Enclosure

Byron and Braidwood Stations, Units 1 and 2
License Renewal Application
Braidwood Station Environmental Report

Responses to Requests for Additional Information

Environmental RAIs AQ-11 to AQ-15

AS AMENDED BY EXELON GENERATION LETTER # RS-14-283 (ML14281A019) DATED 10/08/2014

Enclosure

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RAI #: AQ-11a Category: Aquatic Resources

Statement of Question:

Section 2.2.5, Page 2-15 of the Environmental Report (ER) discusses fish kill events in the Braidwood cooling pond.

a. The ER states that five fish kills occurred between 2001 and 2007. NRC staff is aware of the fish kill events that occurred on July 22, 2001 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML012390121), August 27, 2001 (ADAMS Accession No. ML012680140), and June 28, 2005 (ADAMS Accession No. ML052160140). Provide the dates of the remaining two events as well as copies of the non-routine event reports associated with each event.

Response:

In addition to three fish kill events in the Braidwood cooling pond for which non-routine event reports were submitted to the NRC, two other events that resulted from observations of dead fish were investigated between 2001 and 2007. All five events occurred under conditions of high water temperatures and low dissolved oxygen levels, but two of the five events were determined to be non-reportable under the Braidwood Environmental Protection Plan (EPP) (Appendix B to Facility Operating License Nos. NPF-72 and NPF-77), Section 4.1, which defines the requirement for reporting fish kill events to the NRC as follows (emphasis added):

> 4.1 Unusual or Important Environmental Events
> Any occurrence of an unusual or important event *that indicates or could result in significant environmental impact causally related to plant operation* shall be recorded and reported to the NRC within 24 hours followed by a written report in accordance with Subsection 5.4.2. If an event is reportable under 10 CFR 50.72, then a duplicate immediate report under this subsection is not required. However, a follow-up written report is required in accordance with Subsection 5.4.2. The following are examples: excessive bird impaction events, onsite plant or animal disease outbreaks, mortality or unusual occurrence of any species protected by the Endangered Species Act of 1973, fish kills, increase in nuisance organisms or conditions, and unanticipated or emergency discharge of waste water or chemical substances.

The two events judged to be non-reportable were recorded in the station's corrective action system for trending purposes and were included in the total number of fish kills mentioned in Section 2.2.5 of the ER. These two events—one on June 3, 2004 and the other on August 21, 2007—are further described below.

June 3, 2004

Event Description

At approximately 6:00 PM on June 3, 2004, a plant employee performing roving inspections noted what appeared to be an abnormal number of dead fish along the bar racks at the Lake Screen House (LSH). Chemistry/Environmental personnel immediately performed a check of the area adjacent to the LSH in search of evidence of a fish kill. The immediate inspection found no evidence that a fish kill was in progress. There was no accumulation of dead fish along the shorelines adjacent to the LSH nor were fish floating into the intake bays from the cooling pond at the LSH. An estimated 500 dead fish were observed along the bar racks in front of the LSH, with the greatest accumulation being in front of the 2A intake bay and rapidly decreasing accumulations in front of the other five bays toward the west.

It was observed that the fish basket receiving back wash from the traveling screens was filled and overflowing into the pit from which the screen back wash water returns to the lake. This had caused fish from the traveling screens to flow back out into the cooling pond and accumulate predominantly along the 2A and 2B intake bay bar racks.

It was determined that plant operations were not being impacted. Therefore, since darkness was coming, it was decided that further investigation would continue the next morning.

Analysis and Evaluation

On the morning of June 4, 2004, Chemistry/Environmental personnel continued to search for evidence of a fish kill caused by plant operations. The fish observed in front of the intake bays (with the majority at the 2A and 2B intakes) were estimated to be 99+% gizzard shad. These fish were judged to have been dead for some time because most were already beginning to decompose. The fish basket had been emptied that morning, and the contents were observed to contain significantly decomposed matter, which appeared to have caused the mesh in the fish basket to become plugged. This plugging had caused the basket to overflow into the return pit the night before, which caused fish collected in the basket to be washed back into the cooling pond at the east end of the intake structure.

An inspection of the cooling pond shoreline revealed an occasional gizzard shad here and there, but no accumulation of dead fish, as would be expected from a fish kill. One area specifically viewed was the northeast corner of the area of the cooling pond in front of the LSH. With winds primarily out of the west on the preceding few days, if a fish kill had occurred there, a major accumulation of shad along this portion of the shoreline should have occurred. However, no such accumulation was present. Also, no evidence of dead fish was observed in the main body of the cooling pond.

Chemistry Department personnel reviewed lake parameters, chemical feeds, and temperature data for the five days preceding the event to check for abnormal trends that could have caused a fish kill. No abnormal data trends were found.

Probable Cause of Event

The absence of dead fish along the shore and in the cooling pond water on the night of June 3, 2004 and the following day, combined with the decomposed state of the dead fish observed at the LSH intake as well as the absence of any abnormal water parameter trends, suggested that the dead fish near the intake resulted from an accumulation of fish over time, rather than a fish kill event. Shad are very sensitive to changing conditions, and dead numbers appear in the intake bays and fish basket year-round. Hence, although the reason for so many dead fish to have accumulated at once near the intake trash racks could not be definitively established, it was concluded that a fish kill event had not occurred.

Agencies Notified

After reviewing the evidence, Braidwood personnel determined that the observed conditions did not constitute a fish kill event and therefore did not trigger reportability requirements. Hence, no non-routine event report was filed.

August 21, 2007

Event Description

During the early morning on August 21, 2007, a plant employee performing roving inspections noted a large number of dead gizzard shad in the circulating water intake at the Braidwood Lake Screen House (LSH). An inspection of the intake area and cooling pond banks revealed a significant number of fish floating against the trash racks, near the North Boat Ramp, and along shorelines in the eastern part of the cooling pond. Some fish were also noted floating in the main body of the cooling pond.

Plant operating conditions were reviewed, but no plant-related cause for a fish kill event on August 21 could be identified. All chemical injection systems were in proper operating condition with no leaks. Circulating water total residual oxidant concentrations for the preceding two months were all lower than the lower limit of detection. Thermal data from the preceding two weeks indicated that circulating water intake temperatures at the LSH had peaked at 96.5 degrees Fahrenheit (F) on August 12, but had fallen to 84.6 degrees F on August 20 after several days of overcast and rainy weather conditions. Inspections conducted for dead fish during the same two-week period showed none to low numbers of dead fish before the morning of August 21, and the event was effectively over by the afternoon of August 22.

Analysis and Evaluation

Beginning at approximately 12:00 Noon on August 21, 2007, an Exelon Fishery Specialist performed dissolved oxygen (DO) measurements at various locations in the cooling pond and observed several thousand dead gizzard and threadfin shad floating across visible areas of the cooling pond. Dozens of channel catfish were also observed, but no other species was observed that counted more than 2 individuals. DO concentrations ranged from 3.1 parts per million (ppm) early in the afternoon to 6.7 ppm at approximately 3:30 PM following several hours of direct sunlight. By 5:00 PM, however, the DO concentration had fallen again to 5.9 ppm.

Unlike similar previous fish kill events in the Braidwood cooling pond, which predominantly occurred at peaks of periods of elevated circulating water intake temperatures, the circulating water intake temperature on August 21, 2007 was not at a peak.

Probable Cause of Event

Based on the observed late afternoon decline in DO concentrations on August 21 and the absence of either a circulating water intake temperature peak or any other plant-related contributing factor, the Exelon Fishery Specialist, in consultation with an Illinois Department of Natural Resources (IDNR) biologist, concluded that the fish kill event occurred because the several days of overcast and rainy weather conditions preceding August 21 caused die off and decay of phytoplankton in the cooling pond, which triggered a rapid decline in DO concentrations during overnight hours, thus suffocating a large number of fish.

Agencies Notified

After reviewing the evidence, Braidwood personnel determined that the observed fish kill event was not reportable because it was not caused by plant operations and did not involve an endangered species. Hence, no non-routine event report was filed.

List of Attachments Provided:

None.

RAI #: AQ-11b Category: Aquatic Resources

Statement of Question:

Section 2.2.5, Page 2-15 of the Environmental Report (ER) discusses fish kill events in the Braidwood cooling pond.

b. Provide the dates of all fish kill events for the period 2008 through present as well as copies of the associated non-routine event report. The NRC staff is aware of the June 24, 2009, fish kill event and associated non-routine event report (ADAMS Accession No. ML092390348).

Response:

In addition to the fish kill event in the Braidwood cooling pond on June 24, 2009 for which a non-routine event report was submitted to the NRC, one other event that resulted from observations of dead fish has been investigated since January 2008. The second event was determined to be non-reportable under the Braidwood Environmental Protection Plan (EPP) (Appendix B to Facility Operating License Nos. NPF-72 and NPF-77), Section 4.1, which defines the requirement for reporting fish kill events to the NRC as follows (emphasis added):

> 4.1 Unusual or Important Environmental Events
> Any occurrence of an unusual or important event *that indicates or could result in significant environmental impact causally related to plant operation* shall be recorded and reported to the NRC within 24 hours followed by a written report in accordance with Subsection 5.4.2. If an event is reportable under 10 CFR 50.72, then a duplicate immediate report under this subsection is not required. However, a follow-up written report is required in accordance with Subsection 5.4.2. The following are examples: excessive bird impaction events, onsite plant or animal disease outbreaks, mortality or unusual occurrence of any species protected by the Endangered Species Act of 1973, fish kills, increase in nuisance organisms or conditions, and unanticipated or emergency discharge of waste water or chemical substances.

The non-reportable event, which occurred during July 2012, was recorded in the station's corrective action system for trending purposes and is further described below.

July 7-8, 2012

Event Description

Following the weekend of July 7-8, 2012, Braidwood personnel estimated that totals of approximately three thousand small gizzard shad and one hundred bass, catfish and carp had died in the cooling pond.

Monitoring results indicated that, on July 7, 2012, water temperature near the Braidwood Lake Screen House exceeded an average of 100°F for several hours while dissolved oxygen (DO) levels in the cooling pond remained at between 7 and 8 mg/L. The temperature excursion above 100°F in the ultimate heat sink due to prolonged hot weather was approved by the NRC in a Notice of Enforcement Discretion issued orally on July 7, 2012 and documented in writing by letter dated July 12, 2012 (ML12194A681). By July 12, 2012, cooling pond temperatures had significantly decreased and the rate of fish deaths had slowed, although it was expected that some additional fish losses might occur.

Analysis and Evaluation

For the following reasons, Braidwood personnel concluded that fish were dying as a result of the sustained elevated water temperatures in the cooling pond.

- DO levels in the cooling pond were noticeably higher than 3 mg/L, which is the level at which fish mortality due to low DO levels typically occur. Therefore, low DO did not appear to be the cause of fish mortality in this event.
- The vast majority of the dead fish were juvenile gizzard shad, which are particularly susceptible to fluctuations in water thermal conditions.
- On July 8, the air temperature moderated and local wind speeds increased resulting in a corresponding decrease in cooling pond water temperature. As water temperatures decreased, the rate of fish deaths slowed noticeably.

Probable Cause of Event

From July 4 through July 8, 2012, northern Illinois experienced unprecedented weather conditions, with no precipitation and air temperatures at or above 100°F for three consecutive days. As a result, cooling of the water in the Braidwood cooling pond that would typically occur due to precipitation inflow and lower nighttime air temperatures was minimal during that time, which caused a sustained elevation of the water temperature.

Agencies Notified

After reviewing the evidence, Braidwood personnel determined that the observed fish kill event was not reportable because it was not caused by plant operations and did not involve an endangered species. Hence, no non-routine event report was filed. Nevertheless, courtesy notifications were made verbally to the NRC Resident Inspector and Illinois Department of Natural Resources.

List of Attachments Provided:

None

RAI #: AQ-12a **Category: Aquatic Resources**

Statement of Question:

Section 2.2.5, Page 2-16 of the ER states that "HDR [HDR Engineering] assessed water quality and fish populations in the cooling pond in late summer 2009 and 2010 to develop a better understanding of the factors contributing to fish kills and design a water quality or fish monitoring program that could be used to predict (and conceivably mitigate) fish kills in the pond."

a. Provide copies of the 2009 and 2010 HDR studies mentioned in the ER.

Response:

The HDR studies mentioned in the ER are provided.

List of Attachments Provided:

1. (Exelon Nuclear 2010) Exelon Nuclear, 2010. Braidwood Station – Braidwood Lake Additional Biological Sampling Program, 2009. Prepared by HDR Engineering, Inc. Copyright by Exelon Corporation.
2. (Exelon Nuclear 2011) Exelon Nuclear. 2011. Braidwood Station - Braidwood Lake Additional Biological Sampling Program, 2010. Prepared by HDR Engineering, Inc. Copyright by Exelon Corporation.

Attachment #1 to Response -- RAI # AQ-12a

BRAIDWOOD STATION

BRAIDWOOD LAKE ADDITIONAL BIOLOGICAL SAMPLING PROGRAM, 2009

Prepared for
EXELON NUCLEAR

February 2010

HDR Engineering, Inc.
Environmental Science & Engineering Consultants
10207 Lucas Road
Woodstock, Illinois 60098

BRAIDWOOD STATION

BRAIDWOOD LAKE ADDITIONAL BIOLOGICAL SAMPLING PROGRAM, 2009

Prepared for

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ACKNOWLEDGMENTS

The field work and data analysis for this project was conducted by HDR Engineering, Inc. (HDR). Particular appreciation is extended to Rob Miller of the Illinois Department of Natural Resources (IDNR), Jim Smithson of Strategic Environmental Actions, Inc. (SEA), and John Petro of Exelon Nuclear for providing historical fisheries and water quality data.

This report was prepared by HDR and reviewed by Exelon Nuclear. A special debt of gratitude is owed to the environmental staff at Braidwood Station and in particular Mr. Jeremiah Haas of Exelon Nuclear for his technical assistance, cooperation, and guidance during the preparation of this document and the study plan. Mr. Haas's experience and insight has been invaluable and is greatly appreciated by the authors.

ABSTRACT

HDR Engineering, Inc. (HDR) was contacted on March 12, 2009 by Braidwood Nuclear Generating Station, requesting HDR to design and conduct a fish sampling program in the Braidwood Cooling Lake. The information gathered during this study was to be used by Exelon to develop an effective sampling program and set of procedures that could potentially predict fish die-offs in the cooling lake. Large die-offs of fish challenge the integrity of the traveling screens at the Station. With advanced warning, the Station could be informed of a potential reportable event; regulatory agencies could be notified in advance; and crews responsible for fish disposal could be put on alert to help manage the risk associated with a substantial fish die-off. Currently, there are no practical or simple methods that can be used to predict or prevent the occurrence of fish die-offs at Braidwood Cooling Lake.

Sampling has been conducted at Braidwood Lake by the IDNR since 1980. From 1980 through 2007 IDNR has collected 47 taxa of fish. Twenty-six taxa representing seven families were included among the 2143 fish collected by HDR by electrofishing, trap netting, and gill netting at Braidwood Lake during July and August 2009. Several taxa listed as collected by IDNR since 1980 were not captured by HDR in 2009. Many of those species were only rarely captured, have not been captured during recent years, or represent taxa that were stocked. However, five species were captured by HDR in 2009 that were not listed as collected during IDNR sampling efforts. They include shortnose gar, blue catfish, bigmouth buffalo, fathead minnow, and rosyface shiner. A single specimen of each species was collected. Dominant species collected in 2009 in terms of both numbers and weight were similar to results reported by IDNR in recent years. Braidwood Lake is dominated by warmwater species including gizzard shad, threadfin shad, carp, channel catfish, flathead catfish, largemouth bass, bluegill, and cyprinid species such as spotfin shiner and bluntnose minnow.

Water quality data recorded in conjunction with fish sampling was measured at each location prior to every sample collection. Water temperature (°C), dissolved oxygen (ppm), pH, and conductivity (μmhos/cm) measurements were taken 0.5 m below the water surface. Water temperatures during both the July and August sampling periods were similar ranging from 28.5

°C at Location E-5 (near the make-up water discharge into the lake from the Kankakee River) to 35.5 °C at Location E-1 (the most southern location closest to the Braidwood Station discharge). Diurnal swings in dissolved oxygen (DO) were observed at the lake with DO ranging from 4.1 to 9.5 ppm. Dissolved oxygen readings were generally slightly lower during the August sampling period. Examination of pH data collected during these studies show pH ranged from 8.7 to 9.1 in July and from 8.5 to 8.7 in August. Conductivity ranged from 760 to 899 μmhos/cm in July and from 908 to 931 μmhos/cm in August.

Review of historical water quality data reported in 2002 by Strategic Environmental Actions, Inc. (SEA Inc.) at Braidwood Lake indicates that abnormally high levels of total dissolved solids (TDS), alkalinity, hardness, sulfates, magnesium, calcium, and total phosphorus exist throughout the cooling loop. This is not unexpected based upon the evaporation that takes place within the cooling loop coupled with the relatively low make-up and blow-down rates associated with the operation of Braidwood Station. These elevated levels within the lake were measured at two to nearly eight times higher than those of the make-up water from the Kankakee River. Elevated levels of water hardness are of concern to the Station because high levels have the potential to increase problems associated with scaling at the Station.

Phosphorus and nitrogen are two essential nutrients required by aquatic plants. Studies conducted by SEA in 2002 indicated that nutrients within the cooling lake were at levels high enough to continue to cause problems associated with phytoplankton blooms. These blooms result in oxygen production via photosynthesis during daylight hours and oxygen depletion through respiration during darkness. When algal populations crash and decompose they can produce severe oxygen depletion within the water column. Diurnal swings in oxygen readings have been routinely observed at Braidwood Lake during the past several years. In addition, DO levels of less than 3 ppm have been recorded at the lake immediately following fish die-offs. Dissolved oxygen levels of 3 ppm and less cannot be tolerated for an extended period of time by most fish species. Deeper portions of the lake were also reported to stratify in 2002. In the deeper zones of the lake, DO levels approaching 0 ppm and reduced water temperatures were measured below the thermocline.

Review of historical fisheries information that was provided to HDR indicated that five separate fish kills were reported from 2001 to 2007. Numerically, the majority of fish observed during these events were either gizzard shad or threadfin shad. These two species have typically comprised over 90% to 95% of all fish observed. Remaining species included carp, freshwater drum, bluegill, channel catfish, flathead catfish, quillback and largemouth bass. Each of the reported fish die-offs was attributed to oxygen depletion at the lake and not any result of Station operation.

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1.0 INTRODUCTION

The Braidwood Lake Fish and Wildlife Area is comprised of approximately 2640 acres of terrestrial and aquatic habitat that is located in Will County, Illinois. Braidwood Lake is owned by Exelon and is a partially perched, cooling lake that was constructed in the late 1970s. The lake was filled during 1980 and 1981 with water pumped from the Kankakee River. Several surface mined pits existed at the site prior to the filling of the impoundment. Fisheries management activities began in these surface mine pits in 1978, prior to the creation of Braidwood Cooling Lake. Originally the lake was considered a semi-private area used by employees of Commonwealth Edison Company until the end of 1981 when the Department of Conservation (now the Illinois Department of Natural Resources). Braidwood Lake is currently used for fishing, waterfowl hunting, fossil hunting, and acquired a long-term lease agreement from the company which allowed for general public access as a waterfowl refuge. From the late 1970's to the present time, Braidwood Lake has been stocked with a variety of warm- and coolwater fish species. These stockings include largemouth and smallmouth bass, blue catfish, striped bass, crappie, walleye, and tiger muskie. Monitoring programs have documented the failure of the coolwater stockings to create a meaningful fishery. This is attributed to the extreme water temperatures that occur within the cooling lake during the warm summer months.

Construction of the Braidwood Nuclear Generating Station and its associated riverside intake and discharge structures provided an opportunity to gather fisheries information from the Kankakee River and Braidwood Lake. These studies were initiated to determine the effects of construction and plant operation on the river and the lake. Units I and II began commercial operation on 29 July and 17 October, 1988, respectively. Fisheries surveys at Braidwood Lake were conducted annually by the Illinois Department of Natural Resources (IDNR) from 1980 through 1992. Since 1992, fishery surveys have been conducted by IDNR every other year except 1995 and 1996. Fishery surveys on the Kankakee River near the Station's intake have also been conducted annually since the late 1970's by the Illinois Natural History Survey (1977-1979 and 1981-1990), LMS Engineers (1991-1992 and 1994-2004), Environmental Research and Technology (1993), HDR/LMS (2005-2007), and HDR (2008-2009).

The objectives of the 2009 Braidwood Lake Additional Sampling Program were to:

1. Conduct fish surveys at Braidwood Lake for comparison with historical data that has been collected by IDNR.

2. Summarize any existing data related to fish kills that have occurred at Braidwood Lake.

3. Develop a sampling procedure or protocol that will help anticipate fish die-offs in the cooling lake that could potentially effect Station operations.

2.0 METHODS

2.1 Electrofishing

Electrofishing was conducted using a boat-mounted boom-type electrofisher utilizing a 5000 watt, 230 volt AC, 10 amp, three-phase Model GDP-5000 Multiquip generator equipped with volt/amp meters and a safety-mat cutoff switch. The electrode array consisted of three pairs of stainless steel cables (1.5 m long, 6.5 mm in diameter) arranged 1.5 m apart and suspended perpendicular to the longitudinal axis of the boat 1.5 m off the bow. Each of the three electrodes was powered by one of the phases. Electrofishing samples were collected on 22 and 23 July during the first sampling effort and on 20 August during the final survey period.

Eight locations around the dike and islands at Braidwood Lake were electrofished during both the first and second sampling periods (Figure 2-1). Electrofishing was conducted near the shoreline at each location to collect fish utilizing shallow water zones. Each electrofishing area was sampled for 30 minutes. Voltage and amperage of the electrofishing unit was recorded at each location at the beginning and end of each sampling effort. Sampling was restricted to the period of time ranging from one-half hour after sunrise to one-half hour before sunset.

The electrofishing crew consisted of two people. One crew member operated the boat while the second crew member dipped fish from the bow of the boat. The boat operator also dipped fish whenever necessary. When fish surfaced behind the boat the boat operator backed up to retrieve all stunned fish. All stunned fish were collected without bias of size or species.

Fish at each location were put into barrels of water in the front of the boat for analysis at the end of each 30 minute collection period. All fish were processed in the field immediately following collection at each location. Special emphasis was placed on the return of all collected game fish species to the water as quickly as possible following field analysis. Catches were standardized to catch-per-effort (CPE) from actual fishing time (30 min) to numbers caught per hour by dividing the total numbers of fish collected by the actual fishing time in hours.

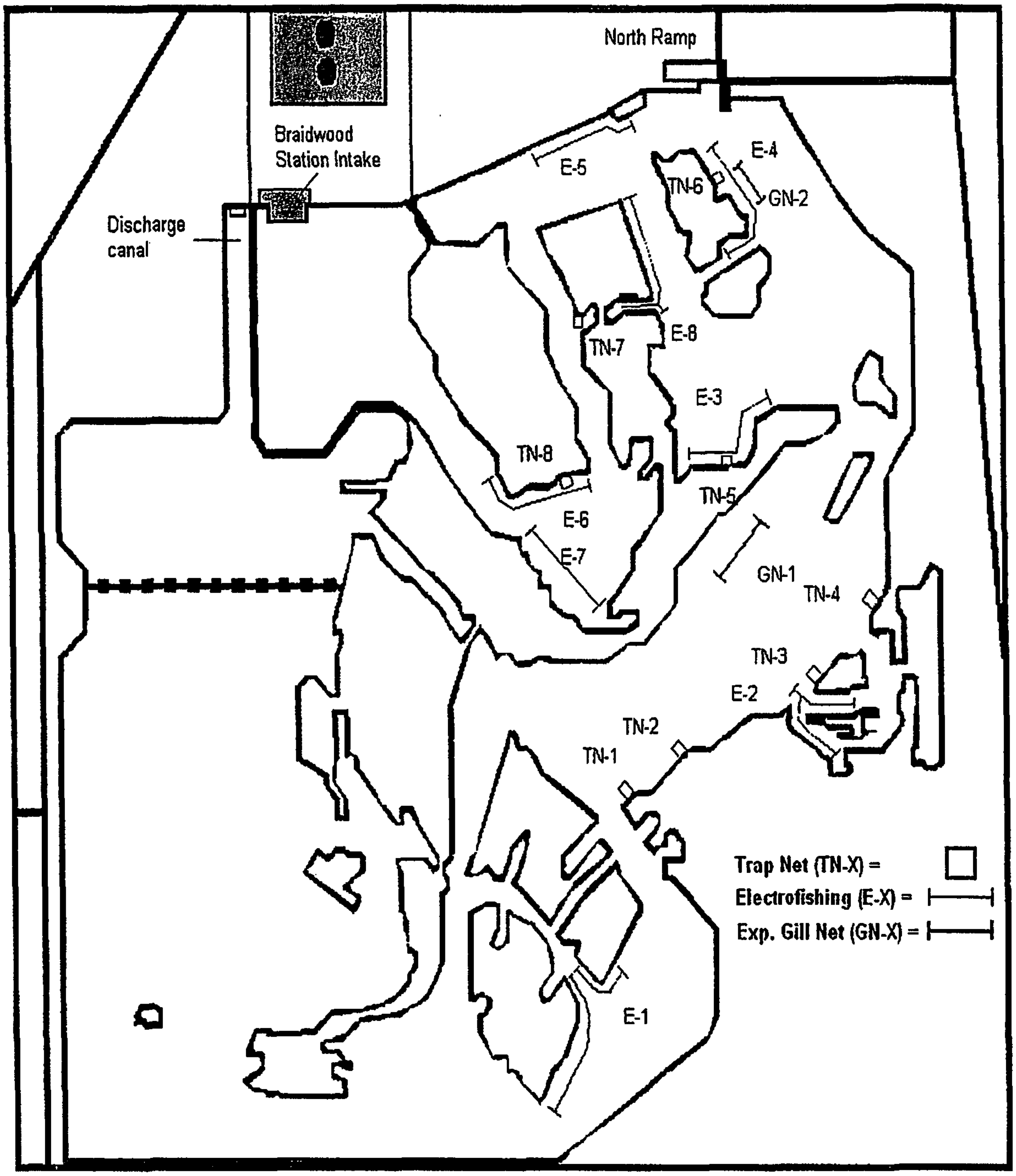

FIGURE 2-1. SAMPLING LOCATIONS AT BRAIDWOOD LAKE DURING JULY AND AUGUST, 2009.

2.2 Trap Netting

Trap nets were set at eight separate locations in Braidwood Lake (Figure 2-1). Each trap net consisted of a 25-ft. lead that was 4-ft. deep and attached to a series of rectangular frames. The last rectangular frame was attached to a hoop net constructed of 1.5-in. (bar) mesh nylon webbing on hoops 3.5 ft in diameter. Two separate throats were contained within each trap net. One was located in the series of rectangular frames at the front end of the net, while the second throat was located toward the back of the net inside the 3.5 ft diameter hoop net. Trap nets were set during late afternoon or early evening and were allowed to fish overnight for approximately 12 hrs before being retrieved the following morning. Trap nets were set on 21 July and retrieved on 22 July during the first sampling period and set on 17 August and retrieved on 18 August during the second sampling period.

Fish at each location were put into barrels of water in the front of the boat for analysis at the end of each collection period. All fish were processed in the field immediately following removal from the trap net. Special emphasis was placed on the return of all collected game fish species to the water as quickly as possible following field analysis. Catches were standardized to catch-per-effort by dividing the total number of fish caught by the total number of hours the nets were allowed to fish (fish/12-hr set).

2.3 Gill Netting

Two 125-ft. long and 6-ft. deep monofilament experimental gill nets were used to collect fish from two locations in Braidwood Lake (Figure 2-1). Each net consisted of five separate panels that were 25-ft long by 6-ft deep. Bar mesh sizes of each panel were 0.5, 0.75, 1.0, 2.0, and 3.0 inches, respectively. Nets were set in water depths of approximately six to ten feet deep. Gill net samples were collected on 21 July during the first sampling period and on 17 and 18 August during the second sampling period.

Gill nets were set for 1.5 hours at Location GN-1 and for one hour at Location GN-2 before they were lifted and fish were removed during both the July and August sampling period. Elevated water temperatures in the cooling lake prohibited longer set times due to the high mortality that occurred shortly after the fish became entangled in the monofilament netting. Gill net sampling was conducted either early in the morning (0630 to 0800 hrs) or late in the afternoon (1600 to 1910 hrs).

All fish were processed in the field as they were removed from the net. Special emphasis was placed on the return of game fish species to the water as quickly as possible. Catches were standardized to catch-per-effort (CPE) from actual fishing time the nets were in the water to numbers caught per hour by dividing the total numbers of fish collected by the actual fishing time in hours.

2.4 Sample Processing

All fish were identified to the lowest positive taxonomic level and enumerated. For each gear type, up to 25 individuals of a species were measured for total length (mm) and weight (g) at each location. Any remaining individuals of that species were counted and weighed en masse. Minnow species (excluding carp) were counted and weighed en masse. Specimens that could not be positively identified in the field were either photographed in the field or returned to the laboratory for identification. References used to facilitate identification included Pflieger (1975), Smith (1979), and Trautman (1981).

