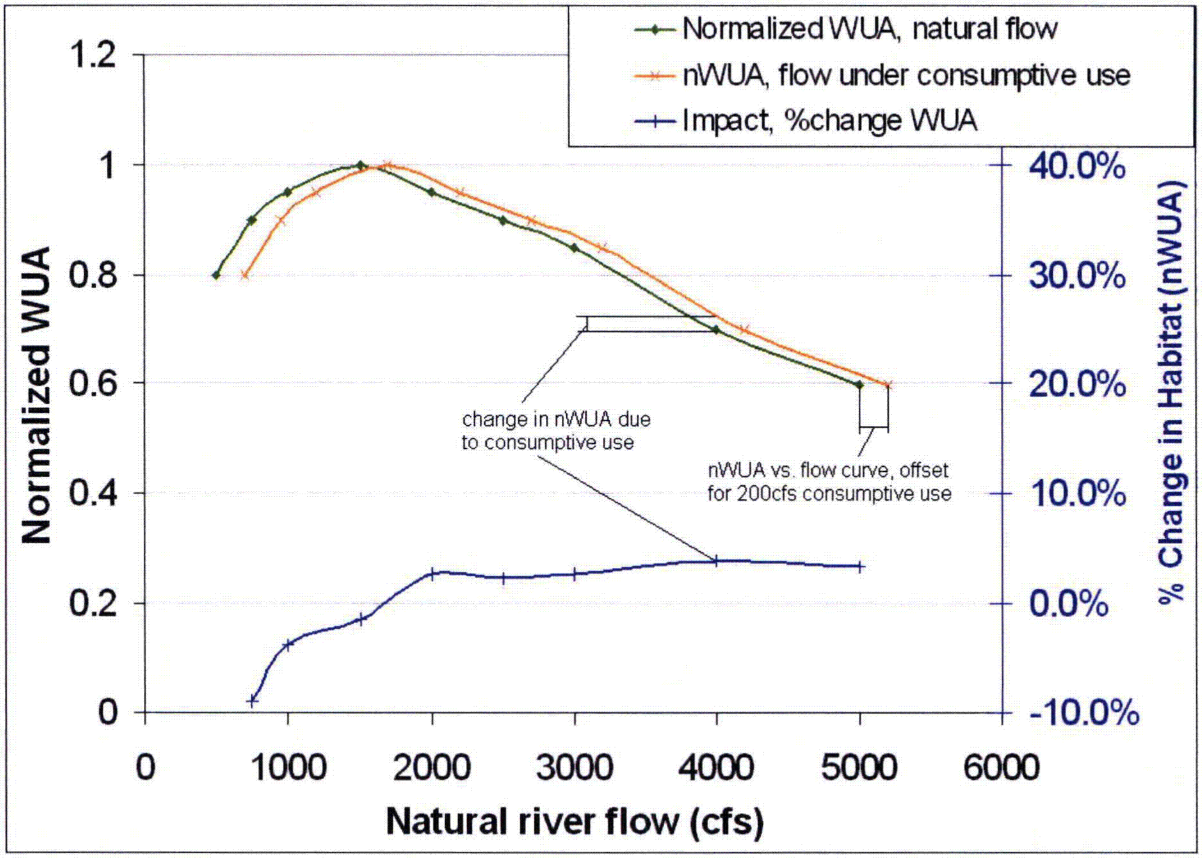

Figure 6-5 An example of habitat impact analysis, based on a hypothetical normalized WUA vs. river flow curve.

The curve at natural river flow is offset to the right to simulate a 200 cfs consumptive use; that is, the available habitat at a given natural flow under a consumptive use is the same as the available habitat at a natural flow 200 cfs lower. The vertical distance between the curves represents the change in habitat (positive or negative) due to the consumptive use at a given natural flow. This change is then expressed as either an area or a percent of the habitat available at the natural flow, resulting in the relationship of habitat impact to flow.

This calculation can also be expressed in equation form. Given:

WUA(q) = relationship of usable habitat to flow (per species, lifestage, guild, etc)

I = impact: % difference between habitat with flow alteration and habitat without flow alteration

CU = consumptive use

CU(q) = flow-related consumptive use (e.g., with passby limit in effect)

then the habitat impact % at a given (natural) flow q is:

$$I(q) = (WUA(q-CU(q)) - WUA(q)) / WUA(q)$$

The resulting relationship of "percent change in habitat" (or alternately, "change in habitat area") vs. flow can be examined directly to evaluate the habitat impacts, positive or negative, of a consumptive use at different river flows. Habitat impacts calculated with varying levels of passby flow and for different levels of net consumptive use will allow evaluation and comparison of different mitigation efforts, such as addition of "make up" water to the river. An analysis of this type is shown in Figure 6-6

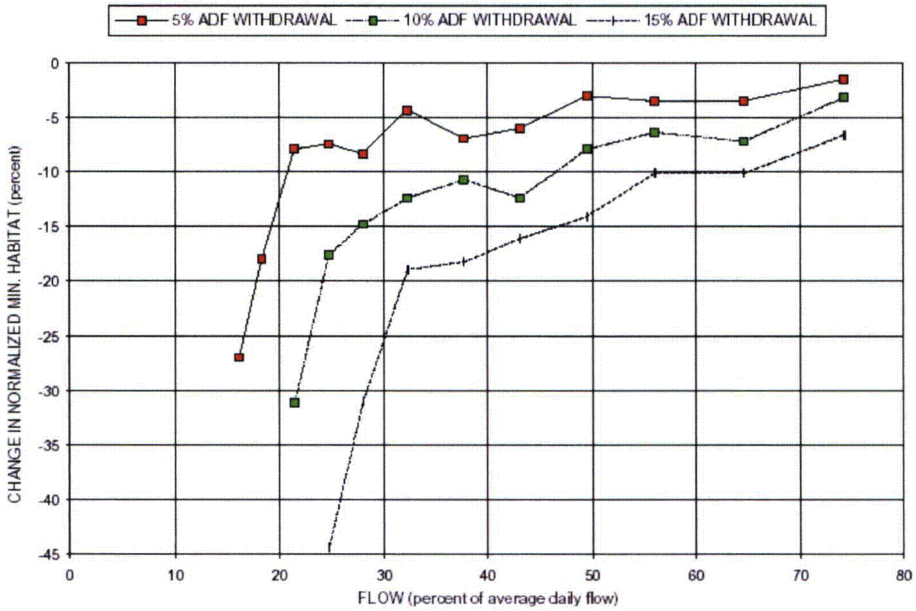

Figure 6-6 An example of habitat impact vs. river flow relationships for alternative water management schemes

Source: SRBC Pub.191 Figure 6.17. Habitat Change and Flow for Selected Withdrawals for Bear Run, Union County, Brook Trout, Summer Season

The impact vs. flow relationships can also be converted into "habitat impact duration curves" for various time periods (monthly, seasonally, annually) to further examine the overall expected impact of the consumptive use alone or to show the improvement potentially afforded by different passby flows or amounts of consumptive use makeup. Figure 6-7 is an example of how habitat impact duration curves might illustrate the expected impact of a hypothetical consumptive use with and without a passby flow. The duration analysis shows what percent of time (based on the historical flow record) a given percent change in usable habitat area can be expected to be equalled or exceeded in the positive (improvement) direction. Two or more water management alternatives can then be compared for both magnitude and duration of impact. The same management alternatives evaluated with habitat duration analysis will also be evaluated by habitat impact analysis. The same analysis can be performed using the absolute change in habitat area as well as the percent change.

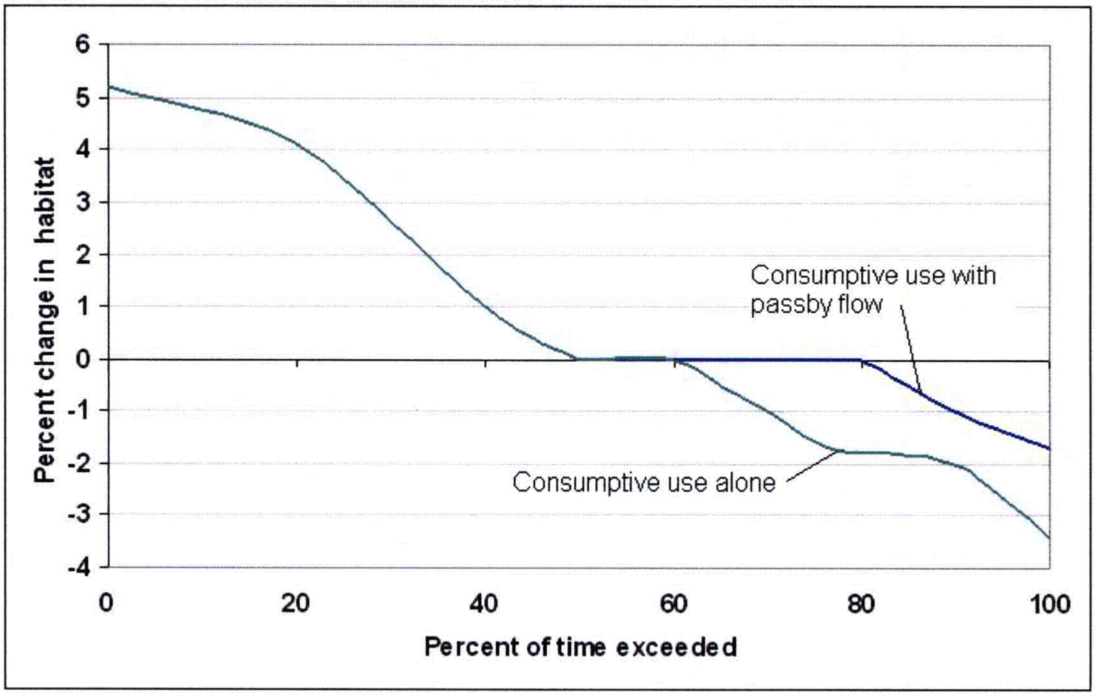

Figure 6-7 An example comparison of the impact of alternative water management schemes using impact duration analysis.

Habitat impact is expressed as percent change in habitat from a natural flow regime. Positive impact represents a net increase in habitat, and negative impact represents a net decrease in habitat. In this hypothetical example, a passby flow has no effect on the habitat impact of consumptive use about 60 % of the time, but there is an extended period of zero impact, when flows are below the passby level and no consumption is permitted.

7. *WATER QUALITY ASSESSMENT OF NESCOPECK AMD DISCHARGES*

This section of the study plan describes the analysis that will be undertaken to assess changes in AMD distribution in the Susquehanna River due to BBNPP consumptive use. The source of AMD is the Nescopeck Creek. Potential concerns are twofold:

> (1) that a decrease in Susquehanna River flow will decrease the rate of dilution of the AMD component of the Nescopeck Creek and consequently impact downstream users; and,
>
> (2) that a decrease in Susquehanna River flow will increase the size of the Nescopeck Creek AMD plume in the immediate vicinity of its confluence with the Susquehanna and that an increase in plume size may decrease habitat because of exclusion of aquatic organisms from low pH areas.

These two concerns will be assessed using a combination of field data collection, mass balance calculations and, if warranted, numerical modeling.

Anecdotal field observations by Ecology III staff (Brian Mangan, personal communication) have suggested that under low flow conditions such as those that occurred in the summer of 2005, the influence of the Nescopeck Creek could be seen a few miles downstream of the Berwick-Nescopeck Bridge.

The initial extent of the study reach for this assessment is from the Nescopeck Creek 13 miles downstream to the Fishing Creek in Bloomsburg (Figure 4-1). The expectation is that complete mixing of the Nescopeck Creek and Susquehanna River will occur within this reach for all combinations of Nescopeck Creek and Susquehanna River flow rates. The final extent of the study reach will be determined from an analysis of pH field data. Because the point of complete mixing is a function of the flow rates in the Nescopeck Creek and Susquehanna River the surveys will be conducted over a range of flows.

7.1. *FIELD DATA COLLECTION*

To quantify the extent of the AMD-influenced plume, a field study will be conducted during the summer of 2010. The intent is to obtain data over a range of flows with emphasis on low flow events. Initially, surveys will be scheduled to occur weekly beginning in June 2010 and continuing through the fall. The sampling frequency will be increased to twice a week if river flows are low (e.g., < 1,500cfs) and pH measurements taken during the preceding surveys are lower than the PA Chapter 93 criterion of 6-9 units. Likewise, the sampling frequency will be decreased if the river flows are sustained at higher levels and pH measurements are > 6 units.

Measurements of pH, alkalinity, temperature, and conductivity will be used to map the longitudinal and lateral extent of AMD downstream of the Nescopeck Creek in a step-wise manner. At the onset of the mapping study, three locations (near-shore on each side of the river and one at the mid-point) on transects spaced approximately 1 mi apart will be sampled for pH, temperature, and conductivity once a week; this spacing will form a large grid which can be subdivided further to more accurately define the extent of the AMD influence.

Concurrent with the field surveys, pH, alkalinity, temperature, and conductivity will be measured in the Susquehanna River upstream of the Nescopeck Creek confluence and in the Nescopeck Creek itself, upstream of any influence of the Susquehanna River.

7.2. PROPOSED ANALYSIS

The survey results will be mapped and contoured to show the spatial extent of the Nescopeck AMD plume for each of the surveys described above. This GIS-based mapping will be used (1) to locate the point of complete mixing as a function of Susquehanna River flow and (2) to identify the exclusion area based on the PA Chapter 93 pH criterion. Numerical modeling of the plume with the alternate hydraulic model may be undertaken to support an understanding of the mixing process as flow rates change.

A mass balance calculation will be performed using the concurrently collected Susquehanna River and Nescopeck Creek pH, alkalinity, temperature, and conductivity data to estimate the fully-mixed value for comparison to the transect data. Additional mass balance calculations will be made using the historical water quality data noted in Section 3.2.1 and Section 3.2. Potential exceedance of water quality standards based on fully-mixed values will be used to assess effects on downstream users. For users upstream of the fully-mixed location, specific impacts from changes in the AMD plume will be assessed against individual user needs with respect to water quality.

For AMD-plume size, additional habitat excluded (if any) under consumptive use will be compared to available habitat within the study reach to determine the overall significance of the additional excluded habitat. If pH values are equal to or greater than 6 and less than 9, the habitat can be considered suitable for all species/life stages.

8. ASSESSMENT OF COOLING TOWER BLOWDOWN IMPACTS

This section describes the analysis that will be undertaken to assess the potential impacts of increases in river water temperature and subsequent reductions of dissolved oxygen (DO) due to the BBNPP cooling tower blowdown discharge.

Increases in river water temperature have been quantified in a prior assessment of the effects of the BBNPP, as noted in Section 3.2.3. The proposed analysis expands that assessment to include seasonal Susquehanna River flow rates that conform to the range of flows adopted for the analysis (Section 5).

The prior analysis showed that temperature rise from the cooling blowdown (the "thermal plume") will be virtually undetectable at the end of the pool on which the SSES and BBNPP intake and discharge structures are located (ERM 2008). Because the cases to be evaluated for this study include more combinations of flow and temperature than presented previously, a reassessment of the study reach will be made. The reassessment is expected to confirm that the study reach is confined to the Pool. However, if an analysis of the potential biological impacts of very low temperatures rise indicate that an extension of the study reach is necessary, the CORMIX and GEMSS models used previously and the alternate hydraulic model developed specifically for the present study can be used to map the full extent of the thermal plume and define the appropriate extend of the study reach.

Assuming that the study reach is confined to the pool, the GEMSS model will be used to simulate combinations of blowdown flows and temperatures and Susquehanna River flows and temperature. These combinations will consist of monthly mean and low Susquehanna River flows and peak Bell Bend blowdown rates with mean Susquehanna River temperatures and maximum blowdown temperatures. Therefore a total of 24 plume maps will be developed (12 months x 2 cases); the two cases being mean and low Susquehanna River flows. These plume maps will be similar to the diagrams shown in Figure 3-2 through Figure 3-5. In addition, plume dimensions will be quantified as surface and bottom areas (see Table 3-9 for an example). The area can be used to quantify regions of potential avoidance by aquatic organisms. Because the plume calculations are done using three-dimensional models and additional plume dimensions could be generated, e.g., volumes of or distances to excess temperature isotherms of interest.

The maps and tables will be used to estimate impact area which will be compared to the area of the entire study reach. If the study reach is extended as a result of considering additional flow and temperature combinations, the alternate hydraulic model, as discussed in Section 6.5, will be used downstream of the pool.

The proposed analysis will also address DO impacts of the cooling tower blowdown. The effects of temperature rise on DO will be presented as the reduction in saturation concentration corresponding to the temperature increase.

DO data collected for the backwater smallmouth bass assessment (Section 9.1 below) includes main channel continuous recording of DO and temperature at three stations, one of which is upstream of the SSES discharge and one of which is below the discharge. Comparison of data from these two stations will provide additional information on DO impacts from cooling tower blowdown at BBNPP.

9. WATER QUALITY ASSESSMENT OF BACKWATER AREAS USED BY JUVENILE SMALLMOUTH BASS

"Diseased" young smallmouth bass were observed by Ecology III staff biologists in the river during the summer of 2005, a period of low river flow and high water temperature (Brian Mangan, personal communication). The summer of 2005 was also the period when the Pennsylvania Fish & Boat Commission biologists first observed mortality of young smallmouth bass with lesions, but apparently not in the area near the BBNPP site. A recent report by Chaplin *et al.* (2009) postulated that sub-optimal dissolved oxygen (DO), particularly during the nighttime and in combination with relatively warm temperatures in habitats of young-of-the-year smallmouth bass, may have played a role in predisposing the fish to the bacterial infections. The bacterium (*Flavobacterium columnare*) is common in soil and water and causes secondary infections in stressed fish (PFBC 2005).

Microhabitats in which such sub-optimal DO and warm temperatures may occur are typically in side channels or backwaters and are characterized by relatively low velocities (<0.1 ft/sec) and shallow depths (<2 ft) compared to the main river channel. These microhabitats, occupied by young smallmouth bass, can be subject to wide fluctuations in DO and elevated water temperature. For illustrative purposes, an example photo of a backwater area in Broadhead Creek, East Stroudsburg, PA is provided as Figure 9-1; it shows a shallow, low velocity area away from the main river channel. A similar site-specific photo from the Susquehanna River is not readily available.

Figure 9-1 Example backwater area (Broadhead Creek, East Stroudsburg, PA)

Shallow areas are more susceptible to heating by solar radiation than the main channel of the Susquehanna River and also may show larger fluctuations in DO over a 24-hour period. Backwaters are relatively calm, shallow areas or channels around islands that are cut off from the dominant flow of a river, particularly in late spring and summer as seasonal low flow approaches. This period may coincide with fish rearing and nursery activities. Young bass utilizing these habitats during a sustained extreme low river flow may be subject to potentially stressful, low DO concentrations at night and elevated water temperature during the day.

9.1. FIELD DATA COLLECTION

A program of continuous monitoring of DO and water temperature in off-channel habitats, combined with weekly depth measurements and visual observations (hydrological conditions permitting) of potential smallmouth bass spawning areas along the shore lines will be conducted. The monitoring program will begin in May. If spawning activity is observed or emerging (black) fry are noted, the frequency of depth measurements and visual observations will be increased. These observations may also be used to adjust the locations of the continuous monitoring locations described below. In addition, observations of potential areas where mussels may be vulnerable to exposure will also be recorded.

To supplement the above data, periodic electrofishing surveys[31] will be conducted for two primary reasons: (a) to examine young smallmouth bass for symptoms of disease (e.g., lesions, open wounds/injury, etc.), particularly in August when the bacterial disease has been reported to be most prevalent, and (b) to use the resulting data, in consultation with the resource agencies, to determine whether any modifications to the proposed habitat suitability indices for use in the Bell Bend flow assessment study (Section 6.2.1) may be needed.

Continuous monitoring of DO and water temperature in representative backwater areas (upstream and downstream of the BBNPP intake) will be conducted from June 1 to July 31, 2010, a period likely to coincide with high water temperature and low nighttime DO values in shallow areas; historical records did not reveal presence of this type of data. This monitoring program will document whether stressful water quality conditions occur during the critical nursery and rearing times of young bass and the extent of these conditions. Figure 9-2 shows the proposed sampling locations for this monitoring study; these locations were selected for accessibility, ease of servicing, and representativeness of potential backwater habitat. An upstream location is selected to describe whether a natural gradient in water temperature and DO exists in the aquatic habitat impact study reach. The downstream locations will provide data in areas with the potential of having stressful water quality conditions for young fish.

As in the Chaplin *et al.* (2009) study, paired sondes will be deployed, one each in a backwater and a corresponding main channel location to monitor DO and water temperature. This pairing will be designed to document the extent of differences in water quality between main channel and backwater locations.

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[31] PFBC has offered to coordinate with PPL Bell Bend to perform smallmouth bass young-of-year electrofishing in the study area in August in order to determine the incidence of disease.

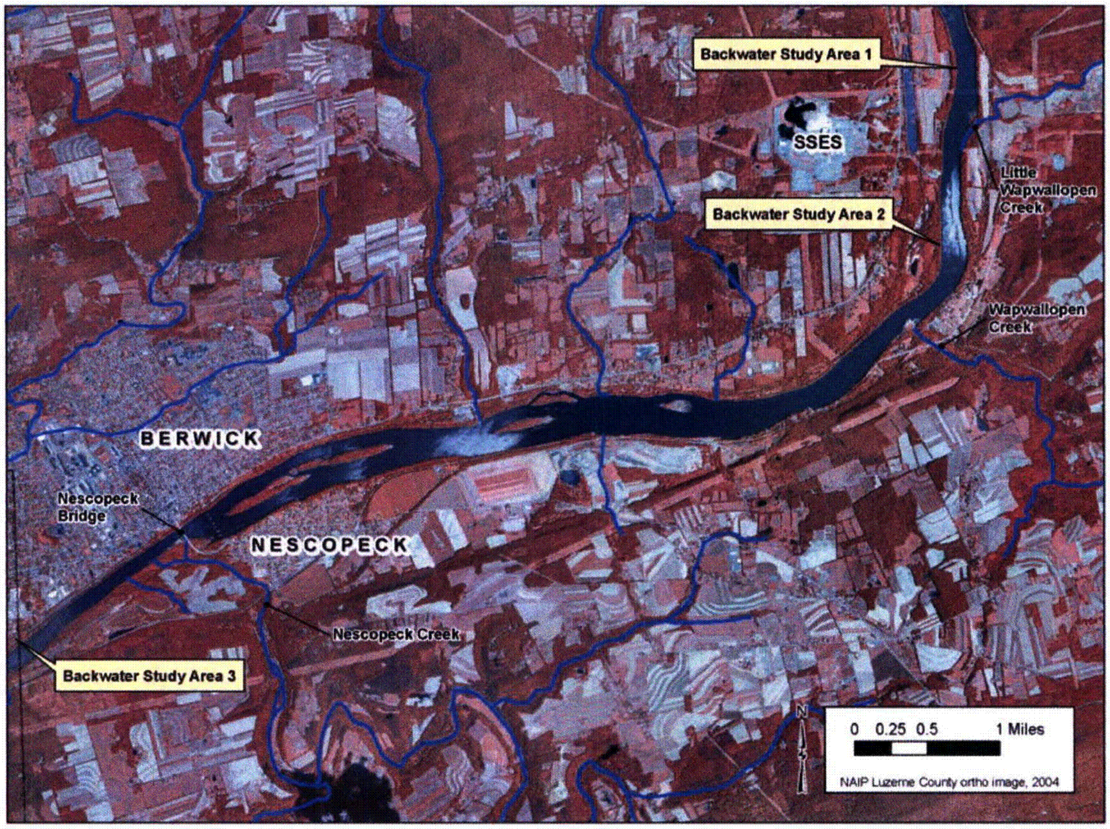

Figure 9-2 Location of backwater temperature and DO study areas

9.2. QA/QC OF SONDE PERFORMANCE

Meteorological and hydrological conditions permitting, the sondes will be serviced between three to seven days during the monitoring period to allow corrective action in a timely fashion. Should some continuous data collection be interrupted, manual measurements will be taken, particularly during nighttime low DO periods.

Performance of the sondes will be checked against a calibrated field DO and temperature meter according to the procedures developed by Ecology III. As in the Chaplin *et al.* (2009) study, freshly calibrated water quality meters will be positioned with the deployed sonde to collect side-by-side measurements of DO and water temperature. The deployed sonde will be cleaned and returned to the river and a second set of side-by-side readings will be recorded. Following these checks, the deployed sondes will be retrieved and the data downloaded to a field data logger. The recorded sonde measurements will be adjusted for any drifts between the two side-by-side readings.

9.3. PROPOSED DATA ANALYSIS

After QA/QC, the data from the monitoring program will be analyzed both qualitatively (for rapid detection of exceedances of PA instantaneous DO standard of 4.0 mg/l) and statistically (for precision) for each sampled location as follows:

- Generation of time series plots (June 1 to July 31 period of sampling) with a 4 mg/l DO (deemed as stressful for fish from the point of view of the PA Chapter 93 standard) as a reference line with uncertainty band of plus/minus 0.5 mg/l around it to show quickly the magnitude and frequency of stressful conditions at each location;

- Depiction of DO and temperature data as joint frequency probability occurrence to show what combinations and at which frequency stressful conditions occur;

- Performance of a regression analysis to establish predictive relationship between upstream and downstream locations with 90% confidence intervals (quantitative uncertainty bands); and,

- Performance of multivariate analysis of variance to detect differences between locations, time of day, and interaction between these two variables.

The data will also be used for comparison to calculations of the response temperature for these shallow backwater pools. These comparisons will provide information on the degree to which depth changes related to consumptive water use modifies the temperature and DO regime of the backwater pools. Response temperature is the temperature of a column of fully-mixed water would have if surface heat exchange were the only active heat transfer process (i.e., water temperature "responding" only to surface heat exchange). This approach will allow direct calculation of the temperature effects of depth changes in isolated pools. Subsequent DO change will be assessed by computing the change in saturation DO under the modified temperatures.

10. ASSESSMENT OF POTENTIAL IMPACTS ON DOWNSTREAM USERS

This section describes the analysis that will be undertaken to assess the potential impacts attributable to BBNPP consumptive water use on downstream water users. In this context, downstream users are those entities whose usage requires NPDES or SRBC withdrawal permits. The impacts may include reduced water availability, decreased river stage, or changed water quality.

The anticipated study reach for this assessment spans the Susquehanna River from the BBNPP intake to Danville. This study reach was established based on a preliminary inventory of downstream water users presented in Sections 3.1.4 and 3.2.4 and on the fact that appreciable flow enters the Susquehanna River below the BBNPP at the Nescopeck Creek and Fishing Creek confluences. The extent of the study reach will be confirmed during the course of this study.

10.1. DATA COLLECTION

The preliminary water user inventories will be confirmed at the outset of this study by examining records of NPDES permits and SRBC withdrawal permits and permit applications, and by performing a general field reconnaissance. The latter will consist of user and permittee interviews to determine the following:

- information on operations, including withdrawal and discharge rates, water sources and uses, critical users, seasonal and minimum Susquehanna River flow requirements, and drought contingency plans;
- the locations and dimensions of intake and discharge structures, including planned changes in capacity and structures;
- experience with drought; and,
- operational water quality requirements relative to Susquehanna River temperature, pH, and DO.

The Pennsylvania State Water Plan will be consulted to ascertain anticipated future water users within the study reach.

If flow-specific water quality issues are identified (e.g., mixing zone limitations), water quality surveys will be undertaken to identify potential impacts of reduced flow, water level and water quality. The design of the surveys will be based on information developed during the interviews.

10.2. ANALYSIS OF IMPACTS

Susquehanna River flow requirements for each user will be compared to the range of flows to be evaluated during this study to determine if operations at any of the withdrawers or dischargers will be impacted. Potential impacts will be identified and quantified to the extent possible, depending on the type of impact. Temperature and DO impacts quantified in Section 8 will be used in this downstream user assessment, as will the results of the AMD assessment discussed separately in Section 7.

11. REPORTING AND SCHEDULE

PPL Bell Bend intends to complete the necessary field studies during 2010 and to have a draft report available for review by the SRBC and cooperating agencies by the first quarter of 2011. This aggressive schedule requires that the IFIM hydraulic data collection survey program begin as soon as river conditions permit. The bathymetric survey supporting the alternate hydraulic modeling will be performed when river flows allow sufficient depth for the survey boat. All other field work will be performed in the spring through fall of 2010, with analysis proceeding as datasets become available. Analyses will be completed in late 2010.

Reporting and consultation milestones for implementation of the study plan are:

- Consultation with SRBC and cooperating agencies at key decision points (e.g., final delineation of the study reaches);
- Coordination with SRBC to allow SRBC and cooperating agencies to accompany PPL Bell Bend staff and consultants to site visits and field work;
- Presentation to the SRBC and cooperating agencies of the results of the field work and preliminary data analyses in the last quarter of 2010;
- Submission of the draft report and accompanying presentation to the SRBC and cooperating agencies in the first quarter of 2011 ; and,
- Submission of the final report to SRBC and cooperating agencies upon receipt and evaluation of SRBC comments. PPL Bell Bend will assume that SRBC's comments reflect comments from the cooperating agencies.

An electronic database will accompany the draft report. This database will provide all data sources used in the analysis, photographs from site visits, documentation of sampled locations with time and dates, and computer model inputs and outputs.