2.5 Water Quality Measurements

Four physicochemical parameters (temperature, dissolved oxygen [DO], pH, and conductivity) were measured in conjunction with the sampling program. These data were collected at each station prior to each sampling effort. Physicochemical measurements were taken a half meter below the water surface at shallow water locations (electrofishing). At deeper locations, temperature, conductivity, and DO were measured 0.5 m below the surface and 0.5 m off the bottom (gill and trap nets). Temperature (°C), dissolved oxygen (ppm), and conductivity (µmhos) were measured using an YSI Model 85 handheld oxygen, conductivity, salinity, and temperature meter. A Cole-Parmer pH Tester1 was used to determine pH. All instruments were calibrated prior to each monthly sampling event.

3.0 RESULTS AND DISCUSSION

3.1 Species occurrence. Fish surveys have been conducted at Braidwood Lake by the Illinois Department of Natural Resources (IDNR) since 1980 when the cooling lake was first impounded with water pumped from the Kankakee River. Sampling was conducted annually from 1980-1992, again in 1994, and every other year from 1997-2007 (Table 3-1). During these 20 years of sampling, 47 taxa of fish have been collected including 45 species and two hybrids (hybrid sunfish and tiger muskie). Gizzard shad, carp, channel catfish, bluegill, and largemouth bass have been the dominate species collected during these surveys. The total number of taxa collected by the IDNR has ranged from 12 in 1980 to 27 in 1989. Several species have been rarely collected or only occasionally observed during this 30 year period. These include, yellow bass, rock bass, redear sunfish, orangespotted sunfish, tiger muskie, grass pickerel, longnose gar, goldfish, highfin carpsucker, silver redhorse, river redhorse, blackstripe topminnow, emerald shiner, common shiner, striped shiner, redfin shiner, slenderhead darter, johnny darter, and bullhead minnow, which have been collected in five or fewer of the 20 years of sampling conducted by the IDNR from 1980 through 2007. The only protected species (one fish collected in 1999) collected during these surveys has been river redhorse (*Moxostoma carinatum*), which is currently listed as threatened in Illinois (Illinois Endangered Species Protection Board 2004). River redhorse have been collected in the Kankakee River in the past (HDR, 2009). Eighteen of the taxa identified by the ILDR have not been captured since 1999.

Braidwood Lake has been stocked with a variety of warmwater and coolwater fish species since the late 1970's. Some of these species, such as striped bass, tiger muskie, and walleye, have not been collected in recent years following the discontinuance of those stocking programs. Currently, the fish community is dominated by warmwater species that are more tolerant of the elevated water temperatures that exist in the cooling lake during summer months.

3.2 Relative Abundance and CPE. In 2009, 26 taxa representing seven families were included among the 2143 fish collected by electrofishing, trap netting, and gill netting (Table 3-2). Several species that were listed as being collected by the IDNR during surveys conducted between 1980 and 2007 were not captured by this program in 2009. Each of these taxa were either rarely captured during previous years, represent taxa that were stocked, or have not been capture during

TABLE 3-1

SPECIES OCCURRENCE OF FISH COLLECTED BY THE ILLINOIS DEPARTMENT OF NATURAL RESOURCES[a] AT BRAIDWOOD LAKE FROM 1980 THROUGH 2007.

	SAMPLING YEAR																			
Taxa	80	81	82	83	84	85	86	87	88	89	90	91	92	94	97	99	01	03	05	07
Longnose gar			3												13					
Threadfin shad		564																11	230	122
Gizzard shad	27	2545	972	143	143	182	141	7	1020	4248	1296	1382	3018	412	925	925	786	1031	872	195
Grass pickerel	2	5	24	7	1															
Tiger muskie				8	3								5		12					
Goldfish														2	3	1	1			
Carp	275	365	414	616	785	532	666	675	511	1915	626	108	227	285	853	385	929	620	204	405
Golden shiner	4	82	1	1									1	1			1	1		1
Emerald shiner					1			2		1		1					48			
Common shiner		31							2	2										
Striped shiner		14																		
Spotfin shiner						1		9	3	37	75	5	4	1	1		198	3	27	249
Sand shiner			1			4		1	1	26	11	2	1					5		75
Redfin shiner																		1		
Bluntnose minnow			1	4		1		5	6	35	32	6	3			3	13		1	6
Bullhead minnow																				11
Quillback	26	39	6	42	37	39	29	53	39	20	42	26	66	20	37	5	3			
Highfin carpsucker		2																		
Silver redhorse		1								1				1						
Golden redhorse								2	1	2	2	2		1						
Shorthead redhorse								1	4	10	5	3	3		4	3				
River redhorse																1				
Black bullhead	18	102	167	25	6	1														
Yellow bullhead		3	11	8	6	18	7	3	1	1	2	1	1	1		3	3		1	1
Channel catfish		9	2	3	12	13	7	39	16	79	177	362	357	463	136	364	866	384	129	228
Flathead catfish															1	2	10		1	1
Blackstripe topminnow											6									
Brook silverside	4	145			1				4	171	17	8	9	13	6	12	50	3	5	1
Yellow bass					1				1											
Striped bass								2	1	1	5	4	1	1	15					

TABLE 3-1 (Continued).

Taxa	SAMPLING YEAR 80	81	82	83	84	85	86	87	88	89	90	91	92	94	97	99	01	03	05	07
Rock bass									1		1	1		2						
Green sunfish	4	57	163	125	16	71	13	13	2	7	1	10	8	23	13	37	139	26	10	77
Orangespotted sunfish												1				1				1
Bluegill	13	458	620	191	69	81	21	9	31	277	121	698	247	252	241	998	1754	1393	1369	2758
Longear sunfish														25	1	7		3		1
Redear sunfish														1			3			
Hybrid sunfish		1	16	12	6	20	11	6		1		2	1	4		9	13	8	5	7
Smallmouth bass										1	3	42	24	17	42	17	9	3	5	
Largemouth bass	23	473	385	390	298	265	241	150	142	142	192	175	91	337	202	711	351	334	88	263
White crappie		41		19	30	17	6	5	4	6	3	10	2			3				
Black crappie	2	36	4	2	7	6	3	1	4	3	11	6	1			20	2	2	1	1
Johnny darter		2																		
Yellow perch	2	66	42	20	35	69	93	74	61	10	3									
Logperch									12	71	47	11	72	6	7					
Slenderhead darter									2	2		1								
Walleye		3	7	13	21	24	53	30	62	38	37	7	8	1	3					
Freshwater drum			1		11	7	14	12	11	61	15	8	15	6	21	14	14	34	9	1
Total fish	400	5044	2840	1629	1489	1351	1305	1099	1942	7008	2730	2882	4165	1875	2536	3521	5193	3862	2957	4403
Total taxa	12	23	19	18	20	18	14	21	25	27	24	26	23	23	20	21	20	17	16	20
Total species	12	22	18	16	18	17	13	20	25	26	24	25	21	22	19	20	19	16	15	19

[a]Information provided by Rob Miller, District Fisheries Biologist with the Illinois Department of Natural Resources.

TABLE 3-2

TOTAL CATCH BY METHOD FOR FISH SPECIES COLLECTED FROM THE BRAIDWOOD STATION COOLING LAKE, 2009.

TAXON	ELECTROFISHING				TRAP NETTING				GILL NETTING				TOTAL			
	NUMBER		WEIGHT		NUMBER		WEIGHT		NUMBER		WEIGHT		NUMBER		WEIGHT	
	No.	%	(g)	%	No.	%	(g)	%	No.	%	(g)	%	No.	%	(g)	%
Threadfin shad	59	4.2	522	0.2					191	71.5	1964	13.3	250	11.7	2486	0.5
Gizzard shad	123	8.7	9730	3.3	18	3.9	4211	2.6	3	1.1	469	3.2	144	6.7	14,410	3.1
Shortnose gar					1	0.2	1750	1.1					1	< 0.1	1750	0.4
Longnose gar					4	0.9	9900	6.2					4	0.2	9900	2.1
Carp	100	7.0	165,657	56.4	42	9.2	52,220	32.7	3	1.1	4450	30.2	145	6.8	222,327	47.5
Striped shiner	34	2.4	59	< 0.1									34	1.6	59	< 0.1
Rosyface shiner	1	0.1	3	< 0.1									1	< 0.1	3	< 0.1
Spotfin shiner	176	12.4	475	0.2									176	8.2	475	0.1
Sand shiner	27	1.9	41	< 0.1									27	1.3	41	< 0.1
Fathead minnow	1	0.1	2	< 0.1									1	< 0.1	2	< 0.1
Bluntnose minnow	164	11.5	332	0.1									164	7.7	332	0.1
Bullhead minnow	153	10.8	335	0.1									153	7.1	335	0.1
Bigmouth buffalo	1	0.1	2550	0.9									1	< 0.1	2550	0.5
Blue catfish					1	0.2	1000	0.6					1	< 0.1	1000	0.2
Channel catfish	96	6.8	34,352	11.7	73	16.0	57,416	36.0	70	26.2	7870	53.3	239	11.2	99,638	21.3
Flathead catfish	3	0.2	38,750	13.2									3	0.1	38,750	8.3
Brook silverside	1	0.1	2	< 0.1									1	< 0.1	2	< 0.1
Sunfish spp.	1	0.1	1	< 0.1									1	< 0.1	1	< 0.1
Green sunfish	20	1.4	857	0.3									20	0.9	857	0.2
Redear sunfish	16	1.1	518	0.2									16	0.7	518	0.1
Bluegill	338	23.8	18,098	6.2	311	68.2	29,916	18.7					649	30.3	48,014	10.3
Longear sunfish	16	1.1	373	0.1									16	0.7	373	0.1
Hybrid sunfish	10	0.7	162	0.1									10	0.5	162	< 0.1
Smallmouth bass	2	0.1	1793	0.6									2	0.1	1793	0.4
Largemouth bass	78	5.5	20,464	7.0	5	1.1	3105	1.9					83	3.9	23,569	5.0
Black crappie					1	0.2	147	0.1					1	< 0.1	147	< 0.1
Totals	1420		293,829		456		159,665		267		14,753		2143		468,247	
Total taxa	22				9				4				26			
Total species	20				9				4				24			

recent years. However, five species were captured in this program during 2009 that were not listed as collected during earlier sampling efforts. They include shortnose gar, blue catfish, bigmouth buffalo, fathead minnow, and rosyface shiner. A single specimen of each of these five species was collected in 2009. The bigmouth buffalo, fathead minnow, and rosyface shiner were collected by electrofishing, while the shortnose gar and blue catfish were collected by trap netting. Species that numerically dominated the catch in 2009 included bluegill (30.3%), threadfin shad (11.7%), channel catfish (11.2%), spotfin shiner (8.2%), bluntnose minnow (7.7%), bullhead minnow (7.1%), carp (6.8%), gizzard shad (6.7%), and largemouth bass (3.9%). All of these species were included among the catch during the 2007 survey conducted by IDNR. Biomass of fish captured by electrofishing, trap netting, and gill netting in 2009 was dominated by carp (47.5%), channel catfish (21.3%), bluegill (10.3%), largemouth bass (5.0%), and gizzard shad (3.1%). These results are similar to data collected by the IDNR and indicate that Braidwood Lake is best suited to support warmwater species.

Electrofishing resulted in the collection of 1420 individuals representing 22 taxa (Table 3-3). The catch was dominated numerically by bluegill, which comprised 23.8% of all fish captured. Spotfin shiner (12.4%), bluntnose minnow (11.5%), bullhead minnow (10.8%), gizzard shad (8.7%), carp (7.0%), channel catfish (6.8%), and largemouth bass (5.5%) were the only other species to individually comprise greater than 5% of the total catch by number. The total number of fish collected by location ranged from 139 at Location E-2 to 250 at Location E-5 near the make-up water discharge. The total number of taxa collected ranged from nine at Location E-2 to 16 at Location E-6. In general, more fish and greater numbers of taxa were collected at locations located on the cooler end of the Braidwood Lake cooling loop (Locations E-5, E-6, and E-7). Electrofishing biomass was dominated by carp, which constituted 56.4% of the 293.8 kg collected (Table 3-2). Other species that individually contributed more than 5% of the total biomass included flathead catfish (13.2%), channel catfish (11.7%), largemouth bass (7.0%), and bluegill (6.2%).

A total of 456 fish including nine species was collected by trap net (Table 3-4). Bluegill was the dominant species captured, comprising 68.2% of all fish taken. The second most abundant species collected was channel catfish (16.0%), followed by carp (9.2%), gizzard shad (3.9%), and largemouth bass (1.1%). The total number of fish collected by location ranged from nine at

TABLE 3-3

FISH CAPTURED BY ELECTROFISHING IN BRAIDWOOD LAKE, 2009.

TAXON	E-1	E-2	E-3	E-4	E-5	E-6	E-7	E8	TOTAL	
	SAMPLING LOCATIONS									
Threadfin shad	1	12	1	3	11	31			59	4.2
Gizzard shad	72	14	7	16	5	2	2	5	123	8.7
Carp	11	6	22	13	14	6	14	14	100	7.0
Striped shiner				34					34	2.4
Rosyface shiner						1			1	0.1
Spotfin shiner	27	9	34	2	12	52	17	23	176	12.4
Sand shiner						16	11		27	1.9
Fathead minnow	1								1	0.1
Bluntnose minnow	1	19	22	19	16	31	18	38	164	11.5
Bullhead minnow	1	11	3	19	5	57	35	22	153	10.8
Bigmouth buffalo	1								1	0.1
Channel catfish	10	25	5	23	13	3	5	12	96	6.8
Flathead catfish					1	1	1		3	0.2
Brook silverside						1			1	0.1
Sunfish spp.							1		1	0.1
Green sunfish	1		1		13		4	1	20	1.4
Redear sunfish			1	3	3	3	4	2	16	1.1
Bluegill	18	22	42	30	133	20	31	42	338	23.8
Longear sunfish					10	3	3		16	1.1
Hybrid sunfish					4	3	3		10	0.7
Smallmouth bass					2				2	0.1
Largemouth bass	12	21	11	4	8	11	8	3	78	5.5
Total fish	156	139	149	166	250	241	157	162	1420	
Total Taxa	12	9	11	11	15	16	15	10	22	
CPE (fish/hr)[a]	156.0	139.0	149.0	166.0	250.0	241.0	157.0	162.0	177.5	

[a] Based on 1.00 hrs electrofishing effort.

TABLE 3-4

FISH CAPTURED BY TRAP NETTING IN BRAIDWOOD LAKE, 2009.

	SAMPLING LOCATIONS									
TAXON	TN-1	TN-2	TN-3	TN-4	TN-5	TN-6	TN-7	TN-8	TOTAL	%
Gizzard shad	4	7	3	2	1		1		18	3.9
Shortnose gar					1				1	0.2
Longnose gar					3			1	4	0.9
Carp	24		1	4	4	2	4	3	42	9.2
Blue catfish		1							1	0.2
Channel catfish	13	6	11	11	12	3	9	8	73	16.0
Bluegill	41	21	37	64	46	4	51	47	311	68.2
Largemouth bass	1	1		2	1		1		5	1.1
Black crappie									1	0.2
Total fish	83	36	52	83	68	9	66	59	456	
Total Taxa	5	5	4	5	7	3	5	4	9	
CPE (fish/trap net set)[a]	41.5	18.0	26.0	41.5	34.0	4.5	33.0	29.5	28.5	

[a] Based on two over night sets of approximately 12 hr duration.

Location TN-6 to 83 at Locations TN-1 and TN-4. The total number of species collected by location ranged from three at Location TN-6 to seven at Location TN-5. Total biomass of fish captured by trap net was 159.7 kg (Table 3-2). Species collected by trap netting that comprised greater than 5% of the catch by weight included channel catfish (36.0%), carp (32.7%), and bluegill (18.7%).

Gill netting resulted in the collection of 267 individuals representing four species (Table 3-2). Threadfin shad dominated the catch by comprising 191 (71.5%) of the 267 total fish collected. Seventy channel catfish (26.2%), three carp (1.1%), and three gizzard shad (1.1%) comprised the remainder of the gill net catch. Channel catfish comprised 7.9 (53.3%) of the total 14.8 kg of fish collected by gill netting (Table 3-2), followed by carp at 4.4 kg (30.2%), threadfin shad at 1.9 kg (13.3%), and gizzard shad at 0.5 kg (3.2%).

The mean electrofishing catch-per-effort (CPE) for all locations combined was 177.5 fish/hr (Table 3-3). CPE ranged from 139.0 fish/hr at Location E-2 to 250.0 fish/hr at Location E-5. Mean trap netting CPE was 28.5 fish/net (12-hr sets) and ranged from 4.5 fish/net at Location TN-6 to 41.5 fish/net at Locations TN-1 and TN-4. Gill net CPE at Location GN-1 was 39.0 fish/hr based on 117 fish collected during three hours of sampling time during the July and August sampling efforts. CPE at Location GN-2 was 75.0 fish/hr based on 150 fish collected during two hours of total sampling effort during the July and August sampling periods. Mean CPE for Locations GN-1 and GN-2 was 53.4 fish/hr based on 267 fish collected during 5 total hours of fishing effort.

3.3 Physicochemical Data

Water quality data recorded in conjunction with fish sampling was measured at each location prior to every sample collection (Appendix Tables A-1 to A-3). During July 21-23, water temperature at Braidwood Lake ranged from 28.5 at Location E-5 (near the make-up water discharge into the lake from the Kankakee River) to 35.5 °C at Location E-1 (the most southern location located closes to Braidwood Station discharge). Make-up water from the Kankakee River was being pumped into the lake at Location E-5 during the time water quality parameters were being measured. Water temperatures during the second sampling period (August 17-20) were similar to those measured in July. Temperatures during this period ranged from 30.4 °C at Location E-3 to 35.3 °C at Location E-1. As expected, the temperature gradient generally declined as the cooling water in Braidwood Lake moved toward the Braidwood Station intake.

Dissolved oxygen (DO) ranged from 6.1 to 9.5 ppm at Locations E-1 and TN-5, respectively, during the July sampling period and from 4.1 to 9.5 ppm at Locations E-1 and TN-5, respectively, during the August sampling period. Diurnal variations in the lake led to increased dissolved oxygen reading from early morning to late afternoon. These variations were directly related to the intense phytoplankton blooms that were prevalent within the lake during the July and August sampling schedule.

Braidwood Lake is a very productive system with heavy oxygen demand (respiration and decomposition) occurring during the night and intense oxygen production (photosynthesis) occurring during clear sunny days. Currently, the majority of the photosynthetic activity within Braidwood Lake is attributable to phytoplankton, which has decreased water clarity and replaced aquatic macrophtyes as the primary producer. In a report submitted to Exelon by SEA in 2001 (Appendix Report B-1); it states that "Several perched cooling ponds in the Midwest have had high macrophyte densities in their earlier years but usually become dominated by phytoplankton if they have heavy thermal loading. A switch to phytoplankton dominance is usually accompanied by a reduction in water transparency."

Braidwood Lake appears to be relatively well buffered with only minor diurnal variation in pH readings. Examination of pH data collected during the present surveys show that pH ranged from 8.7 to 9.1 during the July sampling period and from 8.5 to 8.7 during the August sampling period. The pH of water typically increases with increasing photosynthetic activity and oxygen production that may explain upward shifts in pH readings during the course of bright sunny days. During the July sampling period, conductivity ranged from 760 μmhos at Location E-5 to 899 μmhos at Location E-1. Conductivity during the August sampling period ranged from 908 μmhos at Location TN-7 to 931 μmhos at Location E-1.

Make-up water was being pumped into Braidwood Lake from the Kankakee River during some portion of each sampling period during July and August, 2009. As a result, water quality parameters were generally more favorable near the make-up water discharge (Location E-5) compared to the remainder of the sampling locations. However, the affects of the make-up water discharge were quickly dissipated because of the relatively low volume of make-up flow being pumped into the lake. During the July sampling period, water quality parameters were within the range of values acceptable for warmwater fish species. During the August sampling period, water temperatures, pH and conductivity were all relatively similar to the values recorded during July. However, dissolved oxygen readings in August were exhibiting greater diurnal variation ranging from 4.1 ppm in the morning to 9.5 ppm during the late afternoon. The early morning dissolved oxygen readings that were measured during the August 20 sampling date were approaching values that begin to adversely affect most fish species. As previously described, these diurnal oxygen fluctuations can be attributed to oxygen depletion (respiration and decomposition) during the night and oxygen production (photosynthesis) during the day. On cloudy calm days, photosynthesis and oxygen production can be slowed to levels that cannot compensate for the oxygen depletion that occurs throughout the night. If this occurs over an extended period of time, an oxygen deficit can build up and cause substantial fish die-offs if suitable refuges within the system are not available.

3.4 Historical Information

3.4.1 Water Quality

Water quality parameters were measured on seven separate occasions at Braidwood Lake from May 29, 2001 through 8/27-28/2002 (Appendix Reports B-1 through B-7). The purpose and scope of these investigations varied, but the most intensive sampling was conducted during the August 27-28, 2002 sampling event. Results of these investigations indicated that abnormally high levels of total dissolved solids (TDS), alkalinity, hardness, sulfates, magnesium, calcium, and total phosphorus existed throughout the cooling loop. This data was not unexpected based on the evaporation that occurs within the cooling loop coupled with the relative low make-up and blow-down flows associated with the operation of the Station. The cooling lake exhibited elevated values for these parameters at levels of two to nearly eight times higher than those of the make-up water from the Kankakee River. These elevated levels of water hardness can be of concern to the Station because they have the potential to intensify problems associated with scaling.

Phosphorus and nitrogen are two essential nutrients required by aquatic plants. Concentrations of these nutrients are typically low in water because phytoplankton and aquatic macrophytes quickly assimilate and utilize these nutrients for growth and reproduction. The studies conducted by SEA in 2002 indicated that the high levels of these nutrients within the cooling lake would continue to cause problems associated with phytoplankton blooms. Unlike most water bodies, phosphorus levels within Braidwood Lake were in excess and nitrates were the limiting factor. Bluegreen algae appeared to be the dominant summer form of algae within Braidwood Lake because they are not as limited by low nitrate levels as other algal species.

Water quality analysis has indicated that dissolved oxygen levels within the cooling lake can exhibit large diurnal variation in response to algal blooms that are most problematic during the summer months (June through August). The nutrient rich water of Braidwood Lake is ideal for the development of algal blooms that produce large amounts of oxygen during the day (photosynthesis) and oxygen depletion in the dark (respiration and decomposition). As oxygen is produced through photosynthesis, pH tends to increase if the water is not well buffered. Dissolved oxygen levels of 4-5 ppm (levels that most fish species become stressed) and lower have been recorded throughout the cooling loop 0.5 m below the waters surface. The lowest DO readings occur during the early morning period and they typically increase throughout the day. Increases in DO of 4 to 5 ppm or more have been observed from morning to late afternoon at Braidwood Lake. In addition, stratification of the water column has also been reported during the same period of time when DO readings are measured at less than 3 ppm. During these events, DO readings in the hypolimnion (the zone below the thermocline to the bottom of the lake) can approach zero. When this occurs, it further limits the refuge available for fish and other aquatic organisms.

3.4.2 Fish Kills

Historical fisheries data summarizing fish kills that have occurred at Braidwood Lake was provided to HDR by Exelon Nuclear, IDNR, and SEA (Appendix Reports B-2 through B-7). Five fish kills that occurred from 2001 through 2007 were identified in the information provided to HDR. Each of these events occurred during June, July, or August. Two of the kills occurred in 2001. The first took place in late July and the second on August 27-28. A third kill was reported on July 30, 2004, the fourth on June 28, 2005, and the fifth on August 27-28, 2007.

Little information was provided for the fish kills that occurred in late July and August, 2001. The species involved and the extent of dead fish observed during the first event in July were not included in the information received by HDR. The second fish die-off in late August was dominated primarily by gizzard shad that comprised more than 95% of all the fish observed. The remaining species involved in the die-off in decreasing order of relative abundance included, freshwater drum, quillback, carp, largemouth bass, channel catfish, redhorse spp., smallmouth bass, and bluegill. With the exception of gizzard shad, the majority of the fish were located from the mid-point of the cooling loop to the intake. A report submitted by SEA indicated that warm water temperatures and/or low dissolved oxygen levels were the most likely factors that contributed to the fish die-off in July. SEA also indicated that the die-off in late August was most likely the result of depleted dissolved oxygen levels that occurred in the lake following an extensive phytoplankton bloom collapse, which is a natural phenomenon that can occur in highly productive waters during summer months. Dissolved oxygen measurements throughout the majority of the lake were at or below minimum levels necessary to support most fish species.

A third fish die-off at Braidwood Lake was investigated on July 30, 2004. Gizzard shad was the dominant species involved, although channel catfish were also observed. The gizzard shad appeared to be in an advanced state of decay suggesting that the actual die-off occurred earlier in the week. Water quality parameters at the time of the incident were not included in the brief summary report provided to HDR, which suggest they were not measured concurrent with the fish die-off. Water quality measurements were taken in early October following the fish die-off. During this period of time DO levels of 3.8 ppm and a water temperature of 29.2 °C were recorded at a depth of one foot below the surface just north of the south boat ramp. At a location several hundred feet from the lake make-up discharge, more favorable dissolved oxygen (7.6 ppm) and water temperatures (26.5 °C) were measured. DO readings at this location were stratified exhibiting a decline to 5.3 ppm at 40 feet, while water temperature showed minimal decrease with water depth.

In 2005, an inspection of a fish die-off was conducted on 28 June. Formal counts of fish were not conducted at this time, but field assessments indicated that a fairly substantial die-off involving several species had occurred. Gizzard shad was again the most numerous species affected and fish carcasses were observed throughout the majority of the lake. Additional species observed included threadfin shad, quillback, largemouth and smallmouth bass, carp, and channel catfish. Water quality measurements during this event were not provided to HDR and are assumed to be unavailable.

Rob Miller of IDNR and Jeremiah Haas of Exelon Nuclear investigated another fish die-off that was first reported at Braidwood Lake on August 21, 2007. The majority of the dead fish observed were either large gizzard shad or threadfin shad up to five inches in length. Channel catfish were also prevalent, with only a few carp, largemouth bass, and flathead catfish being observed. Most of the fish were distributed in close proximity to the north boat ramp due to prevailing south winds. The number of dead fish observed decreased towards the south (hot) end of the cooling loop. During the afternoon of 21 August, surface water temperature was 35.3 ℃ and DO was near 3 ppm at a sampling point several hundred yards from the south ramp. Four separate water temperature and DO readings were also conducted at the north ramp between 1210 hrs and 1658 hrs. Water temperature increased from 30.3 to 33.9 ℃ over the course of that time interval. Dissolved oxygen was measured at 3.1 ppm at 1210 hrs and increased to 6.7 ppm during the third reading at 1530 hrs. DO levels decreased during the last reading at 1658 hrs to 5.9 ppm. Oxygen depletion appeared to be the factor responsible for the August fish kill that occurred at Braidwood Lake in 2007.

4.0 SUMMARY AND RECOMMENDATIONS

4.1 ***Summary.*** Braidwood Lake is a 2640 acre, partially perched cooling lake that was first impounded in 1980-1981 after several old strip-mine pits were inundated with water from the Kankakee River. The lake has received supplemental stockings of both warm and coolwater fish species since the late 1970's. However, stocking efforts of species including walleye, tiger muskie, smallmouth bass, and hybrid stripped bass have not produced a sustainable quality fishery, which is most likely because of the warm water temperatures that are presently common in the cooling lake during summer months. Water quality, particularly water temperature, improves as the water moves from the southern (hot) end of the cooling loop toward the northern (cool) end of the lake.

Fisheries surveys have been conducted by IDNR at Braidwood Lake annually from 1980 through 1992, in 1994, and at two year intervals from 1997 through 2007. Forty-five species of fish and two taxa (tiger muskie and hybrid sunfish) have been included among the 12 families of fish collected. River redhorse (one individual captured in 1999) is the only species that has been collected which is currently listed as protected in Illinois. Several of these species were rarely collected, were the result of supplemental stocking efforts, or have not been collected during the past ten years of sampling. In 2009, HDR collected 24 species and two taxa (hybrid sunfish and small unidentified young-of-year sunfish species) among the 2143 fish collected. Several taxa that were collected during previous surveys were not collected in 2009. However, five species (shortnose gar, blue catfish, bigmouth buffalo, fathead minnow, and rosyface shiner) that had not been captured during previous sampling efforts were collected. A single specimen of each species was collected by either electrofishing or trap netting. No threatened or endangered species were encountered in the 2009 lake surveys. Since 1980, 50 species of fish and two hybrids (tiger muskie and hybrid sunfish) have been collected at Braidwood Lake by the IDNR and HDR.

The Braidwood Lake Fish and Wildlife Area has evolved through three distinct phases since its inception prior to the 1980's. Originally, several surface mined pits existed at the site until the lake was impounded with water from the Kankakee River during 1980 and 1981. The lake continued to function in this capacity until July 29 and November 17, 1988 when Braidwood Station began commercial operation of Unit I and Unit II, respectively. From 1980 through July

1988, Braidwood Lake did not receive any thermal loading from Braidwood Station. Since 1988, the lake has functioned as a cooling loop for the operation of the Station. Currently, the lake is best suited to support a warmwater fishery due to the warm temperatures prevalent in the lake during summer months. Dominant species currently found in Braidwood Lake include gizzard shad, threadfin shad, bluegill, channel catfish, and carp. Additional species such as largemouth bass, green sunfish, flathead catfish, spotfin shiner, bluntnose minnow, and sand shiner are also commonly encountered. Excluding several of the stocked taxa that have been introduced into the lake, the taxa encountered have also been collected from the Kankakee River, which is the source of make-up water for the lake. With the possible exception of common carp, these species are better suited to conditions that exist within the river. Survival of individuals that may be introduced into the lake with the make-up water is limited by the elevated water temperatures that exist within the cooling loop particularly during summer months.

Braidwood Lake can be currently described as a well buffered body of water with elevated water temperatures, high levels of total dissolved solids (TDS), phosphates, and nitrates. Primary productivity in the lake can be very high in conjunction with algal blooms that occur throughout the lake, especially during the June through August period. These blooms are driven by the high nutrient levels that occur within the lake. In recent years, phytoplankton has replaced aquatic macrophytes as the principal source of primary production. The lake can also display relatively large diurnal fluctuations in dissolved oxygen measurements, particularly during the summer when oxygen is produced in large quantities by photosynthesis during the day and used in large quantities by respiration and decomposition during the night. In addition, Braidwood Lake can also stratify during certain portions of the year, which has led to anoxic (oxygen depletion) or near anoxic conditions throughout the hypolimnion (stratified bottom layer of water below the thermocline) as a result of respiration and decomposition from a collapsing algal bloom. Even in the surface waters of the epilimnion, dissolved oxygen readings of 4 ppm and below have been reported following an extensive and rapid die-off of an existing phytoplankton bloom. It is during these periods when water temperatures are elevated and dissolved oxygen levels are low that fish die-offs occur within lake. The conditions described in this paragraph should not be expected to change at Braidwood Lake in the foreseeable future.

4.2 Recommedations. Five separate fish die-offs attributed to low DO levels were observed at Braidwood Lake between 2001 and 2007. It is expected that the conditions which led to those five events will not change or improve in the foreseeable future. Therefore, it should be assumed that fish die-offs will continue to occur and be problematic for the Station when algal blooms crash and oxygen depletion occurs. Substantial fish die-offs within the cooling loop could adversely affect both the operation and maintenance of Braidwood Nuclear Station.

Currently, there are no practical or simple solutions that could prevent the occurrence of fish die-offs at Braidwood Lake. It should be anticipated that fish die-offs will continue to occur at the lake on a fairly regular basis. Therefore, it would be advantageous if a reliable sampling program or set of procedures were developed that would reasonably predict fish die-offs which may adversely affect the operation and/or maintenance of the Station. With advanced warning the Station would be informed of a potential reportable incident, regulatory agencies could be notified, and crews responsible for fish disposal could be put on alert to help manage the risk associated with a substantial fish die-off. HDR believes this can be accomplished by conducting routine visual inspections of the lake, monitoring dissolved oxygen levels, and by having a basic understanding of environmental conditions that may trigger these events, especially weather conditions.

HDR recommends a two tier sampling procedure that may be utilized to help predict the onset of a possible reportable fish die-off. We recommend that visual inspections of the lake and water quality measurements be conducted routinely throughout the year, particularly during the warm weather months, if budget constraints and staff are available to monitor the lake. The frequency of observations and the intensity of the water quality measurements should be discussed by the management at Braidwood Station who would analyze risk management. Historically, all the fish die-offs at Braidwood Lake have occurred during the warm weather period of June through August. This is the period of time when water in the cooling loop is the warmest and dissolved oxygen levels can fall substantially following die-offs of extensive phytoplankton booms. Therefore, this is the most critical period of time to monitor existing conditions that could result in a potential problem (May through September). Sampling on a less frequent basis throughout the remainder of the year may provide additional information that could be useful to the Station and possibly alert the Station of an impending problem which may not have been identified in the past.

Water quality measurements should include dissolved oxygen readings at a minimum because fisheries biologists that have investigated these events in the past have concluded that the mortality of fish was the result of oxygen depletion. The most effective way to monitor dissolved oxygen levels within the lake would be through the use of a permanently fixed continuous water quality sampler and data logger that could be programmed to take measurements at predetermined time intervals. The number of water quality samplers purchased or the type of sampler utilized would be dependent upon the desired results and cost of the equipment. Ideally, the best system would allow the sampling unit to take measurements at programmed time interval (perhaps every 15 minutes to daily), would measure at least DO, water temperature, and pH, could provide instantaneous readouts to Braidwood staff without having to manually go into the field to download data, and would require minimal maintenance or calibration to operate. The price range of this type of equipment is highly variable depending on the unit selected, the anchoring mechanism for the unit if required, battery life, the number of parameters measured, etc. An alternative to this approach would be to utilize a technician to manually take these measurements. The disadvantage of this approach is the number of readings that could be taken on a daily basis and the time involved to conduct the water quality analysis in the field.

Water quality at Braidwood Lake should be monitored on some predetermined routine basis. That could be at least weekly throughout the year or perhaps only through the more critical time period of approximately May through September. The two tiered sampling approach would be initiated when dissolved oxygen readings hit a pre-determined trigger point (perhaps 5 to 6 ppm). Once DO readings decrease to the trigger point, sampling frequency should be increased to at least daily (preferably hourly). If automatic samplers are not used, field technicians should be in the field by sunrise when DO readings are typically the lowest. If automatic samplers were utilized, dissolved oxygen, temperature and other water quality parameters could be tracked throughout the day. This would become important if DO reading ranged from 4 or 5 ppm in the morning to 7 or 8 ppm in the afternoon. This information would indicate that photosynthesis is still occurring during the daylight period, which would replenish DO levels in the water and reduce the risk of a fish die-off. However, if DO levels were 4 or 5 ppm in the morning and only increased slightly throughout the day, this would indicate very little oxygen production due to photosynthesis. This condition would lead to a greater oxygen deficit during the evening, and could indicate the onset of a phytoplankton bloom die-off that could trigger a fish kill. Once DO levels approach 3 ppm

Station management could be notified of a potential problem, increased visual inspections of the lake could be conducted, and fish disposal crews could be notified and put on standby status.

Additionally, Braidwood staff should be aware of weather patterns that can influence these events. When phytoplankton blooms are prevalent and several cloudy days with little or no wind are forecast, massive dies offs of the bloom and subsequent oxygen depletion throughout the water column may be anticipated. Increased sampling of DO during these weather patterns is advisable in conjunction with an increase in the frequency of visual inspections at the lake for moribund or dead fish. An increase in water clarity or transparency within the lake would also be expected to occur as the phytoplankton population crash is in progress.

Visual inspections for fish die-offs should be conducted around the entire cooling loop as prevailing winds may push most of the fish toward one end of the lake. HDR recommends water quality measurements be conducted at a depth of approximately one meter, if multiple depths are not sampled. If only one sampling location is selected, that location should be located near the approximate mid-point of the cooling loop. The number of water quality stations sampled should be determined by Exelon management or an advisory staff. It is further recommended that an advisory team should be formed to devise an effective sampling program and set of procedures that can effectively monitor conditions within the lake. HDR is willing to participate and interact with the advisory team to provide expertise in the development of an effective sampling program.

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APPENDIX A

PHYSICOCHEMICAL DATA

LIST OF TABLES

TABLE A-1

PHYSICOCHEMICAL MEASUREMENTS RECORDED CONCURRENTLY WITH ELECTROFISHING SAMPLES COLLECTED FROM BRAIDWOOD LAKE

Braidwood Station – 2009

PARAMETER	E-1	E-2	E-3	E-4	E-5	E-6	E-7	E-8
Date (First Sample Period)	**JUL 22**	**JUL 22**	**JUL 22**	**JUL 22**	**JUL 22**	**JUL 23**	**JUL 23**	**JUL 22**
Time	0955	1050	1225	1320	1530	0820	0925	1420
Temperature (° C)	35.5	32.7	30.5	31.9	28.5	30.5	30.7	32.1
Dissolved oxygen (ppm)	6.1	8.9	8.5	7.5	8.2	6.4	6.5	8.6
Ph	9.1	9.1	8.8	8.7	8.7	8.8	8.7	8.8
Conductivity (μmhos/cm)	899	894	892	892	760	891	884	888
Date (Second Sample Period)	**AUG 20**	**AUG 20**	**AUG 20**	**AUG 20**	**AUG 20**	**AUG 20**	**AUG 20**	**AUG 20**
Time	1045	1150	1255	1505	0710	0830	0930	1345
Temperature (° C)	31.7	31.1	30.4	31.5	30.9	30.6	30.5	31.2
Dissolved oxygen (ppm)	4.1	4.9	6.4	8.1	4.3	4.5	4.7	6.2
pH	8.6	8.6	8.5	8.6	8.6	8.6	8.6	8.6
Conductivity (μmhos/cm)	931	927	923	923	926	914	914	920

TABLE A-2

PHYSICOCHEMICAL MEASUREMENTS RECORDED CONCURRENTLY WITH TRAP NETTING SAMPLES COLLECTED FROM BRAIDWOOD LAKE

Braidwood Station – 2009

PARAMETER	TN-1	TN-2	TN-3	TN-4	TN-5	TN-6	TN-7	TN-8
Date (First Sample Period)	**JUL 21**	**JUL 21**	**JUL 21**	**JUL 21**	**JUL 21**	**JUL 21**	**JUL 21**	**JUL 21**
Time	1645	1700	1715	1730	1800	1820	1840	1855
Temperature (° C)	32.6[a] 32.6[b]	32.5 32.5	32.1 32.2	32.0 31.9	29.9 29.3	30.7 30.8	30.1 30.2	29.6 29.7
Dissolved oxygen (ppm)	9.1[a] 7.8[b]	8.9 8.7	9.4 9.0	8.6 8.6	9.5 9.4	9.4 9.3	7.6 7.4	8.6 8.6
Ph	9.1[a] 9.1[b]	9.1 9.1	9.1 9.1	8.9 8.9	8.8 8.8	8.7 8.7	8.7 8.7 8.8	8.8 8.8
Conductivity (μmhos/cm)	895[a] 895[b]	895 895	895 894	894 894	893 893	897 896	878 877	883 884
Date (Second Sample Period)	**AUG 17**	**AUG 17**	**AUG 17**	**AUG 17**	**AUG 17**	**AUG 17**	**AUG 17**	**AUG 17**
Time	1655	1645	1640	1630	1620	1600	1550	1535
Temperature (° C)	35.3[a] 35.3[b]	34.3 34.3	33.6 33.6	33.6 33.6	32.6 32.6	33.1 33.0	31.7 31.7	32.0 32.0
Dissolved oxygen (ppm)	8.9[a] 8.9[b]	8.9 8.9	8.6 8.5	8.0 8.0	9.5 9.5	9.0 8.9	6.8 6.8	7.0 7.1
pH	8.7[a] 8.7[b]	8.7 8.7	8.6 8.6	8.6 8.6	8.7 8.7	8.6 8.6	8.5 8.5	8.7 8.7
Conductivity (μmhos/cm)	920[a] 920[b]	920 920	921 922	921 921	917 917	920 919	908 908	912 912

[a]Top number represents subsurface readings taken 0.5 meter below the surface.

[b]Bottom number represent bottom readings taken 0.5 meter above the bottom.

TABLE A-3

PHYSICOCHEMICAL MEASUREMENTS RECORDED CONCURRENTLY WITH GILL NETTING SAMPLES COLLECTED FROM BRAIDWOOD LAKE

Braidwood Station – 2009

	GN-1		GN-2	
PARAMETER	**Surface**	**Bottom**	**Surface**	**Bottom**
Date (First Sample Period)	**JUL 21**	**JUL 21**	**JUL 21**	**JUL 21**
Time	1600	1600	1810	1810
Temperature (° C)	32.0	32.1	30.8	30.9
Dissolved oxygen (ppm)	8.8	8.8	8.8	8.9
Ph	8.7	8.7	8.9	8.9
Conductivity (μmhos/cm)	895	895	896	896
Date (Second Sample Period)	**AUG 18**	**AUG 18**	**AUG 17**	**AUG 17**
Time	0630	0630	1605	1605
Temperature (° C)	33.7	33.6	33.1	33.1
Dissolved oxygen (ppm)	5.2	5.1	9.0	8.9
pH	8.5	8.5	8.6	8.6
Conductivity (μmhos/cm)	929	928	920	920

APPENDIX B

HISTORICAL WATER QUALITY AND FISHERIES DATA

LIST OF TABLES

APPENDIX REPORT B-1.

Results of Initial Braidwood Cooling Pond Survey by SEA Inc.

SEA Inc. was asked to conduct an initial water quality and ecological assessment of Braidwood Cooling Pond. The objective was to determine if the dense macrophytes were contributing to an increasing trend toward a higher pH in the pond. The results and discussion presented in this report are primarily based upon the samples taken and observations made on May 29 and 30, 2001, and on a preliminary review of water quality data from three sites taken on May 18, and June 14, 2001. SEA Inc. was also asked to investigate a fish kill on Braidwood Cooling Pond on August 27 and 28. The results of that investigation are in a separate report but some of that information is referenced in this report.

Overview of Methods and Results Presentation.

SEA's initial survey (May 29-30) consisted of:

- water quality parameters at several key sites with a Hydrolab Surveyor III, during both daylight and night conditions,
- measuring phytoplankton community respiration (light & dark bottle method),
- identification of macrophytes and observations on their distribution and abundance, and
- monitoring temperatures throughout the cooling loop.

The survey results are summarized in Tables 1,2, 3, and 4. Table 1 provides the results from key sampling sites that were selected to characterize the cooling pond. These sites were sampled three to four times over a 36-hour period. Parameters sampled with the Hydrolab included: Depth, Temperature, Dissolved Oxygen (D.O.), pH, Specific Conductance, and Redox Potential. Sample times included midday, just before sunset, and prior to sunrise.

Table 2. includes results from two sites for depth profiles, 24 hour duration light & dark bottles, and the SX discharge. Table 3. provides D.O. and temperatures sequentially around the cooling loop at midday. Table 4. lists the D.O. levels and % saturation at four sites prior to sunrise. Table 5 list the water quality analysis preformed by Test America at three locations on two dates. Figure 1. is a map identifying the sample locations listed in the tables.

Discussion of Results and Observations:

Braidwood Cooling Pond was characterized to SEA Inc. as a pond that was dominated or choked by macrophytes. Based on this characterization, we feel that Braidwood Cooling Pond has undergone a transformation to a system dominated by phytoplankton. Although we were not prepared to sample the phytoplankton for densities and identification, it was very obvious that an

intensive phytoplankton bloom was in progress. Secchi disc readings were only 0.30 to 0.35 m throughout the pond. Although we were unable sample the phytoplankton, we would suspect it is dominated by Blue-Green algae (Cyanophyta), based on the water temperatures, total phosphorous levels, high pH and apparent high densities.

Braidwood Cooling Pond appears to be a very dynamic system that receives energy subsidies in the form of heat, pumped circulation and make-up water from the Kankakee River. Several perched cooling ponds in the Midwest have had high macrophyte densities in their earlier years but usually become dominated by phytoplankton if they have heavy thermal loading. A switch to phytoplankton dominance is usually accompanied by a reduction in water transparency. Our Secchi disc readings were about 0.3 m which is about one half of the 2 ft or 0.6m)value listed in a privately produced fishing guide (Sportsman' Connection) published in 2000. Although we did not examine many of the isolated coves, we found Milfoil (*Myriophyllum verticillatum*) only in the last 1/3 of the cooling loop(Figure 1. sites7,8,9) and its abundance was spotty. The Sportsman' Connection fishing guide map had a much wider distribution of submerged, emergent and floating vegetation and appeared to be more in line with earlier descriptions SEA Inc. were given of Braidwood. Nutrients that were previously tied up by the macrophytes are now likely being taken up by the phytoplankton. The reduced water transparency due to the phytoplankton bloom will limit light to the submerged macrophytes and likely cause further reductions.

The intensive phytoplankton bloom that Braidwood is currently experiencing may have more potential for adverse impacts to the biological community than on operational impacts to the station. The water seems to be fairly well buffered and diurnal swings in pH were insignificant. Analysis of the water for alkalinity could confirm the buffering capacity. Blue-Green algae blooms may present problems with D.O. levels and in some rare cases may release toxins with impact other aquatic life.

The light & dark bottle (Table 2.) and the pre-sunrise D. O. levels (Table 4.) illustrated the intensity of the bloom. The light and dark bottles were at a 0.5 m depth at end of the discharge canal for 24 hours. Respiration in the dark bottled depleted the initial D.O. from 10.8 mg/l (158% saturation) to 1.37 mg/l (20 % saturation). The light bottle was supersaturated to the point the entire inside surface was coated with oxygen bubbles and the D.O. was 11.8 (174% saturation). The photosynthetic rate was much higher than could be measured due to the extensive formation of oxygen bubbles in the light bottle. The photosynthetic rate was so high that the light bottle should have been limited to 6 hours to obtain a better measurement of the gross plankton photosynthetic rate.

The pre-sunrise D.O. measurements (Table 4.) also reflect the high respiration rate of the plankton community. Most notable was Site #3 where D.O. levels dropped to 4.1 mg/l. The midday sampling on the first day (Table 1.) was conducted during bright and sunny conditions and D.O. levels at most sites were higher than midday samples on the following day when it was overcast. This

plankton community is so productive that D.O. levels can be expected to swing rapidly. During our survey, air temperatures were mild (high 65 F) and it was windy both days. Under a scenario of several hot summer days, with little wind, full operation of the station, followed by a cloudy day, D.O. levels could drop to the point that fish kills could occur. Some fish species will be already stressed by heat, saturation levels for D.O. will be lower, and high, predawn respiration rates could create a significant problem. Unfortunately, there are no operational changes the station can make to reduce this risk. The fish kill that did occur in late August was apparently a result of depleted DO that most likely resulted from the phytoplankton bloom die off.

Thermal refuges are critical to the survival of fish in heavily loaded cooling ponds. The deeper areas in the warmer end of the lake will not be refuges since adequate levels of oxygen are already absent from depths below 4 meters (Table 2.). However, the flow and slightly cooler temperatures at site 7 (figure1.) have maintained oxygen levels down to nearly 10 meters. If these refuges are eroded away during the summer, fishes will be stressed. Of the three key species listed in the Sportsman's Connection for Braidwood, both the walleye and crappie would be sensitive to D.O. at higher temperatures. Two fish kills occurred in Braidwood this summer, the first in late July was likely related to temperature, the second in lake August resulted from DO depletion.

Although our expertise is not in water chemistry, Braidwood Cooling Pond may be facing some water quality issues. One of the objectives of the survey was to determine if macrophytes were contributing to the increasing pH. A chart of pH values from 1989 to 1998 provided by the Braidwood Station indicated the increasing trend in pH has become more pronounced since 1997. Since this survey indicated macrophytes abundance was in a sharp decline, it is clear they are not contributing to the elevated pH of 9.1 to 9.2 (Table 1). The intensive phytoplankton boom present during the survey could have contributed to the elevated pH. The phytoplankton bloom had crashed by August 27 and 28 (fish kill investigation) and the pH had dropped to 8.6. It was not possible from this limited data to determine to what extent several factors may be contributing to the elevated pH. The cooling pond's buffering capacity, photosynthetic activity, blowndown rate, and plant operations are all potential factors to be investigated.

The Test America analytical results from three sites on 5/18/01 and 6/14/01 provides some information on water quality (Table 5). Orthro phosphate is a readily available form for plants and is quickly taken up. The detection limit listed by the lab was 0.06 ppm, which was too high to show any differences between sites or sample dates. Orthro phosphate levels in many Illinois lakes would be below 0.025 ppm. Total phosphate at the plant discharge on 5/18/01 was 5.5 ppm, which is very high. The Illinois General Use Water Quality standard is not to exceed 0.05 ppm in lakes or reservoirs over 20 acres. The plant appears to be the phosphate source and one possible explanation may be scale inhibitors commonly used by power plants. Scale inhibitors are typically high in phosphates but it is generally in a form not available to aquatic plants. Total phosphate levels on 6/14/01 were lower (0.18 to 0.28 ppm) but still elevated relative to other lakes.

Phosphates are a major concern as elevated levels can contribute to nuisance phytoplankton blooms.

Total Suspended Solids (TSS) on 5/18/01 were high (164 ppm) at the discharge and generally higher than expected throughout the pond. It is suspected that the plankton bloom may have been responsible for much of that elevation. This could have been confirmed by comparing the volatile to the non-volatile portion of the TSS.

Total Dissolved Substances (TDS), total hardness, calcium, sulfates and specific conductance are all correlated and generally exhibited increases from 5/18/01 to 6/14/01. The high evaporation rates in the cooling pond during the summer probably contributed to this increase. These parameters are of concern since they are indicators of potential scaling in heat exchangers. Lowering these levels would require an increase in make-up and blow-down rates. However it is recognized there are restrictions on make up withdraws and blow-down concentrations are regulated.

<u>Summary</u>

It appears that the Braidwood Cooling Pond plant community is changing from one dominated by macrophytes to phytoplankton. The phytoplankton bloom in May was very rich and has the potential to deplete D.O. to the point that fish kills could occur. There are few operational changes that the plant can take to prevent these potential events. Monitoring the cooling pond and preparing regulatory agencies for these potential changes may be a way to help manage these risks. Unfortunately the fish kill in late August confirmed the potential for these kills. The phytoplankton bloom may a contributor to the increasing pH. The high total phosphate level that appears to be coming from the plant may be fueling the phytoplankton bloom. Further investigation of the factors that may be contributing

APPENDIX REPORT B-2.

DRAFT

Investigation of Fish Kill on Braidwood Cooling Pond August 27-28, 2001

Executive Summary:
Strategic Environmental Actions Inc. (SEA Inc.) conducted an investigation of an on-going fish kill on Braidwood Cooling Pond on August 27 & 28, 2001. The investigation consisted of surveying the shoreline to determine the extent of the kill and the species involved, and water quality analyses for pH, temperature, and dissolved oxygen.

Most of the fish appeared to have been dead for about 24 hours and more than 95% were gizzard shad. The other species involved in descending order of relative abundance were freshwater drum, quillback, carp, largemouth bass, channel catfish, redhorse, smallmouth bass and bluegill. Other than gizzard shad most of the dead fish were located between the mid –point in the cooling loop to the intake. Throughout most of the cooling pond, dissolved oxygen levels were at or below the minimum levels necessary to support most fish and was the most likely cause of the kill. Water clarity was very high and suggested a recent die off of much of the phytoplankton, which is usually followed by oxygen depletion. This is a natural phenomenon that can occur in highly productive lakes during summer months. Temperatures throughout most of the lake were within the tolerance limits of the species involved in the kill. It does not appear that operations of the power station had a direct impact on the fish kill.

Methods Overview and Results Presentation:

SEA Inc. arrived at 5:00 PM on August 27 and conducted an initial survey of the main portion of the cooling loop and checked temperature, dissolved oxygen (DO), and pH at two locations. The investigation continued at sunrise on August 28, and included investigation of many of the coves on the lake and water quality analyses at sixteen sites. Water quality analysis was conducted with a Hydrolab Surveyor III. Measurements were for depth, temperature, DO, pH, specific conductance, and redox potential at the surface (0.5 Meters) and then at one-meter intervals to the bottom.

The water quality sampling locations are shown on Figure 1. Dissolved oxygen profiles from selected sites are illustrated in Figure 2. Figure 3 illustrates DO concentrations at one-meter depth at all sites. The results of the water quality analyses are presented in Table 1. The station hourly inlet and outlet water temperatures for August 24 through August 27 are listed in Table 2.

Discussion of Results and Observations:

Upon arrival the investigation began at the south access boat ramp near Site 3 (Figure 1.) and proceeded around the cooling loop toward the plant intake. Near Site 3 several gizzard shad in the 170 to 220 mm were observed. They appeared to have been dead for 12 to 24 hours. In the portion of the pond between sites 5.5 and 5.75 there were greater numbers of gizzard shad along the shoreline and a few largemouth bass. The largemouth bass appeared to have been dead for more than 36 hours. The number of fish appeared to increase as the investigation progressed around the cooling loop. The largest concentrations of dead fish were in several coves on the East side of the lake near Site 8. The back 20 to 35 ft. of the cover were covered solid with dead fish. Gizzard shad comprised more than 95% of the fish in these coves and were represented by three size classes. The other species involved in descending order of relative abundance were freshwater drum, quillback, carp, largemouth bass, channel catfish, redhorse, smallmouth bass and bluegill.

There are two factors that may have influenced the distribution of dead fish. First, the temperature gradient becomes more favorable for fish toward the intake end of the cooling loop. Second, the circulation of water around the cooping loop would tend to concentrate dead fish in the intake area of the cooling pond. The concentration of fish in coves at Sites 8 and 8.5 was most likely an accumulation resulting the above mention factors and wind direction. However DO levels at Site 8.5 were only 2 ppm (Table 1, page 3) at a time of day when they should have been much higher. This level of DO is not adequate to support most fishes. Several YOY freshwater drum were observed at the surface which had recently died or were about to. This kill did involve many fish, but during this survey many live fish were observed on sonar in the cooler end on the lake. Bluegills exhibiting normal behaviors were observed in the cove just East of Site 2.5.

Dissolved oxygen levels at the plant intake were 3.5 ppm at the surface and 1.2 ppm at 3 meters (Table 3) during the evening of August 27. Percent DO saturation was 49% and 17% respectively. Surface DO level taken on May 29 by SEA Inc. at this same location, at the same time of day was 9.3 ppm and 117% saturation. The DO levels at Site 3 were 3.8 ppm on August 27 which was much lower than the 8.0 ppm taken at sunset on May 29. On August 28 just prior to sunrise the DO at Site 3 was 3.2 ppm only slightly lower than the previous evening indicating little diurnal variation. On May 29 the overnight drop in DO at Site 3 was 50%.

The surface DO level at Site 4 on August 28 was 2.9 ppm and dropped to 0.7 ppm at 4 meters. Surface DO levels Sites 4.5, 5, 5.5, and 5.7 were even lower

ranging from 2.4 to 2.1 ppm. Site 6 had one of the higher DO levels at 4.4 ppm. Site 8 and 9 had the highest surface DO levels at 4.8-ppm (Table 1).

Temperatures throughout most of the cooling pond were within the tolerance limits of most fish species and there had been no major temperature changes in the last few days (Table 2). The oxygen levels throughout most of the lake suggest that depleted oxygen levels were the most likely cause for the fish kill. Such kills can naturally occur in highly productive lakes or ponds that may exhibit large diurnal swings in DO levels due to high daytime photosynthetic rates and high respiration during the night. The survey SEA Inc. conducted on May 28 and 29 suggested Braidwood Cooling Pond was a very productive and the potential existed for an oxygen depletion fish kill. This survey noted several changes in the cooling pond that suggested such a kill had occurred. There was no indication that the fish kill was directly related to the operation of the power station.

SEA Inc.'s initial investigation in May was to assess if the historically high abundance of macrophytes (rooted aquatic vegetation) was contributing an increasing trend in pH. What was observed was an intensive phytoplankton bloom that limited light penetration and almost no healthy macrophytes remained. Water transparency measured with a Secchi Disc was only 0.3 meters. Diurnal swings in DO levels were very pronounced and at some locations dropped to 4 ppm just prior to sunrise and reached supersaturation levels by mid day. Under these conditions any major change in nutrients, reduced light intensity, increase in biological oxygen demand, or other factors could result in oxygen depletion. Braidwood Cooling Pond appeared to be undergoing a transition from a system dominated by macrophytes to one dominated by phytoplankton.

One of the most notable changes during this investigation was the dramatic change in water transparency. There was no phytoplankton bloom and Secchi Disc readings had increased up to 2.7 meters. Plankton samples indicated very low levels of phytoplankton but high abundance of zooplanktors (primarily. Rotifers and Cladocera). Oxygen levels were typically from 29% to 66% of saturation as opposed to May when most midday levels were at or above saturation. As discussed earlier, there were only minor differences in diurnal oxygen levels. All the above factors suggest the phytoplankton bloom had recently crashed. There were no remaining macrophytes to fill the niche as primary producers. Not only was there a reduction in photosynthetic activity to produce oxygen, there was an increased oxygen demand from decomposition and respiration of the abundant consumers. It is suspected that oxygen levels a day or two prior to this investigation may have been even lower than observed.

The one-meter DO levels were lowest toward the center portion of the cooling loop (Figure 2). From Site 3 to Site 6.5 (with the exception of Site 6) DO levels were 3.1ppm or less. A similar pattern of low DO was noted at Sites 3 and 4 in early morning samples taken in the May survey. Factors contributing to lower DO

levels were not clear, but it suggest this may be one of the most sensitive areas of the cooling pond to oxygen depletion. Additional sampling would be required to attempt to identify the cause and to eliminate any data bias associated with the time of day samples were taken.

The unique changes in water depths and flow velocities in Braidwood Cooling Pond have a major influence on DO levels and temperature stratification. Areas of the cooling pond which were deep and not in a high velocity areas exhibited a more normal DO curve from top to bottom (Figure 3). At Site 2.5, DO declined quickly between 6 and 8 meters and coincided with thermal stratification. At Site 4, the DO declined rapidly between 2 and 3 meters where thermal stratification was apparent (Table 1). In contrast, Sites 5.5 and 7 were located in areas with high velocities and had fairly consistent DO levels and temperatures from top to bottom (Figure 3). This is quite different from the DO and temperature profiles in more typical perched cooling ponds and better utilizes the entire volume for cooling and may also provide for better thermal refuges for fish. During this last incident it is unlikely Site 5.5 was an effective refuge for DO since levels were below 2.5 ppm. These DO levels were however due to lower DO levels throughout the cooling pond rather than depletion at this site.