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APPENDICES

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DEEP-SLOW GUILD (> 2 FT DEPTH, < 1 FT/SEC VELOCITY)

DEEP-FAST GUILD (> 2 FT DEPTH, > 1 FT/SEC)

HABITAT SUITABILITY CURVES FOR SPECIES OF SPECIAL CONCERN:

SMALLMOUTH BASS

AMERICAN SHAD

GREEN FLOATER MUSSEL

YELLOW LAMPMUSSEL

APPENDIX A BACKGROUND DATA EXCERPTS

ECOLOGY III SAMPLE LOCATIONS

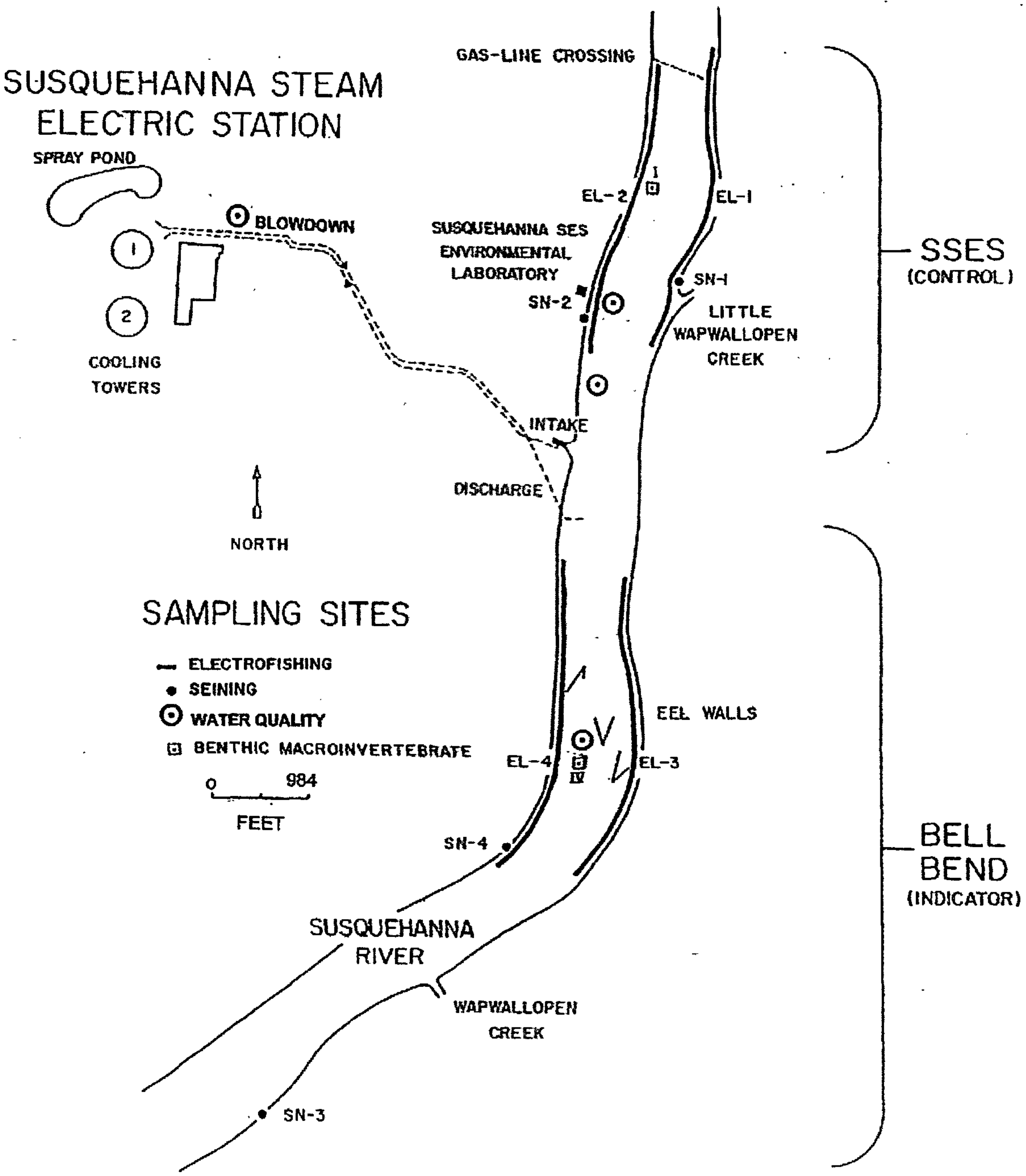

Fig. 1

Sampling sites for water quality, benthic macroinvertebrates, electrofishing (EL), and seining (SN) at SSES and Bell Bend on the Susquehanna River, 2008.

ECOLOGY III SUMMARY OF WATER QUALITY ANALYSIS **1972-2008**

Table A-3. Physicochemical parameters determined for each program in 1972

Parameters	Program				
	Daily	Diurnal	Simultaneous Diurnal	River Run	Extended River Run
Air temperature	X	X	X	X	X
Water temperature	X	X	X	X	X
Dissolved oxygen	X	X	X	X	X
pH	X	X	X	X	X
Total alkalinity				X	X
Sulfate	X	X	X	X	X
Specific conductance	X	X	X	X	X
Turbidity	X				
Beam transmission	X	X		X	
Irradiance	X	X		X	
Secchi disc depth	X	X		X	
Nonfiltrable residue	X	X	X	X	X
Fixed nonfiltrable residue	X	X	X	X	X
Total iron	X	X	X	X	X
Dissolved (filtrable) iron	X	X		X	X
Nitrate				X	X
Total phosphate				X	X
Chlorophyll a		X	X	X	X
Chlorophyll a (active)		X	X	X	X
Phaeo-pigment		X	X	X	X
Chlorophyll b		X	X	X	X
Chlorophyll c		X	X	X	X
Carotenoids		X		X	X
Total bacteria		X		X	
Total coliform		X		X	
Fecal coliform		X		X	
River level	X	X			
River discharge				X	
Barometer	X	X			
Weather	X	X	X	X	X

Table A-2. Physicochemical parameters determined for each program in 1973

	PROGRAM				
Parameters	Daily	Diurnal	Simultaneous Diurnal	River Run	Extended River Run
Air temperature	X	X	X	X	X
Water temperature	X	X	X	X	X
Dissolved oxygen	X	X	X	X	X
pH	X	X	X	X	X
Total alkalinity		X	X	X	X
Sulfate	X	X	X	X	X
Specific conductance	X	X	X	X	X
Turbidity	X	X	X	X	X
Secchi disc depth	X	X		X	
Nonfiltrable residue	X	X	X	X	X
Fixed nonfiltrable residue	X	X	X	X	X
Total iron	X	X	X	X	X
Dissolved (filtrable) iron	X	X	X	X	X
Nitrate		X	X	X	X
Total phosphate		X	X	X	X
Chlorophyll a		X	X	X	X
Chlorophyll a (active)		X	X	X	X
Phaeo-pigment		X	X	X	X
Chlorophyll b		X	X	X	X
Chlorophyll c		X	X	X	X
Carotenoids		X	X	X	X
Total coliform		X	X		
Fecal coliform		X	X		
Fecal streptococcus		X	X		
River current	X				
River level	X	X			
River discharge			X	X	
Barometer	X	X			
Weather	X	X	X	X	X

Table A-1. Physicochemical parameters determined for each program in 1974

Parameters	Program		
	Semiweekly	Diurnal	River Run
River level above msl	X	X	
River current	X		
River discharge	X		X
Air temperature	X	X	X
Water temperature	X	X	X
Dissolved oxygen	X	X	X
pH	X	X	X
Total alkalinity	X	X	X
Specific conductance	X	X	X
Sulfate	X	X	X
Total iron	X	X	X
Dissolved (filtrable) iron	X	X	X
Total residue	X	X	X
Fixed total residue	X	X	X
Nonfiltrable residue	X	X	X
Fixed nonfiltrable residue	X	X	X
Turbidity	X	X	X
Secchi disc depth	X	X	
Total soluble phosphate		X	X
Nitrate		X	X
Barometer	X	X	
Weather	X	X	X
Total coliform		X	
Fecal coliform		X	
Fecal streptococcus		X	

Table A-1. Physicochemical parameters determined in each program, 1975.

Parameters	Program Daily	 Weekly	 Diurnal
River level above msl	X	X	X
River current		X	
River discharge	X		
Air temperature		X	X
Water temperature	X	X	X
Dissolved oxygen[a]		X	X
pH		X	X
Total alkalinity		X	X
Specific conductance		X	X
Sulfate		X	X
Total iron		X	X
Dissolved iron		X	X
Total residue		X	X
Fixed total residue		X	X
Nonfiltrable residue		X	X
Fixed nonfiltrable residue		X	X
Turbidity		X	X
Secchi disc depth		X	X
Barometric pressure		X	X
Weather		X	X
Total coliform			X
Fecal coliform			X
Fecal streptococcus			X

[a] Percentage calculated.

Table A-1. Physicochemical parameters and methods of analyses, 1976.

Parameter	Method	Reference
River level	Seven-day continuous recordings from an ACCO Bristol, Model No. G500-15 bubbler-type water level gauge.	ACCO (1971)
River velocity	Direct reading current meter, Gurley (Price), Model No. 665, suspended from an anchored boat to 0.6 depth. Current was a mean of readings at 5-s intervals for 2 min.	Teledyne Gurley (1973)
River flow	River flow = 0.222 (a-b) + b, where a and b are mean daily River flows at Danville and Wilkes-Barre, respectively. Data provided by U.S. Geological Survey.	White (1973)
Air temperature	Calibrated, mercury thermometer.	EPA (1974)
Water temperature	Seven-day continuous recordings from a calibrated, Leeds and Northrup Speedomax Thermistor-type, Model R temperature recorder. Calibrated, mercury thermometer.	EPA (1974) EPA (1974)
Dissolved oxygen	Modified Winkler full-bottle technique, proprietory reagents.	EPA (1974)
pH	Glass electrode.	EPA (1974)
Total alkalinity	Potentiometric titration.	EPA (1974)
Specific conductance	Self-contained conductance meter, Hydrolab, Model No. TC-2 at 25 C.	EPA (1974)
Sulfate	Turbidimetric, Hach Model DR-EL Portable Water Engineer's Laboratory (Jan-Jun). Turbidimetric (Jul-Dec).	Hach (1969) EPA (1974)
Total iron	Phenanthroline (Jan-Jun). Atomic absorption spectrophotometric determination of soluble iron (Jul-Dec).	APHA (1975) EPA (1974)
Dissolved iron	Atomic absorption spectrophotometric determination of dissolved iron.	EPA (1974)
Total residue	Evaporation at 103 C.	EPA (1974)
Fixed total residue	Ignition of total residue at 550 C.	APHA (1975)
Nonfiltrable residue	Suspended solids analysis by membrane filter technique (matched-weight filters).	Millipore (1973)
Fixed nonfiltrable residue	Ignition of nonfiltrable residue at 550 C.	APHA (1975)
Turbidity	Colorimetric, Hach Model DR-EL Portable Water Engineer's Laboratory (Jan-Jun). Nephelometric (Jul-Dec).	Hach (1969) EPA (1974)
Secchi disc depth	Limit of visibility.	Welch (1948)

Table A-1. Physicochemical parameters and methods of analyses, 1977. – 1979

Parameter	Method	Reference
River level (depth)	Seven-day continuous recordings from an ACCO Bristol, Model No. G500-15 bubbler-type water level gauge.	ACCO (1971)
River flow	River flow = 215.8 + 106.4 (river level -149) + 322.3 $(\text{river level} -149)^2$.	HP (1972)
River temperature	Seven-day continuous recordings from a calibrated, Leeds and Northrup Speedomax Thermistor-type, Model R temperature Recorder.	EPA (1974)
	Calibrated, mercury thermometer.	EPA (1974)
Air temperature	Calibrated, mercury thermometer.	EPA (1974)
Dissolved oxygen	Modified Winkler full-bottle technique, proprietory reagents.	EPA (1974)
pH	Glass electrode.	EPA (1974)
Total alkalinity	Potentiometric titration.	EPA (1974)
Specific conductance	Self-contained conductance meter at 25 C.	EPA (1974)
Sulfate	Turbidimetric.	EPA (1974)
Total iron	Atomic absorption spectrophotometric determination of soluble iron.	EPA (1974)
Dissolved iron	Atomic absorption spectrophotometric determination of dissolved iron.	EPA (1974)
Total residue	Evaporation at 105 C.	EPA (1974)
Fixed total residue	Ignition of total residue at 550 C.	APHA (1975)
Nonfiltrable residue	Suspended solids analysis by membrane filter technique (matched-weight filters).	Millipore (1973)
Fixed nonfiltrable residue	Ignition of nonfiltrable residue at 550 C.	APHA (1975)
Turbidity	Nephelometric.	EPA (1974)
Secchi disc depth	Limit of visibility.	Welch (1948)

Table A-1

Physicochemical parameters and methods of analyses, 1980-1981

Parameter	Method	Reference
River level (depth)	Seven-day continuous recordings from an ACCO Bristol, Model No. G500-15 bubbler-type water level gauge	ACCO (1971)
River flow	River flow = 231.4857 + 321.2703 (river level -149) + 106.6087 (river level -149)^2	Hewlett Packard (1972)
River temperature	Seven-day continuous recordings from a calibrated, Leeds and Northrup Speedomax Thermistor-type, Model R temperature recorder	APHA (1975)
	Calibrated, mercury thermometer	APHA (1975)
Air temperature	Calibrated, mercury thermometer	APHA (1975)
Dissolved oxygen	Azide modification of Winkler	APHA (1975)
pH	Glass electrode	APHA (1975)
Total alkalinity	Potentiometric titration	APHA (1975)
Specific conductance	Self-contained conductivity meter	APHA (1975)
Sulfate	Turbidimetric	APHA (1975)
Total iron	Atomic absorption spectrophotometric determination of extractable iron	APHA (1975)
Dissolved iron	Atomic absorption spectrophotometric determination of dissolved iron	APHA (1975)
Total residue	Evaporation at 105 C	APHA (1975)
Fixed total residue	Ignition of total residue at 550 C	APHA (1975)
Nonfiltrable residue	Residue retained on a glass fiber filter, dried at 105 C	APHA (1975)
Filtrable residue	Evaporation of a filtered aliquot, dried at 180 C	APHA (1975)
Turbidity	Nephelometric	APHA (1975)
Secchi disc depth	Limit of visibility	Welch (1948)

Table A-1

Physicochemical parameters and methods of analyses, 1982- 1985

Parameter	Method	Reference
River level	Seven-day continuous recordings from an ACCO Bristol, Model No. G500-15 bubbler-type water level gauge	ACCO (1971)
River flow	River flow = 231.4857 + 321.2703 (river level −149) + 106.6087 (river level −149)^{2}	Hewlett Packard (1972)
River temperature	Seven-day continuous recordings from a calibrated, Leeds and Northrup Speedomax Thermistor-type, Model R temperature recorder	APHA (1980)
	Calibrated, mercury thermometer	APHA (1980)
Air temperature	Calibrated, mercury thermometer	APHA (1980)
Dissolved oxygen	Azide modification of Winkler	APHA (1980)
pH	Glass electrode	APHA (1980)
Total alkalinity	Potentiometric titration	APHA (1980)
Specific conductance	Self-contained conductivity meter	APHA (1980)
Sulfate	Turbidimetric	APHA (1980)
Total iron	Atomic absorption spectrophotometric determination of extractable iron	APHA (1980)
Dissolved iron	Atomic absorption spectrophotometric determination of dissolved iron	APHA (1980)
Total residue	Evaporation, dried at 105 C	APHA (1980)
Fixed total residue	Ignition of total residue at 550 C	APHA (1980)
Nonfiltrable residue	Residue retained on a glass fiber filter, dried at 105 C	APHA (1980)
Filtrable residue	Calculation; total residues minus nonfiltrable residue	--
Turbidity	Nephelometric	APHA (1980)
Secchi disc depth	Limit of visibility	Welch (1948)

Table A-1

Physicochemical parameters and methods of analyses, 1986.

Parameter	Method	Reference
River Level	Seven-day continuous recording from an Acco Bristol, Model No. G500-15 bubbler-type water level gauge	ACCO (1971)
River Flow	River flow = 231.4857 + 321.2703 (river level -149) + 106.6087 $(\text{river level} - 149)^2$	Hewlett Packard (1972)
River Temperature	Seven-day continuous recordings from a calibrated, Leeds and Northrup Speedomax Thermistor-type, Model R temperature recorder Calibrated, mercury thermometer	APHA (1985) APHA (1985)
Air Temperature	Calibrated, mercury thermometer	APHA (1985)
Dissolved Oxygen	Membrane electrode	APHA (1985)
pH	Glass electrode	APHA (1985)
Total Alkalinity	Potentiometric titration	APHA (1985)
Specific Conductance	Self-contained conductivity meter	APHA (1985)
Sulfate	Turbidimetric	APHA (1985)
Total Iron	Atomic absorption spectrophotometric determination of extractable iron	APHA (1985)
Dissolved Iron	Atomic absorption spectrophotometric determination of dissolved iron	APHA (1985)
Total Solids	Evaporation, dried at 105 C	APHA (1985)
Total Suspended Solids	Solids retained on a glass fiber filter, dried at 105 C	APHA (1985)
Total Dissolved Solids	Calculation; total solids minus total suspended solids	—
Turbidity	Nephelometric	APHA (1985)

Table A-1

Physicochemical parameters and methods of analyses utilized at the Susquehanna SES Biological Laboratory, 1987.

Parameter	Units	Method	Reference[a]
River Level	m above mean sea level	Seven-day continuous recording from an Acco Bristol, Model No. G500-15 bubbler-type water level gauge.	ACCO (1971)
River Flow	m^3/s	River flow = 231.4857 + 321.2703 (river level −149) + 106.6087 (river level −149)^2	Soya & Jacobsen (1981)
River Temperature	C	Seven-day continuous recordings from a calibrated, Leeds and Northrup Speedomax Thermistor-type, Model R temperature recorder. Method 212	Standard Methods (1985)
	C	Calibrated, mercury thermometer. Method 212	Standard Methods (1985)
Air Temperature	C	Calibrated, mercury thermometer. Method 212	Standard Methods (1985)
Dissolved Oxygen	mg/l	Membrane electrode. Method 421F	Standard Methods (1985)
pH	--	Glass electrode. Method 423	Standard Methods (1985)
Total Alkalinity	mg/l	Potentiometric titration to 4.5 pH. Method 403	Standard Methods (1985)
Conductivity	µmhos/cm	Self-contained conductivity meter. Method 205	Standard Methods (1985)
Sulfate	mg/l	Turbidimetric. Method 426C	Standard Methods (1985)
Total Iron	mg/l	Atomic absorption spectrophotometric determination of extractable iron. Method 302B	Standard Methods (1985)
Dissolved Iron	mg/l	Atomic absorption spectrophotometric determination of dissolved iron upon filtration through a glass fiber filter. Method 302A	Standard Methods (1985)
Total Solids	mg/l	Evaporation, dried at 105 C. Method 209A	Standard Methods (1985)
Total Suspended Solids	mg/l	Solids retained on a glass fiber filter, dried at 105 C. Method 209C	Standard Methods (1985)
Total Dissolved Solids	mg/l	Calculation: total solids minus total suspended solids.	--
Turbidity	NTU	Nephelometric. Method 214A	Standard Methods (1985)

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[a] Listed in references cited.

Table A-1

Physicochemical parameters and methods of analyses utilized at the Susquehanna SES Biological Laboratory, 1988.

Parameter	Units	Methods	Reference*
River Level	ft above mean sea level	Seven-day continuous recording from an Acco Bristol, Model No. G500-15 bubbler-type water level gauge.	ACCO (1971)
River Flow	cfs	River flow = 0.222 (a-b) + b; where a and b are mean daily river flows at Danville and Wilkes-Barre, respectively. Data provided by U.S. Geological Survey.	IA, Inc. (1976b)
River Temperature	C	Seven-day continuous recordings from a calibrated, Leeds and Northrup Speedomax Thermistor-type, Model R temperature recorder. Method 212	Standard Methods (1985)
	C	Calibrated, mercury thermometer. Method 212	Standard Methods (1985)
Air Temperature	C	Calibrated, mercury thermometer. Method 212	Standard Methods (1985)
Dissolved Oxygen	mg/l	Azide modification of Winkler. Method 421A	Standard Methods (1985)
pH	--	Glass electrode. Method 423	Standard Methods (1985)
Total Alkalinity	mg/l	Potentiometric titration to 4.5 pH. Method 403	Standard Methods (1985)
Conductivity	µmhos/cm	Self-contained condutivity meter. Method 205	Standard Methods (1985)
Sulfate	mg/l	Turbidimetric. Method 426C	Standard Methods (1985)
Total Iron	mg/l	Atomic absorption spectrophotometric determination of extractable iron. Method 302B	Standard Methods (1985)
Dissolved Iron	mg/l	Atomic absorption spectrophotometric determination of dissolved iron upon filtration through a membrane filter. Method 302A	Standard Methods (1985)
Total Solids	mg/l	Evaporation, dried at 105 C. Method 209A	Standard Methods (1985)
Total Suspended Solids	mg/l	Solids retained on a glass fiber filter, dried at 105 C. Method 209C	Standard Methods (1985)
Total Dissolved Solids	mg/l	Calculation: total solids minus total suspended solids.	
Turbidity	NTU	Nephelometric. Method 214A	Standard Methods (1985)

*Listed in references cited.

Table A-1

Physicochemical parameters and methods of analyses utilized at the Susquehanna SES Biological Laboratory, 1989.

PARAMETER	METHOD	REFERENCE*
River level	Seven-day continuous recording from an Acco Bristol, Model No. G500-15 bubbler-type water level gauge.	ACCO (1971)
River flow	River flow = 0.222 (a-b) + b, where a and b are mean daily river flows at Danville and Wilkes-Barre, respectively. Data provided by U.S. Geological Survey.	IA, Inc. (1976b)
River temperature	Seven-day continuous recordings from a calibrated, Leeds and Northrup Speedomax Thermistor-type, Model R temperature recorder. Method 212	Standard Methods (1985)
	Calibrated, mercury thermometer. Method 212	Standard Methods (1985)
Turbidity	Nephelometric. Method 214A	Standard Methods (1985)
pH	Glass electrode. Method 423	Standard Methods (1985)
Conductivity	Self-contained conductivity meter. Method 205	Standard Methods (1985)
Dissolved oxygen	Membrane electrode. Method 421F	Standard Methods (1985)
Total alkalinity	Potentiometric titration to 4.5 pH. Method 403	Standard Methods (1985)
Sulfate	Turbidimetric. Method 426C	Standard Methods (1985)
Total iron	Atomic absorption spectrophotometric determination of extractable iron. Method 302B	Standard Methods (1985)
Dissolved iron	Atomic absorption spectrophotometric determination of dissolved iron upon filtration through a membrane filter. Method 302A	Standard Methods (1985)
Total solids	Evaporation, dried at 105 C. Method 209A	Standard Methods (1985)
Total suspended solids	Solids retained on a glass fiber filter, dried at 105 C. Method 209C	Standard Methods (1985)
Total dissolved solids	Calculation: total solids minus total suspended solids.	

*Listed in references cited.

Table A-1

Water quality parameters and methods of analyses utilized at the Susquehanna SES Biological Laboratory, 1990.

PARAMETER	METHOD	REFERENCE[a]
River level	Seven-day continuous recording from an Acco Bristol, Model No. G500-15 bubbler-type water level gauge.	ACCO (1971)
River flow	River flow = 0.222 (a-b) + b, where a and b are mean daily river flows at Danville and Wilkes-Barre, respectively. Data provided by U.S. Geological Survey.	IA, Inc. (1976b)
River temperature	Seven-day continuous recordings from a calibrated, Leeds and Northrup Speedomax Thermistor-type, Model R temperature recorder. Method 2550 B	Standard Methods (1989)
	Calibrated, mercury thermometer. Method 2550 B	Standard Methods (1989)
Turbidity	Nephelometric. Method 2130 B	Standard Methods (1989)
pH	Glass electrode. Method 4500-H+ B	Standard Methods (1989)
Conductivity	Self-contained conductivity meter. Method 2510 B	Standard Methods (1989)
Dissolved oxygen	Membrane electrode. Method 4500-O G	Standard Methods (1989)
Total alkalinity	Potentiometric titration to 4.5 pH. Method 2320 B	Standard Methods (1989)
Sulfate	Turbidimetric. Method 4500-SO_4^{2-} E	Standard Methods (1989)
Total iron	Atomic absorption spectrophotometric determination of extractable iron. Method 3030 C	Standard Methods (1989)
Dissolved iron	Atomic absorption spectrophotometric determination of dissolved iron upon filtration through a membrane filter. Method 3030 B	Standard Methods (1989)
Total solids	Evaporation, dried at 105 C. Method 2540 B	Standard Methods (1989)
Total suspended solids	Solids retained on a glass fiber filter, dried at 105 C. Method 2540 D	Standard Methods (1989)
Total dissolved solids	Calculation, total solids minus total suspended solids.	

[a] Listed in references cited.

1991-1992

Table A-1

Water quality parameters and methods of analyses utilized by the Susquehanna SES Environmental Laboratory, 1991 - 1992

PARAMETER	METHOD	REFERENCE[a]
River level	Seven-day continuous recording from an Acco Bristol, Model No. G500-15 bubbler-type water level gauge.	ACCO (1971)
River flow	At level <486.0 ft, log flow = $-0.0525(\text{level})^2 + 51.478501(\text{level}) - 12612.85672$ At level ≥486.0 ft, flow = $319.96989(\text{level})^2 - 309316.24395(\text{level}) + 74753300$	Soya (1991)
River temperature	Seven-day continuous recordings from a calibrated, Leeds and Northrup Speedomax Thermistor-type, Model R temperature recorder. Method 2550 B	Standard Methods (1989)
	Calibrated, mercury thermometer. Method 2550 B	Standard Methods (1989)
Turbidity	Nephelometric. Method 2130 B	Standard Methods (1989)
pH	Glass electrode. Method 4500-H+ B	Standard Methods (1989)
Conductivity	Self-contained conductivity meter. Method 2510 B	Standard Methods (1989)
Dissolved oxygen	Membrane electrode. Method 4500-O G	Standard Methods (1989)
Total alkalinity	Potentiometric titration to 4.5 pH. Method 2320 B	Standard Methods (1989)
Sulfate	Turbidimetric. Method 4500-SO_4^{2-} E	Standard Methods (1989)
Total iron	Atomic absorption spectrophotometric determination of extractable iron. Method 3030 C	Standard Methods (1989)
Dissolved iron	Atomic absorption spectrophotometric determination of dissolved iron upon filtration through a membrane filter. Method 3030 B	Standard Methods (1989)
Total solids	Evaporation, dried at 105 C. Method 2540 B	Standard Methods (1989)
Total suspended solids	Solids retained on a glass fiber filter, dried at 105 C. Method 2540 D	Standard Methods (1989)
Total dissolved solids	Calculation; total solids minus total suspended solids.	

[a] Listed in references cited.

1993-2004

Table A-1

Water quality parameters and methods of analyses utilized by the Susquehanna SES Environmental Laboratory, 1993- 2004

PARAMETER	METHOD	REFERENCE[a]
River level	Seven-day continuous recording from an Acco Bristol, Model No. G500-15 bubbler-type water level gauge.	ACCO (1971)
River flow	At level <486.0 ft, log flow = $-0.0525(\text{level})^2 + 51.478501(\text{level}) - 12612.85672$ At level ≥486.0 ft, flow = $319.96989(\text{level})^2 - 309316.24395(\text{level}) + 74753300$	Soya (1991)
River temperature	Seven-day continuous recordings from a calibrated, Leeds and Northrup Speedomax Thermistor-type, Model R temperature recorder. Method 2550 B	Standard Methods (1992)
	Calibrated, mercury thermometer. Method 2550 B	Standard Methods (1992)
Turbidity	Nephelometric. Method 2130 B	Standard Methods (1992)
pH	Glass electrode. Method 4500-H^+ B	Standard Methods (1992)
Conductivity	Self-contained conductivity meter. Method 2510 B	Standard Methods (1992)
Dissolved oxygen	Membrane electrode. Method 4500-O G	Standard Methods (1992)
Total alkalinity	Potentiometric titration to 4.5 pH. Method 2320 B	Standard Methods (1992)
Sulfate	Turbidimetric. Method 4500-SO_4^{2-} E	Standard Methods (1992)
Total iron	Atomic absorption spectrophotometric determination of extractable iron. Method 3030 C	Standard Methods (1992)
Dissolved iron	Atomic absorption spectrophotometric determination of dissolved iron upon filtration through a membrane filter. Method 3030 B	Standard Methods (1992)
Total solids	Evaporation, dried at 105° C. Method 2540 B	Standard Methods (1992)
Total suspended solids	Solids retained on a glass fiber filter, dried at 105° C. Method 2540 D	Standard Methods (1992)
Total dissolved solids	Calculation; total solids minus total suspended solids.	

[a] Listed in references cited.

Table 2

2005-2007

Water quality parameters and methods of analyses utilized by the Susquehanna SES Environmental Laboratory, 2007.

PARAMETER	METHOD	REFERENCE[a]
River level	Seven-day continuous recording from an Acco Bristol, Model No. G500-15 bubbler-type water level gauge.	ACCO (1971)
River flow	At level <486.0 ft, $\log flow = -0.05251(level)^2 + 51.478501(level) - 12612.85672$	Soya (1991)
	At level ≥486.0 ft, $\log flow = 319.96989(level)^2 - 309316.24395(level) + 74753300$	
River temperature	Seven-day continuous recordings from a Yokogawa AX 102-1-2 temperature recorder. Method 2550 B.	APHA (1995)
	Calibrated, mercury-filled thermometer. Method 2550 B.	
Dissolved oxygen	Membrane electrode. Method 4500-O G.	APHA (1995)

[a] Listed in references cited.

Table 2

Water quality parameters and methods of analyses utilized by the Susquehanna SES Environmental Laboratory, 2008.

PARAMETER	METHOD	REFERENCE[a]
River depth (ft)	Seven-day continuous recording from an Acco Bristol, Model No. G500-15 bubbler-type water level gauge.	ACCO (1971)
River level (ft above msl)	$Level = Depth + 482.96$	Soya (1991)
River flow (cfs)	Insert river level into the appropriate regression equation. At level <486.0 ft, $\log flow = -0.05251(level)^2 + 51.478501(level) - 12612.85672$ At level ≥486.0 ft, $flow = 319.96989(level)^2 - 309316.24395(level) + 74753300$	Soya (1991)
Temperature (°F)	Constant monitor of river temperature: Seven-day continuous recording from a Yokogawa AX 102-1-2 temperature recorder.	Omega (2001) Yokogawa (2003)
(°C)	River and blowdown temperature of samples collected: Calibrated, mercury-filled thermometer. Method 2550 B	APHA (1995)
	Convert Fahrenheit to Celsius for tabulation: $°C = (°F - 32) \div 1.8$ or $\frac{°C}{°F - 32} = {}^{5}\!/_{9}$	[b] Internet site
Dissolved oxygen (mg/L)	Membrane electrode. Method 4500-O G.	APHA (1995)

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[a] Listed in references cited.

[b] http://mathforum.org/library/drmath/view/58393.html. Accessed: 19 February 2009.

ECOLOGY III THERMAL PLUME SURVEYS

THERMAL PLUME STUDIES
IN THE SUSQUEHANNA RIVER AT THE DISCHARGE DIFFUSER OF THE SUSQUEHANNA STEAM ELECTRIC STATION
1986-87

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INTRODUCTION

The Susquehanna Steam Electric Station (Susquehanna SES) is a nuclear power station with two boiling water reactors that have a total generating capacity of 2,100 megawatts. The station is located along the Susquehanna River in northeastern Pennsylvania (Figure 1). Commercial production of electricity at the Unit 1 reactor began on 8 June 1983 and at Unit 2 on 12 February 1985. The Pennsylvania Power and Light Company (PP&L) owns 90% of the Susquehanna SES and the Allegheny Electric Cooperative, Inc. retains title to 10%.