Braidwood Cooling Pond appears to be undergoing a transition from a pond dominated by marcophytes to one dominated by phytoplankton. During such a transition major swings may be expected as different components of this ecosystem adapt to this change. Over time one would expect the amplitude of these changes to moderate. During the May survey the intense phytoplankton bloom appeared to eliminate the macrophytes. There were major differences in diurnal DO levels suggesting a very productive system with heavy respiration and decomposition demands at night and supersaturation from photosynthesis during the day. This survey indicated a major loss of the phytoplankton, no remaining macrophytes to carry on primary production and enough respiration and decomposition to reduce oxygen below the levels to maintain many fishes. Additional studies on nutrients and the dynamics of the plankton would be needed to better identify the changes that may be taking place in this cooling pond. Decisions on the operational management of this cooling pond as well as the fishery management need to consider that this pond may be going through transitional changes.

APPENDIX REPORT B-3.

Results of Braidwood Cooling Pond Water Quality Analysis from August 27 & 28, 2002

SEA Inc. was asked to sample Braidwood Cooling Pond for a number of water quality parameters on August 27, 2002. This sampling effort was to provide data to address operational concerns related to a trend toward an increasing pH and increased scaling at the plant intake. This report provides the results of the August 27and 28, 2002 sampling and makes comparisons with data from previous sampling efforts by SEA Inc. and with other data provided by the Braidwood Station to SEA Inc.

Executive Summary:

Braidwood Cooling Pond has high levels of alkalinity, total hardness, TDS, sulfates, magnesium, calcium and total phosphates. These parameters are of concern since they have the potential for increased problems with scaling, increasing pH, compliance with cooling pond blow down limits, and maintaining a recreational fishery. Several of these parameters had significant increases in the past year and could lead to greater operational costs and problems in the near future.

The excess of nutrients in the water has contributed to plankton blooms that have eliminated the submerged aquatic plants, contributed to diurnal increases in pH, and lowered dissolved oxygen levels. Swings in the dissolved oxygen level associated with the plankton blooms could lead to fish kills.

The plan to increase the blow down rate from the cooling pond is a good long-term solution to the continued viability of the cooling pond. Continued monitoring of the cooling lake water quality would be important in evaluating the effectiveness of the increased blown down rate, the impacts of H2SO4 additions, and other water treatment changes.

Overview of Methods and Scope of the Sampling Effort.

The investigation on August 27 and 28 of 2002 consisted of collection of water samples from various depths at six sites around Braidwood Cooling Pond (BCP), as well as in-situ profile measurements for temperature, conductivity, pH, and dissolved oxygen. A contract laboratory analyzed the water samples for the eleven chemical parameters as listed in Table 1. In addition to chemical samples, the primary production rate of the phytoplankton community was determined at two sites by the light/dark bottle method, and plankton samples were taken for

qualitative analysis. Water transparency was measured with a Secchi disc at each site. The sampling sites used in this investigation are identified on Figure 1.

Additional investigations by SEA Inc. referenced in this report include June 28, 2002, April 29,2002, March 6, 2002, January 10, 2002, August 28, 2001 and May 29, 2001. The purpose and scope of each of these investigations varied but none were as extensive for water quality as the August 2002 investigation. In several cases SEA Inc. collected the water samples for Betz and the results were not made available to SEA Inc. Data from the above referenced studies is included to help identify trends and provide a single summary of data for ongoing investigations. The discussion of results is based on and limited to the studies referenced in this report and those provided to SEA Inc.

Presentation of Results and Related Discussion:

The analytical results of the water quality analysis are presented in Table 1. The eleven parameters were selected to provide input to the water quality issues that were described to SEA Inc. These issues include increasing trends for rising pH, scaling, algal blooms, and recent fish kills.

Table 1 indicates abnormally high levels for TDS, alkalinity, hardness, sulfates, magnesium, calcium, and total phosphorus throughout the cooling pond. These values were not unexpected and support the ongoing program to increase the blow down rate from the cooling pond. These values can be put into perspective by comparing the cooling lake sites to the same values for the make –up water pond (Site 7P in Table 1), which is the source water. The cooling pond values for the above mentioned parameters ranged from 2X to nearly 9X higher than the make-up water.

The alkalinity is a measure of water's capacity to neutralize acids and is a result of the quantity of compounds in the water that shift the pH to the alkaline side. Bicarbonate and carbonate ions normally make up most of the alkalinity. However in waters with a pH of greater than 8.3, carbonate alkalinity is the primary form. Alkalinity is very high throughout the cooling pond and ranged from 340 to 360 mg/l in the upper water layers (Table 1). In contrast, the make-up water pond alkalinity was 150mg/l. Other comparisons include a 14-year average for Clinton Lake of 168 mg/l and an IEPA survey of 63 lakes around the state with alkalinity ranging from 20 to 270 mg/l. The high alkalinity gives Braidwood Cooling Pond has a great capacity to neutralize acids.

Hardness is a measure of the divalent metallic cations present in water (such as calcium, magnesium, ferrous iron, and manganous manganese). Calcium reacts with bicarbonate ions in water to form calcium carbonate

scale. Magnesium typically reacts with sulfate; the ferrous ion with nitrate; and the manganous ion with silicates.

Hardness and alkalinity in water are related. Carbonate hardness is the part of total hardness that is chemically equivalent to the bicarbonate plus carbonate alkalinities present in the water. If alkalinity is greater than total hardness then total hardness is equal to the carbonate hardness. In cases such as in BCP where alkalinity is less than the total hardness then alkalinity equals carbonate hardness (as $CaCO3$) and the remaining part of hardness is the noncarbonate compounds such as magnesium sulfate.

The total hardness in the upper layers of August 2002 samples ranged from 680 to 720 mg/l (nearly twice the alkalinity level) so other ions are contributing significantly to the hardness. The total hardness levels in 2002 were significantly higher than the 435 to 531mg/l range reported for two dates in 2001 by Test America (Table 2). This increase in hardness is a reason for concern.

Sulfate levels in the August 2002 samples ranged from 330 to 390 mg/l (Table 1). These levels are much higher than the make up water (58 mg/l) and to some extent may reflect the history of portions of the cooling pond as strip mine lakes that are characteristically high in sulfates. However there seems to be a significant increase in sulfates in the past year. In the Test America data from two dates in 2001, sulfates ranged from 230 to 270 mg/l (Table 2). Sulfate levels in samples collected by SEA Inc. on April 29, 2002 were 250 mg/l (Table 3). Samples collected by SEA Inc. on June 28,2002 had levels ranging from 320 to 340 mg/l (Table 4). The sulfate increase noted in the summer of 2002 may reflect the use of H_2SO_4 to reduce pH levels in the cooling pond. This level of sulfates may be a concern since it significantly contributes to the non-carbonate hardness and can be a factor in scaling.

Calcium levels in the August 2002 samples were about twice the levels in 2001and ranged from 130 to 140 mg/l (Table 1). The 2001 Test America data ranged from 41 to 58 mg/l (Table 2) and the make-up water in August 2002 was 57 mg/l. The increase in calcium may be a major concern since with the high carbonate alkalinity there is a high potential for scaling.

Magnesium levels in the August 2002 sampling ranged from 84 to 93 mg/l. These levels were essentially the same as the 81 to 91 mg/l reported by Test America in 2001. Magnesium levels are however elevated compared to the make-up water that had only 20mg/l or when compared to the 14-year average for Clinton Lake of 32.2 mg/l. Magnesium levels are also a concern due to their potential for scaling.

Total dissolved solids include all of the above parameters and other dissolved solids in the water. As would be expected, the August 2002 samples are elevated and are higher than the previous year. The August 2002 TDS ranged from 930 to

1100 mg/l (Table 1) compared to a range of 684 to 788 in the 2001 Test America data (Table 2). The make-up water was 280 mg/l in the August 2002 sample.

Sodium levels in the August 2002 samples ranged from 60 to 64 mg/l in the upper water layers. Comparable data from 2001 was not available, but the sodium levels in the make–up water was 9.1 mg/l in the August 2002 sample (Table 1).

There were only minor variations in the concentrations of the above parameters from site to site in the upper water layers. Sulfates and TDS were slightly higher at the discharge (Site 2) end of the cooling pond. Levels for alkalinity, sulfates, TDS, and total hardness were slightly lower near the bottom at the 10 and 11-meter depths at Site 4 and Site 7 respectively.

Phosphorus and nitrogen are essential nutrients for aquatic plants. Concentrations in the water are typically low since phytoplankton or macrophytes quickly assimilate these nutrients. Total phosphate levels in the August 2002 samples were at 1.5 mg/l throughout the cooling pond (Table1). Samples collected on April 2002 ranged from 1.3 to 1.6 mg/l (Table 3). Total phosphates at two sites in the June 2002 samples were 1.8 mg/l (Table 4) in the upper water layers and 4.9 mg/l at a well stratified, 10-meter depth at Site 4. The Test America data for 2001 had total phosphate levels from 0.16 to 5.5 mg/l (Table 2). The 5.5 mg/l occurred at the discharge on May 18 of 2001 and levels dropped to 0.77mg/l at the plant intake on the same date. This suggests the Station was the source of the phosphate. Although the levels were slightly lower in 2002, they were consistent throughout the cooling pond suggesting that phosphates are in excess and not a limiting factor for phytoplankton. The total phosphate levels in the make- up water were 0.12 mg/l and 0.19mg/l in June (Table 4) and August of 2002 respectively.

Relative to most lakes the phosphate level in BCP is quite high. Since BCP is a cooling pond and not a lake, it is not subject to the Section 302.205 regulation that limits phosphorus in a lake of 20 acres or more to < 0.05mg/l. The high phosphate level is of concern since these levels support phytoplankton blooms and the breakdown of the phosphorus compounds can also contribute to increased pH.

Ortho-phosphate is the form that is most readily available to aquatic plants. These levels are usually very low in lakes since plants normally take it up within minutes. Ortho-phosphate levels were consistent throughout the lake in the August 2002 samples and ranged from 0.38 to 0.44mg/l. Like the total phosphate levels, the ortho-phosphate levels are consistently high suggesting it is in excess of the needs of the phytoplankton. The August 2002 levels were significantly higher than the <0.06mg/l reported by Test America in 2001(Table 2). Ortho-phosphate level in the make-up water was 0.19 and although lower than the lake levels is relatively high.

Nitrate-nitrites are the other essential or potentially limiting nutrient for phytoplankton. The August 2002 nitrate-nitrate levels were rather low in most of BCP with the highest level of 0.1mg/l at the discharge. The rest of the cooling pond ranged for <0.01mg/l (below detection limit) to 0.08 mg/l in the upper waters. Unlike most other parameters, the nitrate-nitrite level in the make-up water was significantly higher at 2 mg/l (Table 1). Nitrate-nitrite data could not be compared to the 2001 Test America data because the detection limit of 1.0 mg/l was too high for a meaningful assessment.

The ratios of phosphates to nitrates-nitrites suggest BCP would be described as a nitrate-nitrites limited water rather than phosphate limited with respect to phytoplankton growth. However the limited phytoplankton data that SEA Inc. has collected on BCP suggests that bluegreen algae dominate BCP for much of the summer. Bluegreen algae have the unique ability to utilize atmospheric nitrogen and are not as limited by low nitrate-nitrite levels. Bluegreen algae made up 88.5 % and 76.4% of the algae at Sites 3 and 7 respectively in the August 2002 sample. The dominant bluegreen algae were *Lynabya* and *Oscillatoria*. Bluegreen algae are the least desirable algae and are favored by high pH and warmer temperatures. Bluegreen blooms can impart a smell or taste to water, deplete dissolved oxygen, and in some cases generate toxins that may impact aquatic life.

The ammonia levels appear reasonable relative to the high productivity in BCP. As productivity increases and oxygen is reduced at deeper depths there may be increases in ammonia. The abnormally high level at 5 meters at Site 9 (Table 1 may have resulted from the water sampler disturbing the bottom sediments where ammonia is likely to be higher.

The aquatic plant community in BCP appears to have undergone a change in the last two years. SEA Inc.'s first investigation of BCP on May 29, 2001 was to assess the impact of the extensive growth of macrophytes (rooted aquatic plants) on the pond's increasing pH. That investigation found an extensive phytoplankton bloom and the few macrophytes that remained were being shaded out by the phytoplankton bloom. SEA Inc. projected that BCP was changing from a macrophyte dominated water to a phytoplankton-dominated water and that would see more plankton blooms. The phosphate levels from the 2001 Test America data suggested there was an excess of phosphorus to support those blooms. Based upon SEA Inc.'s 2002 observations, BCP has transformed into a phytoplankton dominated water and is experiencing regular plankton blooms. This change not only reflects an increasing load of nutrients in BCP but also creates a higher risk to the fishery. As plankton blooms come and go they can create oxygen depletion problems that impact fishes and other aquatic life.

SEA Inc. has measured the primary production rates as an index to the activity of the plankton community. The rate of oxygen production by the plankton

community is measured in a light (clear) bottle and the plankton respiration (oxygen depletion) is measured in a dark bottle. In the first measurement in May of 2001, there was so much oxygen production in the normal 24 hr measurement period that the oxygen was super saturated and only a portion could be measured (Table 5). Subsequent measurements were limited to shorter time periods and provided a more useful index. The highest primary production rate was 1.525 mg/l of O_2/hr at Site 9 (Intake) on June 28, 2002. This correlated well with the highest chlorophyll a level provided by the Braidwood Station (Figure 2). In the August 2002 measurement, the rate at Site 9 had dropped to 0.653 mg/l of O_2/hr. This rate correlated with lower chlorophyll levels that occurred throughout most of August. Temperatures during the August 28,2002 measurements were high enough at the discharge (Site 2) to suppress photosynthetic activity. The temperature at the discharge was 115.1° F (Table 5) and the intake (Site 9) temperature was 92.2°F and the corresponding production rates were 0.142 and 0.653 mg/l of O_2/hr respectively. The temperature suppression of photosynthesis and an apparent die off of a phytoplankton bloom may account for the low dissolved oxygen levels observed during the August 2002 sampling.

All of sampling by SEA Inc. has involved in-situ sampling with a HydroLab for temperature, dissolved oxygen, pH, and specific conductivity. The data from all 2002 HydroLab sampling is presented in Tables 1,3,4,6, and 7.

The dissolved oxygen (DO) levels on August 28 of 2002 were notably lower than the same date in 2001(Table 6). As lakes undergo eutrophication and productivity increases, the DO level can exhibit wide diurnal changes that may stress aquatic life. Afternoon DO levels may rise to supersaturated levels, but during the night and early morning hours respiration demands may nearly deplete the DO and can result in fish kills. There also becomes a more pronounced difference in DO levels between the upper and lower layers of the water column due to increased oxygen demand from decomposition.

Dissolved oxygen levels at the same four sites in August 2001 and 2002 are compared in Figure 3. These comparisons indicate that the DO levels were generally lower at the same sites in 2002, were slower to rise during the day, and there was a greater differences between depths. Site 2 and Site 2.5 illustrate the lower DO levels in 2002 even later in the day when it should rise. Oxygen levels were less than 1ppm at 2 meters and below. Site 4, 2002 levels reflect the increase in DO later in the day compared to earlier in the day in 2001. The consistent drop in DO at 4 meters is typical of a stratified site. At Site 7 the higher DO in 2002 reflect the later time of day than the 2001 sample. However the more significant difference is the drop in DO with increasing depth in 2002. This drop suggests a more productive system that has a higher demand for oxygen in 2002. Site 7 has good flow and in 2001 had a nearly constant DO level down to the bottom and provided a good thermal refuge for fish. In 2002 the area below 6 meters would be stressful for most fish. The Site 9 AM chart again demonstrates the 2002 DO level was lower even when taken later in the morning than the 2001

sample. The Site 9 PM chart shows some recovery of DO level in the mid afternoon but levels are still below 4ppm. The more rapid drop in deeper samples from the 2001 most likely reflects the loss of late afternoon light to the deeper depths.

The 2002 DO curves appear to reflect a more eutrophic environment that may place additional oxygen stress on the fishery. During the August 2002 sampling there were dead and dying gizzard shad from Site 2 to Site 4. The combinations of stress from the low DO and warmer temperatures were the most likely explanation for the loss of these fish. This loss was not extensive enough to have a significant impact on the fishery. No other species were involved in the kill but small bluegills were exhibiting some signs of DO stress. As BCP continues to become more eutrophic the DO stress may be a greater problem for the fishery.

The increasing pH levels have been a concern in BCP. Comparison of HydroLab data from August 28 in 2001 (Table 6) and 2002 (Table 1) indicated only a little variation in pH. During the summer of 2002 the Station was adding H_2SO_4 into the circulating water. The impact was only apparent at Site 2 (discharge canal) and Site 3. The 2002 samples collected in the morning hours at Site 2 ranged from 8.34 to 8.38 compared to 8.5 in 2001 (Table 2). At Site 3 the 2002 levels ranged from 8.35 in the morning to 8.54 at midday compared to a range of 8.4 to 8.6 in 2001. The pH levels at Sites 4,7 and 9 had slight variations depending upon time of day but had similar ranges in 2001 and 2002. With the high alkalinity levels in BCP, it is not surprising that the addition of H_2SO_4 did not result in larger changes. This assessment is also based on only a few data points. Correlating H_2SO_4 feed rates with continuous pH monitoring at the intake would provide more reliable information on the effects of the acid additions.

Questions have been raised on the impact of the phytoplankton on the increasing pH levels. As phytoplankton carries on photosynthesis and extract CO_2 from the water it increases the pH. This however may not be as apparent in BCP due to the high buffering capacity (alkalinity). In general the higher pH levels in the afternoon reflect the photosynthetic activity. Conversely the lower pH levels in the early morning samples reflect the increase in CO_2 resulting from respiration during the night. The role of phytoplankton in increasing pH is quantified in the measurement of primary productivity. A comparison of the starting pH with the ending pH in the light bottles illustrates the change due to photosynthesis. The pH during the 24-hour measurement on May 29, 2001at Site 2 went from 9.22 to 9.52 (Table 5).

Summary and Conclusions:

Braidwood Cooling Pond has high levels of alkalinity, total hardness, TDS, sulfates, magnesium, calcium and total phosphates. These parameters are of concern since they have the potential for increased problems with scaling, increasing pH, compliance with blow down limits, and maintaining a recreational

fishery. The additional of treatment chemicals and evaporative loss of the recycled cooling water with limited blown down rates are most likely the primary factor in the increased levels of these parameters. The make-up water does not have elevated levels of the above-mentioned parameters. With increasing capacity factors and increasing concentrations for these parameters in the cooling water, water treatment costs and operational concerns are likely to increase.

Baseline water quality data is important in evaluating options and solutions to address water quality in the cooling pond. The comparison of the August 2002 sampling to the 2001 Test America data indicated significant increases in total hardness, sulfates, and calcium in the past year. Increases of this magnitude can be important predictors of future problems. Critical assessments of the impact of H_2SO_4 additions and other treatment changes are dependent upon having pretreatment and post treatment data. The plan to increase the blow down rate from BCP is a good long-term solution to the continued viability of the cooling pond. The effectiveness of increasing the blown down rate from BCP can be quantified by continued monitoring of the cooling lake concentrations.

The high nutrient levels in BCP will continue to cause plankton blooms. Unlike many waters, phosphates appear to be in excess and nitrates are more of a limiting factor. However, bluegreen algae appear to be the dominant summer form and are not as limited by low nitrates as other algae. The primary production measurements did correlate fairly well with chlorophyll a levels and were a good index to the productivity of BCP. The primary production measurements also illustrated how much of an influence phytoplankton have on diurnal increases in pH.

Algal blooms are occurring in the pond and based on two comparable samplings, appear to be influencing the DO levels. The DO levels in the early hours were generally lower in 2002 than in 2001 and the DO at a deep site experienced a decline with depth that did not occur in 2001. These changes suggest a trend toward an increasing rate of eutrophication. If nutrient levels continue to increase the potential for fish kills associated with oxygen depletion resulting from the blooms would also increase.

Jim Smithson
SEA Inc.
11/04/02

APPENDIX REPORT B-4.

Fish Kill Reports Going Back to 2003

john.petro@exeloncorp.com [john.petro@exeloncorp.com]

Sent: Wednesday, September 23, 2009 2:42 PM

To: Jeremiah.Haas@exeloncorp.com

2003

There were no fish kills in Braidwood Lake in 2003.

~~June~~ July 30, 2004

Investigated a fish mortality on July 30, 2004. Most fish were in the advanced state of decay by the time the kill was investigated. Gizzard shad were the dominant species involved although channel catfish were observed as well. During this investigation, the shallow water near shore was teaming with plankton which under magnification proved to be daphnia as well as Cypris, which is an Ostacod resembling a small clam.

Temperature/dissolved oxygen profiles were conducted in early October. Water temperature just north of the south boat access was 29.2 °C/84.5 °F at a depth of one foot with a dissolved oxygen reading of 3.8 ppm, a pH of 8.03 and a secchi disk reading of 2.1 feet. Readings were somewhat improved in the area near the rearing cove. In a location several hundred feet from the lake make-up, more favorable dissolved oxygen levels were found. At one foot, a water temperature of 26.5 °C/79.7 °F with a dissolved oxygen reading of 7.6 and a pH of 8.47 were observed. Water temperature showed minimal decrease to 40 feet while the dissolved oxygen declined to 5.3 ppm.

June 28, 2005 Fish Kill

An on the water inspection of a thermal fish kill was conducted on June 28, 2005. No formal counts were made however field assessments indicate a fairly significant kill that involved a variety of species including (in no specific order) gizzard shad, threadfin shad, common carp, channel catfish, quillback carpsucker, black bass. Gizzard shad were the most numerous species effected by this kill and fish carcases were observed at most all areas of the lake that were checked.

August 27-28, 2007 Fish Kill

- Rob Miller, IDNR investigated a thermal kill on August 27 and 28, 2007 and conducted temperature/dissolved oxygen evaluations. The majority of the dead fish which were observed were large gizzard shad and threadfin shad up to 5 inches in length. Channel catfish were also prevalent. Only a few common carp and black bass were observed and no bluegills were noted. Due to moderate prevailing south winds, many dead fish were wind-rowed along the north shore in close proximity of the boat ramp and the bank fishing area. The number of dead fish observed decreased towards the south (hot) side of the lake. At a point several hundred yards from the south ramp surface water temperature was 35.3 C/95.9 F and dissolved oxygen was near 3ppm.

- The following are data which were collected at the north ramp at the time the fish kill was being

investigated:

Time	Temperature (^0C)	Dissolved Oxygen (ppm)
12:10	30.3	3.1
14:25	33.1	5.4
15:30	33.5	6.7
16:58	33.9	5.9

Investigation of Fish Kill on Braidwood Cooling Pond (August 27-28, 2007)

· Strategic Environmental Actions Inc. (SEA Inc.) conducted an investigation of an on-going fish kill on Braidwood Cooling Pond on August 27 & 28, 2007. The investigation consisted of surveying the shoreline to determine the extent of the kill and the species involved, and water quality analyses for pH, temperature, and dissolved oxygen.

· Most of the fish appeared to have been dead for about 24 hours and more than 95% were gizzard shad. The other species involved in descending order of relative abundance were freshwater drum, quillback, carp, largemouth bass, channel catfish, redhorse, smallmouth bass and bluegill. Other than gizzard shad most of the dead fish were located between the mid -point in the cooling loop to the intake. Throughout most of the cooling pond, dissolved oxygen levels were at or below the minimum levels necessary to support most fish and was the most likely cause of the kill. Water clarity was very high and suggested a recent die off of much of the phytoplankton, which is usually followed by oxygen depletion. This is a natural phenomenon that can occur in highly productive lakes during summer months. Temperatures throughout most of the lake were within the tolerance limits of the species involved in the kill. It does not appear that operations of the power station had a direct impact on the fish kill.

APPENDIX REPORT B-5.

FW: Braidwood Lake Fish Kill

john.petro@exeloncorp.com [john.petro@exeloncorp.com]

Sent: Wednesday, September 23, 2009 2:31 PM

To: Jeremiah.Haas@exeloncorp.com

-----Original Message-----
From: ROB MILLER [mailto:ROB.MILLER@illinois.gov]
Sent: Tuesday, August 21, 2007 8:26 PM
To: JOE FERENCAK; STEVE PALLO
Cc: Petro, John R.; CHRIS MCCLOUD; LARRY DUNHAM; MIKE CONLIN
Subject: Re: Braidwood Lake Fish Kill

I was contacted by John Petro and Tim Meents (Braidwood Station) this morning at 11:20 but due to bad accident on I-55 was somewhat delayed in arriving at the lake. When I got there (3:00) I met with Exelon biologist Jeremiah Haas. Jeremiah had arrived earlier and had taken dissolved oxygen/temperature readings. He and I toured the lake via his boat to assess the extent of the kill. Due to moderate prevailing south winds, many dead fish were wind-rowed along the north shore in close proximity of the boat ramp and the bank fishing area. The number of dead fish we observed decreased as we traveled towards the south (hot) side of the lake. At a point several hundred yards from the south ramp, we took a reading and returned to the north ramp to meet up with John Petro. At this location water temperature was 35.3C and dissolved oxygen was near 3ppm. The following are data which were collected at the north ramp:

Time	Temp. (C)	Dissolved Oxygen (ppm)
12:10	30.3	3.1
14:25	33.1	5.4
15:30	33.5	6.7
16:58	33.9	5.9

Based on the declining trend in d.o., it is possible that more fish could succumb throughout the night.

The majority of the dead fish which were observed were large gizzard shad and threadfin shad up to 5 inches. Channel catfish were also prevalent. Only a few common carp and black bass were observed and no bluegills were noted. SET Environmental had arrived at the north ramp and were conducting clean-up operations at 5:00. I will be attended the AFS Continuing Education course in Monticello tomorrow and thursday. If you need any further information, or if there are any further developments, please contact me at 815/409-2426. Thanks.
Rob
Rob Miller

District Fisheries Biologist
Illinois Department of Natural Resources
13608 Fox Road
Yorkville, Illinois 60560
630/553-6680
rob.miller@illinois.gov

>>> STEVE PALLO 08/21/07 12:10 PM >>>
Just got off phone with John Petro, Environmental Manager for Exelon.

John wanted to report a moderate gizzard shad kill at Braidwood Cooling Lake, and a minor kill of catfish. Rob Miller, District Fisheries Manager was already notified. Water temps in the lake had dropped some 12F recently, there are no obvious power plant operational changes or permit exceedances. Exelon is arranging to have the fish picked up.

APPENDIX REPORT B-6.

FW: Braidwood Fish Kill 8-21-07

john.petro@exeloncorp.com [john.petro@exeloncorp.com]

Sent: Wednesday, September 23, 2009 2:28 PM

To: Jeremiah.Haas@exeloncorp.com

-----Original Message-----

From: Haas, Jeremiah J.

Sent: Tuesday, August 21, 2007 9:02 PM

To: Petro, John R.; Tidmore, Joseph W.; Meents, Timothy P.

Cc: Hebeler, Ronald L.; Neels, Vicki J.; Steve Pallo (E-mail); Haas, Jeremiah J.

Subject: Braidwood Fish Kill 8-21-07

All,

Here's the quick and dirty of the incident. I'll right something more formal in the morning.

I arrived at Braidwood Lake at 12:00 and took a dissolved oxygen (DO) reading from the ramp dock which extends about 30 feet into the lake. The DO was 3.1 ppm w/ a temp of 30.3 C. Several thousand gizzard and threadfin shad were floating across most all visible areas of the lake. The currents within the lake were visible with the dead fish movement. Also seen were dozens of channel catfish, most of which were adults from 3-15 lbs. Shad ranged from 4 - 13 inches with the shorter fish being predominately threadfin and the larger ones being gizzard. At this time I informed John P. of the DO situation and began setting up the boat for additional surveys. During the entire day, no other species was observed that counted more than 2 individuals.

I took several water readings throughout the afternoon before Rob Miller (IDNR biologist responsible for Braidwood Lake) arrived. We did a quick boat survey throughout the lake, including the pockets that are not part of the cooling loop. These areas showed the same readings as the rest of the lake. During this time we had a few hours of direct sunshine and DO reading rose as high as 6.7 ppm @ 15:30.

Rob and I determined that the DO crash was a result of the past several days cloud cover and subsequent die-off of phytoplankton. The decay of the phytoplankton would have been sufficient to lower the DO available to the fish during the overnight hours. We also observed the DO beginning to lower @ 16:58 (5.9 ppm) and believe that there is an opportunity to see similar results tomorrow and possibly a few more days depending on the weather conditions.

A local newspaper reporter did arrive on site, took photos, and asked questions. She was familiar with Braidwood Station's Site Communicator and said she would be in contact with them. Rob explained the cycle that was occurring in the lake several times to the reporter.

All in all, I believe that Rob and I are both comfortable with the explanation for the action that occurred to cause the fish kill. This is similar to the "annual" fish kill seen at Braidwood, but the densities were higher than the past few years. There is a survey of the lake scheduled for October and, if possible, I will be at the site for that.

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APPENDIX REPORT B-7.