Water from the Susquehanna River is used to cool the Susquehanna SES in an essentially closed circuit cooling system. When both reactors are generating at 100% capacity, approximately 38,000 gallons/minute of river water is used to replace about 30,000 gallons/minute that is lost to the atmosphere by evaporation from two natural draft cooling towers. The remaining 8,000 gallons/minute of cooling tower blowdown is discharged back into the Susquehanna River through a diffuser pipe located on the river bottom about 200 feet from the west bank. The diffuser is constructed from a 42-inch diameter pipe that is 115 feet long. Blowdown water is released into the river through a series of 72 ports which are 4 inches in diameter. These ports are spaced at 18-inch intervals along the upper edge of the downriver side of the diffuser. Over the past 15 years, records at the Susquehanna SES Biological Laboratory show that river flow has varied from about 900 to 250,000 cubic feet/second, and that ambient river temperature has ranged from 32.0 to 86.0 F.

An earlier environmental report, written before construction of the Susquehanna SES, theorized that a sizable thermal plume would be created by this blowdown water before it reached ambient river water temperature below the diffuser (PP&L 1972). Initial temperature measurements at the diffuser, after both units of the Susquehanna SES became operational, revealed that the thermal plume was much smaller than originally anticipated. The edge of the plume (0.5 F isotherm) rarely extended more than 300 feet downriver from the diffuser, and this occurred only during conditions of low river flow. More commonly, the plume edge was found within 150 feet of the diffuser and often it was located within 25 feet during average to high river flows. Therefore, a formal study of the thermal plume was never conducted because it was so limited in size.

In 1985, a review of the ecological monitoring programs for the Susquehanna SES was conducted by Drexel University (Allen et al. 1986). During this review, the water temperature of the river below the discharge diffuser was discussed at length. As a result, it was recommended that "a special study be made to determine by measurement exactly what the temperature change in the river is, even if it is measurable only within inches of the diffuser." In order to fulfill this recommendation, a study of the thermal plume was begun in November 1986, with the objective of defining its size.

METHODS

Three thermal plume studies were conducted at the discharge diffuser of the Susquehanna SES. Autumn, winter, and spring studies were done on 5 November 1986, 9 January 1987, and 14 May 1987, respectively. All studies were conducted when both reactors were at least 85% operational.

Temperatures were measured with a Hydrolab FT-3M Marine Thermometer (thermistor) which was calibrated immediately before each study with a NBS traceable thermometer. All temperatures were measured to the nearest 0.5 F. The temperature of the blowdown was measured in both cooling tower basins prior to the autumn and winter studies. In the spring study, blowdown temperature was measured at the discharge by a scuba diver who inserted the thermistor probe into several diffuser ports.

A plane-table mapping technique was used to draw a profile of the thermal plume in each study. The plane table, with drawing paper attached, was positioned along the west river bank about 150 feet downstream from the diffuser. It was oriented with various prominent structures, such as power poles and the intake building, using a Watts Microptic Alidade. The alidade was used to sight a stadia rod held at various points along the shoreline. Angles and distances to these points were measured and a base map of the shoreline and study area was drawn at a scale of 1 inch = 40 feet.

Two crews in boats, each equipped with a thermistor, measured ambient river temperature and located the diffuser. One of the boats was anchored about 100 feet upriver from the diffuser, and the ambient temperature was measured from surface to bottom at one-foot intervals. From shore, the boat was sighted with the alidade (stadia rod mounted on the boat) and its location was marked on the base map. In the meantime, the other boat was driven to one of two float-ropes that a scuba diver had previously attached to either end of the diffuser. By pulling the float-rope very tightly, it was possible to situate the boat directly above the end of the diffuser. This location was sighted from shore with the alidade and marked on the map.

The other end of the diffuser was marked in the same manner. The diffuser was then drawn on the map by connecting these two points with a line.

Both crews then proceeded to measure the temperature of the plume. In each study, vertical temperature series were determined at from 20 to 27 sites throughout the probable location of the plume downriver from the diffuser. The boats were anchored at each site and the thermistor was used to measure temperatures at one-foot intervals from surface to bottom. Air temperatures were also recorded. All sites were numbered and located on the base map using the alidade. Upon completion of temperature measurements within the plume area, ambient temperature was determined again at the original location. This was done to determine if a change had occurred during the time period in which the plume temperatures were recorded. When ambient changed, plume temperatures were adjusted accordingly.

In each study, the edge of the plume (0.5 F isotherm above ambient river temperature) was drawn on the base map by interpolating its location among the vertical series of temperature measurements at each site. Both planar and three-dimensional drawings were made of the plume.

RESULTS

Autumn Study

The autumn thermal plume study was conducted on 5 November 1986. On this date, the river level was stable at 487.8 feet above mean sea level (msl) which is equivalent to a flow of 4,840 cubic feet/second (2,173,000 gal/min). The water temperature of the cooling tower blowdown (approximately 8,000 gal/min) was 62.0 F. The weather was partly cloudy with a light breeze.

The location of each vertical temperature determination for ambient river temperature and for the 20 sites within the vicinity of the plume, are shown relative to the diffuser in Figure 2. The ambient temperature was 47.0 F and temperatures at the sites ranged from 47.0 to 47.5 F (Table 1). Air temperature decreased from 36.5 to 34.5 F throughout the 71-minute study.

The limits of the thermal plume are presented in Figure 3. The plume was within 5 feet of the diffuser along the inner half of the pipe. However, it extended downriver about 130 feet along the outer half of the diffuser. This portion of the plume remained near the bottom until about 75 feet downriver when it began to billow toward the surface.

Winter Study

The winter plume study was done on 9 January 1987 when the river level was 489.0 feet above msl. This level is equal to a flow of 9,250 cubic feet/second (4,152,000 gal/min). The approximately 8,000 gallons/minute of cooling tower blowdown was 61.0 F. The weather was partly cloudy and calm.

Determinations of ambient river temperature and the temperatures at the 21 plume sites are shown relative to the diffuser in Figure 4. The ambient river temperature was 33.5 F and temperatures within the vicinity of the plume ranged from 33.5 to 34.0 F (Table 2). Air temperature decreased from 39.0 to 35.5 F during the 1-hour and 53-minute study.

The thermal plume remained within 10 feet of the diffuser along the inner half of the pipe, and then extended downriver about 25 feet along the outer half (Figure 5). It tended to billow upward, but it was always less than 10 feet below the surface.

Spring Study

The spring thermal plume study was conducted on 14 May 1987. The river level on this date was stable at 487.9 feet above msl. This level is equivalent to a river flow of 5,120 cubic feet/second or 2,298,000 gallons/minute. The water temperature of the cooling tower blowdown (approximately 8,000 gal/min) was 75.0 F. The weather was cloudy during the first 30 minutes of the study and sunny throughout the remainder.

The locations of each temperature series recorded for ambient river temperature and for temperatures at the 27 sites near the plume are shown relative to the diffuser in Figure 6. Ambient river temperature increased from 65.5 to 66.0 F when the sunlight warmed the river throughout the 1-hour and 40-minute study (Table 3). This natural warming of the river necessitated the adjustment of the temperatures at the last 16 sites by subtracting 0.5 F from each measurement (Table 3). Temperatures within the plume ranged from 65.5 to 66.5 F.

The extent of the thermal plume is presented in Figure 7. Most of the plume was located downriver from the outer half of the diffuser where it extended about 80 feet in length. The plume tended to billow upward, but never reached closer than 7 feet of the surface.

DISCUSSION

The thermal plumes in all three studies were relatively small. This finding in itself is particularly interesting because the temperature of the cooling tower blowdown was 15.0, 27.5, and 9.5 degrees F above ambient river temperature in autumn, winter, and spring, respectively. In spite of these sizable delta t's, none of the plume temperature determinations were greater than 1 degree F above ambient, and most of the recordings were only 0.5 degree F above ambient. At some point in the river, within a few inches of the diffuser ports, the temperature of the blowdown water was reduced to within 1 degree F or less of ambient. The results of these studies did not detect the exact location of this gradient; however, even if it was found, it would be of only minor interest environmentally. The far more important finding is that, during these studies, the diffuser of the Susquehanna SES quickly mixed thermally-enriched water from the cooling tower blowdown with river water so that impact to the Susquehanna River was negligible.

The size of the plume seemed to be more a function of river flow than the difference in temperature between blowdown and ambient when results of the autumn and winter studies were evaluated. Of all the studies, plume size was largest in autumn when river flow was lowest and the delta t was 15.0 F. In the winter study, the delta t was nearly twice as large (27.5 F), but the plume was several fold smaller in a river-flow condition about twice as great as that measured in the autumn study. Results of the spring study were intermediate.

All three studies were conducted at river flows near the low end (9,250 cubic feet/second or 262 cubic meters/second) of the range of flows documented for this portion of the Susquehanna River over an 8-year period (Figure 8). It is doubtful that a plume of any consequence would be detected at river flows greater than those evaluated during the winter study. In the future, however, it may be of some value to conduct a fourth thermal plume study at low river flow in the summer. When this study is completed, the thermal plume will have been profiled once in each of the four seasons for a more complete evaluation.

REFERENCES CITED

Allen, H. E., W. O. Pipes, and C. A. Silver. 1986. Review of ecological monitoring program for the Susquehanna Steam Electric Station. H. E. Allen & Associates, Ltd., Bala Cynwyd, PA.

Pennsylvania Power and Light Company. 1972. Susquehanna Steam Electric Station, Applicant's Environmental Report, Vol. 1. Pa. Power & Light Co., Allentown, PA.

Table 1

Temperatures (F) recorded at 1-foot intervals from surface to bottom at 20 sites on the Susquehanna River near the discharge diffuser of the Susquehanna Steam Electric Station, 5 November 1986.

Site No.	Time	Temperature (F)		Depth in feet																Bottom	
		Air	Surface	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Depth	Temperature
Ambient	1249	36.5	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0					12.0	47.0
1	1250	36.5	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0			14.5	47.0
2	1255	36.5	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.5	47.5	47.5					12.0	47.5
3	1258	36.5	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.5	47.5	47.5	47.5	47.5	47.5		15.0	47.5
4	1300	36.5	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0			14.0	47.0
5	1305	36.5	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0					12.5	47.0
6	1306	36.5	47.0	47.5	47.5	47.5	47.5	47.5	47.5	47.5	47.0	47.5	47.5	47.5	47.5	47.5	47.5			14.0	47.5
7	1314	36.5	47.0	47.0	47.0	47.5	47.5	47.5	47.5	47.5	47.5	47.5	47.5	47.5	47.5	47.5	47.5			14.5	47.5
8	1320	36.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.5	47.5	47.5	47.5	47.5					12.5	47.5
9	1320	36.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0		15.0	47.0
10	1325	35.5	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0			14.5	47.0
11	1327	35.5	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0		15.0	47.0
12	1330	35.5	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0		15.0	47.0
13	1335	35.5	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	16.0	47.0
14	1335	35.5	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0							11.0	47.0
15	1340	34.5	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0			14.0	47.0
16	1342	34.5	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0						11.0	47.0
17	1345	34.5	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0									8.5	47.0
18	1346	34.5	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0						11.5	47.0
19	1351	34.5	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0					12.5	47.0
20	1355	34.5	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0						11.5	47.0
Ambient	1400	34.5	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0					12.0	47.0

Table 2

Temperatures (F) recorded at 1-foot intervals from surface to bottom at 21 sites on the Susquehanna River near the discharge diffuser of the Susquehanna Steam Electric Station, 9 January 1987.

Site No.	Time	Temperature (F)		Depth in feet																	Bottom	
		Air	Surface	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Depth	Temperature
Ambient	1517	39.0	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5				14.0	33.5
1	1526	39.0	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5			15.0	33.5
2	1531	37.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5		16.5	33.5
3	1537	37.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5		16.5	33.5
4	1542	39.0	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5		16.5	33.5
5	1547	39.0	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5		16.0	33.5
6	1552	37.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5					13.0	33.5
7	1556	37.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5		16.5	33.5
8	1600	37.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5		16.0	33.5
9	1604	37.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5			15.0	33.5
10	1609	38.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	34.0	33.5	17.0	33.5
11	1614	37.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5										9.0	33.5
12	1618	37.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5		16.5	33.5
13	1622	37.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5		16.0	33.5
14	1628	37.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	34.0	34.0	34.0	34.0	34.0		16.5	34.0
15	1633	38.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	34.0	34.0	34.0		16.5	34.0
16	1638	35.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	34.0	34.0	34.0	34.0	34.0		16.0	34.0
17	1641	35.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5			15.0	33.0
18	1645	35.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	34.0	34.0	34.0	34.0	34.0	34.0		16.5	34.0
19	1650	35.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	34.0	34.0	34.0	34.0		16.0	34.0
20	1653	35.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5			15.0	33.5
21	1659	35.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5				14.0	33.5
Ambient	1710	35.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5				14.0	33.5

Table 3

Temperatures (F) recorded at 1-foot intervals from surface to bottom at 27 sites on the Susquehanna River near the discharge diffuser of the Susquehanna Steam Electric Station, 14 May 1987.

Site No.	Time	Temperature (F)		Depth in feet																	Bottom	
		Air	Surface	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Depth	Temperature
Ambient	1355	—	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5						12.5	65.5
1	1358	69.0	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5			15.0	65.5
2	1409	—	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5					13.0	65.5
3	1409	—	65.5	65.5	65.5	65.5	65.5	65.5	65.5	66.0	66.0	66.0	66.0	66.0	66.5	66.5	65.5				14.0	66.0
4	1416	—	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5					13.0	65.5
5	1416	—	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5		16.0	65.5
6	1420	—	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5				14.0	65.5
7	1423	—	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5			15.0	65.5
8	1425	—	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5				14.0	65.5
9*	1430	—	66.0	66.0	66.0	66.0	66.0	66.0	66.0	65.5	65.5	65.5	65.5	65.5	65.5						12.0	65.5
10	1430	—	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	66.0	66.0	66.0	66.0				14.0	66.0
11	1435	—	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	66.0	66.5	66.5	66.5	66.5	66.5	66.5	66.5			15.0	65.5
12**	1439	—	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5					13.0	65.5
13	1448	—	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5					13.0	65.5
14	1452	—	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	66.0	66.0	66.0	66.0	66.0	66.0				14.0	66.0
15	1453	—	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5				14.0	65.5
16	1501	—	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	66.0	66.0	66.0	66.0	66.0	66.0	66.0		16.0	66.0
17	1503	77.0	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5						12.0	65.5
18	1504	—	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	66.0	66.0	65.5	65.5	66.0	66.0			15.0	66.0
19	1511	—	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5					13.0	65.5
20	1511	—	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5		16.0	65.5
21	1516	—	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0		16.0	65.0
22	1516	—	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	66.0	66.0	66.0	66.0	66.0	66.0	66.0	66.0	66.0		16.0	66.0
23	1520	—	65.5	65.5	65.5	65.5	65.5	65.5	66.0	66.0	66.0	66.0	66.0	66.0	66.0	66.0	66.0	66.0			15.0	66.0
24	1523	—	65.5	65.5	65.5	65.5	65.5	65.5													5.0	65.5
25	1524	—	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	66.0	66.5	66.5	66.5	66.5	66.0	66.0	66.0			15.0	66.0
26	1526	—	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5					13.0	65.5
27	1531	—	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	66.0	66.0	65.5	65.5	65.5	66.0	65.5			15.0	65.5
Ambient	1535	—	66.0	66.0	66.0	66.0	66.0	66.0	66.0	66.0	66.0	66.0	66.0	66.0	66.0	66.0					13.0	65.5

* River surface temperature increased from sunlight.

** All temperatures (except ambient) measured after 1439 hours were adjusted for an increase in ambient river temperature by subtracting 0.5 F.

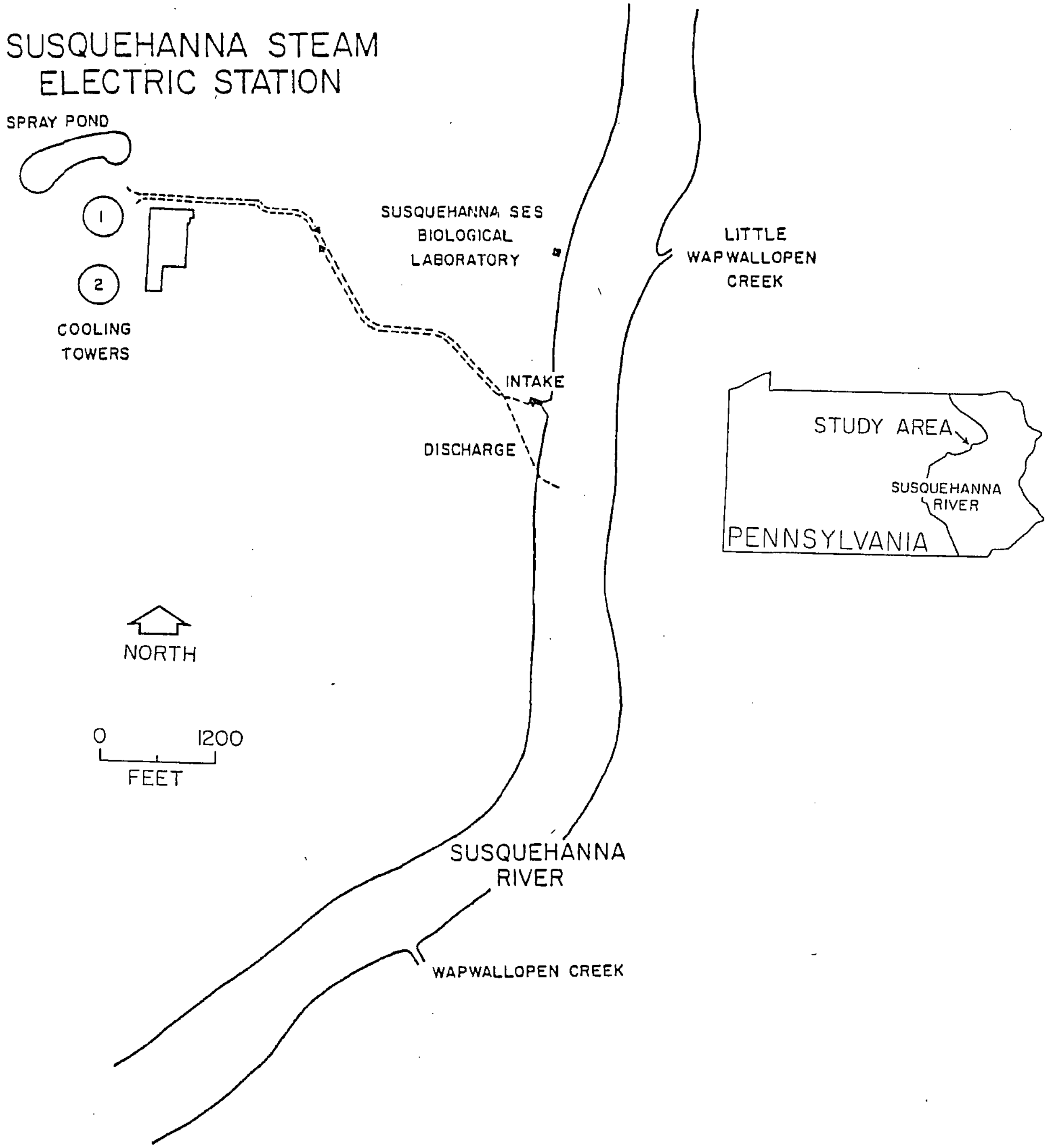

Figure 1

Location of the Susquehanna Steam Electric Station discharge in the Susquehanna River.

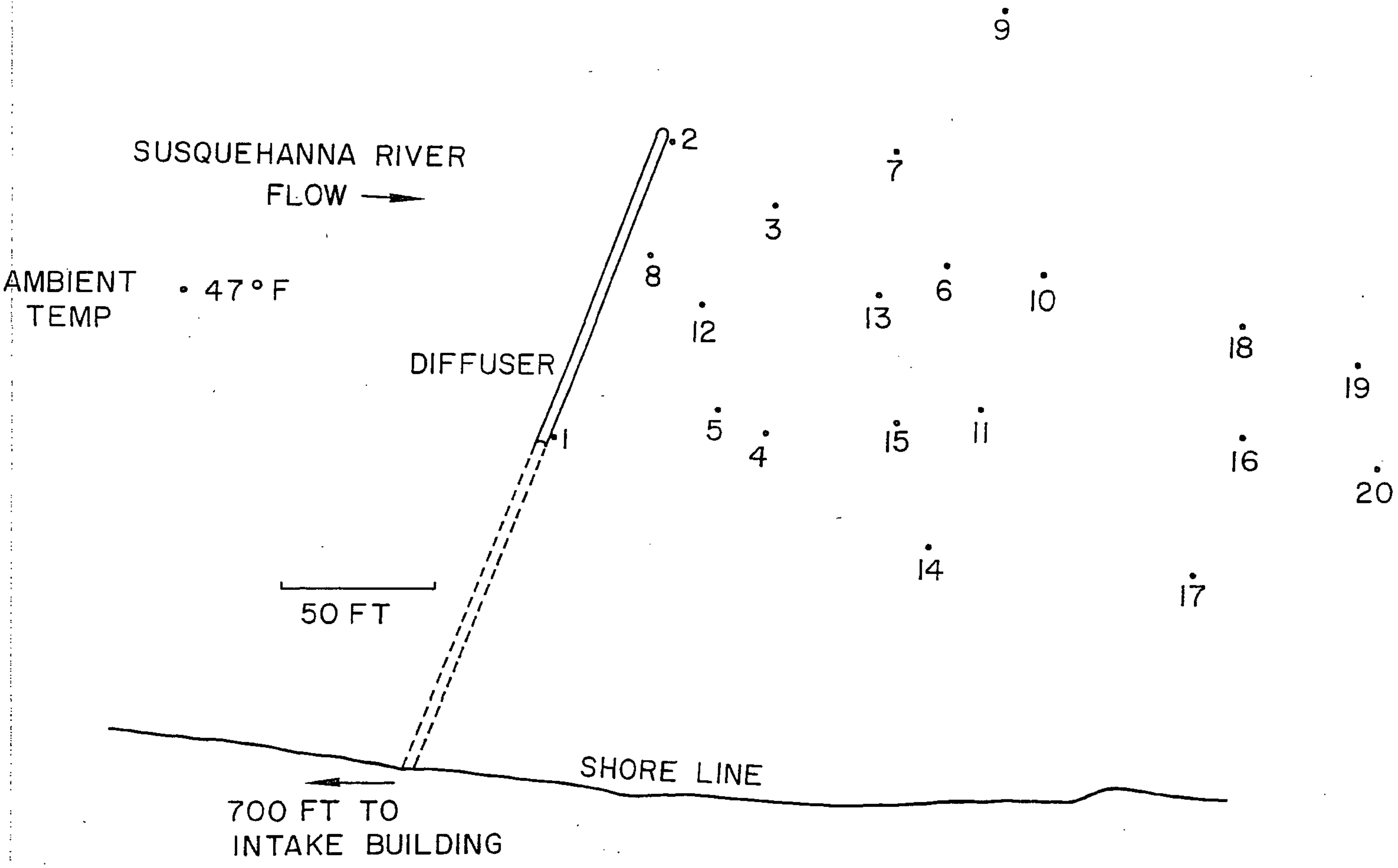

Figure 2

Sites at which water temperatures were recorded at 1-foot intervals from surface to bottom on the Susquehanna River near the discharge diffuser of the Susquehanna Steam Electric Station, 5 November 1986.

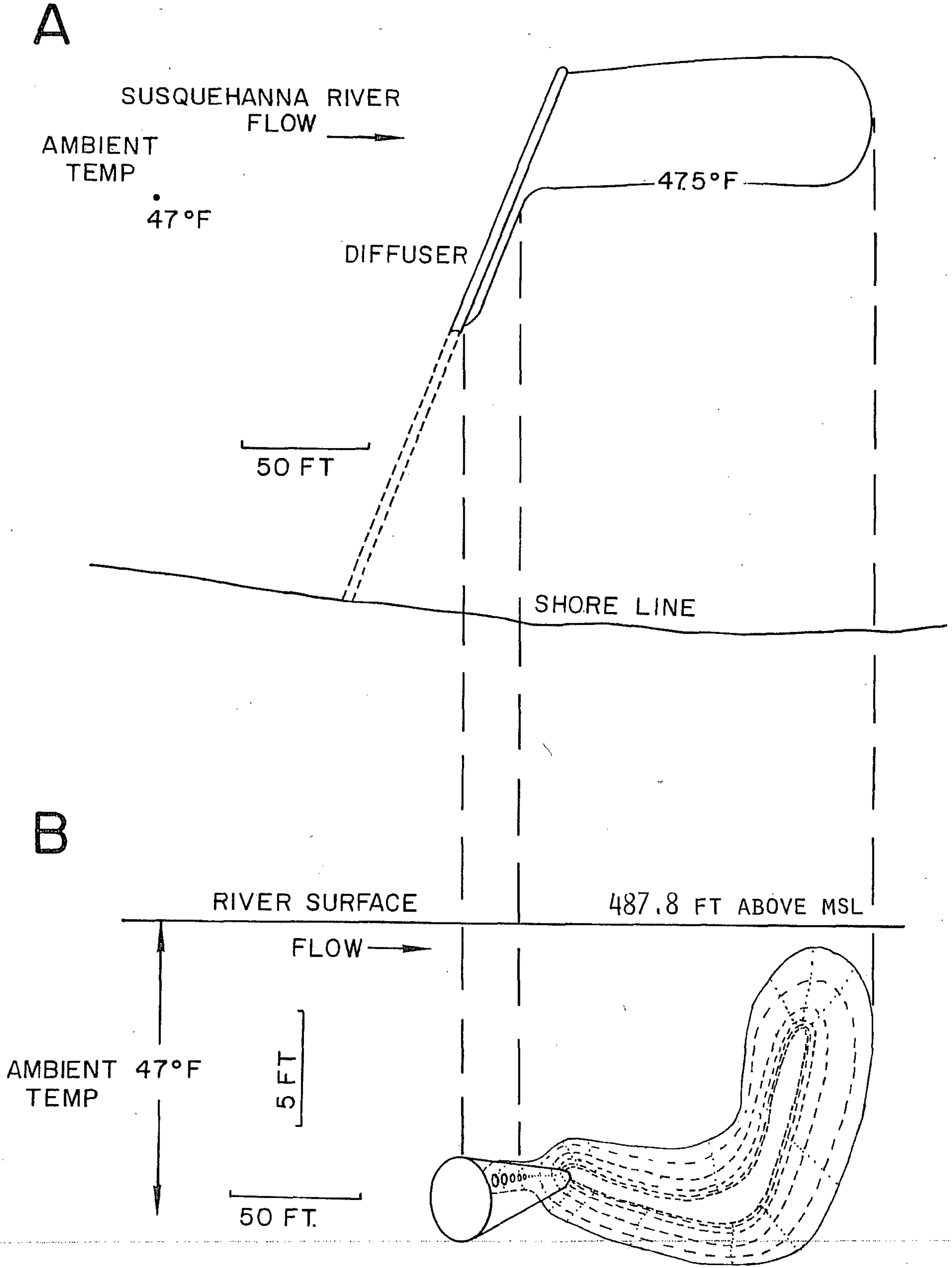

Figure 3

Limits of a thermal plume (0.5 F above ambient water temperature) in the Susquehanna River caused by the release of cooling tower blowdown from the discharge diffuser of the Susquehanna Steam Electric Station, 5 November 1986. (A = planar view, B = three-dimensional view)

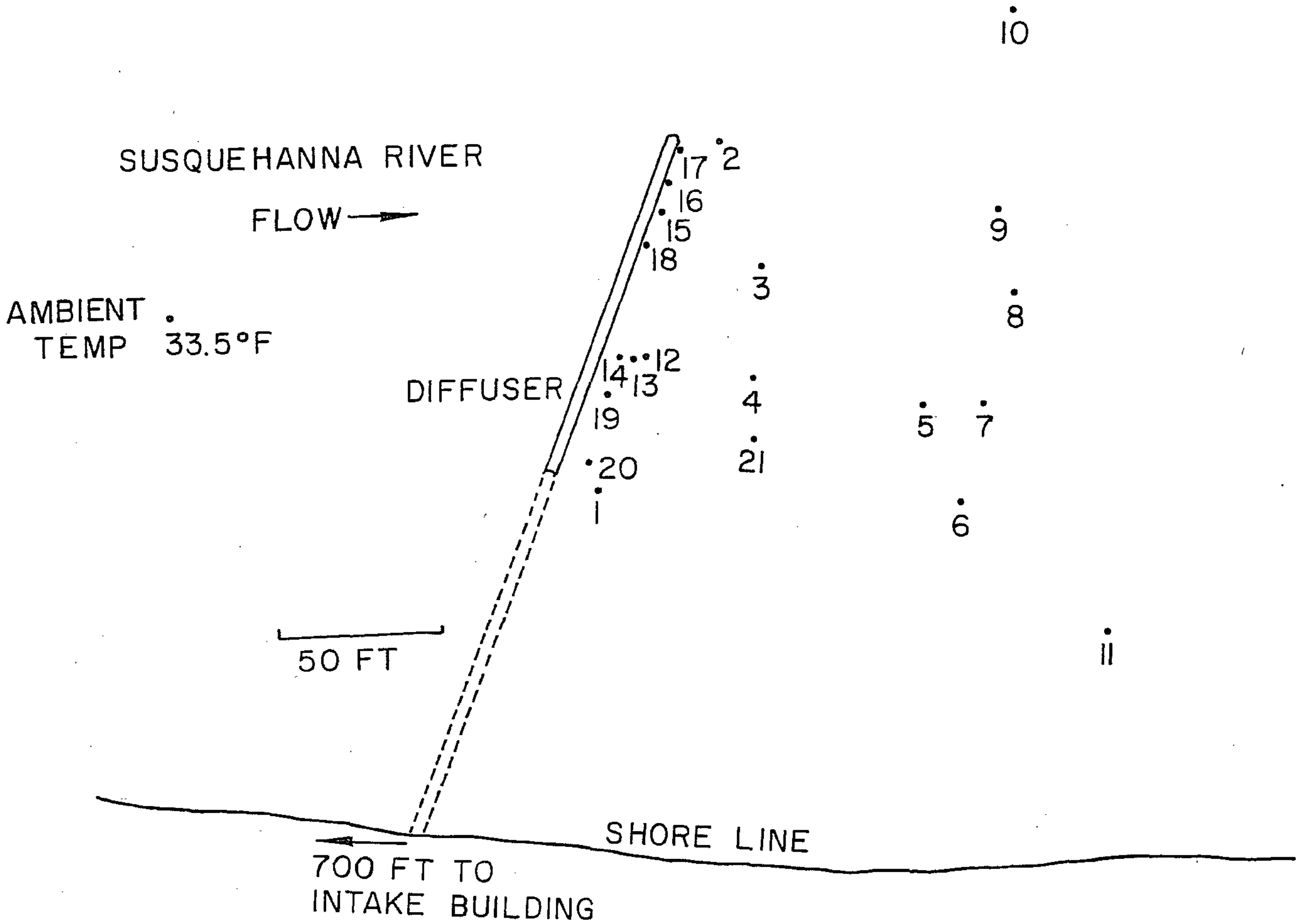

Figure 4

Sites at which water temperatures were recorded at 1-foot intervals from surface to bottom on the Susquehanna River near the discharge diffuser of the Susquehanna Steam Electric Station, 9 January 1987.