Braidwood Fish Kill Clean up
8/22&23/07

I worked with SET Environmental to clean up a fish kill.
This was a major kill and our clean up efforts were confined to the area near North boat ramp on the intake end of the lake. SET had been working on the kill for one or two days when I was called to provide assistance. A total of about 24 cubic yards of fish were removed in this clean up. The species involved in decreasing order of abundance were: gizzard shad (large fish), channel catfish, bluegill, green sunfish, flathead catfish, bigmouth buffalo, quillback and largemouth bass.

I went up in the restricted arm toward the intake and found huge masses of fish in the back of several coves. There were areas 50 to 75 ft by 100 ft of solid floating mats of fish in these coves. We picked up 12 flathead catfish that would have averaged near 50 lb. each. On the second day when we returned to these coves we counted as many large flathead catfish that we had picked up the previous day. They were in a state of decomposition that prevented up from picking them up.

We did not take any water quality measurements or examine other parts of the lake in this clean up effort. From my past work on this cooling pond, I would suspect a combination of DO depletion and high water temperatures caused this fish kill. The plant did not report any abnormal operation conditions prior to the kill. Since 2001 when we first worked on this cooling pond we have seen a switch from macrophytes to phytoplankton with blue green dominating. We have measured wide diurnal swings in DO levels even in the upper part of the water column in late summers. Even with the strong circulation from the circulating water pumps there is mid summer stratification and DO depletion in the deeper areas.

Jim Smithson
SEA Inc.

Attachment #2 to Response -- RAI # AQ-12a

BRAIDWOOD STATION

BRAIDWOOD LAKE ADDITIONAL BIOLOGICAL SAMPLING PROGRAM, 2010

Prepared for

EXELON NUCLEAR
Warrenville, Illinois

February 2011

HDR Engineering, Inc.
Environmental Science & Engineering Consultants
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ACKNOWLEDGMENTS

The field work and data analysis for this project was conducted by HDR Engineering, Inc. (HDR). Particular appreciation is extended to Rob Miller of the Illinois Department of Natural Resources (IDNR), Jim Smithson of Strategic Environmental Actions, Inc. (SEA), and John Petro of Exelon Nuclear for providing historical fisheries and water quality data.

This report was prepared by HDR and reviewed by Exelon Nuclear. A special debt of gratitude is owed to the environmental staff at Braidwood Station and in particular Mr. Jeremiah Haas of Exelon Nuclear for his technical assistance, cooperation, and guidance during the preparation of this document and the study plan. Mr. Haas's experience and insight has been invaluable and is greatly appreciated by the authors.

ABSTRACT

HDR Engineering, Inc. (HDR) was contacted on March 12, 2009 by Braidwood Nuclear Generating Station, requesting HDR to design and conduct a fish sampling program at Braidwood Lake. The information gathered during that study was to be used by Exelon to develop an effective sampling program and set of procedures that could potentially predict fish die-offs in the cooling lake. That same sampling program was conducted again in 2010 with only minor changes to the original program design.

Large die-offs of fish at Braidwood Lake could potentially challenge the integrity of the traveling screens at the Station. With advanced warning, the Station could be informed of a potential reportable event; regulatory agencies could be notified in advance; and crews responsible for fish cleanup and disposal could be put on alert to help manage the risk associated with a substantial fish die-off. Currently, there are no practical or simple methods that can be used to predict or prevent the occurrence of fish die-offs at Braidwood Lake.

Sampling has been conducted at Braidwood Lake by the IDNR since 1980. From 1980 through 2007 IDNR (Illinois Department of Natural Resources) had collected 47 taxa of fish. In 2009, twenty-six taxa representing seven families were included among the 2143 fish collected by HDR (HDR 2010) by electrofishing, trap netting, and gill netting at Braidwood Lake during the July and August sampling periods. Several taxa listed as collected by IDNR from 1980 to 2007 were not captured by HDR in 2009. Many of the species listed by IDNR were only rarely captured, have not been captured during recent years, or represent taxa that were stocked. However, five species were captured in 2009 that were not listed as collected during IDNR sampling efforts. They included shortnose gar, blue catfish, bigmouth buffalo, fathead minnow, and rosyface shiner. A single specimen of each species was collected.

In 2010, similar results were noted when 25 taxa of fish representing eight families were included among the 2432 fish captured by electrofishing, hoop netting, gill netting, and trap netting. Three species that were not listed as being collected by IDNR were captured in 2010. Two of these species, blue catfish and rosyface shiner, were collected by HDR during the 2009 sampling

program. The third species, smallmouth buffalo, had not been captured during any of the previous studies prior to 2010. Thirty-nine blue catfish were collected by gill and hoop nets, 20 rosyface shiner were collected by electrofishing, and one smallmouth buffalo was taken by trap net. No threatened or endangered species were collected in either 2009 or 2010.

The most abundant species collected in 2009 and 2010 were similar to those reported by IDNR in recent years. Braidwood Lake is currently dominated by warmwater species including gizzard shad, threadfin shad, carp, channel catfish, flathead catfish, largemouth bass, bluegill, and spotfin shiner.

Water quality data recorded in conjunction with fish sampling was measured at each location prior to every sample collection. Water temperature (°C), dissolved oxygen (ppm), pH, and conductivity (μmhos/cm) measurements were taken 0.5 m below the water surface at each sampling location. In addition, water quality was also measured approximately 0.5 m off the bottom at all three of the deep water collection sites (Location GN-1, HN-1, and HN-2). Water temperatures during the July sampling period were slightly warmer (33.6 to 38.2 °C) than those observed during August (29.6 to 33.9°C) in 2010 because both units at Braidwood Station were offline during the August sampling period. Diurnal swings in dissolved oxygen (DO) were observed at the lake with DO ranging from 4.7 to 12.2 ppm in July and 1.4 to 9.6 ppm in August. Dissolved oxygen readings were generally slightly lower during the August sampling period in 2010. Cursory observations by the field crew indicated that the water appeared much clearer during the August sampling dates. This suggests that a decline in the phytoplankton population within the lake had occurred between the first and second sampling period, which could explain the decline in the oxygen levels noted in Braidwood Lake during August.

Examination of pH data collected during these studies show pH ranged from 8.3 to 8.5 in July and from 8.3 to 8.7 in August. Conductivity ranged from 770 to 823 μmhos/cm in July and from 832 to 862 μmhos/cm in August.

Review of historical water quality data reported in 2002 by Strategic Environmental Actions, Inc. (SEA Inc.) at Braidwood Lake indicates that abnormally high levels of total dissolved solids (TDS), alkalinity, hardness, sulfates, magnesium, calcium, and total phosphorus exist throughout the cooling loop. This is not unexpected based upon the evaporation that takes place within the cooling loop coupled with the relatively low make-up and blow-down rates associated with the operation of Braidwood Station. These elevated levels within the lake were measured at two to nearly eight times higher than those of the make-up water from the Kankakee River. Elevated levels of water hardness are of concern to the Station because high levels have the potential to increase problems associated with scaling at the Station.

Phosphorus and nitrogen are two essential nutrients required by aquatic plants. Studies conducted by SEA in 2002 indicated that nutrients within the cooling lake were at levels sufficiently high to cause problems associated with phytoplankton blooms. These blooms result in oxygen production via photosynthesis during daylight hours and oxygen depletion through respiration during darkness. When algal populations crash and decompose they can produce severe oxygen depletion within the water column. Diurnal swings in oxygen readings have been routinely observed at Braidwood Lake during the past several years. In addition, DO levels of less than 3 ppm have been recorded at the lake immediately following fish die-offs. Deeper portions of the lake were also reported to stratify in 2002. In the deeper zones of the lake, DO levels approaching 0 ppm and reduced water temperatures have been measured below the thermocline. This is noteworthy because dissolved oxygen levels of 3 ppm and less cannot be tolerated over an extended period of time by most fish species. Piper et al. (1983) states that dissolved oxygen levels below 5 ppm will reduce growth and survival for most species of fish cultured in raceways or ponds. Dissolved oxygen requirements are dependent on species and other factors including water temperature and acclimation period.

Review of historical fisheries information that was provided to HDR indicated that five separate fish kills were reported from 2001 to 2007. Numerically, the majority of fish observed during these events were either gizzard shad or threadfin shad. These two species have typically comprised over 90% to 95% of all fish observed. Remaining species included carp, freshwater drum, bluegill, channel catfish, flathead catfish, quillback and largemouth bass. Each of the reported fish die-offs was attributed to oxygen depletion at the lake and not the result of specific Station operations.

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1.0 INTRODUCTION

The Braidwood Lake Fish and Wildlife Areas are comprised of approximately 2640 acres of terrestrial and aquatic habitat that is located in Will County, Illinois. Braidwood Lake is owned by Exelon and is a partially perched, cooling lake that was constructed in the late 1970s. The lake was filled during 1980 and 1981 with water pumped from the Kankakee River. Several surface mined pits existed at the site prior to the filling of the impoundment. Fisheries management activities began in those surface mine pits in 1978, prior to the creation of Braidwood Cooling Lake. Originally the lake was considered a semi-private area used by employees of Commonwealth Edison Company until the end of 1981 when the Department of Conservation (now the Illinois Department of Natural Resources) acquired a long-term lease agreement from the company, which allowed for general public access to the area. Braidwood Lake is currently used for fishing, waterfowl hunting, and fossil hunting. From the late 1970's to the present time, Braidwood Lake has been stocked with a variety of warm- and coolwater fish species. These stockings include largemouth and smallmouth bass, blue catfish, striped bass, crappie, walleye, and tiger muskie. Monitoring programs have documented the failure of the coolwater stockings to create a meaningful fishery. This is attributed to the extreme water temperatures that occur within the cooling lake during the warm summer months.

Construction of the Braidwood Nuclear Generating Station and its associated riverside intake and discharge structures provided an opportunity to gather fisheries information from the Kankakee River and Braidwood Lake. These studies were initiated to determine the effects of construction and plant operation on the river and the lake. Units I and II began commercial operation on 29 July and 17 October, 1988, respectively. Fisheries surveys at Braidwood Lake were conducted annually by the Illinois Department of Natural Resources (IDNR) from 1980 through 1992. Since 1992, fishery surveys have been conducted by IDNR every other year except 1995 and 1996. Fishery surveys on the Kankakee River near the Station's intake have also been conducted annually since the late 1970's by the Illinois Natural History Survey (1977-1979 and 1981-1990), LMS Engineers (1991-1992 and 1994-2004), Environmental Research and Technology (1993), HDR/LMS (2005-2007), and HDR (2008-2010).

The objectives of the 2010 Braidwood Lake Additional Sampling Program were to:

1. Conduct fish surveys at Braidwood Lake for comparison with historical data that has been collected by IDNR and HDR Engineering, Inc.

2. Summarize any existing data related to fish kills that have occurred at Braidwood Lake.

3. Develop a sampling procedure or protocol that will help anticipate fish die-offs in the cooling lake that could potentially effect Station operations.

2.0 METHODS

2.1 Electrofishing

Electrofishing was conducted using a boat-mounted boom-type electrofisher utilizing a 5000 watt, 230 volt AC, 10 amp, three-phase Model GDP-5000 Multiquip generator equipped with volt/amp meters and a safety-mat cutoff switch. The electrode array consisted of three pairs of stainless steel cables (1.5 m long, 6.5 mm in diameter) arranged 1.5 m apart and suspended perpendicular to the longitudinal axis of the boat 1.5 m off the bow. Each of the three electrodes was powered by one of the phases. Electrofishing samples were collected on 21 and 22 July during the first sampling effort and on 19 August during the final survey period (Appendix Table A-1).

Eight locations around the dike and islands at Braidwood Lake were electrofished during both the first and second sampling periods (Figure 2-1). Electrofishing was conducted near the shoreline at each location to collect fish utilizing shallow water zones. Each electrofishing area was sampled for 30 minutes. Voltage and amperage of the electrofishing unit was recorded at each location at the beginning and end of each sampling effort. Sampling was restricted to the period of time ranging from one-half hour after sunrise to one-half hour before sunset.

The electrofishing crew consisted of two people. One crew member operated the boat while the second crew member dipped fish from the bow of the boat. The boat operator also dipped fish whenever necessary. When fish surfaced behind the boat the boat operator backed up to retrieve all stunned fish. All stunned fish were collected without bias of size or species.

Fish at each location were put into barrels of water in the front of the boat for analysis at the end of each 30 minute collection period. All fish were processed in the field immediately following collection at each location. Special emphasis was placed on the return of all collected game fish species to the water as quickly as possible following field analysis. Catches were standardized to catch-per-effort (CPE) from actual fishing time (30 min) to numbers caught per hour by dividing the total numbers of fish collected by the actual fishing time in hours.

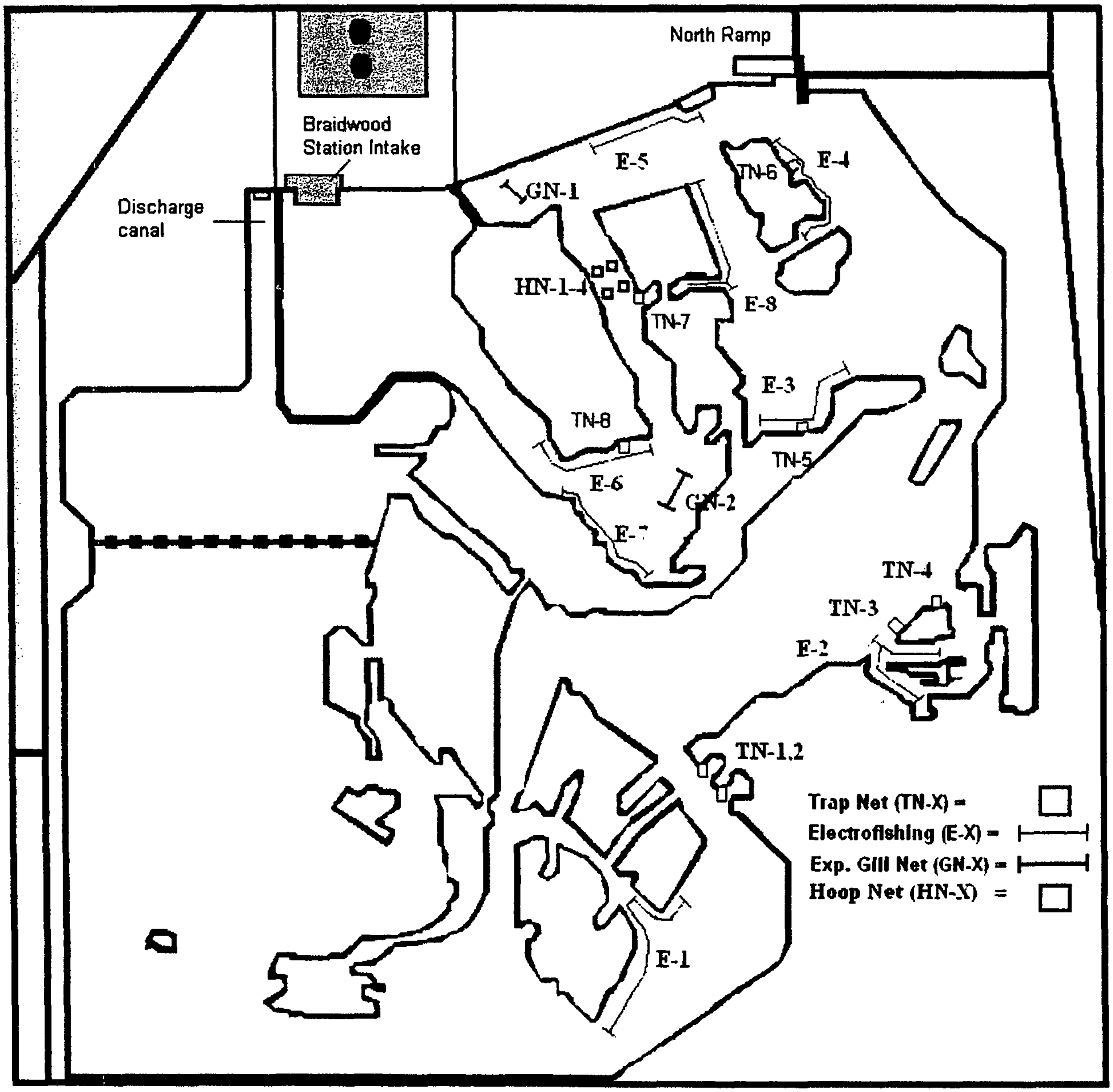

FIGURE 2-1. SAMPLING LOCATIONS AT BRAIDWOOD LAKE DURING JULY AND AUGUST, 2010.

2.2 Trap Netting

Trap nets were set at eight separate locations in Braidwood Lake (Figure 2-1). Each trap net consisted of a 25-ft. lead that was 4-ft. deep and attached to a series of rectangular frames. The last rectangular frame was attached to a hoop net constructed of 1.5-in. (bar) mesh nylon webbing on hoops 3.5 ft in diameter. Two separate throats were contained within each trap net. One was located in the series of rectangular frames at the front end of the net, while the second throat was located toward the back of the net inside the 3.5 ft diameter hoop net. Trap nets were set during late afternoon or early evening and were allowed to fish overnight for approximately 12 hrs before being retrieved the following morning. Trap nets were set on 20 July and retrieved on 21 July during the first sampling period and set on 17 August and retrieved on 18 August during the second sampling period (Appendix Table A-2).

Fish at each location were put into barrels of water in the front of the boat for analysis at the end of each collection period. All fish were processed in the field immediately following removal from the net. Special emphasis was placed on the return of all collected game fish species to the water as quickly as possible following field analysis. Catches were standardized to catch-per-effort by dividing the total number of fish caught by the total number of hours the nets were allowed to fish (fish/12-hr set).

2.3 Gill Netting

Two 125-ft. long and 6-ft. deep monofilament experimental gill nets were used to collect fish from two locations in Braidwood Lake (Figure 2-1). Each net consisted of five separate panels that were 25-ft long by 6-ft deep. Bar mesh sizes of each panel were 0.5, 0.75, 1.0, 2.0, and 3.0 inches, respectively. One of the two gill nets (GN-1) was set in deep water at a depth of approximately 7-8 m, while the second gill net was set in shallow water (GN-2) at a depth of approximately 1-2 m. During the first sampling period, the deep water gill net sample (GN-1) was collected during the late afternoon of 21 July, while the shallow water set (GN-2) was collected during the morning of 22 July. During the second sampling period, both the deep and shallow water gill net sets were collected during the late afternoon of 17 August (Appendix Table A-3).

Gill nets were set for one hour at each location during both sampling dates. Elevated water temperatures in the cooling lake prohibited longer set times due to the high mortality that occurred shortly after the fish became entangled in the monofilament netting. All fish were processed in the field as they were removed from the net. Special emphasis was placed on the return of game fish species to the water as quickly as possible. Catches were standardized to catch-per-effort (CPE) from actual fishing time the nets were in the water to numbers caught per hour by dividing the total numbers of fish collected by the actual fishing time in hours.

2.4 Hoop Netting

Hoop nets used to collect fish at Braidwood Lake were constructed of 1.25-in. (bar) mesh nylon webbing on hoops 3.5 ft in diameter. Four separate nets were sampled during each sampling period (Figure 2-1). Two of the four nets were set in deep water (7.5 m), while the remaining two nets were set in shallow water (2.0 m). In addition, one of the deep (HN-1) and shallow water (HN-3) hoop nets were baited with dead gizzard shad, while the remaining deep (HN-2) and shallow water (HN-4) nets were allowed to fish without bait. All four nets were set during the late afternoon of 20 July and retrieved during the morning of 21 July during the first sampling period. During the second sampling period the hoop nets were set during the late afternoon of 17 August and retrieved during the morning of 18 August (Appendix Table A-4).

Captured fish from each net were put into a barrel of water in the front of the boat for analysis at the end of each collection period. All fish were processed in the field immediately following removal from the net. Special emphasis was placed on the return of all collected game fish species to the water as quickly as possible following field analysis. Catches were standardized to catch-per-effort by dividing the total number of fish caught by the total number of overnight sets conducted (fish/overnight set). Hoop nets were set and retrieved over a 16 to 18 hour period of time during both the July and August sampling periods.

2.5 Sample Processing

All fish were identified to the lowest positive taxonomic level and enumerated. For each gear type, up to 25 individuals of a species were measured for total length (mm) and weight (g) at each location. Any remaining individuals of that species were counted and weighed en masse. Minnow species (excluding carp) were counted and weighed en masse. Specimens that could not be positively identified in the field were either photographed in the field or returned to the laboratory for identification. References used to facilitate identification included Pflieger (1975), Smith (1979), and Trautman (1981).

2.6 Water Quality Measurements

Four physicochemical parameters (temperature, dissolved oxygen [DO], pH, and conductivity) were measured in conjunction with the sampling program. These data were collected at each station prior to each sampling effort. Physicochemical measurements were taken a half meter below the water surface at all locations prior to sample collection. At deeper locations, temperature, conductivity, and DO were measured 0.5 m below the surface and 0.5 m off the bottom. Temperature (°C), dissolved oxygen (ppm), and conductivity (μmhos) were measured using an YSI Model 85 handheld oxygen, conductivity, salinity, and temperature meter. A Cole-Parmer pH Tester1 was used to determine pH. All instruments were calibrated prior to each monthly sampling event.

3.0 RESULTS AND DISCUSSION

3.1 Species occurrence.

Fish surveys have been conducted at Braidwood Lake by the Illinois Department of Natural Resources (IDNR) since 1980 when the cooling lake was first impounded with water pumped from the Kankakee River. Sampling was conducted annually from 1980-1992, again in 1994, and every other year from 1997-2007 (Table 3-1). During these 20 years of sampling, 47 taxa of fish have been collected including 45 species and two hybrids (hybrid sunfish and tiger muskie). Gizzard shad, carp, channel catfish, bluegill, and largemouth bass have been the dominate species collected during these surveys. The total number of taxa collected by the IDNR has ranged from 12 in 1980 to 27 in 1989. Several species have been rarely collected or only occasionally observed during this 30 year period. These include yellow bass, rock bass, redear sunfish, orangespotted sunfish, tiger muskie, grass pickerel, longnose gar, goldfish, highfin carpsucker, silver redhorse, river redhorse, blackstripe topminnow, emerald shiner, common shiner, striped shiner, redfin shiner, slenderhead darter, johnny darter, and bullhead minnow, which have been collected in five or fewer of the 20 years of sampling conducted by the IDNR from 1980 through 2007. The only protected species (one fish collected in 1999) collected during these surveys has been river redhorse (*Moxostoma carinatum*), which is currently listed as threatened in Illinois (Illinois Endangered Species Protection Board 2009). River redhorse have been collected from the Kankakee River during several years during past sampling programs (HDR 2009). Eighteen of the taxa identified by the IDR have not been captured since 1999.

Braidwood Lake has been stocked with a variety of warmwater and coolwater fish species since the late 1970's. Some of these species, such as striped bass, tiger muskie, and walleye, have not been collected in recent years following the discontinuance of those stocking programs. Currently, the fish community is dominated by warmwater species that are more tolerant of the elevated water temperatures that exist in the cooling lake during summer months.

3.2 Relative Abundance and CPE.

In 2009, 26 taxa representing seven families were included among the 2143 fish collected by electrofishing, trap netting, and gill netting. Similar results were recorded in 2010 when 25 taxa

TABLE 3-1

SPECIES OCCURRENCE OF FISH COLLECTED BY THE ILLINOIS DEPARTMENT OF NATURAL RESOURCES[a] AT BRAIDWOOD LAKE FROM 1980 THROUGH 2007.

Taxa	SAMPLING YEAR																			
	80	81	82	83	84	85	86	87	88	89	90	91	92	94	97	99	01	03	05	07
Longnose gar			3												13					
Threadfin shad		564																11	230	122
Gizzard shad	27	2545	972	143	143	182	141	7	1020	4248	1296	1382	3018	412	925	925	786	1031	872	195
Grass pickerel	2	5	24	7	1															
Tiger muskie				8	3								5		12					
Goldfish														2	3	1	1			
Carp	275	365	414	616	785	532	666	675	511	1915	626	108	227	285	853	385	929	620	204	405
Golden shiner	4	82	1	1									1	1			1	1		1
Emerald shiner					1			2		1		1					48			
Common shiner		31							2	2										
Striped shiner		14																		
Spotfin shiner						1		9	3	37	75	5	4	1	1		198	3	27	249
Sand shiner			1			4		1	1	26	11	2	1					5		75
Redfin shiner																		1		
Bluntnose minnow			1	4		1		5	6	35	32	6	3			3	13		1	6
Bullhead minnow																				11
Quillback	26	39	6	42	37	39	29	53	39	20	42	26	66	20	37	5	3			
Highfin carpsucker		2																		
Silver redhorse		1								1				1						
Golden redhorse								2	1	2	2	2		1						
Shorthead redhorse								1	4	10	5	3	3		4	3				
River redhorse																1				
Black bullhead	18	102	167	25	6	1														
Yellow bullhead		3	11	8	6	18	7	3	1	1	2	1	1	1		3	3		1	1
Channel catfish		9	2	3	12	13	7	39	16	79	177	362	357	403	136	364	866	384	129	228
Flathead catfish															1	2	10		1	1
Blackstripe topminnow											6									
Brook silverside	4	145			1				4	171	17	8	9	13	6	12	50	3	5	1
Yellow bass					1				1											
Striped bass								2	1	1	5	4	1	1	15					

TABLE 3-1 (Continued).

Taxa	80	81	82	83	84	85	86	87	88	89	90	91	92	94	97	99	01	03	05	07
	SAMPLING YEAR																			
Rock bass									1		1	1		2						
Green sunfish	4	57	163	125	16	71	13	13	2	7	1	10	8	23	13	37	139	26	10	77
Orangespotted sunfish												1				1				1
Bluegill	13	458	620	191	69	81	21	9	31	277	121	698	247	252	241	998	1754	1393	1369	2758
Longear sunfish														25	1	7		3		1
Redear sunfish														1			3			
Hybrid sunfish		1	16	12	6	20	11	6		1		2	1	4		9	13	8	5	7
Smallmouth bass										1	3	42	24	17	42	17	9	3	5	
Largemouth bass	23	473	385	390	298	265	241	150	142	142	192	175	91	337	202	711	351	334	88	263
White crappie		41		19	30	17	6	5	4	6	3	10	2			3				
Black crappie	2	36	4	2	7	6	3	1	4	3	11	6	1			20	2	2	1	1
Johnny darter		2																		
Yellow perch	2	66	42	20	35	69	93	74	61	10	3									
Logperch									12	71	47	11	72	6	7					
Slenderhead darter									2	2		1								
Walleye		3	7	13	21	24	53	30	62	38	37	7	8	1	3					
Freshwater drum			1		11	7	14	12	11	61	15	8	15	6	21	14	14	34	9	1
Total fish	400	5044	2840	1629	1489	1351	1305	1099	1942	7008	2730	2882	4165	1875	2536	3521	5193	3862	2957	4403
Total taxa	12	23	19	18	20	18	14	21	25	27	24	26	23	23	20	21	20	17	16	20
Total species	12	22	18	16	18	17	13	20	25	26	24	25	21	22	19	20	19	16	15	19

[a]Information provided by Rob Miller, District Fisheries Biologist with the Illinois Department of Natural Resources.

representing eight families were included among the 2432 fish collected by electrofishing, trap netting, gill netting, and hoop netting (Table 3-2). Several species that were listed as being collected by the IDNR during surveys conducted between 1980 and 2007 were not captured by HDR in either 2009 or 2010. Each of these taxa were either rarely captured during previous years, represent taxa that were stocked, or have not been captured during recent years. However, five species were captured during 2009 that were not collected during earlier sampling efforts. They included shortnose gar, blue catfish, bigmouth buffalo, fathead minnow, and rosyface shiner. A single specimen of each of these species was collected (HDR 2010). In 2010, three species that have not been collected by IDNR were captured. Two of these species, blue catfish and rosyface shiner, were also collected in 2009, while the third species, smallmouth buffalo, had not been captured during any of the previous studies. A single specimen of smallmouth buffalo was collected by trap netting, while 39 blue catfish were taken by gill netting and hoop netting, and 20 rosyface shiner were collected by electrofishing. No threatened or endangered species were collected in 2010.

Species that numerically dominated the catch in 2010 (all sampling methods combined) included bluegill at 31.3%, channel catfish at 19.3%, spotfin shiner at 10.3%, carp at 9.7%, threadfin shad at 6.0%, gizzard shad at 5.9%, bluntnose minnow at 4.0%, and largemouth bass at 2.7% (Table 3-3). All of these species were included in the catch during the surveys conducted by IDNR in 2007 (Table 3-1). Biomass of fish captured by electrofishing, trap netting, gill netting, and hoop netting was dominated by carp (51.1%), channel catfish (27.0%), bluegill (6.1%), gizzard shad (4.8%), and largemouth bass (3.1%). These results are similar to data collected during previous years and indicate that Braidwood Lake is best suited to support warmwater species.

3.2.1 Electrofishing

In 2010, electrofishing resulted in the collection of 1341 individuals representing 21 taxa (Table 3-3). The catch was dominated numerically by bluegill, which comprised 37.7% of all fish captured. Spotfin shiner (18.7%), threadfin shad (7.7%), bluntnose minnow (7.2%), largemouth bass (4.5%), longear sunfish (4.3%), bullhead minnow (3.4%), and channel catfish (3.2%) were the only other species to individually comprise greater than 3% of the total catch by number. The total number of fish collected by location ranged from 367 at Location E-5 to 77 at Location E-1 (Table 3-4). The total number of taxa collected ranged from six at Location E-1 to 15 at Location

TABLE 3-2

TOTAL NUMBER, WEIGHT (g) AND PERCENT CONTRIBUTION OF FISH COLLECTED BY ALL SAMPLING GEARS FROM BRAIDWOOD STATION COOLING LAKE, 2009 AND 2010.

	2009[a]				2010[b]			
	NUMBER		WEIGHT		NUMBER		WEIGHT	
TAXON	No.	%	(g)	%	No.	%	(g)	%
Threadfin shad	250	11.7	2486	0.5	147	6.0	2033	0.3
Gizzard shad	144	6.7	14,410	3.1	144	5.9	32,837	4.8
Shortnose gar	1	<0.1	1750	0.4				
Longnose gar	4	0.2	9900	2.1	5	0.2	17,000	2.5
Carp	145	6.8	222,327	47.5	236	9.7	353,432	51.1
Common shiner					1	<0.1	17	<0.1
Striped shiner	34	1.6	59	<0.1				
Rosyface shiner	1	<0.1	3	<0.1	20	0.8	48	<0.1
Spotfin shiner	176	8.2	475	0.1	251	10.3	503	0.1
Sand shiner	27	1.3	41	<0.1	14	0.6	27	<0.1
Fathead minnow	1	<0.1	2	<0.1				
Bluntnose minnow	164	7.7	332	0.1	97	4.0	203	<0.1
Bullhead minnow	153	7.1	335	0.1	46	1.9	103	<0.1
Smallmouth buffalo					1	<0.1	3350	0.5
Bigmouth buffalo	1	<0.1	2550	0.5				
Yellow bullhead					2	0.1	77	<0.1
Blue catfish	1	<0.1	1000	0.2	39	1.6	11,736	1.7
Channel catfish	239	11.2	99,638	21.3	469	19.3	186,789	27.0
Flathead catfish	3	0.1	38,750	8.3	1	<0.1	14,000	2.0
Brook silverside	1	<0.1	2	<0.1	23	0.9	25	<0.1
Sunfish spp.	1	<0.1	1	<0.1				
Green sunfish	20	0.9	857	0.2	37	1.5	919	0.1
Orangespotted sunfish					3	0.1	29	<0.1
Redear sunfish	16	0.7	518	0.1	2	0.1	83	<0.1
Bluegill	649	30.3	48,014	10.3	761	31.3	42,403	6.1

TABLE 3-2 (Continued).

TAXON	2009[a]				2010[b]			
	NUMBER		WEIGHT		NUMBER		WEIGHT	
	No.	%	(g)	%	No.	%	(g)	%
Longear sunfish	16	0.7	373	0.1	57	2.3	959	0.1
Hybrid sunfish	10	0.5	162	< 0.1	4	0.2	75	< 0.1
Smallmouth bass	2	0.1	1793	0.4	3	0.1	1534	0.2
Largemouth bass	83	3.9	23,569	5.0	65	2.7	21,757	3.1
Black crappie	1	< 0.1	147	< 0.1				
Freshwater drum					4	0.2	1073	0.2
Totals	2143		468,247		2432		691,006	
Total taxa	26				25			
Total species	24				24			

[a]Sampling methods included electrofishing, trap netting and gill netting.
[b]Sampling methods included electrofishing, trap netting, gill netting and hoop netting.

TABLE 3-3

TOTAL CATCH BY METHOD FOR FISH SPECIES COLLECTED FROM THE BRAIDWOOD STATION COOLING LAKE, 2010.

TAXON	ELECTROFISHING				TRAP NETTING				GILL NETTING				HOOP NETTING			
	NUMBER		WEIGHT		NUMBER		WEIGHT		NUMBER		WEIGHT		NUMBER		WEIGHT	
	No.	%	(g)	%	No.	%	(g)	%	No.	%	(g)	%	No.	%	(g)	%
Threadfin shad	103	7.7	1309	1.0					44	15.0	724	2.7				
Gizzard shad	36	2.7	6938	5.4	102	15.6	24,212	5.2	6	2.0	1687	6.2				
Longnose gar					5	0.8	17,000	3.6								
Carp	31	2.3	55,422	42.8	203	31.1	295,310	63.3	1	0.3	1200	4.4	1	0.7	1500	2.2
Common shiner	1	0.1	17	< 0.1												
Rosyface shiner	20	1.5	48	< 0.1												
Spotfin shiner	251	18.7	503	0.4												
Sand shiner	14	1.0	27	< 0.1												
Bluntnose minnow	97	7.2	203	0.2												
Bullhead minnow	46	3.4	103	0.1												
Smallmouth buffalo					1	0.2	3350	0.7								
Yellow bullhead	2	0.1	77	0.1												
Blue catfish									34	11.6	10,790	39.7	5	3.4	946	1.4
Channel catfish	43	3.2	23,853	18.4	107	16.4	101,196	21.7	208	70.7	12,694	46.7	111	76.6	49,040	72.6
Flathead catfish													1	0.7	14,000	20.7
Brook silverside	23	1.7	25	< 0.1												
Hybrid sunfish	4	0.3	75	0.1												
Green sunfish	37	2.8	919	0.7												
Orangespotted sunfish	3	0.2	29	< 0.1												
Redear sunfish	2	0.1	83	0.1												
Bluegill	506	37.7	16,866	13.0	229	35.1	23,903	5.1					26	17.9	1634	2.4
Longear sunfish	57	4.3	959	0.7												
Smallmouth bass	3	0.2	1534	1.2												
Largemouth bass	61	4.5	20,381	15.7	3	0.5	1265	0.3	1	0.3	111	0.4				
Freshwater drum	1	0.1	258	0.2	2	0.3	415	0.1					1	0.7	400	0.6
Totals	1341		129,629		652		466,651		294		27,206		145		67,520	
Total taxa	21				8				6				6			
Total species	20				8				6				6			

TABLE 3-4

NUMBERS OF FISH CAPTURED BY ELECTROFISHING AT EACH SAMPLING LOCATION IN BRAIDWOOD LAKE, 2010.

	SAMPLING LOCATIONS									
TAXON	E-1	E-2	E-3	E-4	E-5	E-6	E-7	E8	TOTAL	%%
Threadfin shad	55	1			2	37	6	2	103	7.7
Gizzard shad	2	8	1	3	13	2	6	1	36	2.7
Carp	3	2	8	1	5	2	4	6	31	2.3
Common shiner				1					1	0.1
Rosyface shiner			15			4	1		20	1.5
Spotfin shiner		6	47	39	32	37	20	70	251	18.7
Sand shiner		1	1	6		3	1	2	14	1.0
Bluntnose minnow		1	27	9		15	18	27	97	7.2
Bullhead minnow			8	3		18	5	12	46	3.4
Yellow bullhead						2			2	0.1
Channel catfish	1	15	1	4	5	3	13	1	43	3.2
Brook silverside			21			1		1	23	1.7
Green sunfish			1	3	32		1		37	2.8
Orangespotted sunfish					3				3	0.2
Redear sunfish			1		1				2	0.1
Bluegill	14	33	52	54	258	9	36	50	506	37.7
Longear sunfish		3	7		11	13	16	7	57	4.3
Hybrid sunfish			1	1	1		1		4	0.3
Smallmouth bass				2	1				3	0.2
Largemouth bass	2	24	16	3	2	5	7	2	61	4.5
Freshwater drum					1				1	0.1
Total fish	77	94	207	129	367	151	135	181	1341	
Total Taxa	6	10	15	13	14	14	14	12	21	
CPE (fish/hr)	77.0[a]	94.0[a]	207.0[a]	129.0[a]	367.0[a]	151.0[a]	135.0[a]	181.0[a]	167.6[b]	

[a] Based on 1.00 hrs electrofishing effort.
[b] Based on 8.00 hrs electrofishing effort.

E-3. Fewer fish and taxa were collected at Locations E-1 and E-2 located closest to the Braidwood Station discharge. In general, more fish and greater numbers of taxa were collected at locations located toward the cooler end of the Braidwood Lake cooling loop (Locations E-3, E-5, E-6, and E-10). Electrofishing biomass was dominated by carp, which constituted 47.5% of the 468.2 kg collected (Table 3-3). Other species that individually contributed more than 5% of the total biomass included channel catfish (21.3%), bluegill (10.3%), flathead catfish (8.3%), and largemouth bass (5.0%).

The mean electrofishing catch-per-effort (CPE) for all locations combined was 167.6 fish/hr (Table 3-4). This value is similar to the mean electrofishing CPE of 177.5 fish/hr for all locations combined that was reported in 2009 (HDR 2010). In 2010, CPE ranged from 77.0 fish/hr at Location E-1 to 367.0 fish/hr at Location E-5. Location E-5 also exhibited the highest catch rate in 2009. This site includes the area around the make-up water discharge into the lake from the Kankakee River. Five species, gizzard shad, carp, channel catfish, bluegill, and largemouth bass, were collected at each of the eight electrofishing locations.

3.2.2 Trap Netting

A total of 652 fish including eight species was collected by trap net (Table 3-3). Bluegill was the dominant species captured, comprising 35.1% of all fish taken. The second most abundant species collected was carp (31.1%), followed by channel catfish (16.4%), and gizzard shad (15.6%). The total number of fish collected by location ranged from 41 at Location TN-8 to 190 at Locations TN-2 (Table 3-5). The total number of species collected by location ranged from four at Locations TN-1, TN-3, TN-4, and TN-8 to six at Location TN-5. Total biomass of fish captured by trap net was 466.7 kg (Table 3-3). Species collected by trap netting that comprised greater than 5% of the catch by weight included carp (63.3%), channel catfish (21.7%), gizzard shad (5.2%), and bluegill (5.1%).

During the July and August sampling periods, mean trap netting CPE for all locations combined was 40.8 fish/net (overnight sets of approximately 12-hrs), which is slightly higher than the 28.5 fish/net reported in 2009 (HDR 2010). CPE by location ranged from 20.5 fish/net at Location TN-8 to 95.0 fish/net at Locations TN-2. Carp, channel catfish, and bluegill were the only three species collected at each of the eight sampling locations.

TABLE 3-5

NUMBER OF FISH CAPTURED BY TRAP NETTING AT EACH SAMPLING LOCATION IN BRAIDWOOD LAKE, 2010.

	SAMPLING LOCATIONS									
TAXON	TN-1[a]	TN-2	TN-3	TN-4	TN-5	TN-6	TN-7	TN-8	TOTAL	%
Gizzard shad	28	27	17	13	10	4	3		102	15.6
Longnose gar					3		2		5	0.8
Carp	7	88	34	6	8	13	29	18	203	31.1
Smallmouth buffalo						1			1	0.2
Channel catfish	7	43	13	9	15	7	11	2	107	16.4
Bluegill	2	30	51	44	45	17	20	20	229	35.1
Largemouth bass		1			2				3	0.5
Freshwater drum		1						1	2	0.3
Total fish	44	190	115	72	83	42	65	41	652	
Total Taxa	4	6	4	4	6	5	5	4	8	
CPE (fish/trap net set)	22.0[b]	95.0[b]	57.5[b]	36.0[b]	41.5[b]	21.0[b]	32.5[b]	20.5[b]	40.8[c]	

[a]The webbing of trap net TN-1 was severely damaged during the second sampling period on August 17-18 due to vandalism or either by a muskrat or beaver. It is assumed that an unknown number of fish were lost because of the relatively large hole that was found in the net upon retrieval.
[b]Based on two over night sets of approximately 12 hr duration.
[c]Based on 16 over night sets of approximately 12 hr duration.

3.2.3 Gill Netting

Gill netting resulted in the collection of 294 individuals representing six species (Table 3-3). Channel catfish dominated the catch by comprising 208 (70.7%) of the 294 total fish collected. Threadfin shad was the second most abundant species collected (15.0%). The only other species to individually contribute more than 5% of the total catch was blue catfish (11.6%). Channel catfish comprised 12.7 kg (46.7%) of the 27.2 kg of fish collected by gill netting (Table 3-3), followed by blue catfish at 10.8 kg (39.7%), and gizzard shad at 1.7 kg (6.2%).

A total of 175 fish representing four species was collected from the two deep water sets conducted at Location GN-1 (Table 3-6). Gill nets at this location were set in a deep hole at a depth of approximately 7-8 m. At the shallow water sampling Location GN-2 the gill nets were set at a depth of approximately 1-2 m. One hundred nineteen fish and six species were collected from this sampling location during July and August. Similar results were noted between the deep and shallow water sets, with the exception of blue catfish, which were collected in greater numbers (32 individuals) in the deep water sets compared to the shallow water sets (two individuals).

Gill net CPE at the deep water Location GN-1 was 87.5 fish/hr based on 175 fish collected during two hours of sampling time during the July and August sampling efforts. CPE at the shallow water Location GN-2 was slightly lower at 59.5 fish/hr based upon the 119 fish collected during two hours of sampling effort in July and August. Mean CPE for the two sampling locations was 73.5 fish/hr, which is higher than the 53.4 fish/hr reported in 2009 (HDR 2010). Gizzard shad, threadfin shad, channel catfish, and bluegill were the only species collected at both sampling locations.

3.2.4 Hoop Netting

A total of 145 fish including six species was collected by hoop nets (Table 3-3). Channel catfish was the most abundant species captured, comprising 76.6% of all fish taken. The second and third most abundant species captured were bluegill (17.9%) and blue catfish (3.4%). The only other species collected included one individual each of common carp, flathead catfish, and freshwater drum. A total of 67.5 kg of fish was collected by hoop net (Table 3-3). Channel

TABLE 3-6

NUMBERS OF FISH CAPTURED BY DEEP (GN-1) AND SHALLOW WATER (GN-2) GILL NETS IN BRAIDWOOD LAKE, 2010.

	SAMPLING LOCATION			
TAXA	GN-1[a]	GN-2[b]	TOTAL	%
Threadfin shad	29	15	44	15.0
Gizzard shad	2	4	6	2.0
Carp		1	1	0.3
Blue catfish	32	2	34	11.6
Channel catfish	112	96	208	70.7
Largemouth bass		1	1	0.3
Total fish	175	119	294	
Total taxa	4	6	6	
CPE (fish/hr)	87.5	59.5	73.5	

[a]GN-1 was a deep water set in approximately 7-8 meters of water.
[b]GN-2 was a shallow water set in approximately 1-2 meters of water.

catfish (72.6%) and flathead catfish (20.7%) were the only two species that individually comprised greater than 5% of the total hoop net catch by weight.

The greatest number of fish (76 individuals) was collected at Location HN-1, which was a deep water set baited with dead gizzard shad (Table 3-7). Only one flathead catfish was collected at Location HN-2, which was also a deep water set, but the net was not baited. Similar numbers of fish were collected at the two shallow water locations. The hoop net at shallow water Location HN-3 (33 individuals) was baited with dead gizzard shad, while the shallow water hoop net at Location HN-4 (35 individuals) was not baited. The total number of species collected by location ranged from one at Locations HN-2 to three at Location HN-1 and HN-3. A total of 109 fish was collected from the two baited net locations in July and August as compared to the 36 total fish captured from the two nets that were not baited at Braidwood Lake.

Hoop netting CPE ranged from 38.0 fish/overnight set at Location HN-1 (deep water with bait) to 0.5 fish/overnight set at Location HN-2 (deep water no bait). CPE for the two deep water sets (HN-1 and HN-2) averaged 19.2 fish/overnight set compared to 17.0 fish/overnight set at the shallow water locations (HN-3 and HN-4). The two baited net sets (HN-1 and HN-3) had an average CPE of 27.2 fish/overnight set compared 9.0 fish/overnight set for the two nets (HN-2 and HN-4) that were not baited. Hoop nets were not used to collect fish in 2009. Mean CPE for all nets combined was 18.1 fish/overnight set.

3.3 Length-Frequecy Distributions

Length-frequency distributions of three selected species (bluegill, largemouth bass, and blue catfish) captured by all sampling gears in 2010 were compiled and are presented graphically (Figures 3-1, 3-2, and 3-3). With the exception of electrofishing, the sampling gears used in these studies are biased toward larger fish. Therefore, smaller fish, especially young-of-year and yearlings, were not collected in numbers that would most accurately represent their true abundance in Braidwood Lake. Although not presented graphically in this text, species such as carp and channel catfish were also collected in large numbers with no obviously missing or weak age-classes included in their length-frequency analysis. Two other common species, threadfin and gizzard shad, were also analyzed. All of the threadfin shad collected during the current study

TABLE 3-7

NUMBERS OF FISH CAPTURED IN BAITED AND UNBAITED DEEP AND SHALLOW WATER HOOP NETS IN BRAIDWOOD LAKE, 2010.

	SAMPLING LOCATION					
	DEEP WATER[a]		SHALLOW WATER[b]			
TAXA	HN-1 (BAITED)	HN-2 (UNBAITED)	HN-3 (BAITED)	HN-4 (UNBAITED)	TOTAL	%
Carp	1				1	0.7
Blue catfish	5				5	3.4
Channel catfish	70		26	15	111	76.6
Flathead catfish		1			1	0.7
Bluegill			6	20	26	17.9
Freshwater drum			1		1	0.7
Total fish	76	1	33	35	145	
Total taxa	3	1	3	2	6	
CPE (fish/overnight set)[c]	38.0[c]	0.5[c]	16.5[c]	17.5[c]	18.1[d]	

[a]Deep water hoop nets HN-1 and HN-2 were set in 7.5 meters of water.

[b]Shallow water hoop nets HN-3 and HN-4 were set in approximately 2.0 meters of water.

[c]CPE was based on two overnight sets of approximately 12 hours duration.

[d]CPE was based on eight overnight sets of approximately 12 hours duration.

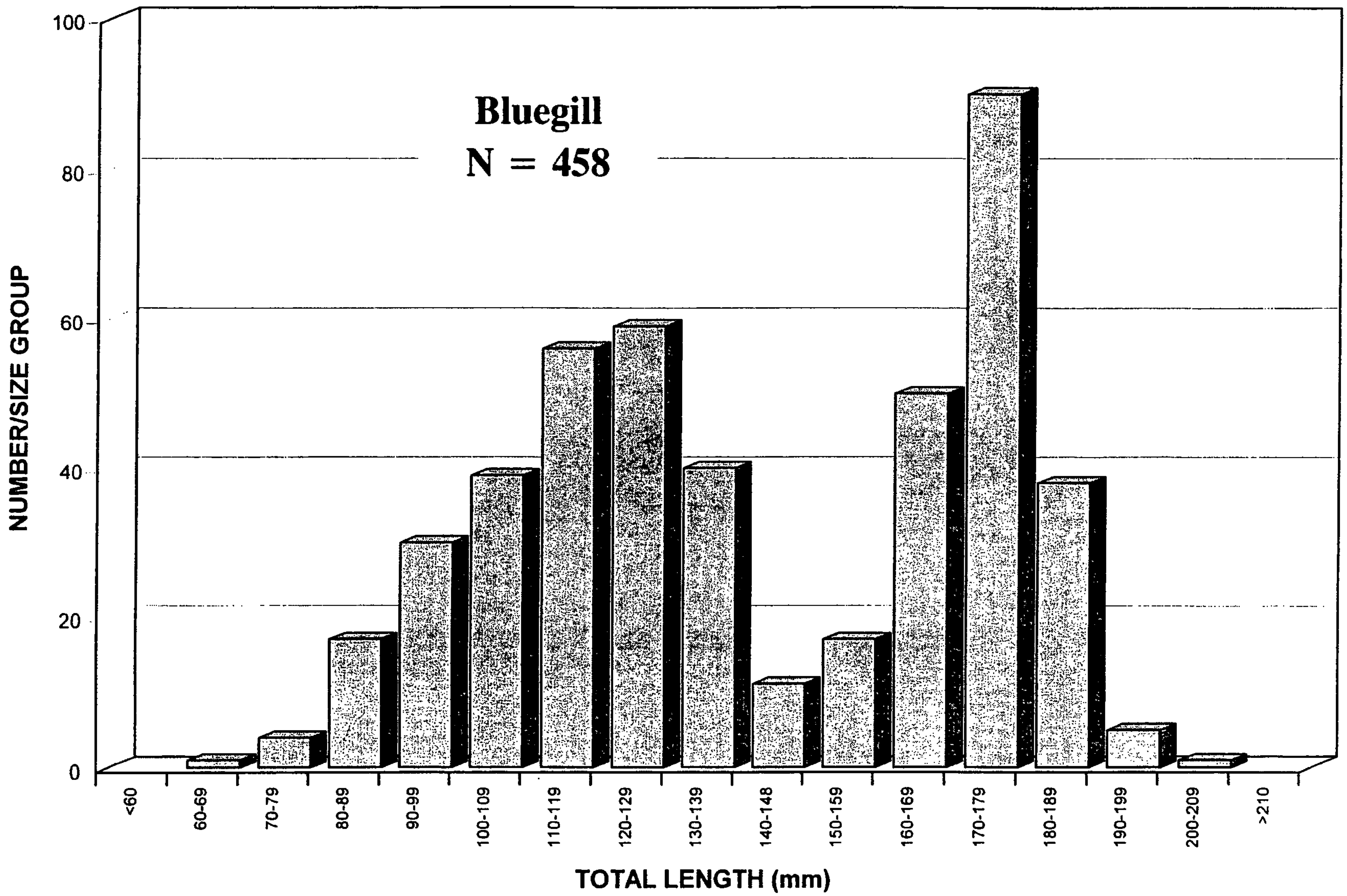

FIGURE 3-1. LENGTH-FREQUENCY DISTRIBUTION OF BLUEGILL COLLECTED FROM BRAIDWOOD LAKE DURING JULY AND AUGUST, 2010.

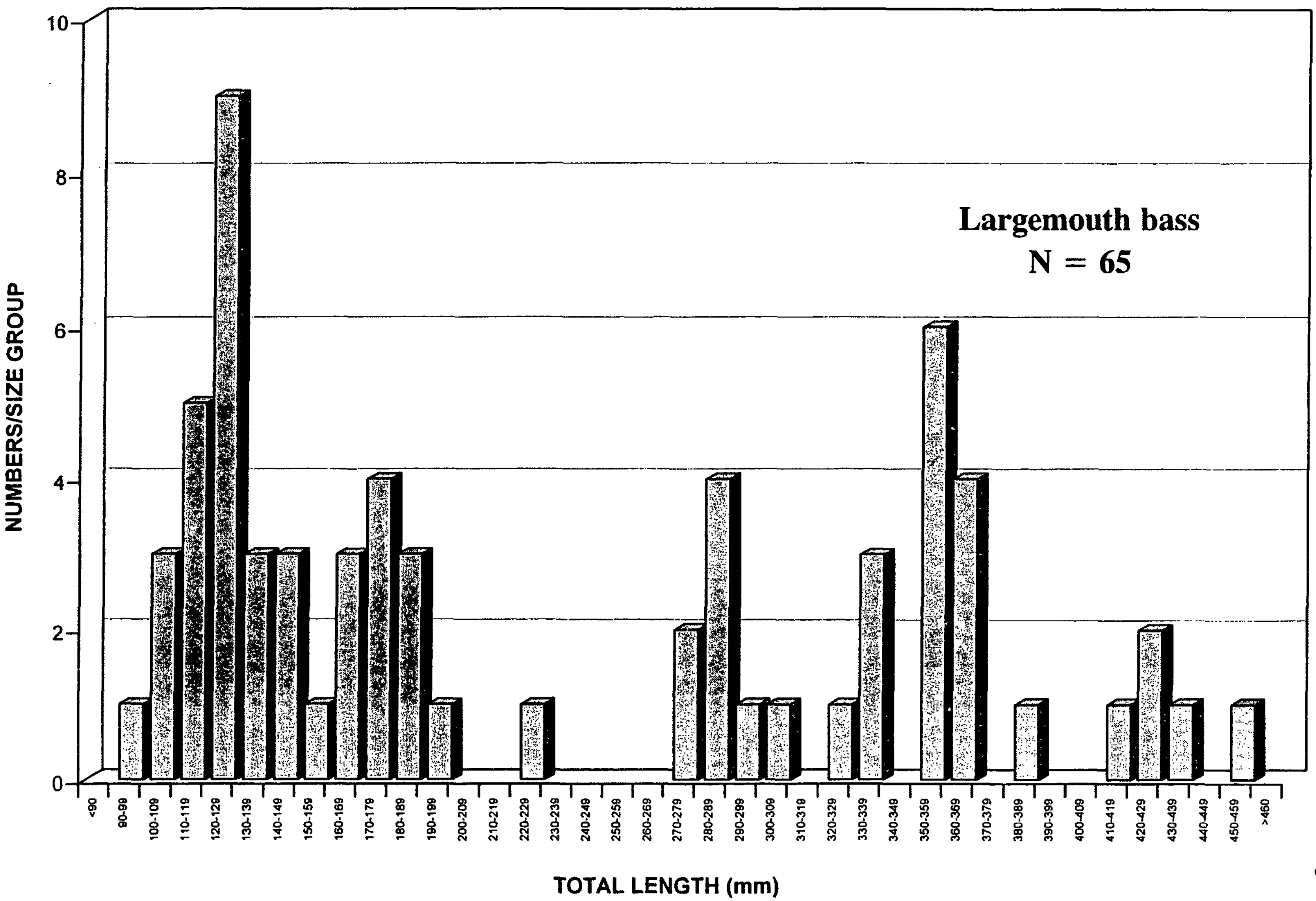

FIGURE 3-2. LENGTH-FREQUENCY DISTRIBUTION OF LARGEMOUTH BASS COLLECTED FROM BRAIDWOOD LAKE DURING JULY AND AUGUST, 2010.

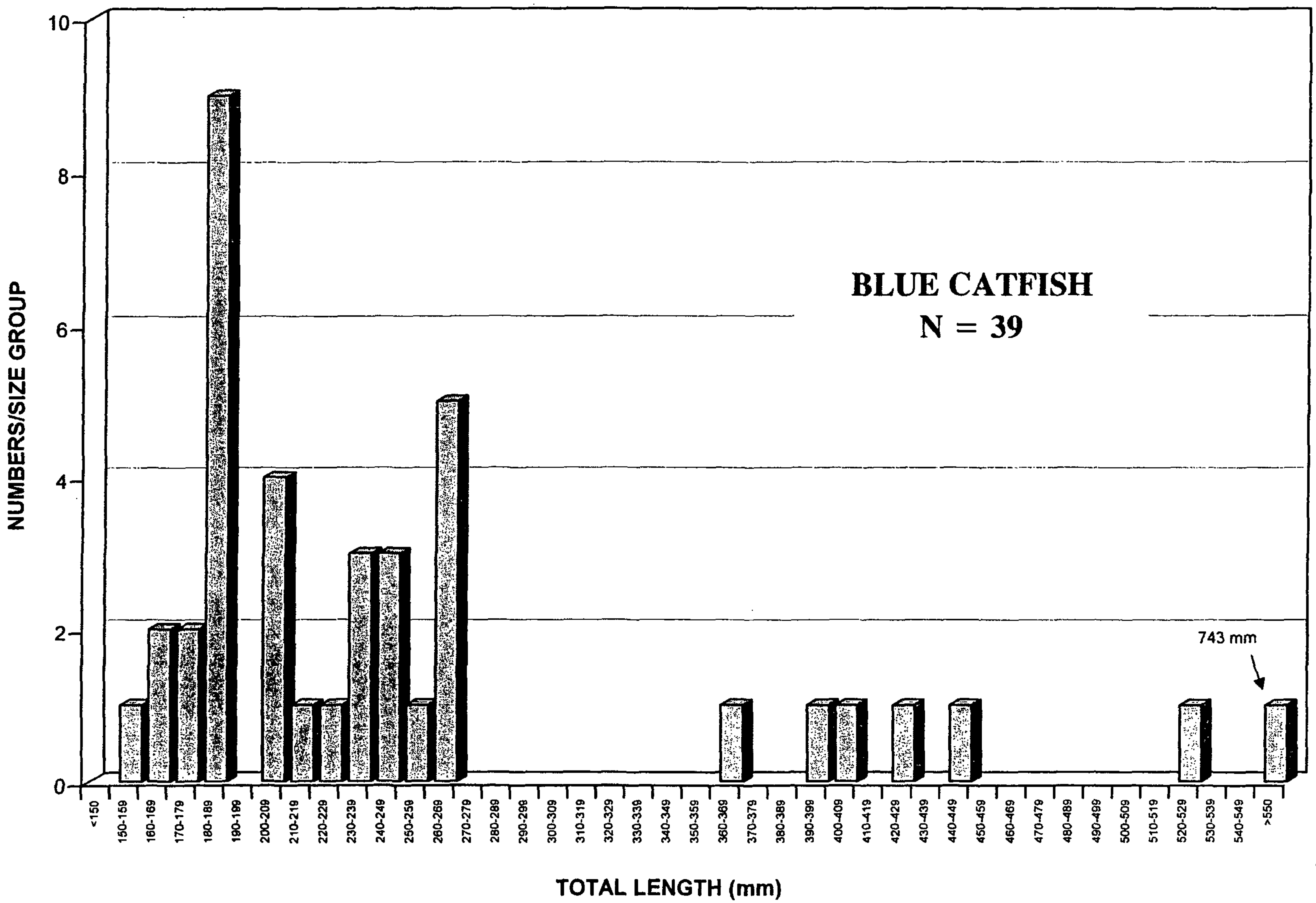

FIGURE 3-3. LENGTH-FREQUENCY DISTRIBUTION OF BLUE CATFISH COLLECTED FROM BRAIDWOOD LAKE DURING JULY AND AUGUST, 2010.

measured from 70 to 123 mm in total length, while 125 (88.7%) of the 141 gizzard shad captured exceeded 250 mm in total length.