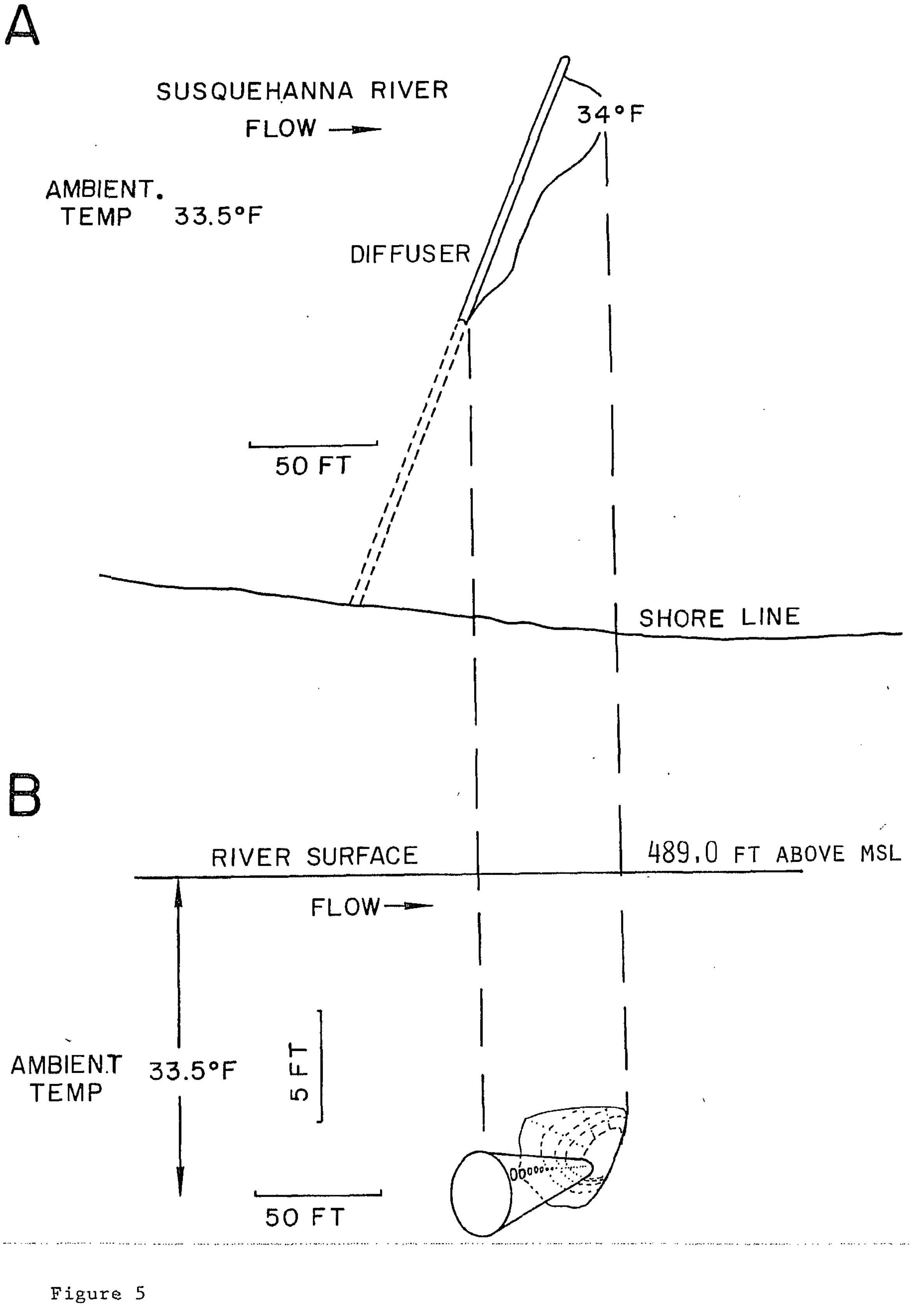

Figure 5

Limits of a thermal plume (0.5 F above ambient water temperature) in the Susquehanna River caused by the release of cooling tower blowdown from the discharge diffuser of the Susquehanna Steam Electric Station, 9 January 1987. (A = planar view, B = three-dimensional view)

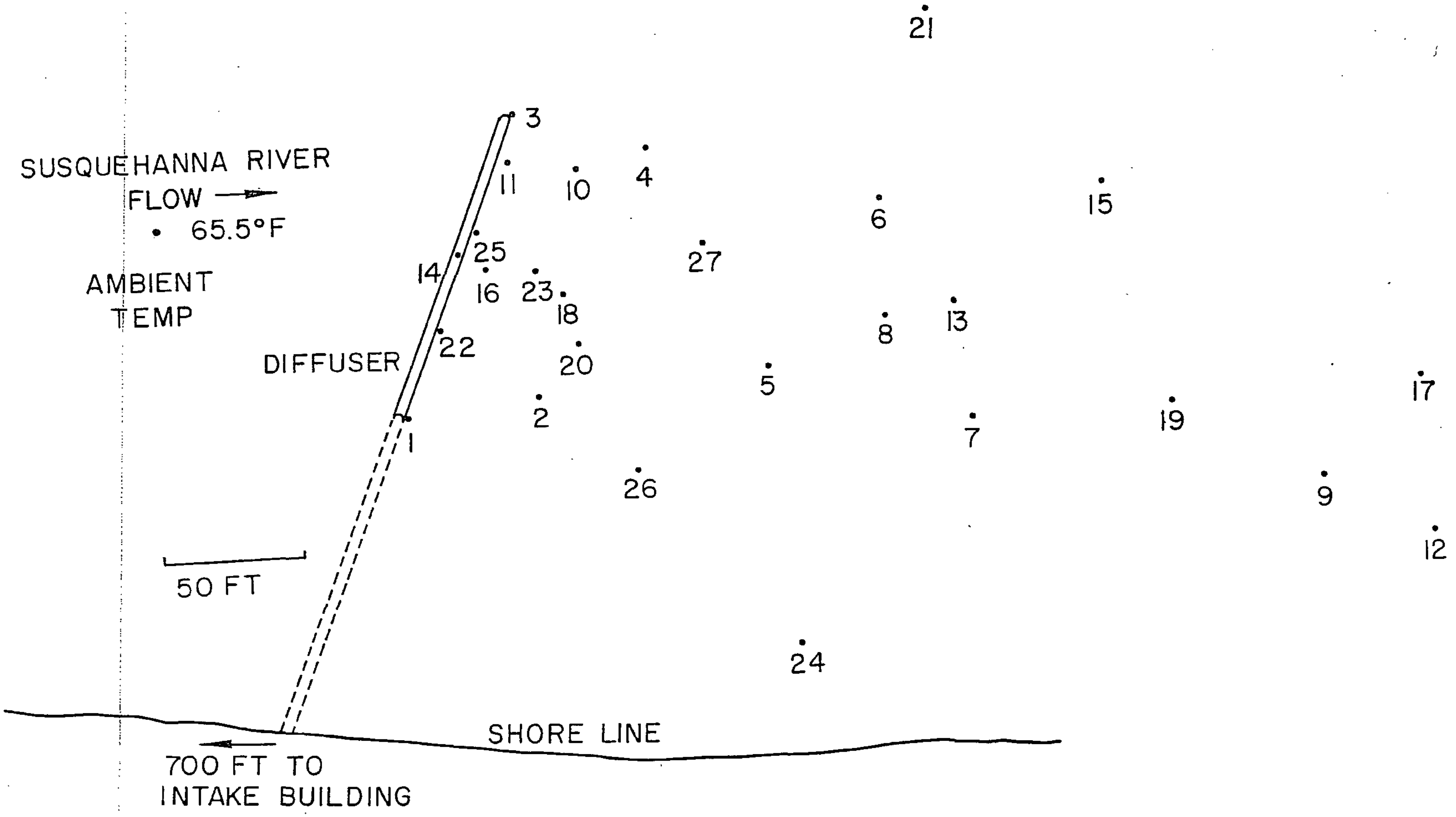

Figure 6

Sites at which water temperatures were recorded at 1-foot intervals from surface to bottom on the Susquehanna River near the discharge diffuser of the Susquehanna Steam Electric Station, 14 May 1987.

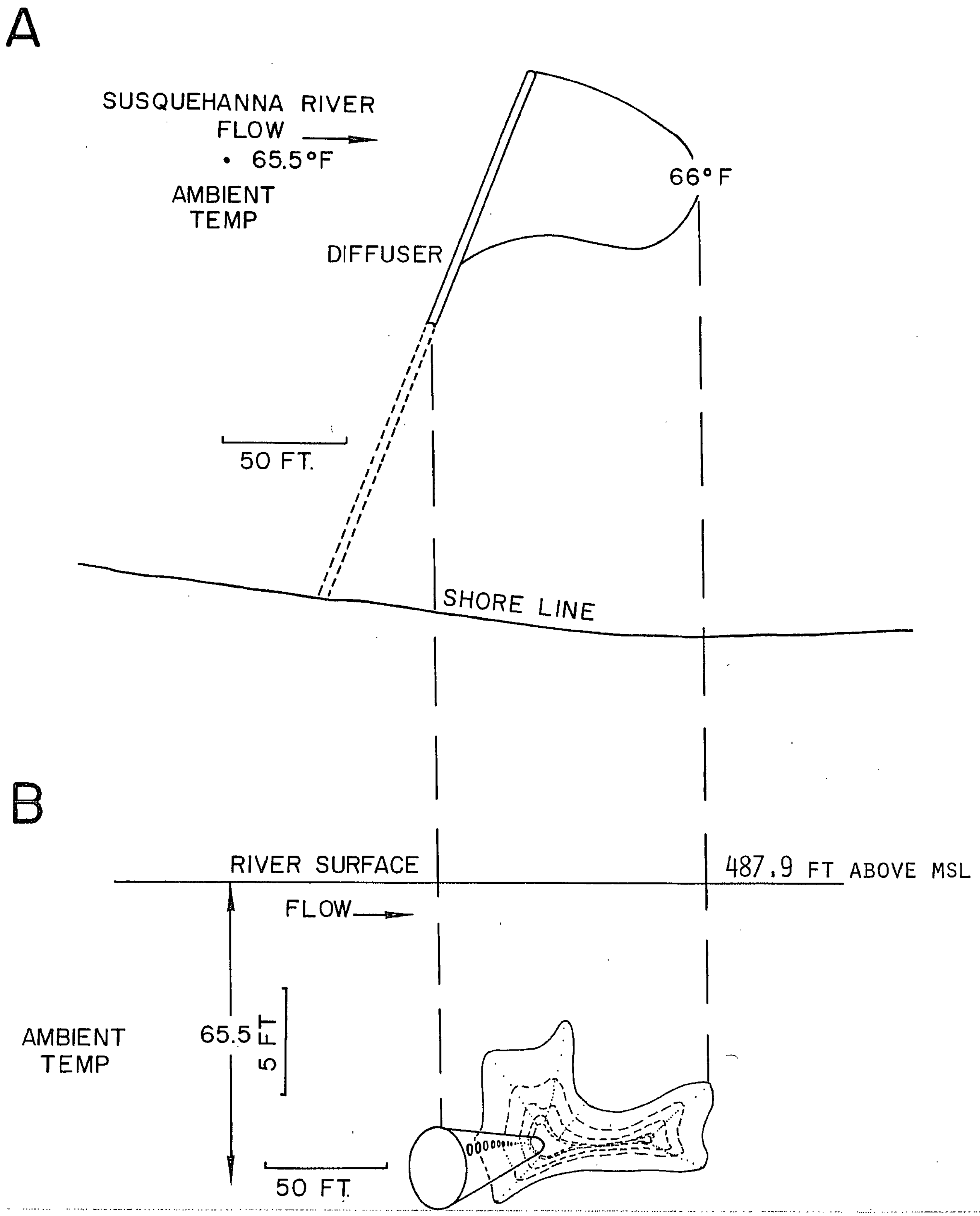

Figure 7

Limits of a thermal plume (0.5 F above ambient water temperature) in the Susquehanna River caused by the release of cooling tower blowdown from the discharge diffuser of the Susquehanna Steam Electric Station, 14 May 1987. (A = planar view, B = three-dimensional view)

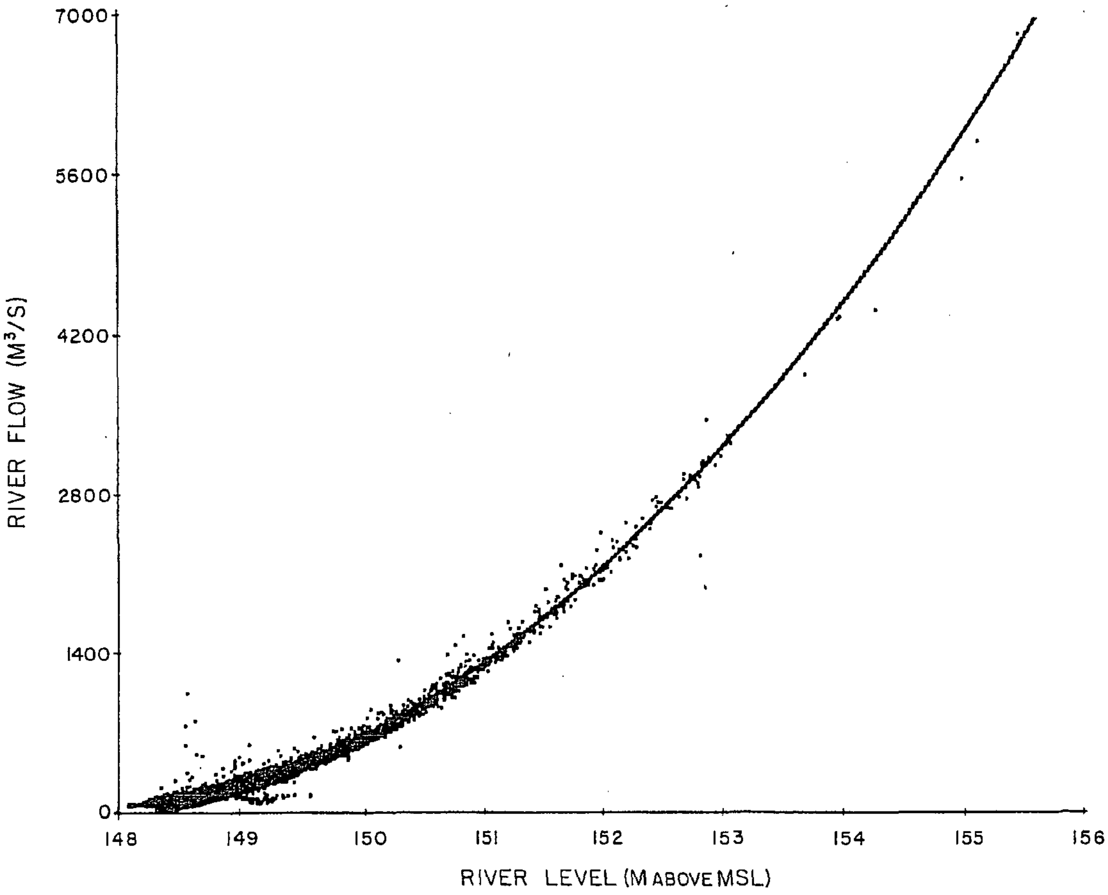

Figure 8

The relationship between flow (m^3/s) and level (m above msl) of the Susquehanna River at the Susquehanna SES Biological Laboratory from July 1973 through November 1980.

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17 February 2009

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SUSQUEHANNA STEAM ELECTRIC STATION
EIPL-1484
THERMAL PLUME SURVEYS – SUMMER 2008 – REV. 2

Attached are the final revised results of "Thermal Plume Surveys in the Susquehanna River at the Susquehanna Steam Electric Station Discharge Diffuser – Summer 2008." Many of the draft comments were incorporated into this final revision.

This report is a supplement to "Thermal Plume Studies in the Susquehanna River at the Discharge Diffuser of the Susquehanna Steam Electric Station, 1986-87".

If you have any questions, please contact me.

Theodore V. Jacobsen,
Project Director

/msh

Attachment

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THERMAL PLUME SURVEYS IN THE SUSQUEHANNA RIVER AT THE SUSQUEHANNA STEAM ELECTRIC STATION DISCHARGE DIFFUSER

SUMMER 2008

REVISION 2

Prepared by

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17 February 2009

CONTENTS

INTRODUCTION

The Susquehanna Steam Electric Station (Susquehanna SES) is a nuclear power station located along the Susquehanna River in northeastern Pennsylvania. Surveys of the thermal plume from the river water discharge diffuser were conducted in the winter, autumn, and spring, 1986-87 (Ecology III, 1987). All three plumes were very limited and posed no environmental hazards to aquatic life in the river. With this documented, and, due to other time constraints, a summer survey was never done.

In 2008, PPL proposed construction of the Bell Bend Nuclear Power Plant (BBNPP) on a site adjacent to the Susquehanna SES. This power plant would construct its own intake 300 feet downriver from the Susquehanna SES intake (315 feet upriver from the SSES diffuser) and its own river discharge diffuser 380 feet downriver from the SSES diffuser (Fig. 1). With the close proximity of these proposed structures to the existing Susquehanna SES diffuser, it was deemed necessary to conduct a summer thermal plume survey(s) at the Susquehanna SES diffuser to complete baseline studies in all four seasons.

The Susquehanna SES diffuser is a 42-inch diameter, 115-feet long pipe located on the river bottom about 200 feet from the west riverbank. Blowdown water is released into the river through a series of 72, 4-inch diameter ports spaced at 18-inch intervals along the upper edge of the downriver side of the diffuser. The effluent pipe connected to the diffuser is also 42-inches in diameter and approximately ¾-mile long from the diffuser to the cooling tower basins at the power station.

PROCEDURES

Summer thermal plume surveys were conducted at the Susquehanna SES river water diffuser at mid-day on 21 August and 3 September 2008. During each survey both boiling water reactors were at full power (Unit 1 = 94.4% and Unit 2 = 100%), for a total generating capacity of about 2,400 megawatts. At this power level, the river water withdrawal at the intake on both days was approximately 39,000 gallons per minute (gpm) with a mean temperature of 74.4°F, and the blowdown, as it exited the cooling tower basins on site, was 12,000 gpm at an average of 82.7°F (Table 1).

During both surveys, river water temperatures were measured with a YSI 650 MDS Sonde that was calibrated prior to use. A vertical series of temperatures were determined to the nearest 0.1°F from the surface to the river bottom at one-foot depths at each site downriver from the diffuser. Ambient river temperatures were measured immediately upriver from the diffuser before and after each survey. The surveys were done within 1½ hours to avoid too much of a change in ambient river temperature.

A crew of three in a boat and a surveyor on shore used a plane table mapping technique to locate the diffuser and each site. The boat driver first anchored over either end of the diffuser and then moved to each site within the probable location of the plume and anchored, while two crewmembers measured a vertical temperature series. At each anchorage, the surveyor sighted a stadia rod mounted on the boat with a Watts microptic alidade on top of the plane table set up along the shoreline. These sightings were then transcribed onto a base map at a scale of 1 inch = 50 feet.

In the laboratory, these data were used to define the edge of the plume at 0.5°F and 1.0°F isotherms above ambient river temperature by interpolating its location among the vertical series of temperatures at each site. Planar views were then drawn for each survey to show the extent of the thermal plume.

RESULTS

During the first survey on 21 August 2008, the weather was overcast and ambient river temperature did not change throughout the survey. The average river flow on this date was 3,230 cubic feet per second (cfs) at a river level of 487.0 feet above mean sea level (msl) as recorded on the calibrated river level gage at the Susquehanna SES Environmental Laboratory (Water Quality Procedures 2004). The relationship of river level to river flow at the Lab was documented by Soya (1991). The plume was detected within 6 of the 28 sites (Table 2). The vertical temperature measurements show that it did not reach the surface before dissipating. The planar view in Fig. 2 defines the plume at the 0.5°F isotherm. It was less than 40 feet wide at the diffuser and narrowed as it extended 120 feet downriver.

In the second survey on 3 September 2008, bright sunlight warmed the river temperature nearly 1°F during the 1½-hour data collection period at 22 sites (Table 3). This warming necessitated the adjustment of the temperatures recorded midway through the period by subtracting 0.5°F from each temperature. The average river flow on this date was 2,140 cfs at a river level of 486.5 ft above msl. This river flow was one-third less than the flow during the first survey.

A thermal plume at 0.5°F was detected at most sites (Fig. 3); it was about 100 feet wide and extended downriver from the diffuser 300 feet. A smaller 1.0°F isotherm was found immediately downriver from the diffuser. Overall, the plume appeared to reach the surface of the river throughout the 0.5°F isotherm (Fig. 3), ranging from 0.1°F or less at Sites 12 and14 and to 0.8°F at Sites 21 and 22 (Table 3). However, surface temperatures at Sites 21 and 22 were probably more influenced by solar warming than by a thermal plume from the blowdown discharge. Furthermore, the adjusted 0.8°F temperatures at these two sites is perhaps quite conservative since they were the last to be measured during the survey and were within 0.1°F of the final ambient temperature recorded at 1252 hours (Table 3). They were actually 0.1°F cooler than the final ambient reading indicating that the surface heating at Sites 21 and 22 may possibly have been closer to zero than to 0.8°F. Additionally, subsurface temperatures from 1 to 3 feet at both sites were lower than the surface temperatures, and since any thermal heating reaching the river surface would first have to pass through these levels, the thermal plume may not have even reached the surface of the river at these sites.

Averaging the delta t surface temperatures of the 20 sites within the 0.5°F plume (less Sites 13 and 14) reveals that the surface temperature of the plume may have increased the ambient river temperature by 0.4°F only immediately above the plume, but that some of this increase was also caused by solar radiation despite an attempt to adjust for it.

SUMMARY

The water temperature in the cooling tower basins was a maximum of 7.4°F and 11.7°F above ambient river temperature during the surveys on 21 August and 3 September 2008, respectively (Table 1). With these delta t's, one might have expected a more extensive thermal plume in the river on both survey dates. However, the blowdown probably cools as it flows through the ¾-mile blowdown effluent pipe and, even more so, when it mixes with the water backed up into the effluent pipe and the diffuser before it exits out of the diffuser ports and into the river.

This cooling effect could be evaluated further with other surveys throughout the blowdown effluent pipe, but the fact remains that the thermal plume from the Susquehanna SES diffuser is very limited even during low river flow conditions. Thermal plumes of this size will pose no thermal environmental hazard to aquatic life in the Susquehanna River.

REFERENCES

Ecology III, Inc. 1987. Thermal plume studies in the Susquehanna River at the discharge diffuser of the Susquehanna Steam Electric Station, 1986-87. Prepared for Pennsylvania Power and Light Company. 8 pp.

Ecology III, Inc. 2004. Water quality procedures, 15 pp. *In* Procedures for Nonradiological Environmental Monitoring Program (Non-Quality) and Safety Programs at the Susquehanna SES Environmental Laboratory. Ecology III, Inc., Berwick, PA.

Soya, W. J. 1991. Depth – level – flow relationship of the Susquehanna River at the Susquehanna SES Environmental Laboratory. Ecology III, Inc., Berwick, PA. 10 pp.

Table 1
River water intake temperature and blowdown discharge temperature (as calculated from monitoring points in the cooling tower basins) at the Susquehanna Steam Electric Station during times of thermal plume surveys, 21 August and 3 September 2008. (Data provided by J. J. Kostyal, PPL Susquehanna)

Archived SSES Data (PI System)
Start: 8/21/2008 11:00
End 8/21/2008 13:00

	River Water Intake Temp (°F)	Unit 1 Blowdown* Temp (° F)	Delta t (° F)	Unit 2 Blowdown* Temp (° F)	Delta t (° F)
Min	74.5	79.6	5.1	81.0	6.5
Avg	74.5	80.6	6.1	81.6	7.0
Max	74.6	81.2	6.6	82.0	7.4

Archived SSES Data (PI System)
Start: 9/3/2008 11:00
End: 9/3/2008 13:00

	River Water Intake Temp (°F)	Unit 1 Blowdown* Temp (° F)	Delta t (° F)	Unit 2 Blowdown* Temp (° F)	Delta t (° F)
Min	74.2	82.1	7.9	83.6	9.4
Avg	74.3	83.7	9.4	84.8	10.6
Max	74.3	85.3	11.0	85.9	11.7

*Average CW/LP Inlet (Basin temperature, °F)

Table 2

Temperatures (°F) recorded at 1-foot intervals from surface to bottom at 28 sites on the Susquehanna River downriver from the Susquehanna Steam Electric Station discharge diffuser, 21 August 2008.

Site No.	Time	Temperature (F)		Depth in Feet																	Bottom	
		Air	Surface	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Depth	Temp
Ambient	1038	77.0	74.0	74.0	74.0	74.0	74.0	73.9	73.9	73.9	73.9	73.9	73.9	73.9	73.9						12	73.9
1	1045		74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.1	74.1	74.1	74.1	74.1	74.1					13	74.1
2	1049		74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.1	74.1	74.1	74.1	74.1	74.1					13	74.1
3	1050		74.0	74.0	74.1	74.1	74.1	74.1	74.1	74.1	74.1	74.1	74.1	74.1	74.0	74.0	74.0	74.0	74.0		16	74.0
4	1054		74.0	74.0	74.0	74.0	74.0	74.1	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0			15	74.0
5	1055		74.0	74.0	74.1	74.1	74.1	74.1	74.1	74.1	74.0	74.0	74.0	74.0	74.0	74.0	74.0				14	74.0
6	1056		74.1	74.1	74.1	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0				14	74.0
7	1058		74.0	74.0	74.0	74.1	74.1	74.1	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0				14	74.0
8	1100		73.9	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0				14	74.0
9	1102		74.0	74.0	74.0	74.1	74.1	74.1	74.5	74.5	74.5	74.5	74.6	74.4	74.4	74.4	74.3	74.2	74.2		16	74.2
10	1104		74.0	74.1	74.1	74.1	74.1	74.3	74.2	74.1	74.1	74.1	74.2	74.1	74.1						12	74.1
11	1106		74.0	74.0	74.1	74.1	74.1	74.1	74.1	74.1	74.1	74.1	74.1	74.1	74.1	74.1					13	74.1
12	1108		74.0	74.0	74.0	74.0	74.1	74.1	74.2	74.1	74.1	74.1	74.1	74.1	74.1	74.1	74.1				14	74.1
13	1111		74.0	74.0	74.1	74.1	74.1	74.1	74.2	74.2	74.4	74.3	74.4	74.5	74.6	74.7	74.5	74.5	74.5		16	74.5
14	1114		74.0	74.0	74.0	74.1	74.1	74.1	74.1	74.1	74.2	74.2	74.1	74.1	74.0	74.1	74.1	74.2	74.2		10	74.2
15	1116		74.0	74.0	74.0	74.1	74.1	74.1	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0		16	74.0
16	1118		74.0	74.0	74.0	74.0	74.1	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0						12	74.0
17	1119		74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0			15	74.0
18	1123		74.0	74.0	74.0	74.1	74.1	74.1	74.1	74.0	74.0	74.0	74.0	74.0	74.0	74.1	74.1	74.1	74.1		16	74.1
19	1126		74.0	74.0	74.1	74.0	74.1	74.0	74.0	74.0	74.0	74.0	74.1	74.0	74.0	74.0	74.0	74.0			15	74.0
20	1128		73.9	74.0	74.0	74.0	74.0	74.1	74.0	74.0	74.0	74.0	74.1	74.0	74.0	74.1					13	74.1
21	1138		74.0	74.0	74.0	74.0	74.0	74.5	74.5	74.5	75.0	75.0	75.0	74.5	74.5	74.5	74.5	75.0	75.0	75.0	17	75.0
22	1141		74.0	74.0	74.0	74.5	74.5	74.5	74.5	74.5	74.5	74.5	75.0	74.5	74.5	74.5	74.5				14	74.5
23	1145		74.0	74.0	74.0	74.0	74.5	74.5	74.5	74.5	74.5	74.5	74.5	74.5							11	74.5
24	1147		74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0			15	74.0
25	1150		74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0		16	74.0
26	1152		74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0								10	74.0
27	1155		74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0											7	74.0
28	1156		74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0						12	74.0
Ambient*	1200	78.0	74.0																			

*Only surface temperature recorded. Constant surface to bottom temperatures at sites 26-28 indicate that ambient temperature remained at 74°F throughout the survey.

Table 3

Temperatures (°F) recorded at 1-foot intervals from surface to bottom at 22 sites on the Susquehanna River downriver from the Susquehanna Steam Electric Station discharge diffuser, 3 September 2008.