Bluegill is one of the most abundant species found in Braidwood Lake. Four hundred fifty-eight individuals measuring from 65 to 200 mm in total length are included in the length-frequency histogram of bluegill that were captured in 2010 (Figure 3-1). Two major peaks in the length-frequency distribution representing at least two different age classes were noted. The first major group of fish includes bluegill measuring from 90 to 140 mm, while the second major group includes fish measuring from 160 to 190 mm. The age of these fish, as well as other species, in thermally enhanced bodies of water, such as Braidwood Lake, is impossible to determine without hard-part (scales, spines, and otoliths) analysis because the growing season extends throughout the winter months. Regardless of age, Braidwood Lake supports a large population of bluegill that are large enough to support a quality sport fishery.

The length-frequency distribution of 65 largemouth bass measuring from 93 to 454 mm in total length were collected from Braidwood Lake during 2010 (Figure 3-2). The length-frequency distribution indicates that several age classes of fish were included among the catch. The largest peak in the length-frequency histogram occurs at 120 mm and likely represents either YOY or Age 1 fish. Sixteen (24.6%) of the 65 fish collected exceeded 350 mm (14 in.). The largest individual that measured 454 mm was likely older than Age 5 or 6. Again, the age of fish in cooling lakes is difficult to ascertain based on length-frequency analysis because of the extended growing season that exist in these thermally enhanced bodies of water.

Braidwood Lake has been stocked with a variety of warm- and coolwater fish specie since the 1970's to the present time. Those efforts have included the introduction of blue catfish to the cooling lake. Because of those stocking efforts, and because of the relatively large number of blue catfish that were collected in 2010, a length-frequency histogram was also created for this species (Figure 3-3). The length-frequency distribution of 39 fish measuring from 158 to 743 mm indicates that as many as five year classes of blue catfish were included in the catch at Braidwood Lake during 2010. Thirty-two (82.1%) of the 39 fish collected measured less than 270 mm in total length, while the remaining seven (17.9%) individuals ranged from 360 to 743 mm in total length. The authors of this report are uncertain of the recent stocking history, if any, of blue catfish in Braidwood Lake. The relatively large number of smaller blue catfish collected in 2010 may indicate that natural reproduction has taken place within Braidwood Lake (See Addendum).

3.4 Physicochemical Data

Water quality data recorded in conjunction with fish sampling was measured at each location prior to every sample collection (Appendix Tables A-1 to A-4). During July 20-22, water temperature at Braidwood Lake ranged from 33.6 °C at Location TN-7 on 20 July to 38.2 °C at Location E-1 (the most southern location located closes to Braidwood Station discharge) on 21 July. Make-up water from the Kankakee River was being pumped into the lake at Location E-5 during the time water quality parameters were being measured. Water temperatures during the second sampling period (August 17-19) were cooler than those measured in July because both Unit I and Unit II were off line. Temperatures during this period ranged from 29.6 °C at Location E-1 (closest to the Braidwood Station discharge) on 19 August to 33.9 °C at Location E-1 on 17 August. Water temperature decreased during the three day sampling period in August as the cooling loop cooled due to the outage. As expected, the temperature gradient during the July sampling period generally declined as the cooling water in the lake moved from the Station's discharge toward the Braidwood Station intake. However, during the second sampling period, temperature generally cooled more quickly near the discharge end of the lake once the units went off line.

Dissolved oxygen (DO) ranged from 4.7 ppm at Locations TN-1 and TN-2 to 12.2 ppm at Location GN-1 during the July sampling period. Oxygen levels were lower during the August sampling period when DO ranged from 1.4 to 9.6 ppm at Locations TN-2 and E7, respectively. Qualitative observations by the field crew indicated that the water appeared much clearer during the August sampling dates. This suggests that a decline in the phytoplankton population may have occurred between the first and second sampling period, which may explain the moderate decline in oxygen levels noted in Braidwood Lake during August.

As was also observed in 2009 (HDR 2010), diurnal variations in the lake led to increased dissolved oxygen reading from early morning to late afternoon during July and August, 2010. These variations can be attributed to the phytoplankton within the lake that produces oxygen throughout the daylight hours.

Surface and bottom water temperature, DO, and conductivity readings were taken at deep water gill net set Location GN-1and the deep water hoop net set Locations HN-1 and HN-2. Similar surface and bottom readings were recorded at the deep water Locations HN-1 and HN-2. At Location GN-1, the bottom temperatures were slightly cooler (0.2 to 1.0 °C) than the surface reading, while the DO levels measured near the bottom were more variable ranging from 0.6 to 4.6 ppm less than the surface readings during the July and August sampling periods.

Braidwood Lake is a very productive system with heavy oxygen demand (respiration and decomposition) occurring during the night and intense oxygen production (photosynthesis) occurring during clear sunny days. Currently, the majority of the photosynthetic activity within Braidwood Lake is attributable to phytoplankton, which has decreased the water clarity and replaced aquatic macrophtyes as the primary producer. In a report submitted to Exelon by SEA in 2001 (Appendix Report B-1); it states that "Several perched cooling ponds in the Midwest have had high macrophyte densities in their earlier years but usually become dominated by phytoplankton if they have heavy thermal loading. A switch to phytoplankton dominance is usually accompanied by a reduction in water transparency."

Braidwood Lake appears to be relatively well buffered with only minor diurnal variation in pH readings. Examination of pH data collected during the present surveys show that pH ranged from 8.3 to 8.5 during the July sampling period and from 8.3 to 8.7 during the August sampling period. The pH of water typically increases with increased photosynthetic activity and the resulting oxygen production can explain upward shifts in pH during the course of bright sunny days.

During the July sampling period, conductivity ranged from 770 μmhos at Location TN-2 on 20 July to 823 μmhos at Location TN-2 on 21 July. Conductivity during the August sampling period ranged from 832 μmhos at Location TN-8 on 17 August to 862 μmhos at Location TN-2 on 18 August. Conductivity and pH readings were relatively similar throughout the entire length of Braidwood Lake. Surface to bottom readings were also similar, suggesting that the water throughout the cooling loop was well mixed during the July and August sampling dates.

Make-up water was being pumped into Braidwood Lake from the Kankakee River during the July sampling period. As a result, water quality parameters can be expected to be generally more favorable near the make-up water discharge (Location E-5) compared to the remainder of the sampling locations. However, the affects of the make-up water discharge is quickly dissipated because of the relatively low volume of make-up flow being pumped into the lake. Make-up water was not being pumped into Braidwood Lake during the time of sample collection in August.

During the July sampling period, water quality parameters were within the range of values acceptable for warmwater fish species. During the August sampling period, pH and conductivity were measurements were relatively similar to the values recorded during July. However, temperature and dissolved oxygen readings in August were lower than those observed in July. The cooler water temperatures can be explained by the plant outage that occurred during the August sampling period. There was also a decline in DO readings that ranged from 1.4 ppm on the morning of 18 August to 9.6 ppm during the afternoon of 19 August. The early morning dissolved oxygen readings that were measured during the August sampling dates were approaching values that adversely affect most fish species. As previously noted, these diurnal oxygen fluctuations can be attributed to oxygen depletion (respiration and decomposition) during the night and oxygen production (photosynthesis) during the day. On cloudy calm days, photosynthesis and oxygen production can be slowed to levels that cannot compensate for oxygen depletion that occurs throughout the night. When this occurs over an extended period of time (days), an oxygen deficit can develop and cause substantial fish die-offs if suitable refuges within the system are not available.

3.5 Historical Information

3.5.1 Water Quality

Water quality parameters were measured on seven separate occasions at Braidwood Lake from May 29, 2001 through August 27-28, 2002 (Appendix Reports B-1 through B-7). The purpose and scope of these investigations varied, but the most intensive sampling was conducted during the August 27-28, 2002 sampling event. Results of these investigations indicated that abnormally high levels of total dissolved solids (TDS), alkalinity, hardness, sulfates, magnesium, calcium, and total phosphorus existed throughout the cooling loop. This data was not unexpected based on the evaporation that occurs within the cooling loop coupled with the relative low make-up and blow-down flows associated with the operation of the Station. The cooling lake exhibited elevated values for these parameters at levels of two to nearly eight times higher than those of the make-up water from the Kankakee River. These elevated levels of water hardness can be of concern to the Station because they have the potential to intensify problems associated with scaling.

Phosphorus and nitrogen are two essential nutrients required by aquatic plants. Concentrations of these nutrients are typically low in water because phytoplankton and aquatic macrophytes quickly assimilate and utilize these nutrients for growth and reproduction. The studies conducted by SEA in 2002 indicated that the high levels of these nutrients within the cooling lake would continue to cause problems associated with phytoplankton blooms. Unlike most water bodies, phosphorus levels within Braidwood Lake were in excess and nitrates were the limiting factor. Bluegreen algae appeared to be the dominant summer form of algae within Braidwood Lake because they are not as limited by low nitrate levels as other algal species.

Water quality analysis has indicated that dissolved oxygen levels within the cooling lake can exhibit large diurnal variation in response to algal blooms that are most problematic during the summer months (June through August). The nutrient rich water of Braidwood Lake is ideal for the development of algal blooms that produce large amounts of oxygen during the day (photosynthesis) and oxygen depletion in the dark (respiration and decomposition). As oxygen is produced through photosynthesis, pH tends to increase if the water is not well buffered. Dissolved oxygen levels of 4-5 ppm (levels that most fish species become stressed) and lower have been recorded throughout the cooling loop 0.5 m below the waters surface. The lowest DO readings occur during the early morning period and they typically increase throughout the day. Increases in DO of 4 to 5 ppm or more have been observed from morning to late afternoon at Braidwood Lake. In addition, stratification of the water column has also been reported during the same period of time when DO readings are measured at less than 3 ppm. During these events, DO readings in the hypolimnion (the zone below the thermocline to the bottom of the lake) can approach zero. When this occurs, it further limits the refuge available for fish and other aquatic organisms.

3.5.2 Fish Kills

Historical fisheries data summarizing fish kills that have occurred at Braidwood Lake was provided to HDR by Exelon Nuclear, IDNR, and SEA (Appendix Reports B-2 through B-7). Five fish kills that occurred from 2001 through 2007 were identified in the information provided to HDR. Each of these events occurred during June, July, or August. Two of the kills occurred in 2001. The first took place in late July and the second on August 27-28. A third kill was reported on July 30, 2004, the fourth on June 28, 2005, and the fifth occurred over an extended period of time during August 21-28, 2007. No additional information regarding fish kills has been provided to HDR since 2009. Therefore, it is assumed that no reportable fish kills have been observed at Braidwood Lake since August, 2007.

Little information was provided for the fish kills that occurred in late July and August, 2001. The species involved and the extent of dead fish observed during the first event in July were not included in the information received by HDR. The second fish die-off in late August was dominated primarily by gizzard shad that comprised more than 95% of all fish observed. The remaining species involved in the die-off in decreasing order of relative abundance included, freshwater drum, quillback, carp, largemouth bass, channel catfish, redhorse spp., smallmouth bass, and bluegill. With the exception of gizzard shad, the majority of the fish were located from the mid-point of the cooling loop to the intake. A report submitted by SEA indicated that warm water temperatures and/or low dissolved oxygen levels were the most likely factors that contributed to the fish die-off in July. SEA also indicated that the die-off in late August was most likely the result of depleted dissolved oxygen levels that occurred in the lake following an extensive phytoplankton bloom collapse, which is a natural phenomenon that can occur in highly productive waters during summer months. Dissolved oxygen measurements throughout the majority of the lake were at or below minimum levels necessary to support most fish species.

A third fish die-off at Braidwood Lake was investigated on July 30, 2004. Gizzard shad was the dominant species involved, although channel catfish were also observed. The gizzard shad appeared to be in an advanced state of decay suggesting that the actual die-off occurred earlier in the week. Water quality parameters at the time of the incident were not included in the brief summary report provided to HDR, which suggest they were not measured concurrent with the fish die-off. Water quality measurements were taken in early October following the fish die-off. During this period of time, DO levels of 3.8 ppm and a water temperature of 29.2 °C were recorded at a depth of one foot below the surface, just north of the south boat ramp. At a location several hundred feet from the lake make-up discharge from the Kankakee River, more favorable dissolved oxygen (7.6 ppm) and water temperatures (26.5 °C) were measured. DO readings at this location were stratified exhibiting a decline to 5.3 ppm at 40 feet, while water temperature showed minimal decrease with water depth.

In 2005, an inspection of a fish die-off was conducted on 28 June. Formal counts of fish were not conducted at this time, but field assessments indicated that a fairly substantial die-off involving several species had occurred. Gizzard shad was again the most numerous species affected and fish carcasses were observed throughout the majority of the lake. Additional species observed included threadfin shad, quillback, largemouth and smallmouth bass, carp, and channel catfish. Water quality measurements during this event were not provided to HDR and are assumed to be unavailable.

Rob Miller of IDNR and Jeremiah Haas of Exelon Nuclear investigated another fish die-off that was first reported at Braidwood Lake on August 21, 2007. The majority of the dead fish observed were either large gizzard shad or threadfin shad up to five inches in length. Channel catfish were also prevalent, with only a few carp, largemouth bass, and flathead catfish being observed. Most of the fish were distributed in close proximity to the north boat ramp due to prevailing south winds. The number of dead fish observed decreased towards the south (hot) end of the cooling loop. During the afternoon of 21 August, surface water temperature was 35.3 °C and DO was near 3 ppm at a sampling point several hundred yards from the south ramp. Four separate water temperature and DO readings were also conducted at the north ramp between 1210 hrs and 1658 hrs. Water temperature increased from 30.3 to 33.9 °C over the course of that time interval. Dissolved oxygen was measured at 3.1 ppm at 1210 hrs and increased to 6.7 ppm during the third reading at 1530 hrs. DO levels decreased during the last reading at 1658 hrs to 5.9 ppm. Oxygen depletion appeared to be the factor responsible for the August fish kill that occurred at Braidwood Lake in 2007.

4.0 SUMMARY AND RECOMMENDATIONS

4.1 Summary. Braidwood Lake is a 2640 acre, partially perched cooling lake that was first impounded in 1980-1981 after several old strip-mine pits were inundated with water from the Kankakee River. The lake has received supplemental stockings of both warmwater and coolwater fish species since the late 1970's. However, stocking efforts of species including walleye, tiger muskie, smallmouth bass, and hybrid striped bass have not produced a sustainable quality fishery, which is most likely due to warm water temperatures that are currently common in the cooling lake throughout the summer months. Water quality, particularly water temperature, improves as the water moves from the southern (hot) end of the cooling loop toward the northern (cool) end of the lake.

Fisheries surveys have been conducted by IDNR at Braidwood Lake annually from 1980 through 1992, in 1994, and at two year intervals from 1997 through 2007. Forty-five species of fish and two hybrid taxa (tiger muskie and hybrid sunfish) have been included among the 12 families of fish collected. River redhorse (one individual captured in 1999) is the only species that has been collected which is currently listed as protected in Illinois. Several of these species were rarely collected, were the result of supplemental stocking efforts, or have not been collected during the past ten years of sampling. In 2009, HDR collected 24 species and two taxa (hybrid sunfish and small unidentified young-of-year sunfish species) among the 2143 fish collected. Similar results were observed in 2010 when 25 taxa representing eight families were included among the 2432 fish collected by electrofishing, trap netting, gill netting, and hoop netting. Several taxa that were collected by IDNR during previous surveys conducted from 1980 to 2007 were not collected in either 2009 or 2010. However, five species (shortnose gar, blue catfish, bigmouth buffalo, fathead minnow, and rosyface shiner) were captured in 2009 that had not been captured during previous sampling efforts (HDR 2010). In 2010, three species that had not been collected by the ILDR were captured. Two of these species, blue catfish and rosyface shiner, were also collected in 2009, while a third species, smallmouth buffalo, had not been captured during any of the previous studies. In 2010, 39 blue catfish were collected by gill nets and hoop nets, 20 rosyface shiner were collected by electrofishing, and a single smallmouth buffalo was collected by one of the trap nets. No threatened or endangered species were encountered in either the 2009 or 2010 lake surveys. Since 1980, 51 species of fish and two hybrids (tiger muskie and hybrid sunfish) have been collected at Braidwood Lake by the IDNR and HDR.

The Braidwood Lake Fish and Wildlife Area has evolved through three distinct phases since its inception prior to the 1980's. Originally, several surface mined pits existed at the site until the lake was impounded with water from the Kankakee River during 1980 and 1981. The lake continued to function in this capacity until July 29 and November 17, 1988 when Braidwood Station began commercial operation of Units I and Unit II, respectively. From 1980 through July 1988, Braidwood Lake did not receive any thermal loading from Braidwood Station. Since 1988, the lake has functioned as a cooling loop for the operation of the Station. Currently, the lake is best suited to support a warmwater fishery due to the warm temperatures prevalent in the lake during summer months. Dominant species currently found in Braidwood Lake include gizzard shad, threadfin shad, bluegill, channel catfish, and carp. Additional species such as largemouth bass, green sunfish, flathead catfish, spotfin shiner, bluntnose minnow, and sand shiner are also commonly encountered. Excluding several of the stocked taxa that have been introduced into the lake, the taxa encountered have also been collected from the Kankakee River, which is the source of make-up water for the lake. With the possible exception of common carp and channel catfish, these species are better suited to conditions that exist within the river. Survival of individuals that may be introduced into the lake with the make-up water is limited by the elevated water temperatures that exist within the cooling loop during summer months.

Braidwood Lake can be currently described as a well buffered body of water with elevated water temperatures, high levels of total dissolved solids (TDS), phosphates, and nitrates. Primary productivity in the lake can be very high in conjunction with algal blooms that occur throughout the lake, especially during the June through August period. These blooms are driven by the high nutrient levels that occur within the lake. In recent years, phytoplankton has replaced aquatic macrophytes as the principal source of primary production. The lake can also display relatively large diurnal fluctuations in dissolved oxygen measurements, particularly during the summer when oxygen is produced in large quantities by photosynthesis during the day and used in large quantities by respiration and decomposition during the night. In addition, Braidwood Lake can stratify during certain portions of the year, which has led to anoxic (oxygen depletion) or near anoxic conditions throughout the hypolimnion (stratified bottom layer of water below the thermocline) as a result of respiration and decomposition from a collapsing algal bloom. Even in the surface waters of the epilimnion, dissolved oxygen readings of less than 4 ppm have been reported following an extensive and rapid die-off of an existing phytoplankton bloom. It is during these periods when water temperatures are elevated and dissolved oxygen levels are low that fish die-offs occur within lake. The conditions described in this paragraph should not be expected to change at Braidwood Lake in the foreseeable future.

*4.2 **Recommedations.*** Five separate fish die-offs attributed to low DO levels were observed at Braidwood Lake between 2001 and 2007. It is expected that the conditions which led to those five events will not change or improve in the foreseeable future. Therefore, it should be assumed that fish die-offs will continue to occur when algal blooms crash and oxygen depletion occurs. Substantial fish die-offs within the cooling loop could adversely affect both the operation and maintenance of Braidwood Nuclear Station.

Currently, there are no practical or simple solutions that could prevent the occurrence of fish die-offs at Braidwood Lake. It should be anticipated that fish die-offs will continue to occur at the lake on a fairly regular basis. Therefore, it would be advantageous if a reliable sampling protocol or set of procedures were developed that would reasonably predict fish die-offs which may adversely affect the operation and/or maintenance of the Station. With advanced warning the Station would be informed of a potential reportable incident, regulatory agencies could be notified, and crews responsible for fish disposal could be put on alert to help manage the risk associated with a substantial fish die-off. HDR believes this can be accomplished by conducting routine visual inspections of the lake, monitoring dissolved oxygen levels, and by having a basic understanding of environmental conditions that may trigger these events, especially weather conditions.

HDR recommends a two tier sampling procedure that may be utilized to help predict the onset of a possible reportable fish die-off. We recommend that visual inspections of the lake and water quality measurements be conducted routinely throughout the year, particularly during the warm weather months, if budget allows and staff is available to monitor the lake. The frequency of observations and the intensity of the water quality measurements should be discussed by the management who would analyze risk management at Braidwood Station. Historically, all the fish die-offs at Braidwood Lake have occurred during the warm weather period of June through August. This is the period of time when water in the cooling loop is the warmest and dissolved oxygen levels can fall substantially following die-offs of extensive phytoplankton booms. Therefore, this is the most critical period of time to monitor existing conditions that could result in a potential problem (May through September). Sampling on a less frequent basis throughout the remainder of the year may provide additional information that could be useful to the Station and possibly alert the Station of an impending problem which may not have been identified in the past. Water quality measurements should include dissolved oxygen readings at a minimum because fisheries biologists that have investigated these events in the past have concluded that the mortality of fish was the result of oxygen depletion. The most effective way to monitor dissolved oxygen levels within the lake would be through the use of a permanently fixed continuous water quality samplers and data loggers installed at several depths that could be programmed to take measurements at predetermined time intervals. The number of water quality samplers purchased or the type of sampler utilized would be dependent upon the desired results and cost of the equipment. Ideally, the best system would allow the sampling unit to take measurements at programmed time interval (perhaps every 15 minutes to daily), would measure at least DO, water temperature, and pH, could provide instantaneous readouts to Braidwood staff without having to manually go into the field to download data, and would require minimal maintenance or calibration to operate. The price range of this type of equipment is highly variable depending on the unit selected, the anchoring mechanism for the unit if required, battery life, the number of parameters measured, etc. An alternative to this approach would be to utilize a technician to manually take these measurements. The disadvantage of this approach is the number of readings that could be taken on a daily basis and the time involved to conduct the water quality analysis in the field.

Water quality at Braidwood Lake should be monitored on some predetermined routine basis. That could be at least weekly throughout the year or perhaps only through the more critical time period of approximately June through August. The two tiered sampling approach would be initiated when dissolved oxygen readings hit a pre-determined trigger point (perhaps 5 to 6 ppm). Once DO readings decrease to the trigger point, sampling frequency should be increased to at least hourly. If automatic samplers are not used, field technicians should be in the field by sunrise when DO readings are typically the lowest. If automatic samplers were utilized, dissolved oxygen, temperature and other water quality parameters could be tracked throughout the day. This would become important if DO readings ranged from 4 or 5 ppm in the morning to 7 or 8 ppm in the afternoon. This information would indicate that photosynthesis is still occurring during the daylight period, which would replenish DO levels in the water and reduce the risk of a fish die-off. However, if DO levels were 4 or 5 ppm in the morning and only increased slightly throughout the day, this would indicate very little oxygen production due to photosynthesis. This condition would lead to a greater oxygen deficit during the evening, and could indicate the onset of a phytoplankton bloom die-off that could trigger a fish kill. Once DO levels approach 3 ppm, Station management could be notified of a potential problem, increased visual inspections of the lake could be conducted, and fish cleanup and disposal crews could be notified and put on standby status.

Additionally, Braidwood staff should be aware of weather patterns that can influence these events. When phytoplankton blooms are prevalent and several cloudy days with little or no wind are forecast, massive dies offs of the bloom and subsequent oxygen depletion throughout the water column should be anticipated. Increased sampling of DO during these weather patterns is advisable in conjunction with an increase in the frequency of visual inspections at the lake for moribund or dead fish. An increase in water clarity or transparency within the lake would also be expected to occur as the phytoplankton population crash is in progress.

Visual inspections for fish die-offs should be conducted around the entire cooling loop as prevailing winds may push most of the fish toward one end of the lake. HDR recommends water quality measurements be conducted at a depth of approximately one meter, if multiple depths are not sampled. If only one sampling location is selected, that location should be located near the approximate mid-point of the cooling loop. The number of water quality stations sampled should be determined by Exelon management or an advisory staff. It is further recommended that an advisory team should be formed to devise an effective sampling program and set of procedures that can effectively monitor conditions within the lake. HDR is willing to participate and interact with the advisory team to provide expertise in the development of an effective sampling program.

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6.0 ADDENDUM

The following information was provided to the authors of this document after the report had been finalized and prepared for publication. The information received was titled "Braidwood Lake 2010 Fisheries Field Activities Summary". This information is pertinent to Section 3.3 (Length-Frequency Distributions) pages 3-19 and 3-20 that refers to the relatively large percentage of small blue catfish that were captured in 2010. The authors were uncertain of any recent stocking history, if any, of blue catfish in Braidwood Lake. The information that was provided below indicates that the smaller fish that were observed in 2010 were the result of the stocking activities that took place in 2010 by IDNR and not the result of natural reproduction.

Fish Stocking Activity in 2010

- 46,160 4-inch largemouth bass fingerlings equivalent to 20.6 fish/acre.

- 9,812 5.3-inch blue catfish fingerlings equivalent to 4.3 fish/acre.

Field Activities in 2010

- For the fourth consecutive year, MEHS fish habitat units were purchased by Exelon's Braidwood Generating Station. A total of 80 units were placed in groups positioned at previously selected locations throughout the lake in early April. This activity is a cooperative effort between Exelon, IDNR, and local bass fishing clubs.

- In early June the DC electrofishing unit was utilized at settings which have been shown effective for the collection of blue and flathead catfish. The following settings were used to obtain an amperage of close to one (1): pps - 7.5, "high" setting @ roughly 15-20%. Approximately two hours of effort were expended with no blue or flathead catfish collected. The unit did succeed in bringing small channel catfish skittering along the surface. Water temperature ranged from 88 to 95 °F. Skies were mostly sunny with air temperatures in the upper 80's. Areas selected for sampling included the channel leading towards the lake intake, obvious current breaks in the cooler portion of the lake, the "Arrowhead" area, and the lake make-up, which was receiving water. The poor results are felt to be a function of the high water temperatures.

- No major fish kills were reported in 2010.

APPENDIX A

PHYSICOCHEMICAL DATA

LIST OF TABLES

TABLE A-1

PHYSICOCHEMICAL MEASUREMENTS RECORDED CONCURRENTLY WITH ELECTROFISHING SAMPLES COLLECTED FROM BRAIDWOOD LAKE

Braidwood Station – 2010

PARAMETER	E-1	E-2	E-3	E-4	E-5	E-6	E-7	E-8
Date (First Sample Period)	**JUL 21**	**JUL 21**	**JUL 21**	**JUL 21**	**JUL 22**	**JUL 22**	**JUL 22**	**JUL 21**
Time	1230	1330	1430	1515	0705	0810	0905	1630
Temperature (° C)	38.2	36.4	35.4	35.8	33.8	34.0	33.7	35.6
Dissolved oxygen (ppm)	7.8	7.9	10.3	10.2	7.0	7.2	6.9	10.4
pH	8.5	8.5	8.5	8.5	8.4	8.4	8.3	8.5
Conductivity (μmhos/cm)	774	813	804	807	794	805	801	809
Date (Second Sample Period)	**AUG 19**	**AUG 19**	**AUG 19**	**AUG 19**	**AUG 19**	**AUG 19**	**AUG 19**	**AUG 19**
Time	0730	0815	0920	1015	1100	1300	1345	1200
Temperature (° C)	29.6	30.2	30.2	30.5	31.0	31.4	32.0	31.0
Dissolved oxygen (ppm)	3.4	4.8	7.7	7.1	7.9	6.8	9.6	8.6
pH	8.5	8.6	8.6	8.6	8.6	8.6	8.6	8.6
Conductivity (μmhos/cm)	850	850	844	842	840	837	838	840

TABLE A-2

PHYSICOCHEMICAL MEASUREMENTS RECORDED CONCURRENTLY WITH TRAP NETTING SAMPLES COLLECTED FROM BRAIDWOOD LAKE

Braidwood Station – 2010

PARAMETER	TN-1	TN-2	TN-3	TN-4	TN-5	TN-6	TN-7	TN-8
Date (First Sample Period)	**JUL 20-21**	**JUL 20-21**	**JUL 20-21**	**JUL 20-21**	**JUL 20-21**	**JUL 20-21**	**JUL 20-21**	**JUL 20-21**
Time	1730[a] 0750[b]	1737 0700	1749 0635	1753 0620	1716 0810	1803 0837	1844 0906	1635 0900
Temperature (° C)	36.7 35.7	36.8 35.7	35.5 34.3	35.5 34.3	34.4 33.0	34.7 33.8	33.6 33.0	33.8 33.0
Dissolved oxygen (ppm)	8.1 4.7	8.2 4.7	8.7 5.8	8.7 5.1	7.6 6.5	8.4 6.8	7.3 6.8	8.4 6.8
pH	8.5 8.4	8.5 8.4	8.5 8.4	8.5 8.4	8.5 8.4	8.5 8.4	8.5 8.4	8.5 8.4
Conductivity (μmhos/cm)	810 822	770 823	809 817	809 818	810 812	808 814	799 801	799 801
Date (Second Sample Period)	**AUG 17-18**	**AUG 17-18**	**AUG 17-18**	**AUG 17-18**	**AUG 17-18**	**AUG 17-18**	**AUG 17-18**	**AUG 17-18**
Time	1822 0700	1818 0715	1810 0735	1805 0745	1757 0800	1750 0815	1615 0830	1610 0845
Temperature (° C)	33.9 30.8	33.9 31.4	32.7 30.8	32.1 30.8	31.7 30.0	32.3 30.9	31.8 30.8	31.8 30.2
Dissolved oxygen (ppm)	6.2 1.9	6.2 1.4	7.4 3.0	7.7 2.7	9.4 4.5	9.4 3.6	8.2 4.7	8.1 5.1
pH	8.6 8.3	8.6 8.3	8.6 8.4	8.6 8.4	8.7 8.6	8.7 8.5	8.6 8.6	8.7 8.7
Conductivity (μmhos/cm)	860 856	856 862	860 853	856 851	851 846	856 851	850 836	847 832

[a]Top number represents subsurface readings taken 0.5 meter below the surface when the nets were set in the evening on July 20.