Site No.	Time	Temperature (F)		Depth in Feet															Bottom	
		Air	Surface	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Depth	Temp
Ambient	1126	77.6	74.6	74.5	74.5	74.5	74.4	74.4	74.3	74.3	74.3	74.3	74.3	74.3					11	74.3
1	1129		74.9	74.8	74.9	74.9	74.9	74.9	74.9	74.9	75.0	75.0	75.0	75.0	74.9	74.9	74.9		14	74.9
2	1134		75.0	75.1	75.0	75.1	75.0	75.0	75.0	75.0	75.0	75.1	75.0	75.0	75.0	75.0	75.0		14	75.0
3	1138		74.9	75.0	75.0	75.0	75.0	75.0	74.9	74.9	75.0	75.0	74.9	74.9	74.9	74.9			13	74.9
4	1141		75.1	75.0	75.0	74.9	74.9	74.9	75.0	75.0	74.9	74.9	74.9	74.8	74.8				12	74.8
5	1144		75.0	75.0	75.0	74.9	75.0	74.8	74.8	74.8	74.8	74.8	74.8	74.7	74.7				12	74.7
6	1147		74.9	75.0	75.1	74.8	74.8	74.9	74.7	74.8	74.9	74.7	74.9	74.9	74.9	75.0	74.9	74.9	15	74.9
7	1151		75.0	75.0	74.9	74.9	74.8	74.7	74.7	74.7	74.8	74.8	74.7	74.7	74.7	74.8	74.8	74.8	15	74.8
8	1154		75.1	75.1	74.8	74.7	75.1	74.9	74.8	74.7	74.7	74.7	74.7	74.7	74.7	74.7	74.7		14	74.7
9	1201		74.8	74.8	74.7	74.7	74.7	74.7	74.7	74.7	74.7	74.8	74.8	74.7	74.6	74.6	74.6		14	74.6
10	1204		74.9	74.8	74.8	74.8	74.8	74.8	74.9	75.0	74.9	74.8	74.8	74.8	74.7	74.7	74.7		14	74.7
11	1207		75.2	75.1	75.0	74.8	74.9	74.8	74.8	74.8	74.8	74.8	74.8	74.8	74.8				12	74.8
12*	1210		74.5	74.5	74.5	74.5	74.4	74.4	74.4	74.4	74.4	74.4	74.4	74.4					11	74.4
13	1213		74.8	74.7	74.6	74.4	74.3	74.3	74.4	74.3	74.3	74.4	74.4	74.3	74.3	74.3			13	74.3
14	1216		74.7	74.7	74.6	74.5	74.5	74.4	74.4	74.4	74.4	74.3	74.3	74.3					11	74.3
15	1225		75.1	75.1	75.0	75.1	75.0	75.1	75.0	74.8	75.1	75.2	75.0	74.9	74.8	74.7	74.7	74.7	15	74.7
16	1228		75.0	74.9	74.8	74.8	74.7	74.8	74.8	74.8	74.7	74.7	74.7	74.7	74.7	74.6			13	74.6
17	1230		75.1	75.0	75.0	75.0	74.9	74.9	74.9	74.8	74.8	74.8	74.9	74.9	74.9	74.9	74.7		14	74.7
18	1232		75.0	75.0	75.0	75.0	75.0	75.0	74.9	74.9	74.9	74.9	74.8	74.8	74.7	74.6			13	74.6
19	1234		75.0	75.0	75.0	74.9	74.9	74.8	74.9	74.8	74.8	74.8	74.8	74.8	74.8				12	74.8
20	1239		74.8	75.1	75.1	75.2	75.1	75.0	75.0	75.2	75.1	75.0	74.9	75.0	74.9	74.9	74.8		14	74.8
21	1244		75.4	75.0	74.8	74.7	74.5	74.5	74.5	74.4	74.5	74.4	74.5	74.5					11	74.5
22	1249		75.4	74.9	75.2	75.1	75.5	75.5	75.4	75.6	75.5	75.4	75.3	75.3	75.3	75.2	75.2		14	75.2
Ambient	1252	79.5	75.5	75.3	75.3	75.2	75.1	75.1	75.1	75.1	75.0	75.0	75.0	75.0	75.0				12	75.0

*All temperatures (except ambient) measured after 1210 hours were adjusted for an increase in ambient temperature by subtracting 0.5°F.

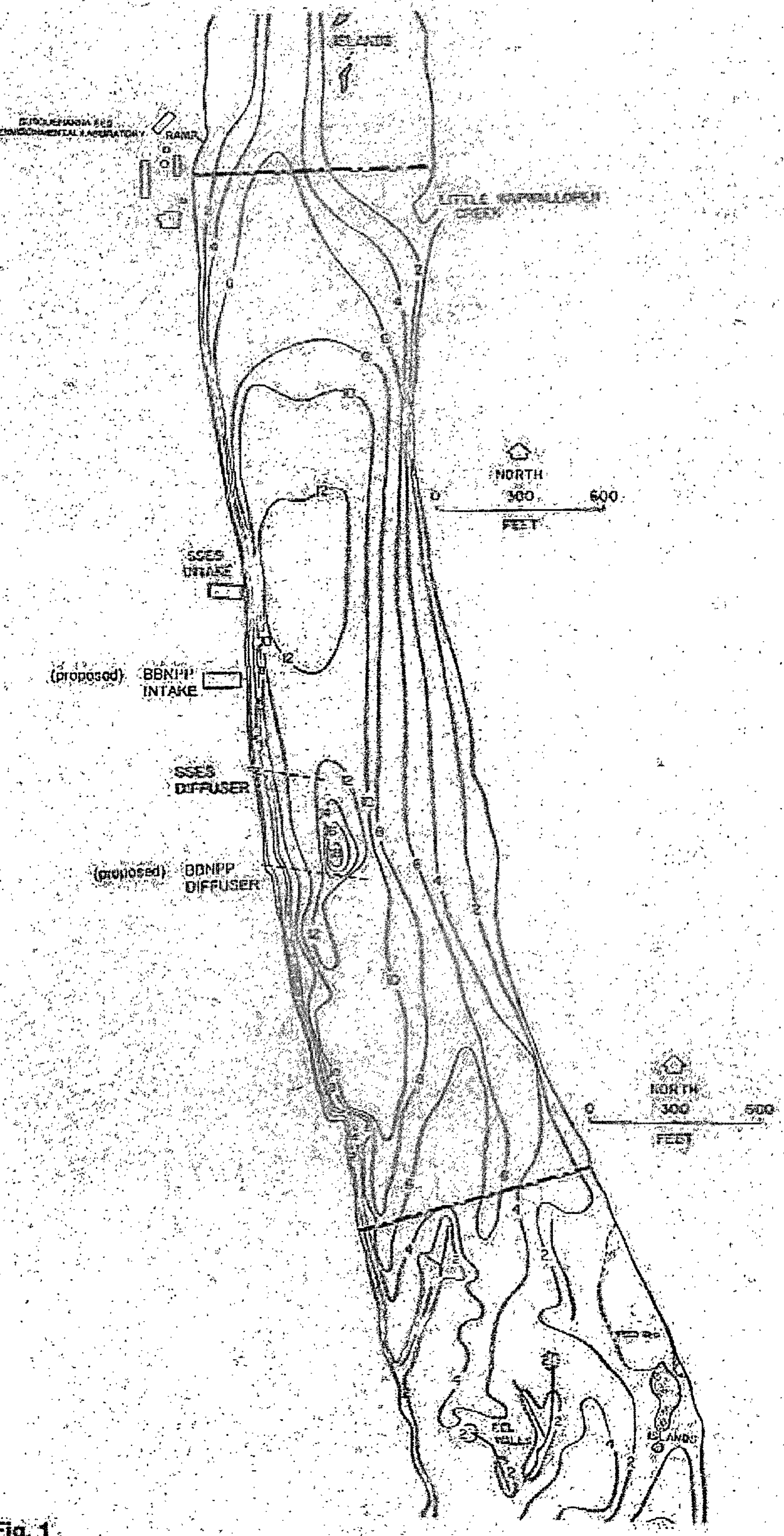


Fig. 1

Location of the Susquehanna Steam Electric Station (SSES) and the proposed Bell Bend Nuclear Power Plant (BBNPP) river water intakes and discharge diffusers along the west bank of a pool in the Susquehanna River, six miles upriver from Berwick, PA, 2008. Depth contours at 2-foot intervals based on a river level at 486.2 feet above mean sea level surveyed in 1983.

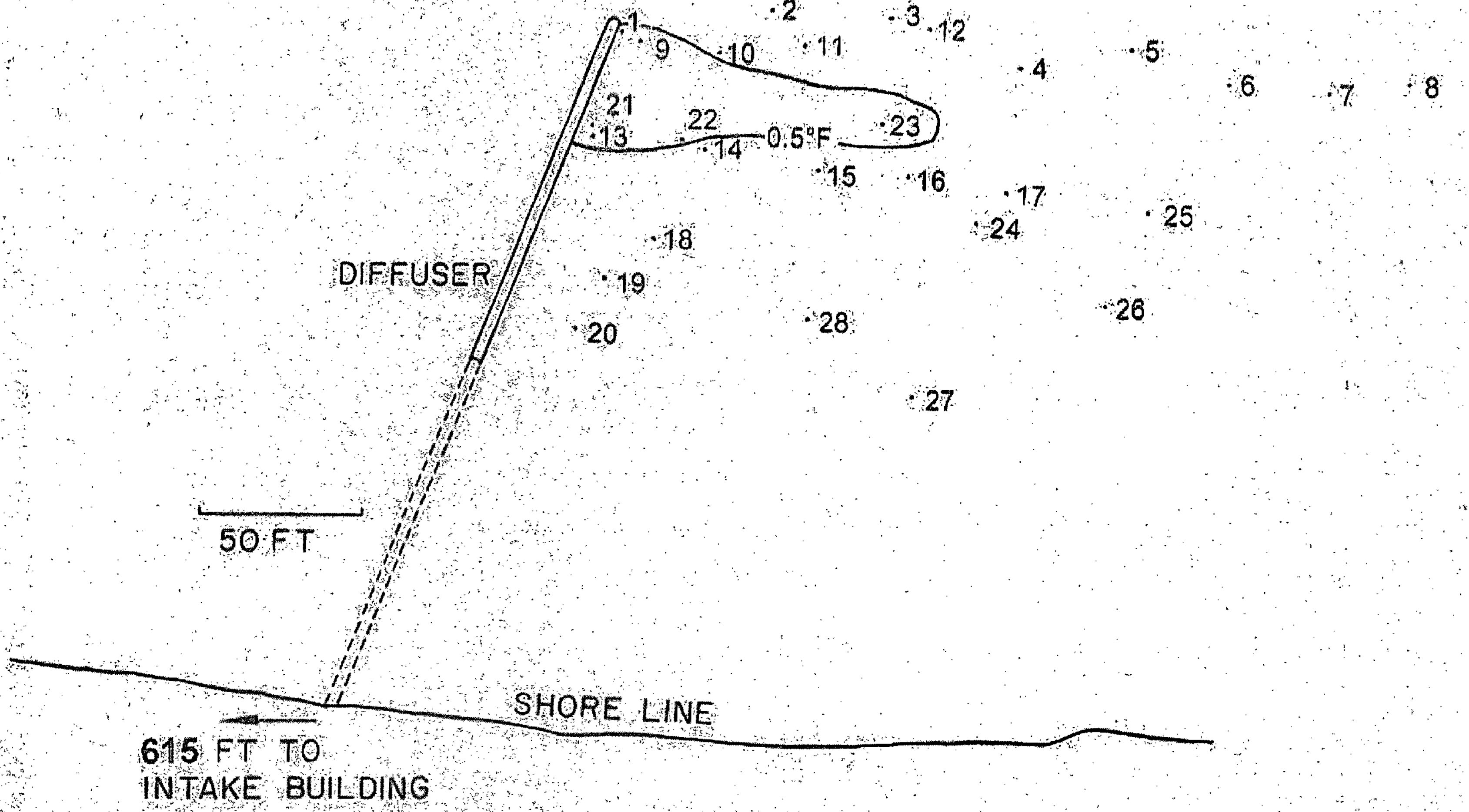


Fig. 2

Limits of a thermal plume (0.5° F above ambient water temperature) in the Susquehanna River caused by the release of cooling tower blowdown (12,000 gpm) from the Susquehanna Steam Electric Station discharge diffuser as measured at 28 sites, 21 August 2008. Average river flow on this date was 3,230 cubic feet/second.

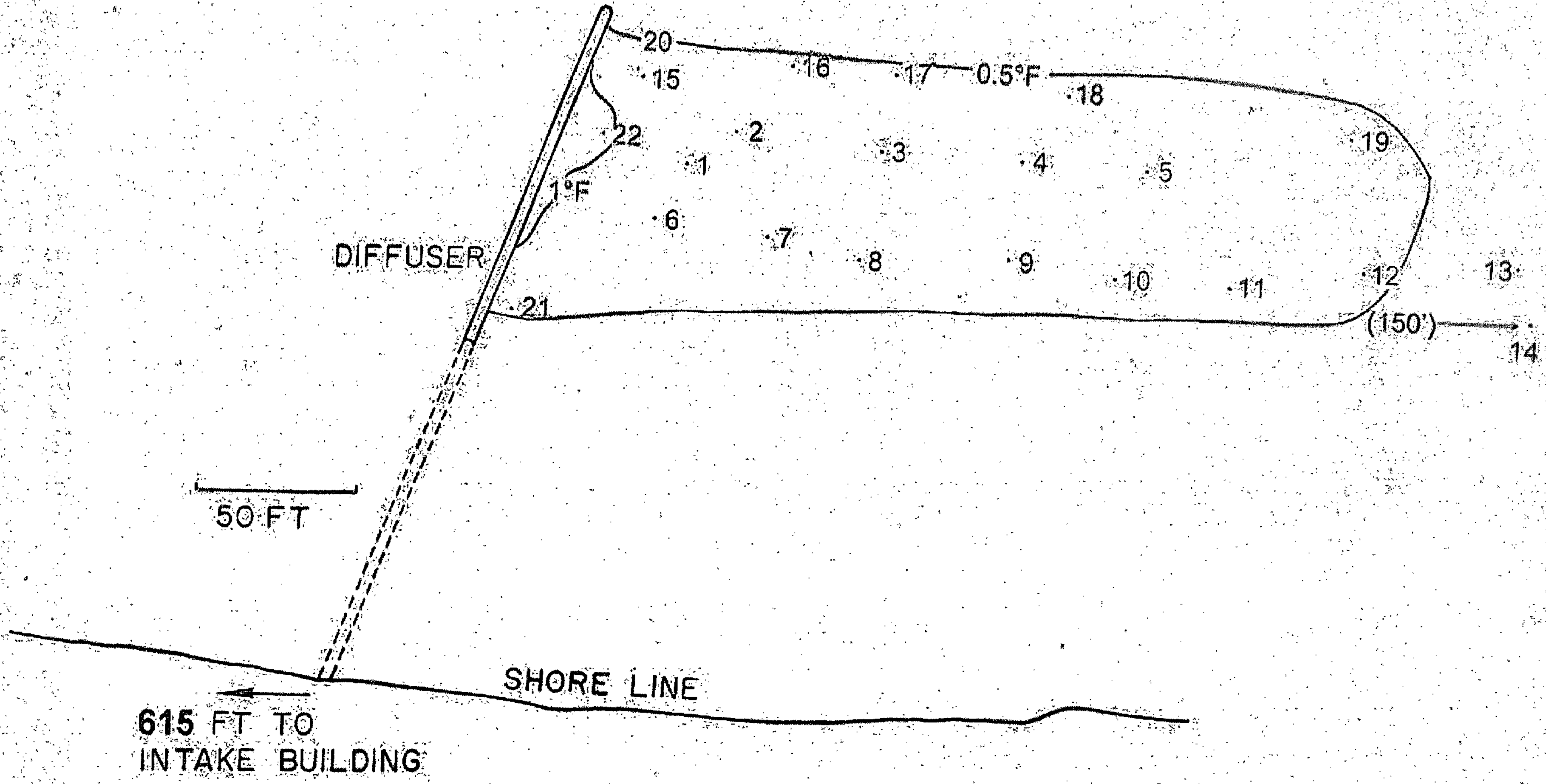


Fig. 3

Limits of a thermal plume (0.5° and 1° F above ambient water temperature) in the Susquehanna River caused by the release of cooling tower blowdown (12,000 gpm) from the Susquehanna Steam Electric Station discharge diffuser as measured at 22 sites, 3 September 2008. Average river flow on this date was 2,140 cubic feet/second.

APPENDIX B SPECIES COMPOSITION OF FISHES AND MACROINVERTEBRATES

FISH SPECIES COMPOSITION

FISH SPECIES COMPOSITION

Number and percent composition of fish collected by seining relative to SSES and Bell Bend Projects on the Susquehanna River, 2004-2007. Reproduced from Ecology III (2008).

	2004		2005		2006		2007		Total	
Taxon	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
					SSES					
Spotfin shiner	49	28.5	52	20.9	116	64.8	195	44.9	412	39.8
Comley shiner		0.0	1	0.4		0.0			1	0.1
Spottail shiner	29	16.9	76	30.5	52	29.1	83	19.1	240	23.2
Bluntnose minnow	64	37.2	12	4.8		0.0	3	0.7	79	7.6
Blacknose dace							12	2.8	12	1.2
Fallfish	1	0.6	8	3.2	1	0.6	1	0.2	11	1.1
White sucker	2	1.2	61	24.5		0.0	73	16.8	136	13.2
Norther pike		0.0	1	0.4		0.0			1	0.1
Muskellunge		0.0	3	1.2		0.0			3	0.3
Channel catfish							1	0.2	1	0.1
Rock bass	7	4.1	1	0.4		0.0	2	0.5	10	1.0
Redbreast sunfish	1	0.6		0.0	2	1.1			3	0.3
Green sunfish							1	0.2	1	0.1
Bluegill		0.0	15	6.0	3	1.7	24	5.5	42	4.1
Smallmouth bass	5	2.9	12	4.8	1	0.6	17	3.9	35	3.4
Black crappie		0.0		0.0	2	1.1			2	0.2
Tessellated darter	11	6.4	4	1.6	2	1.1	9	2.1	26	2.5
Yellow perch	1	0.6		0.0		0.0			1	0.1
Banded darter		0.0	1	0.4		0.0	2	0.5	3	0.3
Walleye	2	1.2	2	0.8		0.0	11	2.5	15	1.5
Total number of fish	172		249		179		434		1034	
Total number of species	11		14		8		14		20	

Continued.

	2004		2005		2006		2007		Total	
Taxon	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
					Bell Bend					
Gizzard shad	1	0.1							1	*
Spotfin shiner	263	36.3	235	36.3	243	49.5	1082	60.1	1823	49.8
Comley shiner			1	0.2					1	0.0
Spottail shiner	325	44.8	47	7.3	245	49.9	338	18.8	955	26.1
Bluntnose minnow	92	12.7	42	6.5	1	0.2	63	3.5	198	5.4
Blacknose dace							3	0.2	3	0.1
Yellow bullhead					1	0.2			1	*
Fallfish	5	0.7							5	0.1
Quillback			5	0.8					5	0.1
White sucker	15	2.1	273	42.1			235	13.1	523	14.3
Northern hog sucker							2	0.1	2	0.1
Rock bass			4	0.6			5	0.3	9	0.2
Redbreast sunfish	1	0.1							1	*
Bluegill			4	0.6			15	0.8	19	0.5
Smallmouth bass	4	0.6	13	2.0	1	0.2	41	2.3	59	1.6
Tessellated darter	12	1.7	11	1.7			14	0.8	37	1.0
Banded darter			2	0.3			2	0.1	4	0.1
Yellow perch	1	0.1	1	0.2					2	0.1
Walleye	6	0.8	10	1.5					16	0.4
Total number of fish	725		648		491		1800		3664	
Total number of species	11		13		5		11		19	

* less than 0.1%

Number and percent composition of fish collected by electrofishing relative to SSES and Bell bend Projects on the Susquehanna River, 2004-2007. Reproduced from Ecology III (2008).

	2004		2005		2006		2007		Total	
Taxon	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
					SSES					
Gizzard shad	1	0.2	3	0.8	1	0.4	6	0.7	11	0.6
Common carp	13	2.9	7	1.8	8	3.3	21	2.5	49	2.6
River chub	2	0.4					1	0.1	3	0.2
Fallfish	3	0.7	3	0.8	1	0.4	13	1.6	20	1.0
Quillback	101	22.3	65	16.3	5	2.1	55	6.6	226	11.8
White sucker	11	2.4	3	0.8	4	1.7	4	0.5	22	1.1
Northern hog sucker	29	6.4	50	12.5	23	9.6	110	13.3	212	11.0
Shorthead redhorse	38	8.4	49	12.3	22	9.2	51	6.2	160	8.3
Sucker spp.	2	0.4	2	0.5					4	0.2
Yellow bullhead			1	0.3					1	0.1
Channel catfish	9	2.0	11	2.8	16	6.7	14	1.7	50	2.6
Northern pike	1	0.2	1	0.3	2	0.8	3	0.4	7	0.4
Muskellunge	4	0.9	6	1.5	3	1.3	2	0.2	15	0.8
Pike spp.			2	0.5	1	0.4			3	0.2
Brown trout			1	0.3					1	0.1
Rock bass	39	8.6	36	9.0	11	4.6	69	8.3	155	8.1
Redbreast sunfish	2	0.4	3	0.8	1	0.4	1	0.1	7	0.4
Green sunfish	6	1.3							6	0.3
Pumpkinseed			2	0.5					2	0.1
Bluegill	11	2.4	9	2.3	1	0.4	2	0.2	23	1.2
Smallmouth bass	66	14.6	71	17.8	61	25.4	216	26.1	414	21.6
Sunfish spp.	6	1.3	10	2.5	1	0.4	7	0.8	24	1.2
Yellow perch							4	0.5	4	0.2
Walleye	42	9.3	27	6.8	46	19.2	195	23.5	310	16.1
Fish (unidentified)	67	14.8	37	9.3	33	13.8	55	6.6	192	10.0
		100.0		100.0		100.0		100.0		100.0
Total number of fish	453		399		240		829		1,921	
Total number of species	17		18		15		17		21	

Continued.

Taxon	2004		2005		2006		2007		Total	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
					Bell Bend					
Gizzard shad			1	0.2	1	0.3	1	0.1	3	0.2
Common carp	21	3.9	27	6.4	17	5.8	26	3.6	91	4.6
River chub	2	0.4		0.0	1	0.3			3	0.2
Fallfish	4	0.7	7	1.7		0.0	5	0.7	16	0.8
Quillback	122	22.6	62	14.7	8	2.7	56	7.8	248	12.6
White sucker	7	1.3	6	1.4	1	0.3	10	1.4	24	1.2
Northern hog sucker	1	0.2	5	1.2	4	1.4	29	4.1	39	2.0
Shorthead redhorse	22	4.1	5	1.2	9	3.1	14	2.0	50	2.5
Sucker spp.			3	0.7	2	0.7			5	0.3
Brown bullhead	1	0.2	1	0.2		0.0			2	0.1
Yellow bullhead							1	0.1	1	0.1
Channel catfish	8	1.5	5	1.2	14	4.8	10	1.4	37	1.9
Northern pike	4	0.7	2	0.5		0.0	5	0.7	11	0.6
Muskellunge	1	0.2	5	1.2	3	1.0			9	0.5
Chain pickerel			1	0.2		0.0			1	0.1
Pike spp.			2	0.5		0.0			2	0.1
Rock bass	61	11.3	41	9.7	11	3.8	48	6.7	161	8.2
Redbreast sunfish	2	0.4	2	0.5	2	0.7			6	0.3
Green sunfish	4	0.7	4	0.9	1	0.3	1	0.1	10	0.5
Pumpkinseed	1	0.2		0.0		0.0			1	0.1

MACROINVERTEBRATES COMPOSITION

MACROINVERTEBRATES COMPOSITION

Comparative densities of organisms/m^2 in dome samples collected from the Susquehanna River at SSES I and Bell Bend IV from 1990-94 and 2007. The data used for this comparison represented the dome sample at each site with the greatest overall density (minus Oligochaetes). Reproduced from Ecology

			SSES I			
Taxon	1990	1991	1992	1993	1994	2007
Crustacea	6	25	0	12	6	583
Plecoptera	110	104	0	43	6	86
Ephemeroptera	2384	4359	570	5595	589	3209
Trichoptera	1661	2322	1771	3083	785	883
Coleoptera	1067	2029	1231	785	840	3473
Diptera	993	552	392	361	110	644
Mollusca	503	160	754	0	18	1521
Other	48	6	42	24	24	1196
Total	6772	9557	4760	9903	2378	11595

			Bell Bend IV			
Taxon	1990	1991	1992	1993	1994	2007
Crustacea	0	0	0	12	6	607
Plecoptera	49	0	0	6	18	12
Ephemeroptera	925	2526	301	2066	324	2842
Trichoptera	208	447	196	110	428	295
Coleoptera	1006	601	257	337	214	1416
Diptera	687	643	325	1398	404	1301
Mollusca	441	275	220	49	79	3602
Other	55	30	24	61	18	281
Total	3371	4522	1323	4039	1491	10356

Table 2.4-20 Number and Percent Total of Benthic Macroinvertebrates Collected with a Dome Sampler at SSES (replicate 1) in the Susquehanna River, August 15, 2007

Group	Taxon	Group		Taxon	
		Number	% Total	Number	% Total
OLIGOCHAETA		1	0.1	1	0.1
CRUSTACEA		59	3.8		
	Amphipoda			59	3.8
PLECOPTERA		20	1.3		
	Agnetina			10	0.6
	Chloroperlidae			1	0.1
	Neoperla			9	0.6
EPHEMEROPTERA		202	13.0		
	Anthopotamus			160	10.3
	Caenis			4	0.3
	Isonychia			1	0.1
	Leucrocuta			10	0.6
	Serratella			1	0.1
	Stenacron			2	0.1
	Stenonema			5	0.3
	Tricorythodes			19	1.2
TRICHOPTERA		74	4.8		
	Ceraclea			10	0.6
	Cheumatopsyche			11	0.7
	Chimarra			3	0.2
	Protoptila			6	0.4
	Hydropsyche			2	0.1
	Macrostemum			28	1.8
	Neureclipsis			14	0.9
COLEOPTERA		548	35.4		
	Dineutus			2	0.1
	Optioservus			4	0.3
	Stenelmis			542	35.0
DIPTERA		73	4.7		
	Chironomidae			73	4.7
MOLLUSCA		543	35.0		
	Ferrissia			5	0.3
	Corbicula			8	0.5
	subviridis			1	0.1
	Leptoxis			1	0.1
	Musculium			500	32.3
	Pisidium			28	1.8
OTHER		30	1.9		
	Acariformes			1	0.1
	Alloeocoela			4	0.3
	Prostoma			1	0.1
	Tricladida			22	1.4
	Coenagrionidae			2	0.1
Total number of organisms		1550		1,550	
Total number of taxa		9		35	

Table 2.4-21 Number and Percent Total of Benthic Macroinvertebrates Collected with a Dome Sampler at SSES (replicate 2) in the Susquehanna River, August 15, 2007

Group	Taxon	Group		Taxon	
		Number	% Total	Number	% Total
CRUSTACEA		95	5.0		
	Amphipoda			95	5.0
PLECOPTERA		14	0.7		
	Agnetina			12	0.6
	Neoperla			2	0.1
EPHEMEROPTERA		523	27.7		
	Anthopotamus			473	25.0
	Caenis			1	0.1
	Isonychia			1	0.1
	Leucrocuta			19	1.0
	Serratella			7	0.4
	Stenacron			1	0.1
	Stenonema			8	0.4
	Tricorythodes			13	0.7
TRICHOPTERA		144	7.6		
	Ceraclea			9	0.5
	Cheumatopsyche			19	1.0
	Chimarra			7	0.4
	Protoptila			12	0.6
	Hydropsyche			3	0.2
	Macrostemum			69	3.7
	Neureclipsis			22	1.2
	Oecetis			3	0.2
COLEOPTERA		566	29.9		
	Dineutus			2	0.1
	Stenelmis			564	29.8
DIPTERA		105	5.6		
	Chironomidae			105	5.6
MOLLUSCA		248	13.1		
	Ferrissia			3	0.2
	Corbicula			4	0.2
	Musculium			202	10.7
	Pisidium			29	1.5
	Sphaerium			10	0.5
OTHER		195	10.3		
	Alloeocoela			7	0.4
	Prostoma			3	0.2
	Tricladida			185	9.8
Total number of organisms		1,890		1,890	
Total number of taxa		8		30	

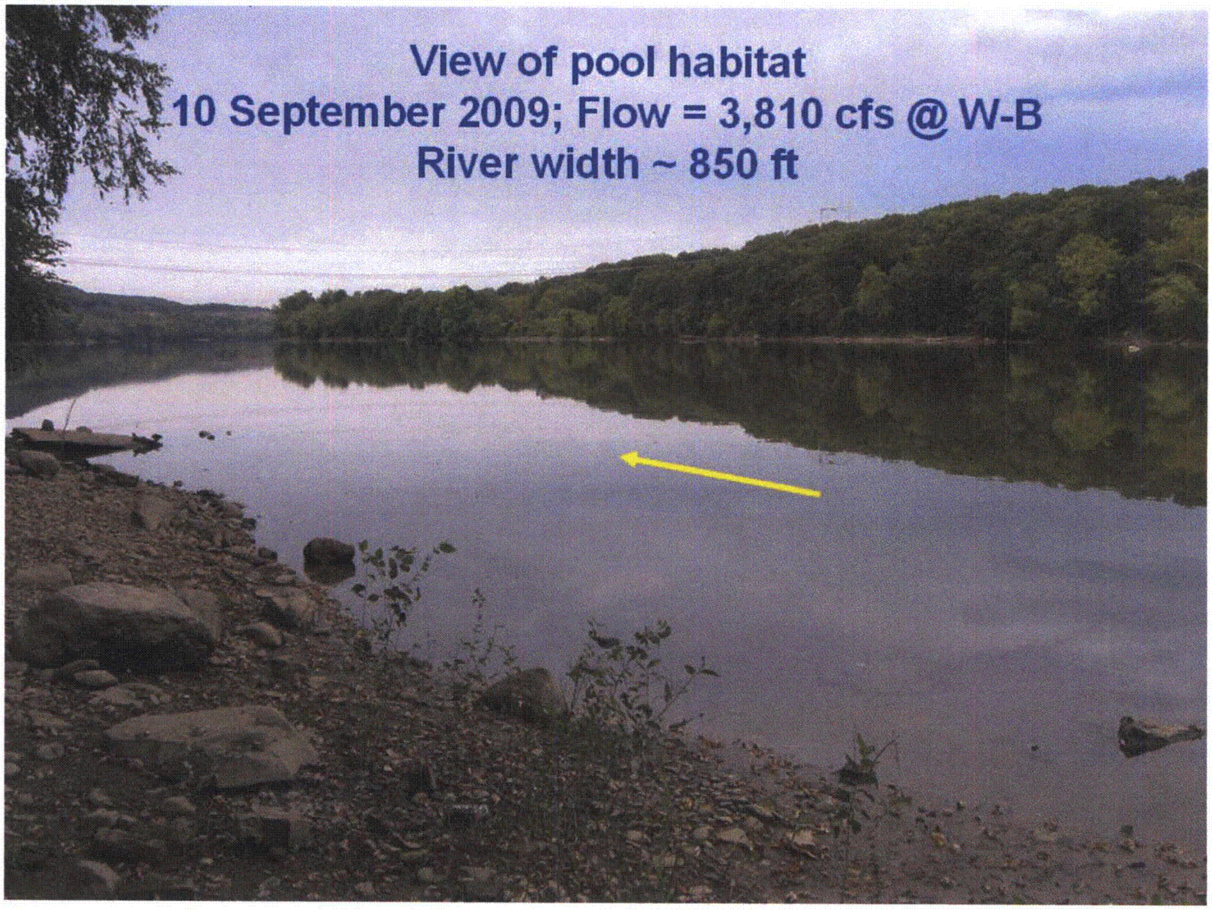
Table 2.4-22 Number and Percent Total of Benthic Macroinvertebrates Collected with a Dome Sampler at Bell Bend (replicate 1) in the Susquehanna River, August 15, 2007

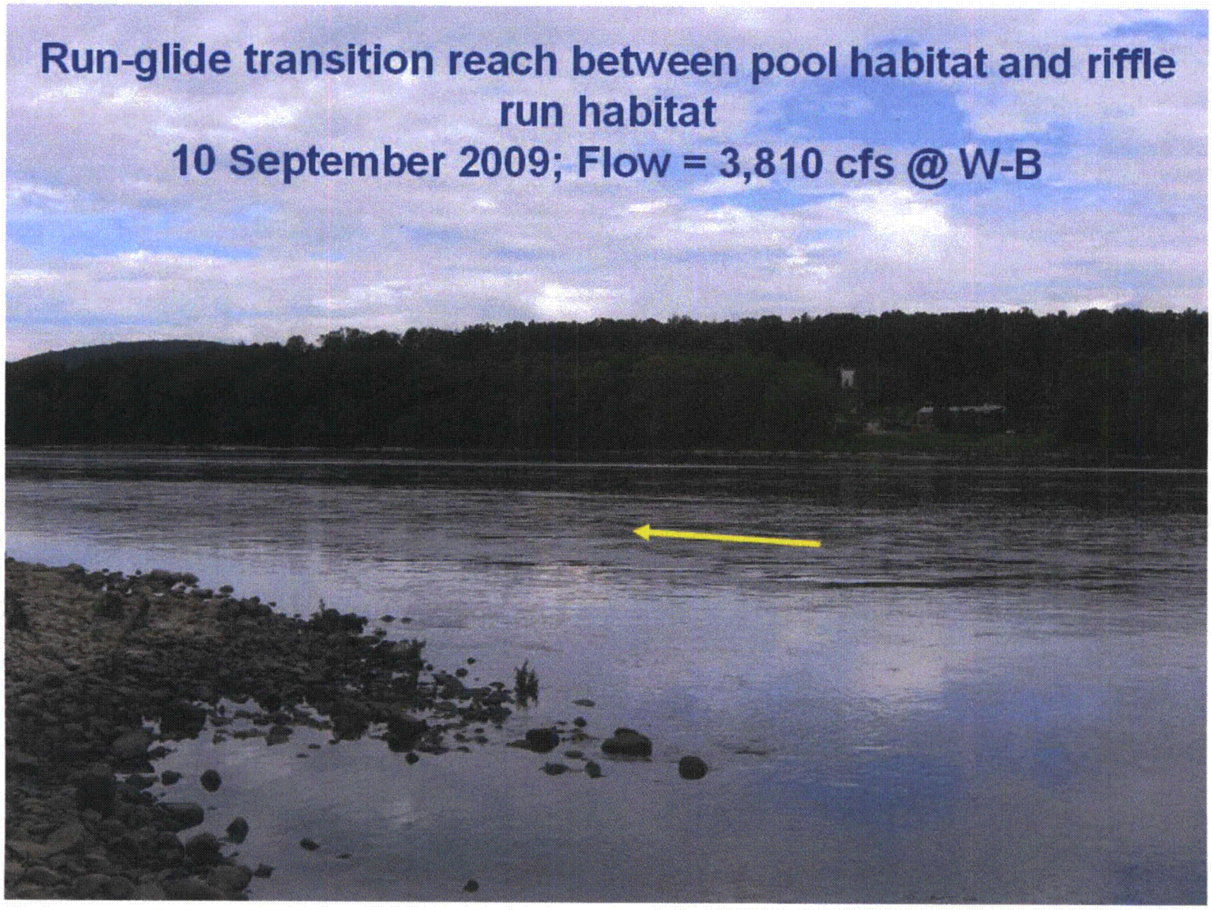
Group	Taxon	Group		Taxon	
		Number	% Total	Number	% Total
OLIGOCHAETA		26	1.7		
	Unidentified			26	1.7
CRUSTACEA		118	7.9		
	Amphipoda			118	7.9
PLECOPTERA		15	1.0		
	Agnetina			12	0.8
	Neoperla			3	0.2
EPHEMEROPTERA		492	33.1		
	Anthopotamus			366	24.6
	Caenis			20	1.3
	Isonychia			2	0.1
	Stenacron			22	1.5
	Stenonema			52	3.5
	Tricorythodes			30	2.0
TRICHOPTERA		24	1.6		
	Ceraclea			6	0.4
	Cheumatopsyche			1	0.1
	Protoptila			3	0.2
	Macrostemum			1	0.1
	Neureclipsis			13	0.9
COLEOPTERA		229	15.4		
	Dineutus			2	0.1
	Dubiraphia			1	0.1
	Psephenus			2	0.1
	Stenelmis			224	15.1
DIPTERA		219	14.7		
	Chironomidae			219	14.7
MOLLUSCA		331	22.3		
	Ferrissia			48	3.2
	Physa			1	0.1
	Corbicula			142	9.6
	Leptoxis			2	0.1
	Musculium			132	8.9
	Pisidium			6	0.4
OTHER		32	2.2		
	Alloeocoela			9	0.6
	Nematoda			6	0.4
	Tricladida			16	1.1
	Gomphidae			1	0.1
Total number of organisms		1,486		1,486	
Total number of taxa		9		30	

Table 2.4-23 Number and Percent Total of Benthic Macroinvertebrates Collected with a Dome Sampler at Bell Bend (replicate 2) in the Susquehanna River, August 15, 2007

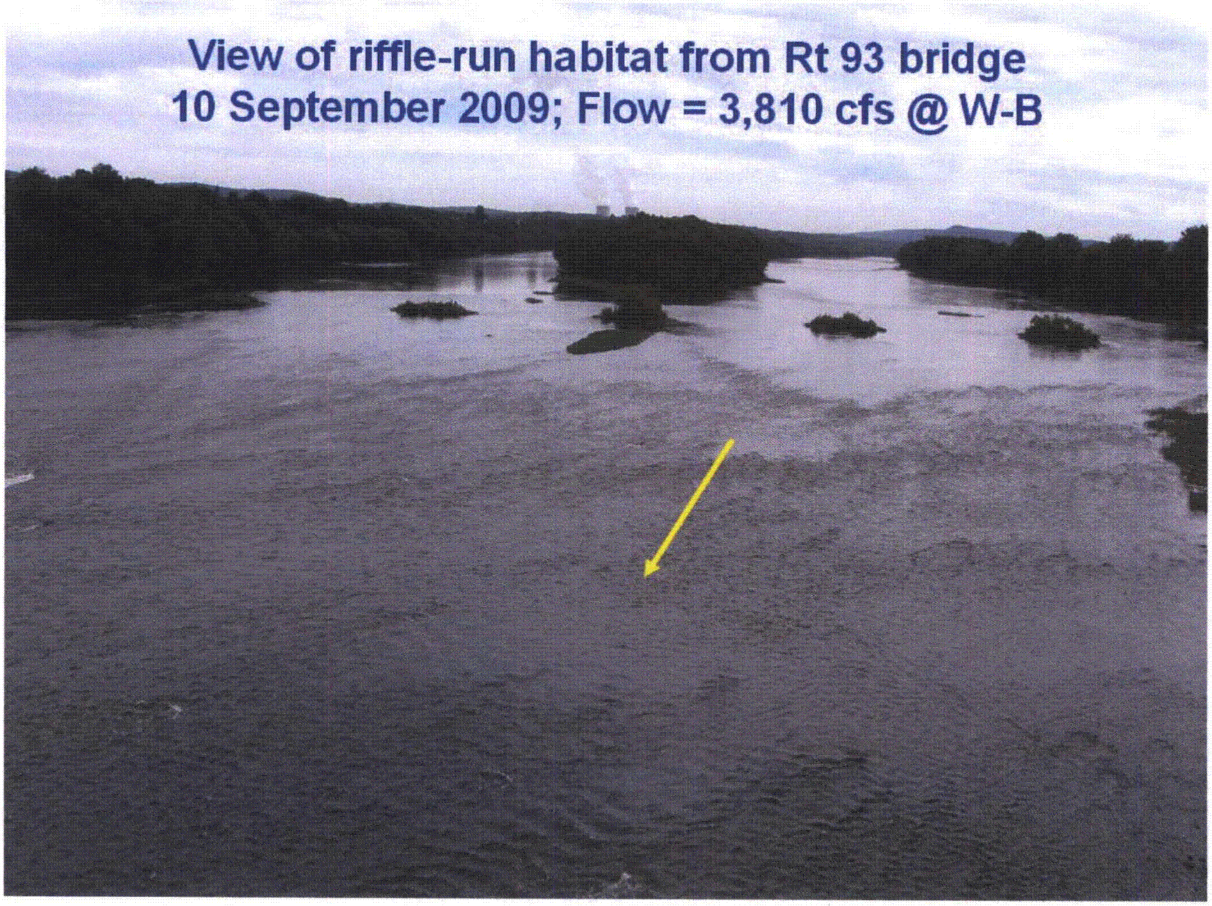
Group	Taxon	Group		Taxon	
		Number	% Total	Number	% Total
OLIGOCHAETA		2	0.1	2	0.1
CRUSTACEA					
	Amphipoda	99	5.9	99	5.9
PLECOPTERA					
	Acroneuria	2	0.1	1	0.1
	Agnetina			1	0.1
EPHEMEROPTERA		463	27.4		
	Anthopotamus			332	19.6
	Caenis			31	1.8
	Habrophleboides			1	0.1
	Isonychia			1	0.1
	Leucrocuta			34	2.0
	Stenacron			38	2.2
	Stenonema			6	0.4
	Tricorythodes			20	1.2
TRICHOPTERA		48	2.8		
	Ceraclea			4	0.2
	Cheumatopsyche			15	0.9
	Protoptila			3	0.2
	Lepidostoma			1	0.1
	Neureclipsis			21	1.2
	Oecetis			4	0.2
COLEOPTERA		231	13.7		
	Dineutus			3	0.2
	Dubiraphia			2	0.1
	Psephenus			1	0.1
	Stenelmis			225	13.3
DIPTERA		212	12.5		
	Chironomidae			212	12.5
MOLLUSCA		587	34.7		
	Ferrissia			54	3.2
	Physa			1	0.1
	Corbicula			296	17.5
	Musculium			216	12.8
	Pisidium			20	1.2
OTHER		46	2.7		
	Alloeocoela			24	1.4
	Tricladida			18	1.1
	Coenagrionidae			1	0.1
	Gomphidae			1	0.1
	Sialis			2	0.1
Total number of organisms		1,690		1,690	
Total number of taxa		9		33	

APPENDIX C SELECTED PHOTOS OF AQUATIC HABITAT

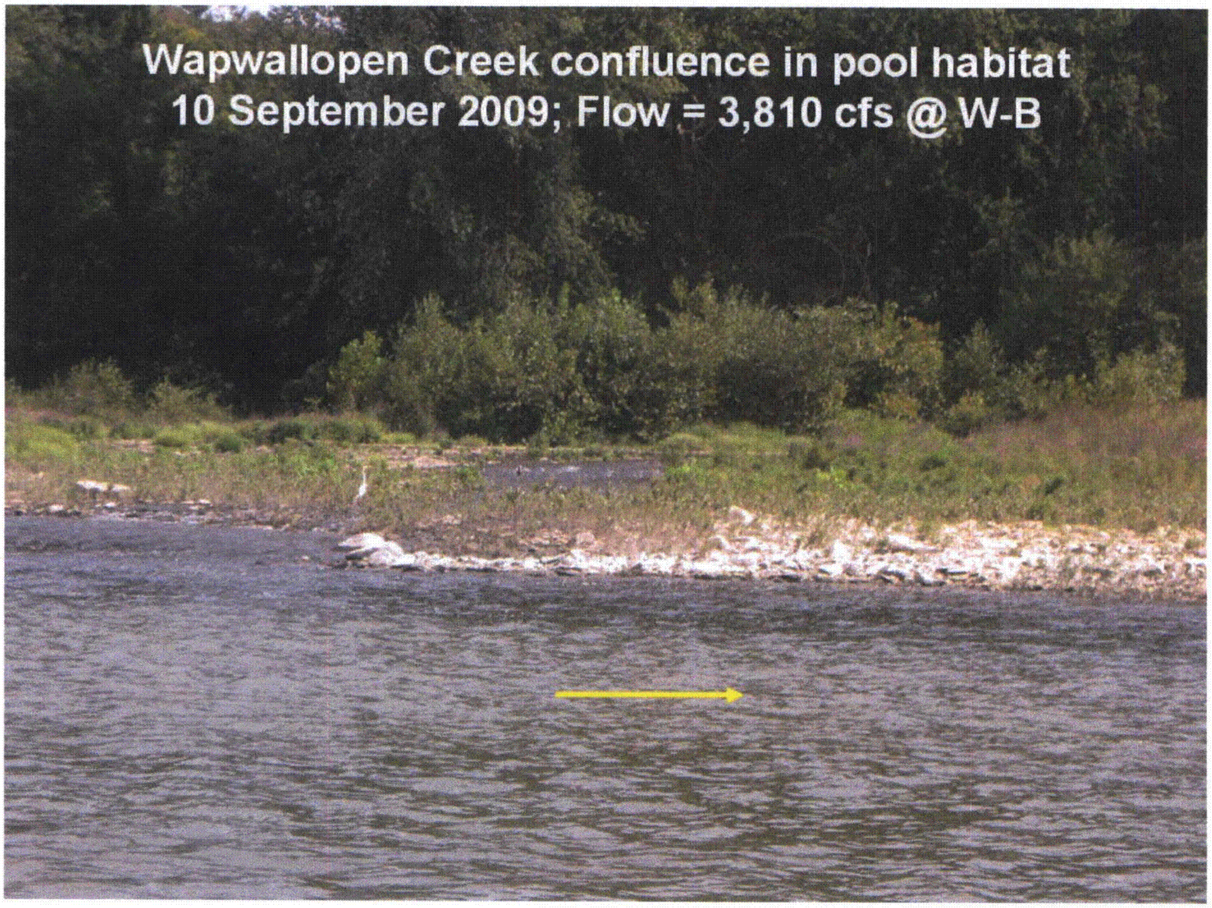

View of pool habitat
10 September 2009; Flow = 3,810 cfs @ W-B
River width ~ 850 ft



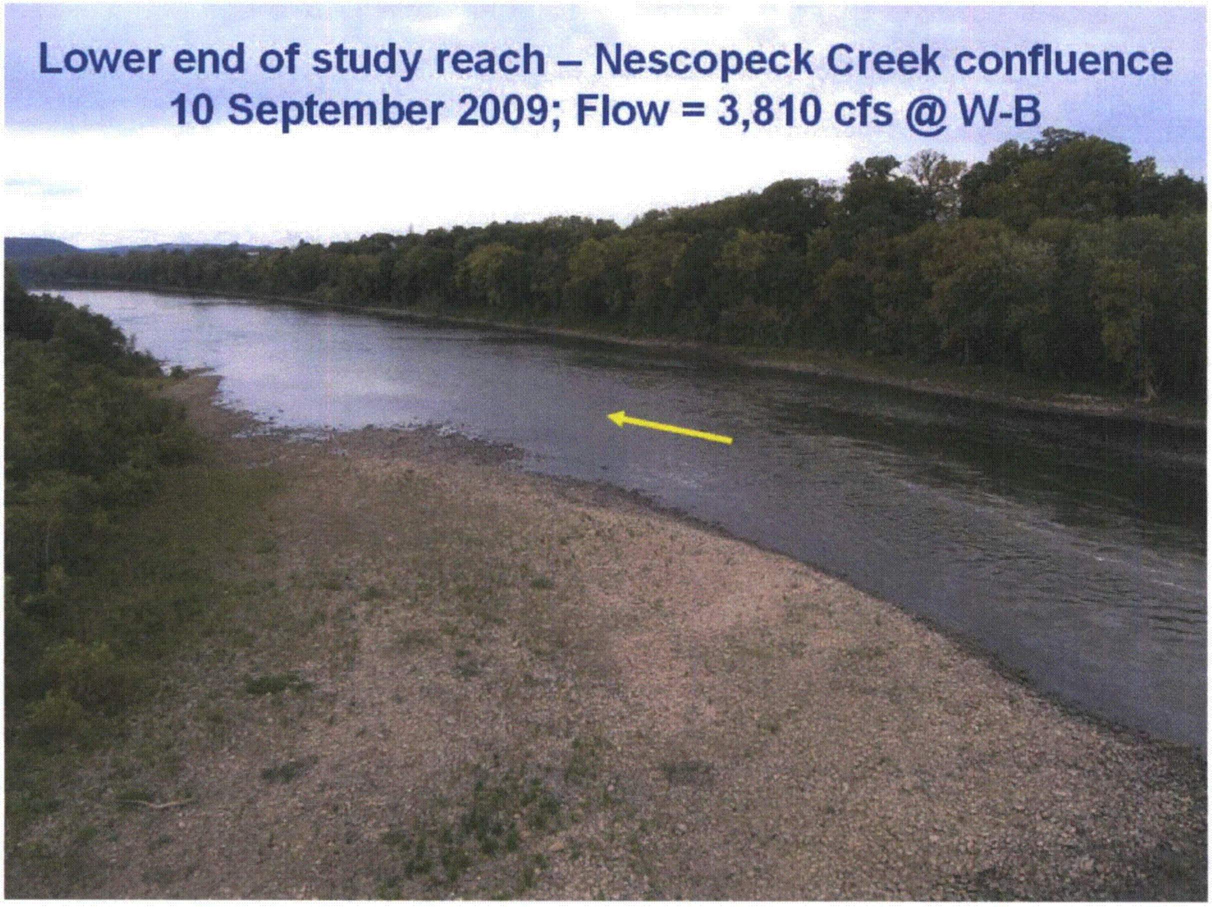
Run-glide transition reach between pool habitat and riffle run habitat
10 September 2009; Flow = 3,810 cfs @ W-B



View of riffle-run habitat from Rt 93 bridge
10 September 2009; Flow = 3,810 cfs @ W-B



Wapwallopen Creek confluence in pool habitat
10 September 2009; Flow = 3,810 cfs @ W-B



Lower end of study reach – Nescopeck Creek confluence
10 September 2009; Flow = 3,810 cfs @ W-B

APPENDIX D HABITAT SUITABILITY CURVES

HABITAT SUITABILITY INDICES FOR:

SHALLOW-SLOW GUILD (< 2 FT DEPTH, < 1 FT/SEC VELOCITY)

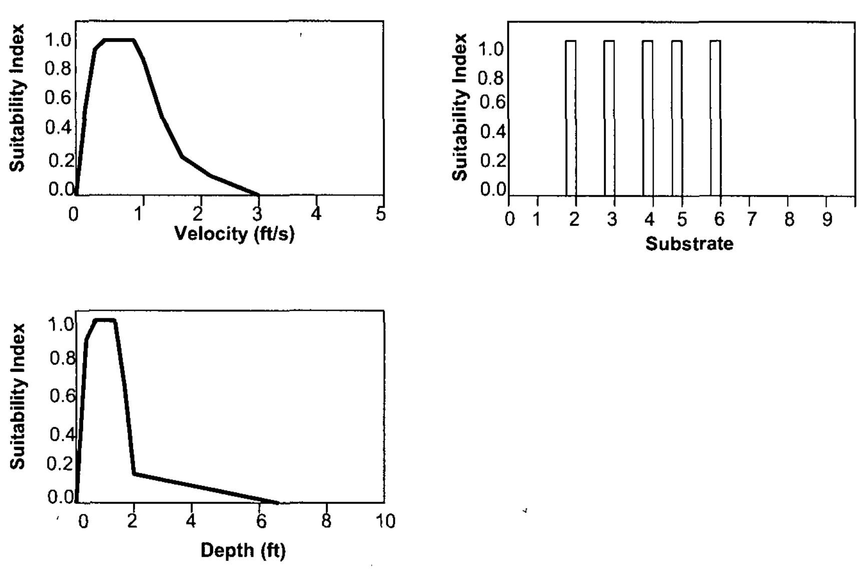
SHALLOW-FAST GUILD (< 2 FT DEPTH, > 1 FT/SEC VELOCITY)

DEEP-SLOW GUILD (> 2 FT DEPTH, < 1 FT/SEC VELOCITY)

DEEP-FAST GUILD (> 2 FT DEPTH, > 1 FT/SEC)

Habitat Suitability Index Curve for Shallow Fast Guild

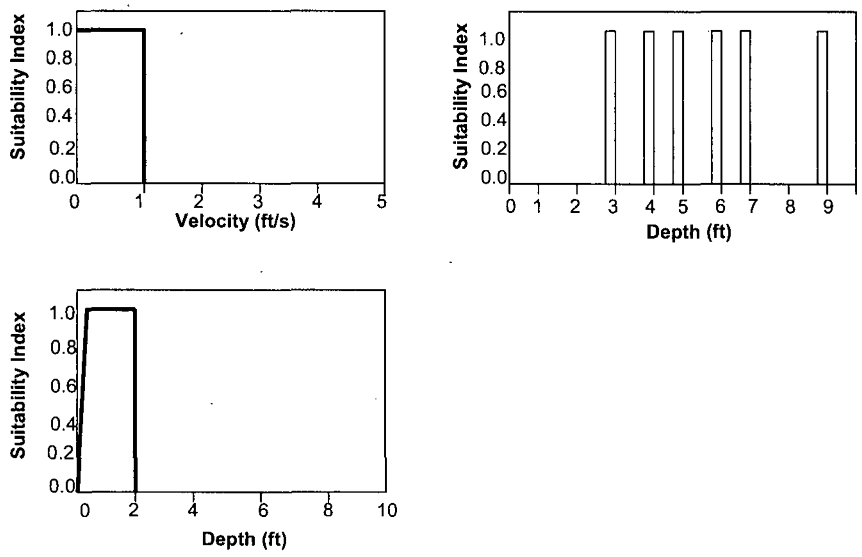
Source: EA 1990, modified by Pee Dee instream Flow Subgroup, June 2004, DTA (2005)



Substrate	
0	Detritus
1	Fines
2	Sm Gravel
3	Lg Gravel
4	Sm Cobble
5	Lg Cobble
6	Sm Boulder
7	Lg Boulder
8	Sm Bedrock
9	Irr Bedrock

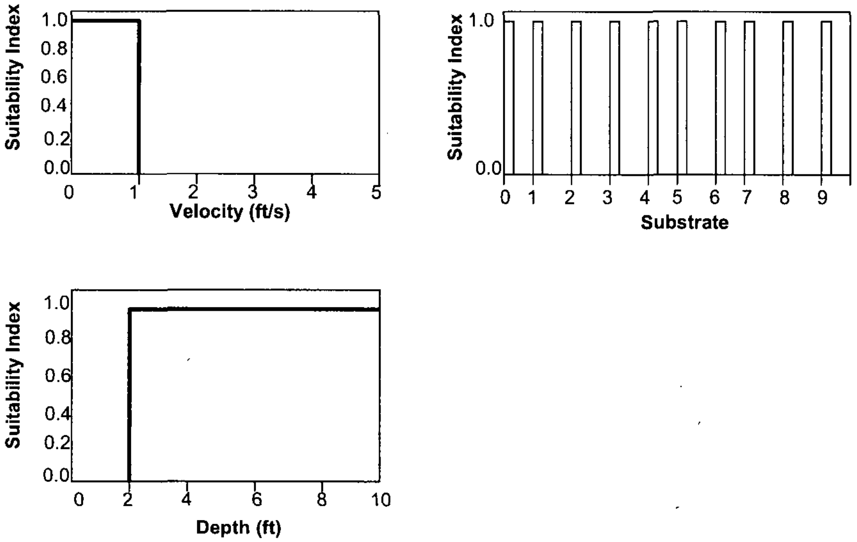
Habitat Suitability Indices for Shallow Slow Guild

Source: Aadland (1993); Brown et al. (1998); NAI (2000); Progress Energy (2004); DTA (2005).



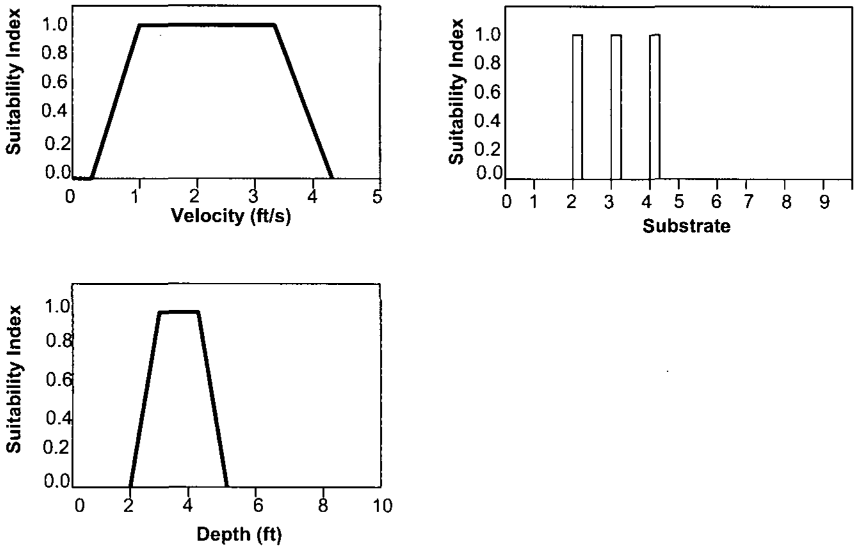
Substrate	
0	Detritus
1	Fines
2	Sm Gravel
3	Lg Gravel
4	Sm Cobble
5	Lg Cobble
6	Sm Boulder
7	Lg Boulder
8	Sm Bedrock
9	Irr Bedrock

Habitat Suitability Indices for Deep-Slow Guild



	Substrate
0	Detritus
1	Fines
2	Sm Gravel
3	Lg Gravel
4	Sm Cobble
5	Lg Cobble
6	Sm Boulder
7	Lg Boulder
8	Sm Bedrock
9	Irr Bedrock

Habitat Suitability Indices for Deep Fast Guild



	Substrate
0	Detritus
1	Fines
2	Sm Gravel
3	Lg Gravel
4	Sm Cobble
5	Lg Cobble
6	Sm.Boulder
7	Lg Boulder
8	Sm Bedrock
9	Irr Bedrock

HABITAT SUITABILITY CURVES FOR SPECIES OF SPECIAL CONCERN:

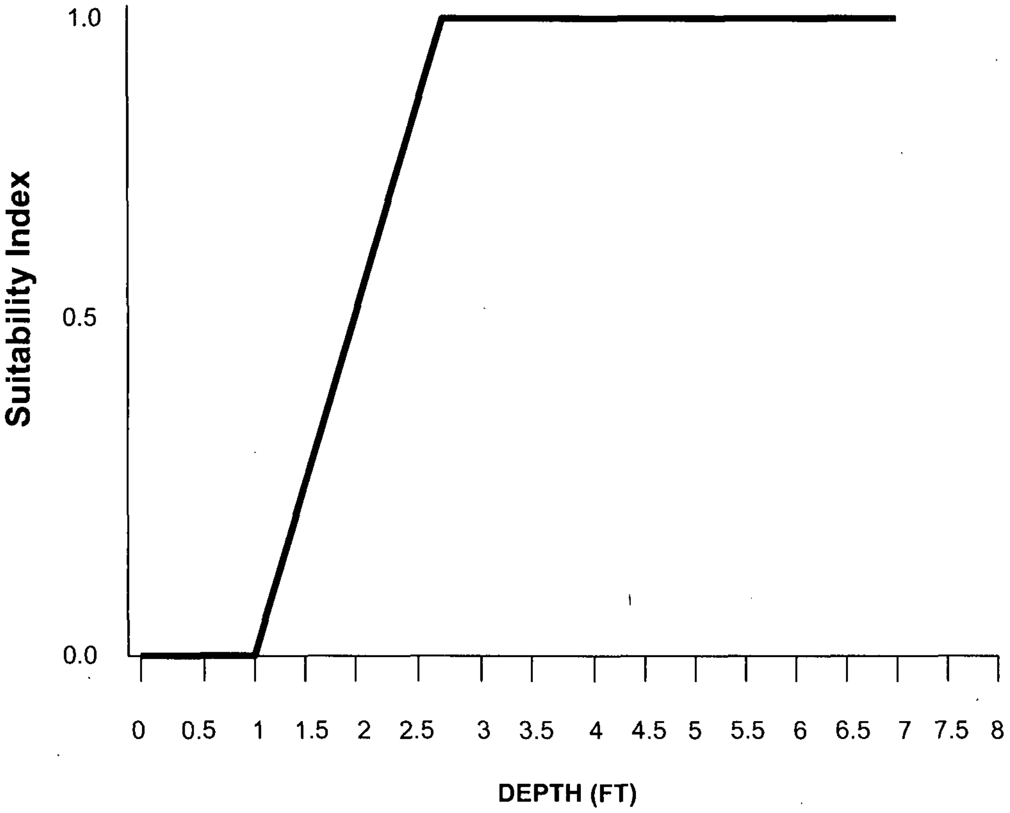
SMALLMOUTH BASS

AMERICAN SHAD

GREEN FLOATER MUSSEL

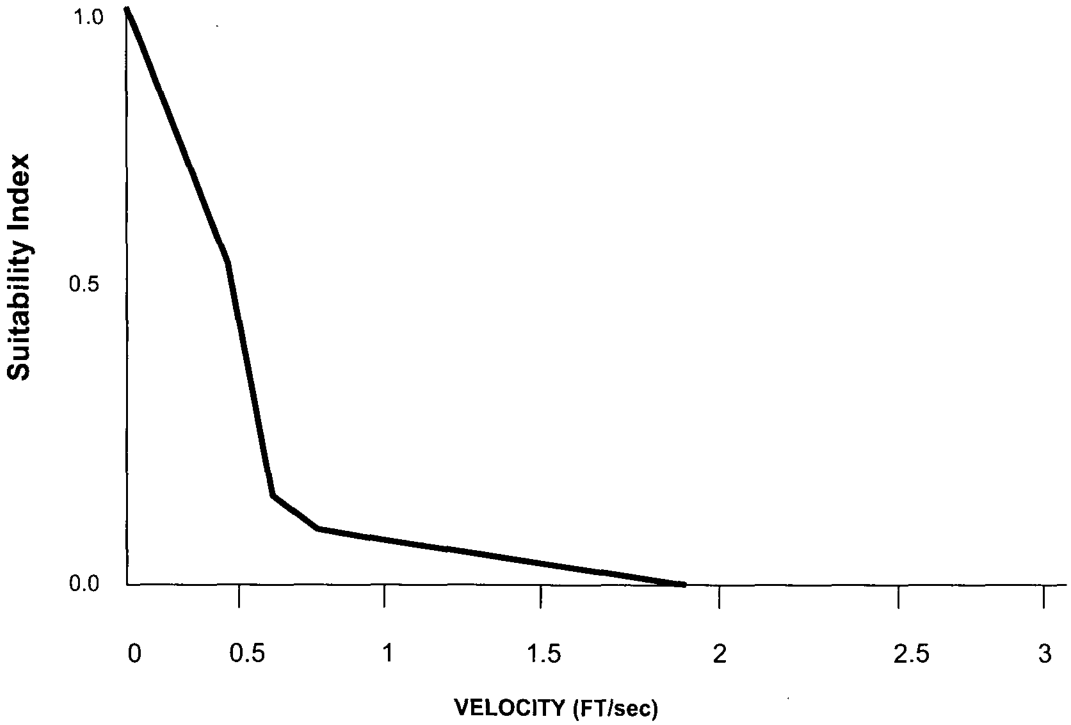
YELLOW LAMPMUSSEL

Depth Suitability Index Curve for Adult Smallmouth Bass
Source: Angermeier (1987), Ross *et al* (1987), Todd and Rabeni (1989)



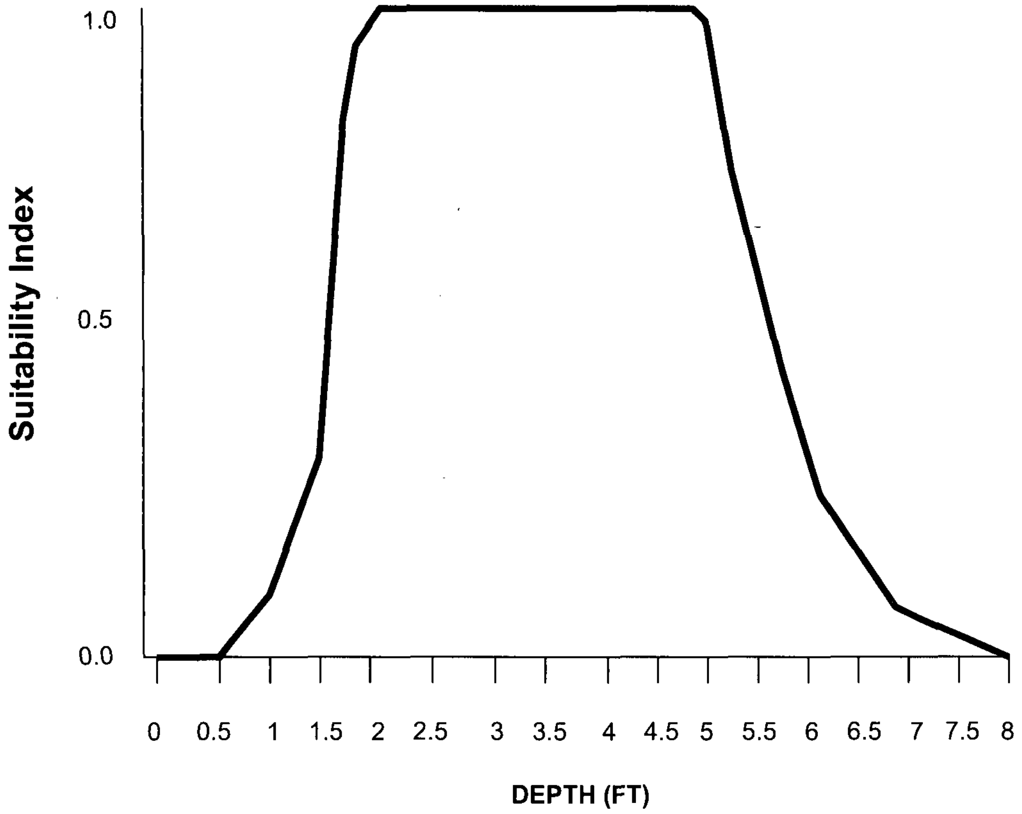
Velocity Suitability Index Curve for Adult Smallmouth Bass

Source: North Carolina Department of Water Resources, RMC (1992)



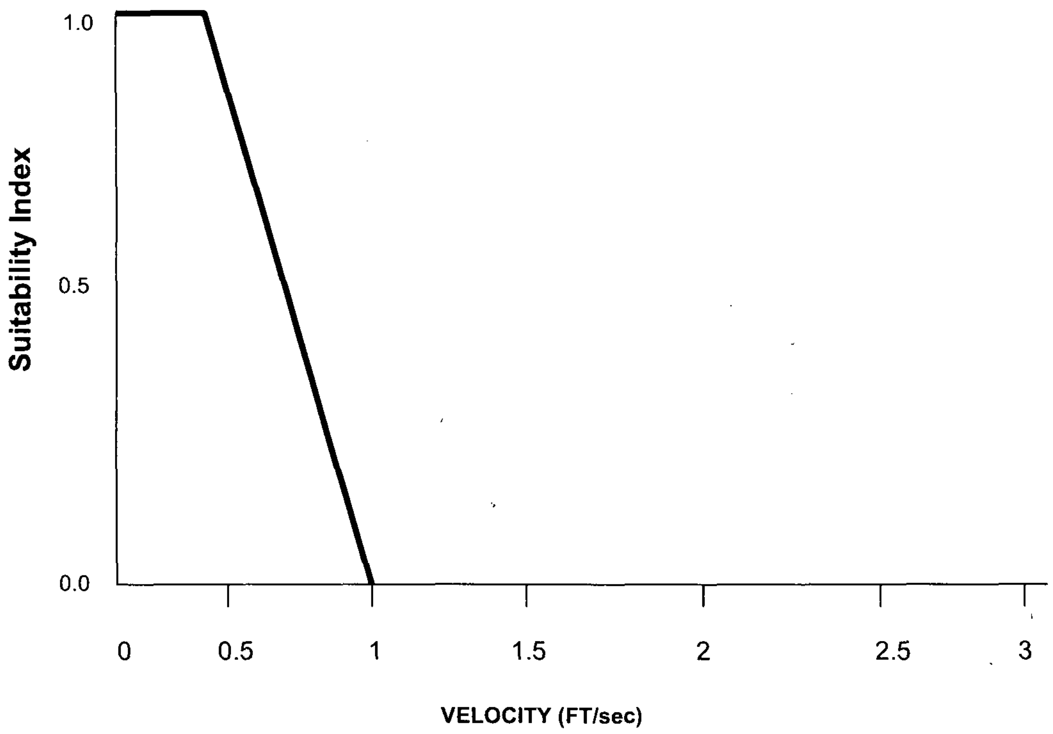
Depth Suitability Index Curve for Spawning Smallmouth Bass

Source: North Carolina Department of Water Resources



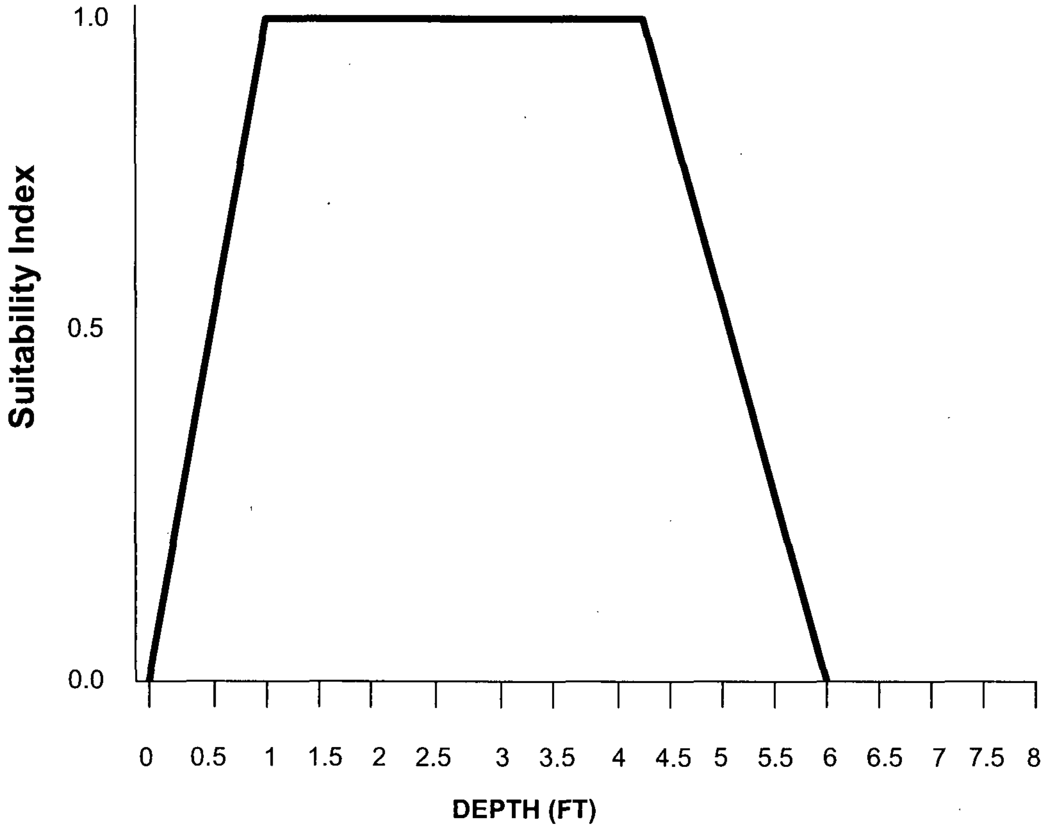
Velocity Suitability Index Curve for Spawning Smallmouth Bass

Source: Simonson and Swenson (1940), Todd and Rabeni (1989)



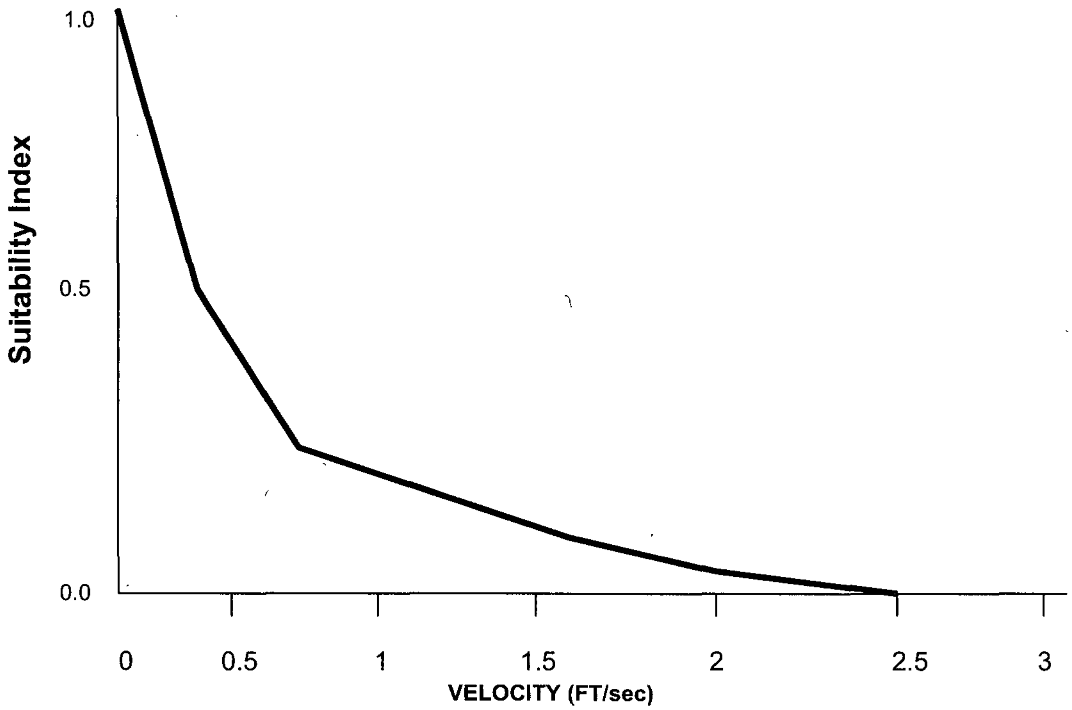
Depth Index Curve for Juvenile Smallmouth Bass

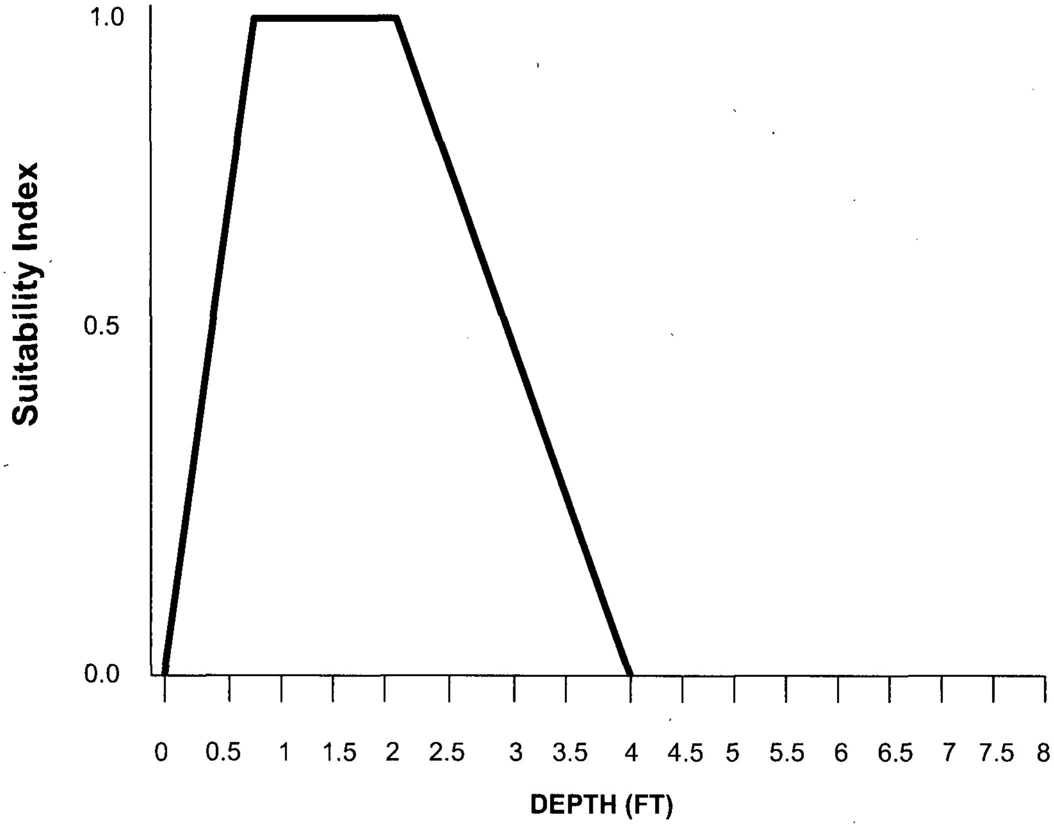
Source: Lobb and Orth (1991), RMC (1992), North Carolina Department of Water Resources



Velocity Suitability Indices for Juvenile Smallmouth Bass

Source: North Carolina Department of Water Resources, RMC (1992)



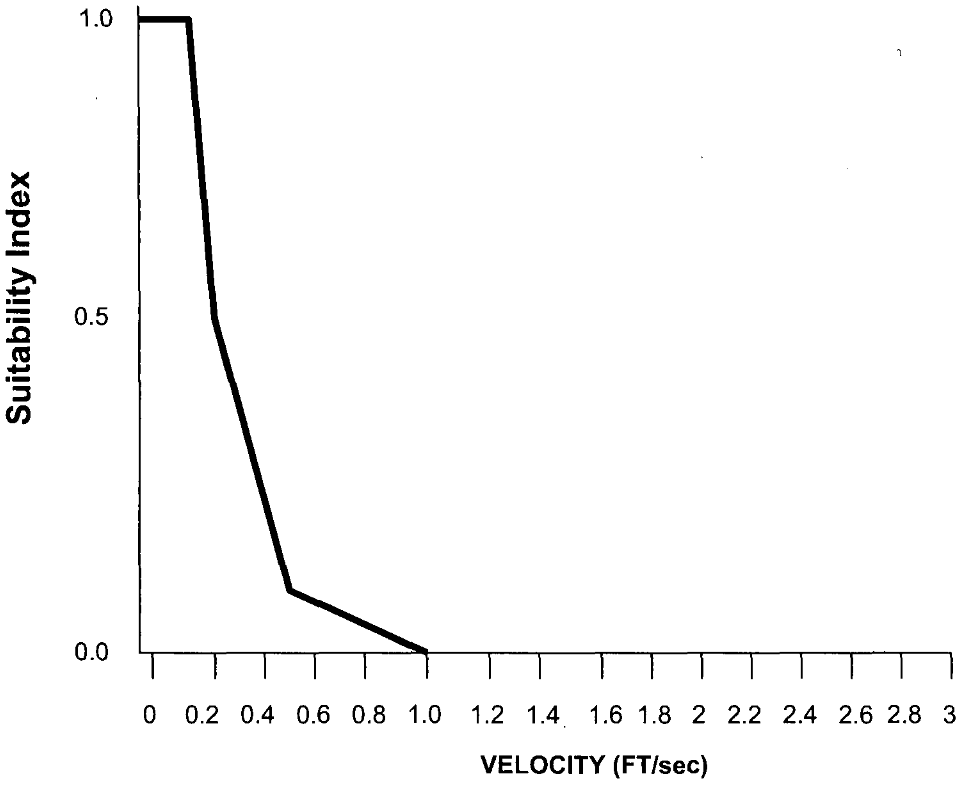


Depth Suitability Index for Smallmouth Bass Fry

Source: Angermeier (1987), Lobb and Orth (1991), Ross *et al* (1987)

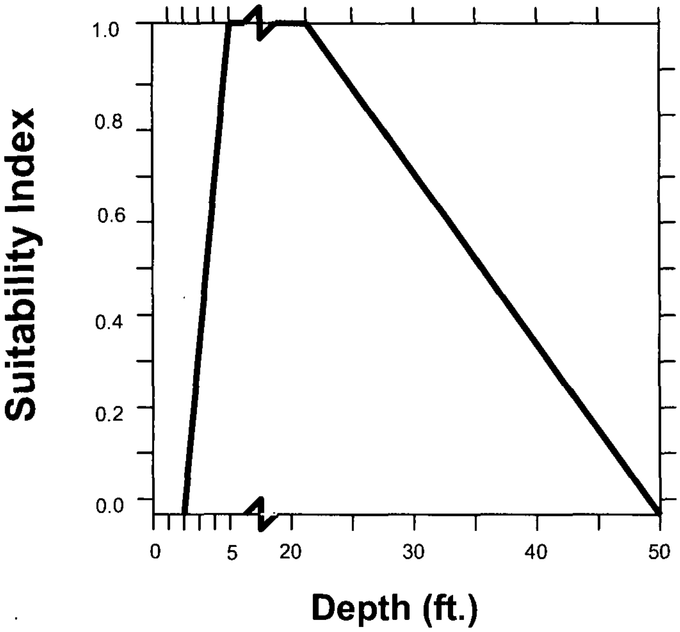
Velocity Suitability Index for Smallmouth Bass Fry

Source: Angermeier (1987), Rankin (1986), Sechnick, *et al* (1986)
Simonson and Swenson (1990), Todd and Rabeni (1989)



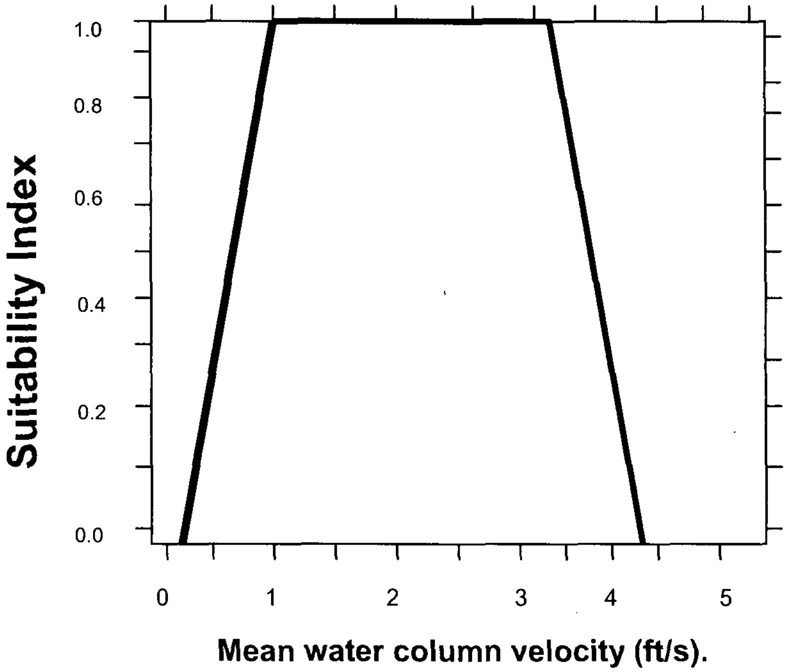
Depth Suitability Curves for American shad spawning

Source: Stier and Crance (1985).



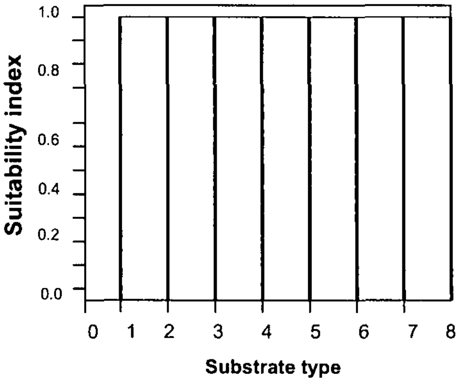
Velocity Suitability Curve for American shad spawning.

Source: Steir and Crance (1985)

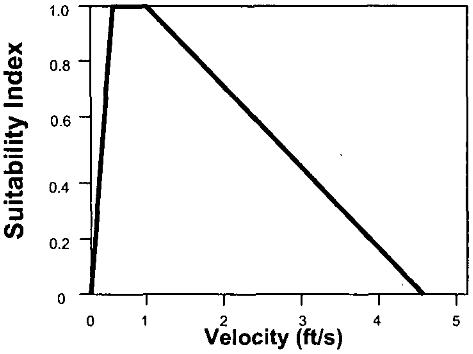


Substrate Suitability Index for American shad spawning.
Source: Atlantic States Marine Fisheries Commission (2009).

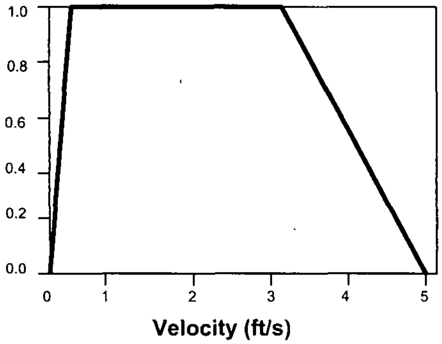
Substrate		Suitability
0	Detritus	0.0
1	Fines (sand)	1.0
2	Sm. gravel	1.0
3	Lg. gravel	1.0
4	Sm. cobble	1.0
5	Lg. cobble	1.0
6	Sm. boulder	1.0
7	Sm. bedrock	1.0
8	Irr. bedrock	1.0



Velocity Suitability Index for Juvenile American shad (rearing) and Outmigration
Source: Stier and Crance (1985)



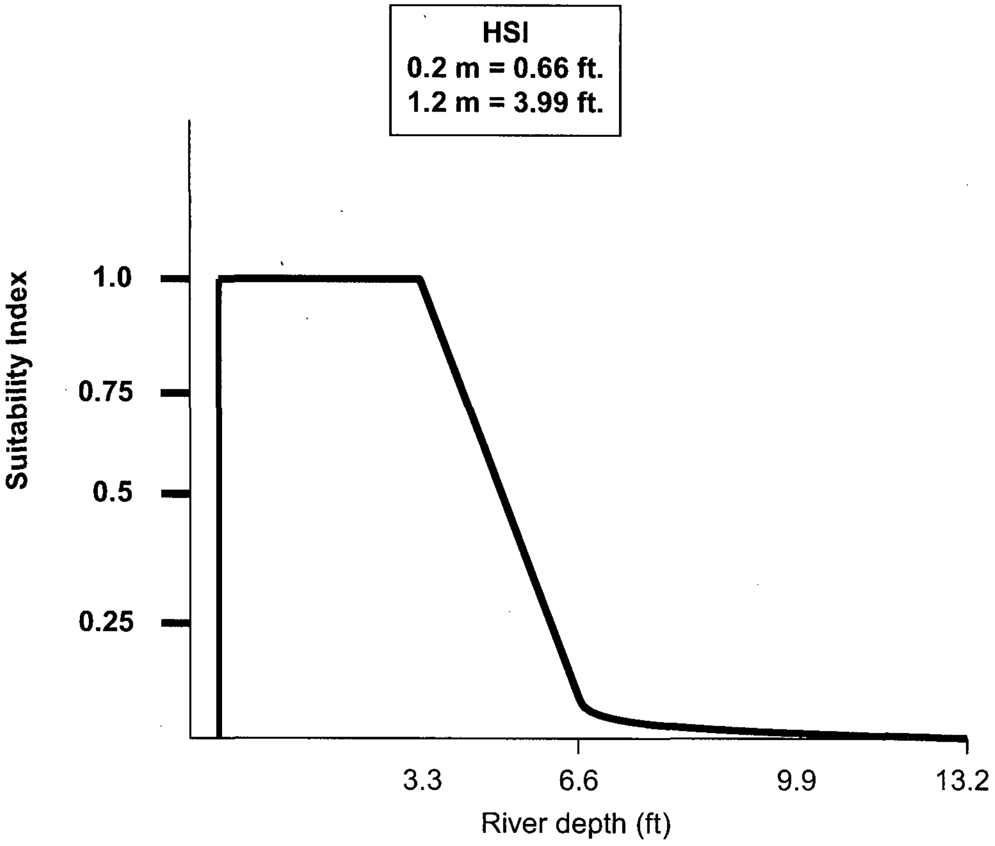
Larval/juvenile, non-migration



Outmigration

Depth Suitability Index for Juvenile American Shad

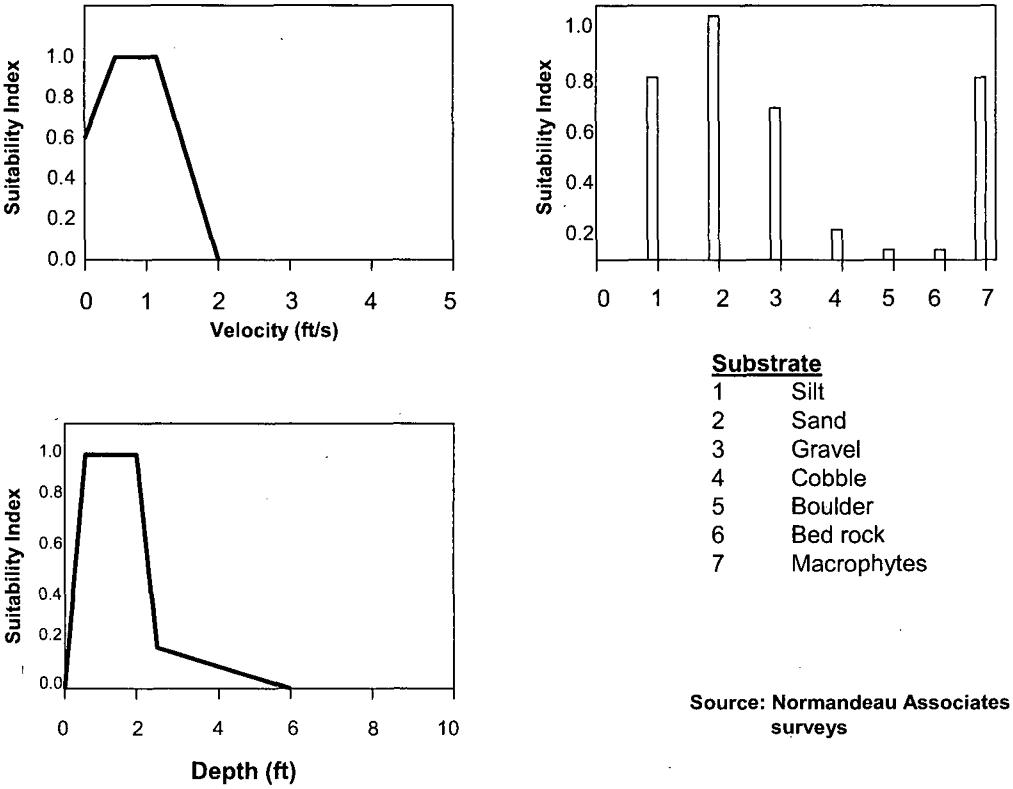
Source: Ross *et al* (1993); original x-axis in meters converted into equivalent feet.



Source: Ross *et al* (1993)

Mussels – Green Floater

Source: Normandeau Associates surveys

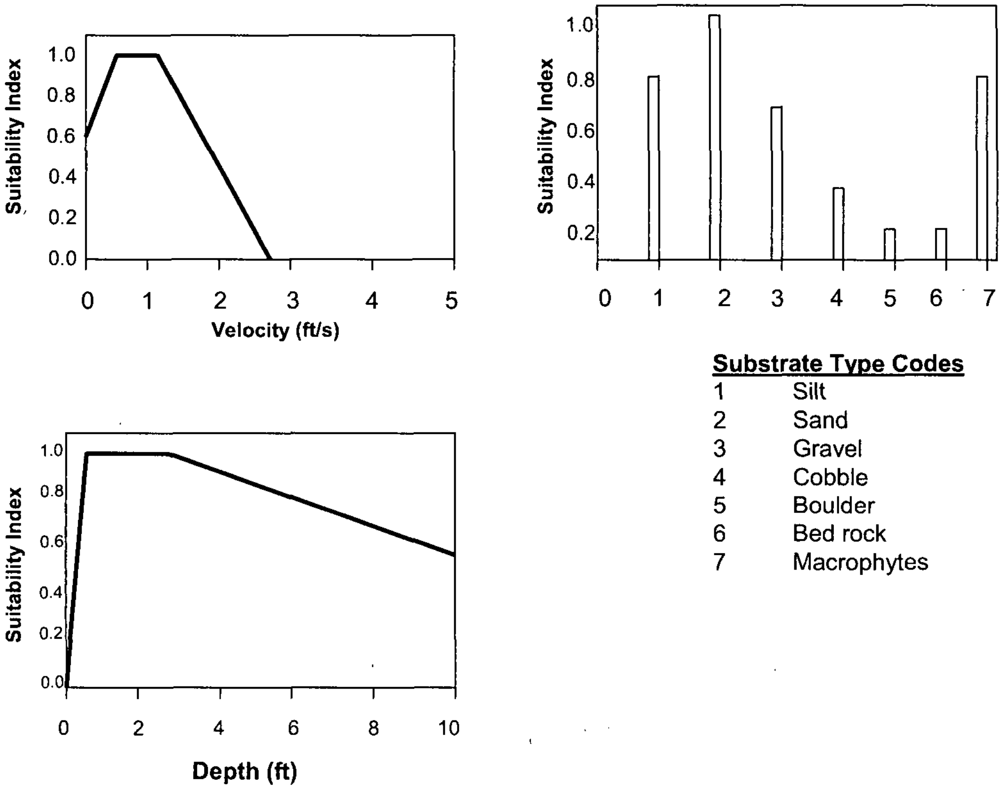


Substrate	
1	Silt
2	Sand
3	Gravel
4	Cobble
5	Boulder
6	Bed rock
7	Macrophytes

Source: Normandeau Associates surveys

Mussels – Yellow Lamp mussel and Eastern elliptio

Source: Normandeau Associates surveys



Substrate Type Codes

1	Silt
2	Sand
3	Gravel
4	Cobble
5	Boulder
6	Bed rock
7	Macrophytes

Enclosure 2

BBNPP Impingement and Entrainment Response

BBNPP Impingement and Entrainment Response

Introduction

In a March 1, 2010 letter to PPL Bell Bend, LLC (PPL) the Susquehanna River Basin Commission (SRBC) advised PPL that it "should determine a method of sampling the number of aquatic organisms impinged or entrained as a result of the proposed surface water withdrawal. The method should account for the impingement or entrainment of organisms throughout the life of the project. Appropriate impingement and entrainment intake designs should be made to ensure impacts to the local aquatic community are avoided." The SRBC cited 18 CFR §806.14(a)(3)(i) in connection with this request.

Furthermore, the SRBC advised PPL that it "should perform an impingement and entrainment study to determine the impact of the project on out-migrating juvenile shad..." The SRBC cited Part I.D.7 and Part V.J. of the SRBC Comprehensive Plan in connection with this request and also stated that "Further studies may be required in the future to determine the impact of the BBNPP and Susquehanna Steam Electric Station (SSES) on migrating adult shad."

Lastly, the SRBC noted that the report entitled "Entrainment and Impingement Sampling at the proposed Bell Bend Nuclear Power Plant (BBNPP) at the SSES Circulating Water Supply Intake Structure" submitted by PPL fails to account for, or provide a reason why juvenile American shad were not included as part of the study; that Table 7 requires further clarification; and that the report fails to correlate the entrainment of 13+ million fish to the study period and results, and the requirements of 18 CFR §806.14(b)(v)(C).

This document responds to each of these SRBC comments.

Regulatory Framework

On December 18, 2001 the U. S. Environmental Protection Agency (EPA) published a final rule implementing section 316(b) of the Clean Water Act (CWA) for new facilities that withdraw water from rivers, streams, and lakes, etc. for cooling purposes. The rule was modified by the EPA on June 19, 2003, and is codified in 40 CFR §125 (also referred to as Phase I 316(b) Rule).

40 CFR §125.84 establishes criteria and standards (requirements) applicable to the location, design, construction, and capacity of new cooling water intake structures. "The requirements are administered through NPDES permits issued under section 402 of the CWA. The purpose of these requirements is to establish the best technology available for minimizing adverse environmental impact associated with the use of cooling water intake structures" including impacts with respect to the potential impingement or entrainment of aquatic organisms. The rule establishes a two-track compliance system. Track I establishes national intake capacity, velocity, and other requirements to minimize impingement mortality and entrainment. Track II allows permit applicants to conduct site-specific studies to demonstrate that alternatives to Track I requirements will provide a comparable level of aquatic protections.

For cooling water intake structures drawing more than 10 MGD from a freshwater river or stream, in its NPDES application under Track I, the applicant must:

- Reduce intake flow, at a minimum, to a level commensurate with that which can be attained by a closed-cycle re-circulating cooling water system,
- Design and construct each cooling water intake structure to a maximum through-screen design intake velocity of 0.5 ft/sec,

- Design and construct the cooling water intake structure so that the total intake flow must be no greater than five (5) percent of the source water annual mean flow,

- Select and implement design and construction technologies or operational measures for minimizing impingement mortality and entrainment of fish and shellfish, if there are threatened and endangered or migratory species of concern, within the hydraulic zone of influence of the cooling water intake, or it is determined that the proposed facility, after meeting the technology-based performance standards, would create unacceptable stress to species of concern.

In addition, an applicant may be required to comply with more stringent requirements deemed "reasonably necessary to comply with any provision of state law, including compliance with applicable state water quality standards (including designated uses, criteria, and anti-degradation requirements)."

Under 40 CFR §125.87, as an owner or operator of a new facility, PPL will be required to perform monitoring to demonstrate compliance with the requirements specified in §125.84 as follows:

(a) *Biological monitoring.* The applicant must monitor both impingement and entrainment of the commercial, recreational, and forage base fish and shellfish species identified in the Source Water Baseline Biological Characterization data required by 40 CFR 122.21(r)(3). The monitoring methods used must be consistent with those used for the Source Water Baseline Biological Characterization data required in 40 CFR 122.21(r)(3). The applicant must follow the monitoring frequencies identified below for at least two (2) years after the initial permit issuance. After that time, the applicant may request less frequent sampling in the remaining years of the permit term, and when the permit is reissued, if supporting data show that less frequent monitoring would still allow for the detection of any seasonal and daily variations in the species and numbers of individuals that are impinged or entrained.

> (1) *Impingement sampling.* The applicant must collect samples to monitor impingement rates (simple enumeration) for each species over a 24-hour period and no less than once per month when the cooling water intake structure is in operation.
>
> (2) *Entrainment sampling.* The applicant must collect samples to monitor entrainment rates (simple enumeration) for each species over a 24-hour period and no less than biweekly during the primary period of reproduction, larval recruitment, and peak abundance identified during the Source Water Baseline Biological Characterization required by 40 CFR 122.21(r)(3). The applicant must collect samples only when the cooling water intake structure is in operation.

(b) *Velocity monitoring.* If the facility uses surface intake screen systems, the applicant must monitor head loss across the screens and correlate the measured value with the design intake velocity. The head loss across the intake screen must be measured at the minimum ambient source water surface elevation (best professional judgment based on available hydrological data). The maximum head loss across the screen for each cooling water intake structure must be used to determine compliance with the velocity requirement in §125.84(b)(2). If the facility uses devices other than surface intake screens, the applicant must monitor velocity at the point of entry through the device. The applicant must monitor head loss or velocity during initial facility startup, and thereafter, at the frequency specified in the facilities NPDES permit, but no less than once per quarter.

(c) *Visual or remote inspections.* The applicant must either conduct visual inspections (at least weekly) or inspections via remote monitoring devices during the period the cooling water intake structure is in operation to ensure that any design and construction technologies required in §125.84(b)(4) and (5), are functioning as designed.

Finally, under §125.88 as an owner or operator of a new facility the applicant is required to keep records and report information and data as follows:

(a) Records of all the data used to complete the permit application and show compliance with the requirements, any supplemental information developed under §125.86, and any compliance monitoring data submitted under §125.87, for a period of at least three (3) years from the date of permit issuance.

(b) The following must be provided in a yearly status report:

(1) Biological monitoring records for each cooling water intake structure as required by §125.87(a);

(2) Velocity and head loss monitoring records for each cooling water intake structure as required by §125.87(b); and

(3) Records of visual or remote inspections as required in §125.87(c).

Design of the Bell Bend River Intake Structure

The BBNPP cooling water river intake will meet the U.S. EPA Track I requirements as established in 40 CFR §125.84, and summarized above. Specifically:

- Intake flow levels will be reduced to a minimum through the installation of a closed-cycle re-circulating water system (cooling towers),
- The intake structure will be designed to a maximum through-screen velocity of 0.5 ft/sec, and
- The maximum surface water withdrawal applied for (44 mgd or 68 cfs) is less than five percent of the source water annual mean flow at the project (approximately 13,700 cfs based on data from the USGS Gage No. 01536500 at Wilkes-Barre, PA for the period of April 1899 to March 2010).

Furthermore, the design of the BBNPP intake water system will be comparable to that of the adjacent SSES intake, and is therefore expected to create a hydraulic zone of influence similar to that of the existing SSES intake. As discussed below, prior studies of other similarly designed/sized stations in the immediate vicinity of the BBNPP (SSES and Hunlock Creek Power Station) indicate no entrainment or impingement of juvenile American shad, threatened or endangered species, and only minimal entrainment or impingement of other species of concern.

Historical Impingement and Entrainment Studies

Pre-construction impact analyses for new cooling water intakes are normally conducted via a desktop analysis that considers other similarly located and designed facilities in order to derive an estimate of potential impingement and entrainment at the new intake location. In this instance, the BBNPP intake structure will be similarly located and of a design nearly identical to

the SSES intake. Therefore, impingement and entrainment studies that have been performed at the SSES are believed to the best potential predictor of potential impingement and entrainment at the BBNPP intake. Also instructive are studies done at the Hunlock Creel Power Station which is a 50 MW coal-fired unit that withdraws water from the Susquehanna River through two conventional travelling screens. The station has an open, once-through cooling system. However, the cooling water volumes are similar to those of SSES and the proposed BBNPP.

The following summarizes existing data on impingement and entrainment of aquatic species at the river intakes at SSES, located approximately 300 feet upstream of the proposed BBNPP intake, and at the Hunlock Creek Power Station located approximately 10 miles upstream of the BBNPP site. This data suggests that the potential adverse environmental impact of impingement and entrainment of aquatic species should be minimal at the BBNPP intake, and that additional design and construction technologies or operational measures to further minimize impingement and entrainment are not required beyond the federal Phase I 316(b) Rule. No threatened, endangered or species of concern have been found to be entrained or impinged at either the SSES or at the Hunlock Creek Power Station. In addition, long-term fish sampling of the Susquehanna River, in the vicinity of SSES, has not detected any change to fish or macro-invertebrate or mussel populations due to the operation of the station.

Impingement and Entrainment Sampling at the SSES

A one-year study of entrainment and impingement at the SSES was undertaken by Normandeau Associates between April 2008 and April 2009 in order to characterize the potential impacts at the BBNPP site. The study consisted of weekly sampling to help assure that organisms susceptible to impingement and entrainment at the intake structure, including migratory species such as American shad, would be collected. The results of the study are summarized herein while details relative to the frequency of sampling, number of samples taken, data analysis, and environmental parameters measured concurrently with each sample are provided in Normandeau Associates (2009)

Weekly impingement sampling was conducted from April 2008 through April 2009. The impingement study collected a total of 45, 24-hr samples. Over the entire sampling period a total of 398 fish and crayfish were collected. Crayfish (*Orconectes* sp.) was the dominant organism, with 220 individuals collected representing 55.3% of the total impingement. The remainder of the impingement catch was composed of 178 fish representing 18 species. The most common fish impinged was bluegill (11.1%) followed by rock bass (8.5%), channel catfish (7.8%), tessellated darter (4.5%), and spotfin shiner (4.0%). The total annual estimated impingement at SSES was 3,228 fish and crayfish. This equates to an average of 8.8 fish and crayfish per day. Estimates for fish alone were 3.95 per day, 120 per month and 1,442 per year. Recreationally important species such as smallmouth bass and walleye accounted for less than 1% of the impinged fish.

In addition, impingement sampling has been performed during the fall outmigration period of American shad by PPL at the SSES intake in several years when larval American shad were stocked upriver from the SSES intake and, therefore, could potentially be impinged at the intake. No young-of-year American shad were collected during any of these investigations.

Weekly entrainment sampling was conducted during the fish spawning periods April to August 2008 and March to April 2009.

Thirty-four entrainment samples were collected during 2008 over the 17-week sampling period. A total of 17 species and 3,039 fish were collected in the 34 samples. Quillback (27.2%), Cyprinidae (17.6%), unidentified darter (12.6%), channel catfish (12.1%), common carp (11.4%), and white sucker (9.4%) were the numerically most abundant taxa. Other species that were collected included brown bullhead, chain pickerel, margined madtom, shield darter, rock bass, smallmouth bass, walleye, tessellated darter, banded darter, and yellow perch. Recreationally important species such as smallmouth bass and walleye accounted for only 2.0% and 1.2%, respectively, of the entrained organisms.

A majority (55.9%) of the entrained fish were larvae in the post yolk-sac life stage. Yolk-sac larvae was the second most abundant life stage comprising 17.0% of all individuals with the numbers of young-of-year and the unknown life stage being, 14.1% and 12.9%, respectively. Only four yearling-plus individuals were collected, and no fish eggs were collected in the entrainment samples in 2008.

Cyprinidae was estimated to be the most abundant taxon entrained, comprising 21.5% of the total entrainment estimate. Other common taxa included channel catfish (19.3%), quillback (16.2%), unidentified darter (12.3%), white sucker (9.8%), and common carp (6.7%).

The sampling in 2009 consisted of 10 sampling events which yielded a single egg of the family Catostomidae (likely white sucker or quillback), indicating that earlier than April, entrainment is essentially non-existent.

The Normandeau Associates 2009 report also provides information regarding the theoretical number of fish entrained based on a simplistic but commonly used method of estimating entrainment numbers (see Table 7 in Normandeau Associates 2009). The number of fish potentially entrained, some 13 million in total, is based on the density of organisms collected on the single sampling day per week which is then multiplied by the total volume of river water withdrawn in that entire week. For example, collecting just one organism in the weekly sampling volume of about 56,000 gallons (target volume for two pumped samples) yields a calculated number entrained of approximately 7,000 for the week assuming that SSES withdraws about 58.3 million gallons per day. The high calculated numbers are an artifact of the small sample volume relative to intake withdrawal volume and the assumption that the specimen density in the weekly samples is exactly representative of all of the water being withdrawn by the intake for that week. The results of this commonly used estimation method was presented in Table 7 simply to give a rough idea of potential impingement and is not meant to be a precise estimate or a useful indicator of potential for adverse environmental impact. The method does not take into account such factors as (1) changes in relative abundance and distribution of eggs and larvae, (2) variations in prevailing hydrology, (3) the large numbers of eggs produced per female, (4) strategies of reproduction (nest builders or non-nest builders), and (5) degree of parental protection afforded the young.

A prior entrainment study at the SSES intake structure was completed in 1981 by PPL (1982). This entrainment study included four sampling events; two in May, and once each in June and July. Eight samples were collected at the entrance to the SSES river intake structure during each sampling event. Each sample consisted of three replicate 5-minute samples, at both the surface and bottom of the water column. In all, 48 replicate samples were obtained during each of the four sampling events. The sampling yielded 3,374 larval fish of 18 species. The most common species were: quillback (37%), common carp (22%), tessellated darter (11%), spottail shiner (8%), and spotfin shiner (4%). Recreationally important species such as smallmouth bass, walleye and channel catfish accounted for only 3% of the entrained fish.

Table 7. Estimated number of each taxon entrained and percent composition at the SSES CWIS, April 22 to August 13, 2008.

Taxon	Estimated Number Entrained	Percent Composition
banded darter	13,778	0.1
brown bullhead	13,799	0.1
common carp	894,149	6.7
chain pickerel	13,635	0.1
channel catfish	2,570,361	19.3
Clupeidae	7,042	0.1
Cyprinidae	2,863,110	21.5
Lepomis sp.	42,151	0.3
margined madtom	69,502	0.5
Percidae	312,507	2.3
quillback	2,164,020	16.2
rock bass	285,177	2.1
shield darter	7,042	0.1
smallmouth bass	427,672	3.2
spottail shiner	160,030	1.2
tessellated darter	6,838	0.1
unidentified fish	48,744	0.4
unidentified darter	1,644,738	12.3
walleye	171,869	1.3
white sucker	1,299,692	9.8
yellow perch	308,528	2.3
Total	13,324,384	

Reference: Normandeau Associates, 2009.

Impingement Sampling at Hunlock Creek Power Station

An impingement study performed in 2006 at Hunlock Power Station, which is about 10 miles upriver from BBNPP, provides additional information with which to evaluate the potential impacts of the proposed BBNPP water intake structure on aquatic life of the Susquehanna River (UGI 2006).

The maximum plant intake flow rate during the study sampling events was 58.18 mgd which is greater than, roughly comparable to, the estimated maximum volume for BBNPP. The impingement study performed in 2006 consisted of 37, 24-hour sampling events distributed throughout the year. A total of 282 fish representing 16 species was collected. This equates to 7.6 fish per day or nearly 228 fish per month. Gizzard shad was the numerically dominant species, accounting for 39% of the total impingement catch. Other common species included bluegill (23%), channel catfish (20%), and white crappie (5%). Most of the impingement (53%) occurred during two sampling events in the early fall and was associated with high river flows. No American shad or rare, threatened, or endangered species were collected.

Discussion of Species of Concern

Mussel species of special concern identified in the Susquehanna River in the vicinity of proposed BBNPP river intake structure are the green floater (*Lasmigona subviridis*) and yellow lampmussel (*Lampsilis cariosa).* It is highly unlikely that juveniles or adults of these species will be susceptible to impingement or entrainment. Mussels are burrowing, bottom- oriented species and it is unlikely that these organisms would become entrained in the water column and enter the BBNPP river intake structure. Neither of these species has been collected in impingement studies at the SSES or at the Hunlock Station. However, a small possibility does exist that fish that have been infected with glochidia (mussel larvae) could become entrained or impinged. This occurrence could make the glochidia susceptible to both entrainment and impingement. The host fish species for larvae of green floater are unknown. Yellow lampmussel glochidial hosts include white perch and yellow perch. No white perch were collected during impingement and entrainment sampling at SSES during 2008-2009. Yellow perch was collected in low numbers in both entrainment (n=52) and impingement samples (n=3) at SSES during 2008.

It is also considered highly unlikely that American shad (juvenile or adult) will be susceptible to impingement or entrainment at the BBNPP intake to any significant degree. Juvenile and adult American shad are expected to have ample opportunity to successfully navigate past the planned intake structure. Furthermore, low numbers of recreationally important fish species are likely to be entrained at the BBNPP intake due to expected nest citing in shallow water locations removed from the BBNPP river intake structure.

Conclusions with Respect to Additional Studies and Monitoring

Analyses of the most representative cooling water intake structures have been conducted and presented. Additional analyses of other existing cooling water intakes via additional desktop studies would not be instructive. Furthermore, inasmuch as the BBNPP intake structure is a new facility and is required to be designed to satisfy EPA Track I requirements of 40 CFR §125.84, entrainment or impingement will comply with the performance standards set by the EPA in the rule. Therefore, no additional pre-construction studies are viewed as warranted. Once the facility is placed in service, PPL will be required under 40 CFR §125.87 to perform regular biological, velocity, and visual monitoring to ensure continued compliance with the performance requirements under the rule.

Literature Cited

Normandeau 2009. Impingement and Entrainment Sampling for the Proposed Bell Bend Nuclear Power Plant at the SSES Circulating Water Supply System Intake Structure, Luzerne County, Pennsylvania, May 2009.

PPL 1982. Susquehanna Steam Electric Station 316(b) Entrainment Demonstration Program, July 1982.

UGI 2007. UGI Hunlock Power Station Impingement Sampling Summary Report for sampling Period 01/4/06 to 12/28/06.

Enclosure 3

Rationale for the Location of the Bell Bend Nuclear Power Plant Intake Structure and Discharge Diffuser

Rationale for the Location of the Bell Bend Nuclear Power Plant Intake Structure and Discharge Diffuser

By

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The discharge of cooling tower blowdown is necessitated by dissolved solids buildup in the cooling water system due to evaporation through the cooling tower. Accepted practice is to place intakes upstream of discharges to avoid recirculation of discharged TDS and heat. Engineering, construction and cost considerations then define locations for intake and discharge structures. Based on the following analysis, it was decided to locate the Bell Bend Nuclear Power Plant (BBNPP) Intake Structure about 300 ft south of the Susquehanna Steam Electric Station (SSES) Intake and about 280 ft north of the SSES Discharge Diffuser. The BBNPP Discharge Diffuser about 380 ft south of the SSES Discharge Diffuser. The following discussion is limited to the North Branch of the Susquehanna River in the vicinity of the SSES.

The starting points in determining where the BBNPP Intake Structure and Discharge Diffuser should be located were the BBNPP power block location, the location of the Susquehanna Steam Electric Station (SSES) and its associated intake structure and discharge diffuser, and the proximity of the Susquehanna River. The BBNPP power block is west and a little south of the SSES. The SSES Intake Structure is located east and a little south of the SSES on the west bank of the North Branch of the Susquehanna River.

A major advantage of the SSES Intake Structure and Discharge Diffuser are the very favorable locations on the Susquehanna River. The Susquehanna River, typically known as a wide-shallow river, is particularly deep in the stretch of the river in front of the SSES Intake. Per the BBNPP Environmental Report (BBNPP ER) Section 2.3.1.1.1.8 and Figure 2.3-11, the Susquehanna River bed elevations in this stretch range from elevation 473 to 484 feet. Normal water level is typically viewed as around elevation 495 feet with the design basis low water level at 484 feet and highest water level recorded as 517 feet. At normal water level the Susquehanna River water depth ranges from 11 to 22 feet. The deepest section of the large pool of water extends about 700 above to 1800 feet below the existing SSES Intake Structure. It is estimated that the pool of water in front of the SSES Intake Structure contains close to 100,000,000 gallons of water even at the design basis low water level.

The intake structure and discharge diffuser have several environmental advantages in this section of the river. These advantages include less impact to the river from dredging, and in general less impact to aquatic habitat and to aquatic life because of the depth and size of the pool. Also less thermal impacts from the heated water discharge occur in the pool. Historical sampling at the SSES Intake structure has shown small impacts from impingement and entrainment. Specific environmental sampling for BBNPP is documented in the BBNPP ER as being a small impact. Aquatic habitat impacts will be quantified in 2010 by performance of the IFIM study described in Enclosure 1.

When the BBNPP Intake Structure and Discharge Diffuser were being sited in the spring of 2008, it was desirable to site the BBNPP Intake and Discharge on land already owned by PPL. The only contiguous land owned by PPL from the river to the BBNPP site without impacting Lake Took-a-while and the Riverlands Recreational Area is land that the existing SSES pipe lines and electrical duct banks (utilities) occupy. This land is just south of Lake Took-a-while and the Riverlands Recreational Area. Running the BBNPP utilities parallel with the existing SSES utilities would also avoid any impact to Lake Took-a-while and the Riverlands Recreational

Area. In addition, paralleling the existing SSES utilities reduces the potential to disturb land that had not been previously disturbed and provides installation feasibility assurance because the SSES installation has already proven successful.

The first option looked at placing the BBNPP Intake Structure north of the existing SSES Intake structure. Going north would increase the length of the various utilities. Also it would mean that the BBNPP utilities would at some point have to cross over or under the existing SSES utilities. Interferences included an existing 230kV transmission line 150 feet right away and known archeological sites on the west bank above the SSES Intake. In addition there is a potential for impact to the Riverlands Recreational Facility and it is desirable to avoid this impact. For these reasons it just did not make sense to try to consider the siting of the BBNPP Intake Structure in this direction.

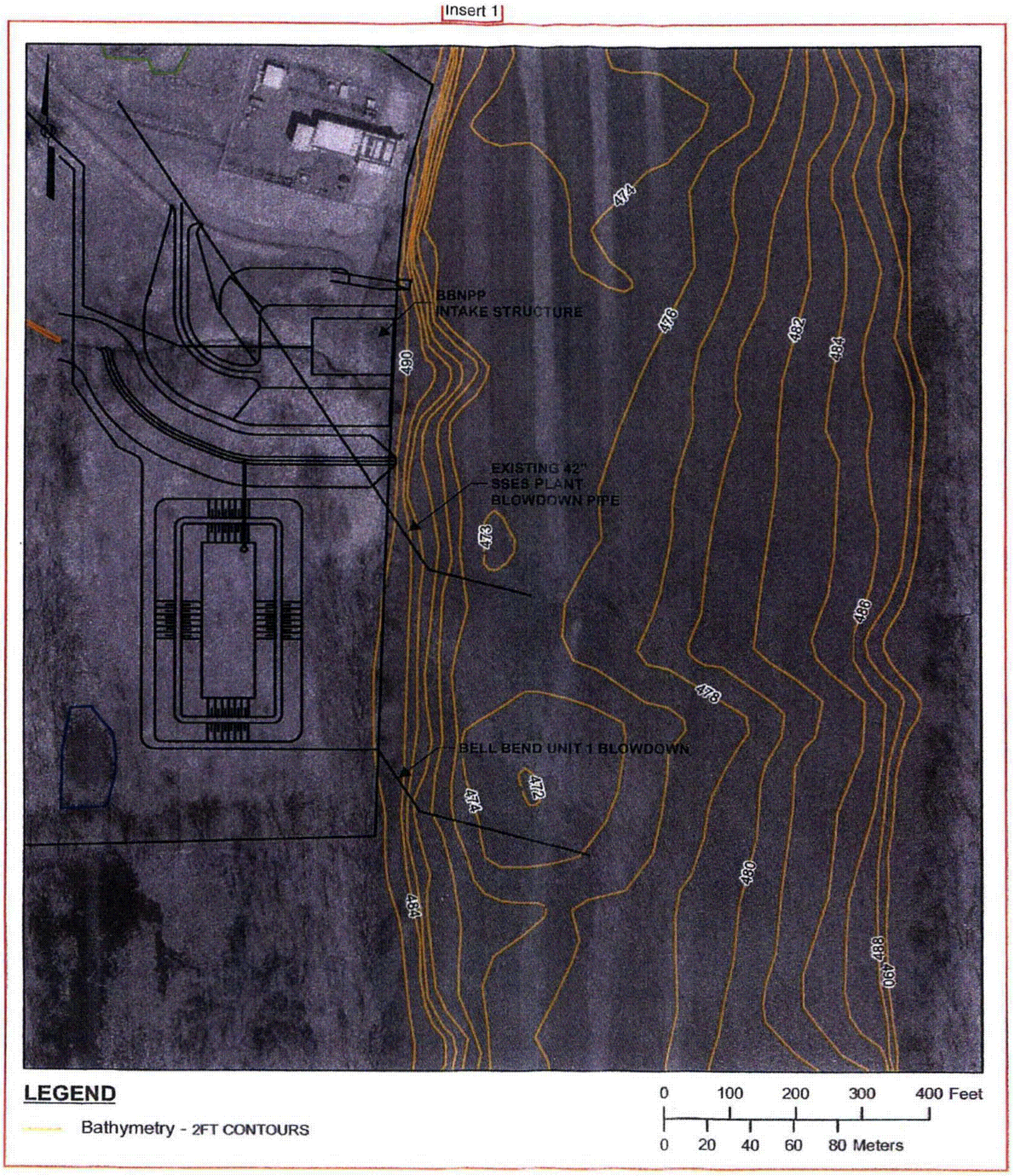
The next option was to try placing the BBNPP Intake Structure south of the existing SSES Intake. There were two immediate interferences identified. First is the outfall from the SSES Sewage Treatment Plant which is located just south of the SSES Intake Structure. It was decided that this would either have to be relocated or, if SSES should contract for offsite processing like BBNPP, then the line could be abandoned in place. In either case this was not a major obstacle.

The second interference is the SSES Diffuser or blowdown line. This is a large 42" line that enters the Susquehanna River about 580 feet below the SSES Intake Structure. The problem is the line comes down from SSES to just west of the SSES Intake Structure and then cuts across at a diagonal until it enters the Susquehanna River. This line supports both Susquehanna Steam Electric Station units and is never taken out-of-service. To relocate this line was viewed as not practical due to the impact on the Susquehanna units. This line must remain where it is currently located.

To locate the BBNPP Intake Structure below the SSES blowdown line would increase the impact from installing pipe, electrical duct banks, and roads through wetlands that parallel much of the west bank of the Susquehanna River in this area. In addition, it is desirable to locate both the BBNPP Intake Structure and the Discharge Diffuser within the large pool of water discussed above. To go too far south would eliminate this possibility. Lastly, this would greatly increase the length of the discharge lines and electrical duct banks from the BBNPP. This would be a large cost impact. This option was not viewed as feasible.

The location of the BBNPP Discharge Diffuser needed to be located in the large pool and south of the SSES discharge. The distance between the two discharges needed to be sufficient so the thermal impacts would not be cumulative. The distance between discharges and the design chosen for BBNPP to avoid cumulative thermal impacts was determined by thermal plume modeling performed by ERM. The BBNPP proposed discharge pipe will be at least 24 inches in diameter. The pipe enters the river about 380 feet below the existing blowdown line for Susquehanna SES. This discharge pipe extends approximately 212 feet out into the river. Connected to the discharge pipe is the diffuser section which is 106.5 feet in length. The diffuser has seventy-two 4-inch diameter port holes facing downstream and spaced center-to-center at 1.5 feet intervals. The angle of discharge of the port hole is 45 degrees above horizontal. The diffuser center elevation is approximately 9 feet below the estimated minimum flow river level of 484 ft.

The maximum distance between the two intake structures without interfering with the SSES blowdown line is about 300 feet centerline-to-centerline. Locating the BBNPP Intake Structure close to the SSES Intake Structure assures that many of the reasons for locating the SSES Intake Structure discussed above also apply to the BBNPP Intake Structure making this the most favorable location for the BBNPP Intake Structure. In addition, by locating the BBNPP intake near the SSES's intake the existing intake access road and laydown area can be shared for routine maintenance. Similarly being able to locate the BBNPP discharge only 380 ft south of the SSES discharge in the pool also makes this a highly favorable location on the North Branch of the Susquehanna River.



Reference: FSAR, Revision 2, Figure 2.4-10, February 12, 2010.