[b]Bottom number represent subsurface readings taken 0.5 meter below the surface when the nets were retrieved the next morning approximately 12 hours later on July 21.

TABLE A-3

PHYSICOCHEMICAL MEASUREMENTS RECORDED CONCURRENTLY WITH GILL NETTING SAMPLES COLLECTED FROM BRAIDWOOD LAKE

Braidwood Station - 2010

	GN-1 in Deep water (7-8 m)		GN-2 in shallow water (1-2 m)	
PARAMETER	**Surface**	**Bottom**	**Surface**	**Bottom**
Date (First Sample Period)	**JUL 21**		**JUL 22**	
Time	1615	1615	0900	a
Temperature (°C)	34.7	33.7	33.7	a
Dissolved oxygen (ppm)	12.2	7.6	7.0	a
pH	8.5	a	8.3	a
Conductivity (μmhos/cm)	804	801	800	a
Date (Second Sample Period)	**AUG 17**		**AUG 17**	
Time	1530	1530	1630	a
Temperature (°C)	31.8	31.6	31.7	a
Dissolved oxygen (ppm)	6.2	5.6	6.5	a
pH	8.5	a	8.5	a
Conductivity (μmhos/cm)	842	846	845	a

[a] Water quality measurement not taken.

TABLE A-4

PHYSICOCHEMICAL MEASUREMENTS RECORDED CONCURRENTLY WITH TRAP NETTING SAMPLES COLLECTED FROM BRAIDWOOD LAKE

Braidwood Station – 2010

PARAMETER	HN-1 DEEP WATER BAITED (7.5 m)		HN-2 DEEP WATER UNBAITED (7.5 m)		HN-3 SHALLOW WATER BAITED (2.0 m)		HN-4 SHALLOW WATER UNBAITED (2.0 m)	
Date (First Sample Period)	**JUL 20 (SET)**	**JUL 21 (LIFT)**	**JUL 20 (SET)**	**JUL 21 (LIFT)**	**JUL 20 (SET)**	**JUL 21 (LIFT)**	**JUL 20 (SET)**	**JUL 21 (LIFT)**
Time	1652	0935	1701	0945	1708	1000	1710	1015
Temperature (° C)	33.5[a] 33.5[b]	33.1 33.2	33.5 33.5	33.1 33.2	33.6	33.3	33.6	33.3
Dissolved oxygen (ppm)	6.8 6.8	6.8 6.5	6.8 7.0	6.8 6.4	7.1	6.7	7.0	6.7
pH	8.5	8.5	8.5	8.4	8.5	8.4	8.5	8.4
Conductivity (μmhos/cm)	798 798	820	797 775	819	799	808	799	812
Date (Second Sample Period)	**AUG 17 (SET)**	**AUG 18 (LIFT)**	**AUG 17 (SET)**	**AUG 18 (LIFT)**	**AUG 17 (SET)**	**AUG 18 (LIFT)**	**AUG 17 (SET)**	**AUG 18 (LIFT)**
Time	1545	0924	1540	0920	1555	0950	1550	0940
Temperature (° C)	32.0 32.0	30.8 30.8	32.0 32.0	30.8 30.8	32.0	30.8	32.0	30.8
Dissolved oxygen (ppm)	7.7 7.7	4.8 4.7	7.7 7.7	4.8 4.7	7.7	5.1	7.7	5.1
pH	8.6	8.7	8.6	8.7	8.6	8.7	8.6	8.7
Conductivity (μmhos/cm)	845 843	840 843	848 851	840 843	841	838	840	838

[a]Top number represents subsurface readings taken 0.5 meter below the surface.

[b]Bottom number represent deep water readings taken 0.5 meter off the bottom.

APPENDIX B

HISTORICAL WATER QUALITY AND FISHERIES DATA

LIST OF TABLES

APPENDIX REPORT B-1.

Results of Initial Braidwood Cooling Pond Survey by SEA Inc.

SEA Inc. was asked to conduct an initial water quality and ecological assessment of Braidwood Cooling Pond. The objective was to determine if the dense macrophytes were contributing to an increasing trend toward a higher pH in the pond. The results and discussion presented in this report are primarily based upon the samples taken and observations made on May 29 and 30, 2001, and on a preliminary review of water quality data from three sites taken on May 18, and June 14, 2001. SEA Inc. was also asked to investigate a fish kill on Braidwood Cooling Pond on August 27 and 28. The results of that investigation are in a separate report but some of that information is referenced in this report.

Overview of Methods and Results Presentation.

SEA's initial survey (May 29-30) consisted of:

- water quality parameters at several key sites with a Hydrolab Surveyor III, during both daylight and night conditions,
- measuring phytoplankton community respiration (light & dark bottle method).
- identification of macrophytes and observations on their distribution and abundance, and
- monitoring temperatures throughout the cooling loop.

The survey results are summarized in Tables 1,2, 3, and 4. Table 1 provides the results from key sampling sites that were selected to characterize the cooling pond. These sites were sampled three to four times over a 36-hour period. Parameters sampled with the Hydrolab included: Depth, Temperature, Dissolved Oxygen (D.O.), pH, Specific Conductance, and Redox Potential. Sample times included midday, just before sunset, and prior to sunrise.

Table 2. includes results from two sites for depth profiles, 24 hour duration light & dark bottles, and the SX discharge. Table 3. provides D.O. and temperatures sequentially around the cooling loop at midday. Table 4. lists the D.O. levels and % saturation at four sites prior to sunrise. Table 5 list the water quality analysis preformed by Test America at three locations on two dates. Figure 1. is a map identifying the sample locations listed in the tables.

Discussion of Results and Observations:

Braidwood Cooling Pond was characterized to SEA Inc. as a pond that was dominated or choked by macrophytes. Based on this characterization, we feel that Braidwood Cooling Pond has undergone a transformation to a system dominated by phytoplankton. Although we were not prepared to sample the phytoplankton for densities and identification, it was very obvious that an

intensive phytoplankton bloom was in progress. Secchi disc readings were only 0.30 to 0.35 m throughout the pond. Although we were unable sample the phytoplankton, we would suspect it is dominated by Blue-Green algae (Cyanophyta), based on the water temperatures, total phosphorous levels, high pH and apparent high densities.

Braidwood Cooling Pond appears to be a very dynamic system that receives energy subsidies in the form of heat, pumped circulation and make-up water from the Kankakee River. Several perched cooling ponds in the Midwest have had high macrophyte densities in their earlier years but usually become dominated by phytoplankton if they have heavy thermal loading. A switch to phytoplankton dominance is usually accompanied by a reduction in water transparency. Our Secchi disc readings were about 0.3 m which is about one half of the 2 ft or 0.6m)value listed in a privately produced fishing guide (Sportsman' Connection) published in 2000. Although we did not examine many of the isolated coves, we found Milfoil (*Myriophyllum verticillatum*) only in the last 1/3 of the cooling loop(Figure 1. sites7,8,9) and its abundance was spotty. The Sportsman' Connection fishing guide map had a much wider distribution of submerged, emergent and floating vegetation and appeared to be more in line with earlier descriptions SEA Inc. were given of Braidwood. Nutrients that were previously tied up by the macrophytes are now likely being taken up by the phytoplankton. The reduced water transparency due to the phytoplankton bloom will limit light to the submerged macrophytes and likely cause further reductions.

The intensive phytoplankton bloom that Braidwood is currently experiencing may have more potential for adverse impacts to the biological community than on operational impacts to the station. The water seems to be fairly well buffered and diurnal swings in pH were insignificant. Analysis of the water for alkalinity could confirm the buffering capacity. Blue-Green algae blooms may present problems with D.O. levels and in some rare cases may release toxins with impact other aquatic life.

The light & dark bottle (Table 2.) and the pre-sunrise D. O. levels (Table 4.) illustrated the intensity of the bloom. The light and dark bottles were at a 0.5 m depth at end of the discharge canal for 24 hours. Respiration in the dark bottled depleted the initial D.O. from 10.8 mg/l (158% saturation) to 1.37 mg/l (20 % saturation). The light bottle was supersaturated to the point the entire inside surface was coated with oxygen bubbles and the D.O. was 11.8 (174% saturation). The photosynthetic rate was much higher than could be measured due to the extensive formation of oxygen bubbles in the light bottle. The photosynthetic rate was so high that the light bottle should have been limited to 6 hours to obtain a better measurement of the gross plankton photosynthetic rate.

The pre-sunrise D.O. measurements (Table 4.) also reflect the high respiration rate of the plankton community. Most notable was Site #3 where D.O. levels dropped to 4.1 mg/l. The midday sampling on the first day (Table 1.) was conducted during bright and sunny conditions and D.O. levels at most sites were higher than midday samples on the following day when it was overcast. This

plankton community is so productive that D.O. levels can be expected to swing rapidly. During our survey, air temperatures were mild (high 65 F) and it was windy both days. Under a scenario of several hot summer days, with little wind, full operation of the station, followed by a cloudy day, D.O. levels could drop to the point that fish kills could occur. Some fish species will be already stressed by heat, saturation levels for D.O. will be lower, and high, predawn respiration rates could create a significant problem. Unfortunately, there are no operational changes the station can make to reduce this risk. The fish kill that did occur in late August was apparently a result of depleted DO that most likely resulted from the phytoplankton bloom die off.

Thermal refuges are critical to the survival of fish in heavily loaded cooling ponds. The deeper areas in the warmer end of the lake will not be refuges since adequate levels of oxygen are already absent from depths below 4 meters (Table 2.). However, the flow and slightly cooler temperatures at site 7 (figure1.) have maintained oxygen levels down to nearly 10 meters. If these refuges are eroded away during the summer, fishes will be stressed. Of the three key species listed in the Sportsman's Connection for Braidwood, both the walleye and crappie would be sensitive to D.O. at higher temperatures. Two fish kills occurred in Braidwood this summer, the first in late July was likely related to temperature, the second in lake August resulted from DO depletion.

Although our expertise is not in water chemistry, Braidwood Cooling Pond may be facing some water quality issues. One of the objectives of the survey was to determine if macrophytes were contributing to the increasing pH. A chart of pH values from 1989 to 1998 provided by the Braidwood Station indicated the increasing trend in pH has become more pronounced since 1997. Since this survey indicated macrophytes abundance was in a sharp decline, it is clear they are not contributing to the elevated pH of 9.1 to 9.2 (Table 1). The intensive phytoplankton boom present during the survey could have contributed to the elevated pH. The phytoplankton bloom had crashed by August 27 and 28 (fish kill investigation) and the pH had dropped to 8.6. It was not possible from this limited data to determine to what extent several factors may be contributing to the elevated pH. The cooling pond's buffering capacity, photosynthetic activity, blowndown rate, and plant operations are all potential factors to be investigated.

The Test America analytical results from three sites on 5/18/01 and 6/14/01 provides some information on water quality (Table 5). Orthro phosphate is a readily available form for plants and is quickly taken up. The detection limit listed by the lab was 0.06 ppm, which was too high to show any differences between sites or sample dates. Orthro phosphate levels in many Illinois lakes would be below 0.025 ppm. Total phosphate at the plant discharge on 5/18/01 was 5.5 ppm, which is very high. The Illinois General Use Water Quality standard is not to exceed 0.05 ppm in lakes or reservoirs over 20 acres. The plant appears to be the phosphate source and one possible explanation may be scale inhibitors commonly used by power plants. Scale inhibitors are typically high in phosphates but it is generally in a form not available to aquatic plants. Total phosphate levels on 6/14/01 were lower (0.18 to 0.28 ppm) but still elevated relative to other lakes.

Phosphates are a major concern as elevated levels can contribute to nuisance phytoplankton blooms.

Total Suspended Solids (TSS) on 5/18/01 were high (164 ppm) at the discharge and generally higher than expected throughout the pond. It is suspected that the plankton bloom may have been responsible for much of that elevation. This could have been confirmed by comparing the volatile to the non-volatile portion of the TSS.

Total Dissolved Substances (TDS), total hardness, calcium, sulfates and specific conductance are all correlated and generally exhibited increases from 5/18/01 to 6/14/01. The high evaporation rates in the cooling pond during the summer probably contributed to this increase. These parameters are of concern since they are indicators of potential scaling in heat exchangers. Lowering these levels would require an increase in make-up and blow-down rates. However it is recognized there are restrictions on make up withdraws and blow-down concentrations are regulated.

<u>Summary</u>
It appears that the Braidwood Cooling Pond plant community is changing from one dominated by macrophytes to phytoplankton. The phytoplankton bloom in May was very rich and has the potential to deplete D.O. to the point that fish kills could occur. There are few operational changes that the plant can take to prevent these potential events. Monitoring the cooling pond and preparing regulatory agencies for these potential changes may be a way to help manage these risks. Unfortunately the fish kill in late August confirmed the potential for these kills. The phytoplankton bloom may a contributor to the increasing pH. The high total phosphate level that appears to be coming from the plant may be fueling the phytoplankton bloom. Further investigation of the factors that may be contributing

APPENDIX REPORT B-2.

DRAFT

Investigation of Fish Kill on Braidwood Cooling Pond August 27-28, 2001

Executive Summary:
Strategic Environmental Actions Inc. (SEA Inc.) conducted an investigation of an on-going fish kill on Braidwood Cooling Pond on August 27 & 28, 2001. The investigation consisted of surveying the shoreline to determine the extent of the kill and the species involved, and water quality analyses for pH, temperature, and dissolved oxygen.

Most of the fish appeared to have been dead for about 24 hours and more than 95% were gizzard shad. The other species involved in descending order of relative abundance were freshwater drum, quillback, carp, largemouth bass, channel catfish, redhorse, smallmouth bass and bluegill. Other than gizzard shad most of the dead fish were located between the mid –point in the cooling loop to the intake. Throughout most of the cooling pond, dissolved oxygen levels were at or below the minimum levels necessary to support most fish and was the most likely cause of the kill. Water clarity was very high and suggested a recent die off of much of the phytoplankton, which is usually followed by oxygen depletion. This is a natural phenomenon that can occur in highly productive lakes during summer months. Temperatures throughout most of the lake were within the tolerance limits of the species involved in the kill. It does not appear that operations of the power station had a direct impact on the fish kill.

Methods Overview and Results Presentation:

SEA Inc. arrived at 5:00 PM on August 27 and conducted an initial survey of the main portion of the cooling loop and checked temperature, dissolved oxygen (DO), and pH at two locations. The investigation continued at sunrise on August 28, and included investigation of many of the coves on the lake and water quality analyses at sixteen sites. Water quality analysis was conducted with a Hydrolab Surveyor III. Measurements were for depth, temperature, DO, pH, specific conductance, and redox potential at the surface (0.5 Meters) and then at one-meter intervals to the bottom.

The water quality sampling locations are shown on Figure 1. Dissolved oxygen profiles from selected sites are illustrated in Figure 2. Figure 3 illustrates DO concentrations at one-meter depth at all sites. The results of the water quality analyses are presented in Table 1. The station hourly inlet and outlet water temperatures for August 24 through August 27 are listed in Table 2.

<u>Discussion of Results and Observations:</u>

Upon arrival the investigation began at the south access boat ramp near Site 3 (Figure 1.) and proceeded around the cooling loop toward the plant intake. Near Site 3 several gizzard shad in the 170 to 220 mm were observed. They appeared to have been dead for 12 to 24 hours. In the portion of the pond between sites 5.5 and 5.75 there were greater numbers of gizzard shad along the shoreline and a few largemouth bass. The largemouth bass appeared to have been dead for more than 36 hours. The number of fish appeared to increase as the investigation progressed around the cooling loop. The largest concentrations of dead fish were in several coves on the East side of the lake near Site 8. The back 20 to 35 ft. of the cover were covered solid with dead fish. Gizzard shad comprised more than 95% of the fish in these coves and were represented by three size classes. The other species involved in descending order of relative abundance were freshwater drum, quillback, carp, largemouth bass, channel catfish, redhorse, smallmouth bass and bluegill.

There are two factors that may have influenced the distribution of dead fish. First, the temperature gradient becomes more favorable for fish toward the intake end of the cooling loop. Second, the circulation of water around the cooping loop would tend to concentrate dead fish in the intake area of the cooling pond. The concentration of fish in coves at Sites 8 and 8.5 was most likely an accumulation resulting the above mention factors and wind direction. However DO levels at Site 8.5 were only 2 ppm (Table 1, page 3) at a time of day when they should have been much higher. This level of DO is not adequate to support most fishes. Several YOY freshwater drum were observed at the surface which had recently died or were about to. This kill did involve many fish, but during this survey many live fish were observed on sonar in the cooler end on the lake. Bluegills exhibiting normal behaviors were observed in the cove just East of Site 2.5.

Dissolved oxygen levels at the plant intake were 3.5 ppm at the surface and 1.2 ppm at 3 meters (Table 3) during the evening of August 27. Percent DO saturation was 49% and 17% respectively. Surface DO level taken on May 29 by SEA Inc. at this same location, at the same time of day was 9.3 ppm and 117% saturation. The DO levels at Site 3 were 3.8 ppm on August 27 which was much lower than the 8.0 ppm taken at sunset on May 29. On August 28 just prior to sunrise the DO at Site 3 was 3.2 ppm only slightly lower than the previous evening indicating little diurnal variation. On May 29 the overnight drop in DO at Site 3 was 50%.

The surface DO level at Site 4 on August 28 was 2.9 ppm and dropped to 0.7 ppm at 4 meters. Surface DO levels Sites 4.5, 5, 5.5, and 5.7 were even lower

ranging from 2.4 to 2.1 ppm. Site 6 had one of the higher DO levels at 4.4 ppm. Site 8 and 9 had the highest surface DO levels at 4.8-ppm (Table 1).

Temperatures throughout most of the cooling pond were within the tolerance limits of most fish species and there had been no major temperature changes in the last few days (Table 2). The oxygen levels throughout most of the lake suggest that depleted oxygen levels were the most likely cause for the fish kill. Such kills can naturally occur in highly productive lakes or ponds that may exhibit large diurnal swings in DO levels due to high daytime photosynthetic rates and high respiration during the night. The survey SEA Inc. conducted on May 28 and 29 suggested Braidwood Cooling Pond was a very productive and the potential existed for an oxygen depletion fish kill. This survey noted several changes in the cooling pond that suggested such a kill had occurred. There was no indication that the fish kill was directly related to the operation of the power station.

SEA Inc.'s initial investigation in May was to assess if the historically high abundance of macrophytes (rooted aquatic vegetation) was contributing an increasing trend in pH. What was observed was an intensive phytoplankton bloom that limited light penetration and almost no healthy macrophytes remained. Water transparency measured with a Secchi Disc was only 0.3 meters. Diurnal swings in DO levels were very pronounced and at some locations dropped to 4 ppm just prior to sunrise and reached supersaturation levels by mid day. Under these conditions any major change in nutrients, reduced light intensity, increase in biological oxygen demand, or other factors could result in oxygen depletion. Braidwood Cooling Pond appeared to be undergoing a transition from a system dominated by macrophytes to one dominated by phytoplankton.

One of the most notable changes during this investigation was the dramatic change in water transparency. There was no phytoplankton bloom and Secchi Disc readings had increased up to 2.7 meters. Plankton samples indicated very low levels of phytoplankton but high abundance of zooplanktors (primarily Rotifers and Cladocera). Oxygen levels were typically from 29% to 66% of saturation as opposed to May when most midday levels were at or above saturation. As discussed earlier, there were only minor differences in diurnal oxygen levels. All the above factors suggest the phytoplankton bloom had recently crashed. There were no remaining macrophytes to fill the niche as primary producers. Not only was there a reduction in photosynthetic activity to produce oxygen, there was an increased oxygen demand from decomposition and respiration of the abundant consumers. It is suspected that oxygen levels a day or two prior to this investigation may have been even lower than observed.

The one-meter DO levels were lowest toward the center portion of the cooling loop (Figure 2). From Site 3 to Site 6.5 (with the exception of Site 6) DO levels were 3.1ppm or less. A similar pattern of low DO was noted at Sites 3 and 4 in early morning samples taken in the May survey. Factors contributing to lower DO

levels were not clear, but it suggest this may be one of the most sensitive areas of the cooling pond to oxygen depletion. Additional sampling would be required to attempt to identify the cause and to eliminate any data bias associated with the time of day samples were taken.

The unique changes in water depths and flow velocities in Braidwood Cooling Pond have a major influence on DO levels and temperature stratification. Areas of the cooling pond which were deep and not in a high velocity areas exhibited a more normal DO curve from top to bottom (Figure 3). At Site 2.5, DO declined quickly between 6 and 8 meters and coincided with thermal stratification. At Site 4, the DO declined rapidly between 2 and 3 meters where thermal stratification was apparent (Table 1). In contrast, Sites 5.5 and 7 were located in areas with high velocities and had fairly consistent DO levels and temperatures from top to bottom (Figure 3). This is quite different from the DO and temperature profiles in more typical perched cooling ponds and better utilizes the entire volume for cooling and may also provide for better thermal refuges for fish. During this last incident it is unlikely Site 5.5 was an effective refuge for DO since levels were below 2.5 ppm. These DO levels were however due to lower DO levels throughout the cooling pond rather than depletion at this site.

Braidwood Cooling Pond appears to be undergoing a transition from a pond dominated by marcophytes to one dominated by phytoplankton. During such a transition major swings may be expected as different components of this ecosystem adapt to this change. Over time one would expect the amplitude of these changes to moderate. During the May survey the intense phytoplankton bloom appeared to eliminate the macrophytes. There were major differences in diurnal DO levels suggesting a very productive system with heavy respiration and decomposition demands at night and supersaturation from photosynthesis during the day. This survey indicated a major loss of the phytoplankton, no remaining macrophytes to carry on primary production and enough respiration and decomposition to reduce oxygen below the levels to maintain many fishes. Additional studies on nutrients and the dynamics of the plankton would be needed to better identify the changes that may be taking place in this cooling pond. Decisions on the operational management of this cooling pond as well as the fishery management need to consider that this pond may be going through transitional changes.

APPENDIX REPORT B-3.

Results of Braidwood Cooling Pond Water Quality Analysis from August 27 & 28, 2002

SEA Inc. was asked to sample Braidwood Cooling Pond for a number of water quality parameters on August 27, 2002. This sampling effort was to provide data to address operational concerns related to a trend toward an increasing pH and increased scaling at the plant intake. This report provides the results of the August 27and 28, 2002 sampling and makes comparisons with data from previous sampling efforts by SEA Inc. and with other data provided by the Braidwood Station to SEA Inc.

Executive Summary:

Braidwood Cooling Pond has high levels of alkalinity, total hardness, TDS, sulfates, magnesium, calcium and total phosphates. These parameters are of concern since they have the potential for increased problems with scaling, increasing pH, compliance with cooling pond blow down limits, and maintaining a recreational fishery. Several of these parameters had significant increases in the past year and could lead to greater operational costs and problems in the near future.

The excess of nutrients in the water has contributed to plankton blooms that have eliminated the submerged aquatic plants, contributed to diurnal increases in pH, and lowered dissolved oxygen levels. Swings in the dissolved oxygen level associated with the plankton blooms could lead to fish kills.

The plan to increase the blow down rate from the cooling pond is a good long-term solution to the continued viability of the cooling pond. Continued monitoring of the cooling lake water quality would be important in evaluating the effectiveness of the increased blown down rate, the impacts of H_2SO_4 additions, and other water treatment changes.

Overview of Methods and Scope of the Sampling Effort.

The investigation on August 27 and 28 of 2002 consisted of collection of water samples from various depths at six sites around Braidwood Cooling Pond (BCP), as well as in-situ profile measurements for temperature, conductivity, pH, and dissolved oxygen. A contract laboratory analyzed the water samples for the eleven chemical parameters as listed in Table 1. In addition to chemical samples, the primary production rate of the phytoplankton community was determined at two sites by the light/dark bottle method, and plankton samples were taken for

qualitative analysis. Water transparency was measured with a Secchi disc at each site. The sampling sites used in this investigation are identified on Figure 1.

Additional investigations by SEA Inc. referenced in this report include June 28, 2002, April 29,2002, March 6, 2002, January 10, 2002, August 28, 2001 and May 29, 2001. The purpose and scope of each of these investigations varied but none were as extensive for water quality as the August 2002 investigation. In several cases SEA Inc. collected the water samples for Betz and the results were not made available to SEA Inc. Data from the above referenced studies is included to help identify trends and provide a single summary of data for ongoing investigations. The discussion of results is based on and limited to the studies referenced in this report and those provided to SEA Inc.

Presentation of Results and Related Discussion:

The analytical results of the water quality analysis are presented in Table 1. The eleven parameters were selected to provide input to the water quality issues that were described to SEA Inc. These issues include increasing trends for rising pH, scaling, algal blooms, and recent fish kills.

Table 1 indicates abnormally high levels for TDS, alkalinity, hardness, sulfates, magnesium, calcium, and total phosphorus throughout the cooling pond. These values were not unexpected and support the ongoing program to increase the blow down rate from the cooling pond. These values can be put into perspective by comparing the cooling lake sites to the same values for the make –up water pond (Site 7P in Table 1), which is the source water. The cooling pond values for the above mentioned parameters ranged from 2X to nearly 9X higher than the make-up water.

The alkalinity is a measure of water's capacity to neutralize acids and is a result of the quantity of compounds in the water that shift the pH to the alkaline side. Bicarbonate and carbonate ions normally make up most of the alkalinity. However in waters with a pH of greater than 8.3, carbonate alkalinity is the primary form. Alkalinity is very high throughout the cooling pond and ranged from 340 to 360 mg/l in the upper water layers (Table 1). In contrast, the make-up water pond alkalinity was 150mg/l. Other comparisons include a 14-year average for Clinton Lake of 168 mg/l and an IEPA survey of 63 lakes around the state with alkalinity ranging from 20 to 270 mg/l. The high alkalinity gives Braidwood Cooling Pond has a great capacity to neutralize acids.

Hardness is a measure of the divalent metallic cations present in water (such as calcium, magnesium, ferrous iron, and manganous manganese). Calcium reacts with bicarbonate ions in water to form calcium carbonate

scale. Magnesium typically reacts with sulfate; the ferrous ion with nitrate; and the manganous ion with silicates.

Hardness and alkalinity in water are related. Carbonate hardness is the part of total hardness that is chemically equivalent to the bicarbonate plus carbonate alkalinities present in the water. If alkalinity is greater than total hardness then total hardness is equal to the carbonate hardness. In cases such as in BCP where alkalinity is less than the total hardness then alkalinity equals carbonate hardness (as $CaCO_3$) and the remaining part of hardness is the noncarbonate compounds such as magnesium sulfate.

The total hardness in the upper layers of August 2002 samples ranged from 680 to 720 mg/l (nearly twice the alkalinity level) so other ions are contributing significantly to the hardness. The total hardness levels in 2002 were significantly higher than the 435 to 531mg/l range reported for two dates in 2001 by Test America (Table 2). This increase in hardness is a reason for concern.

Sulfate levels in the August 2002 samples ranged from 330 to 390 mg/l (Table 1). These levels are much higher than the make up water (58 mg/l) and to some extent may reflect the history of portions of the cooling pond as strip mine lakes that are characteristically high in sulfates. However there seems to be a significant increase in sulfates in the past year. In the Test America data from two dates in 2001, sulfates ranged from 230 to 270 mg/l (Table 2). Sulfate levels in samples collected by SEA Inc. on April 29, 2002 were 250 mg/l (Table 3). Samples collected by SEA Inc. on June 28,2002 had levels ranging from 320 to 340 mg/l (Table 4). The sulfate increase noted in the summer of 2002 may reflect the use of H_2SO_4 to reduce pH levels in the cooling pond. This level of sulfates may be a concern since it significantly contributes to the non-carbonate hardness and can be a factor in scaling.

Calcium levels in the August 2002 samples were about twice the levels in 2001and ranged from 130 to 140 mg/l (Table 1). The 2001 Test America data ranged from 41 to 58 mg/l (Table 2) and the make-up water in August 2002 was 57 mg/l. The increase in calcium may be a major concern since with the high carbonate alkalinity there is a high potential for scaling.

Magnesium levels in the August 2002 sampling ranged from 84 to 93 mg/l. These levels were essentially the same as the 81 to 91 mg/l reported by Test America in 2001. Magnesium levels are however elevated compared to the make-up water that had only 20mg/l or when compared to the 14-year average for Clinton Lake of 32.2 mg/l. Magnesium levels are also a concern due to their potential for scaling.

Total dissolved solids include all of the above parameters and other dissolved solids in the water. As would be expected, the August 2002 samples are elevated and are higher than the previous year. The August 2002 TDS ranged from 930 to

1100 mg/l (Table 1) compared to a range of 684 to 788 in the 2001 Test America data (Table 2). The make-up water was 280 mg/l in the August 2002 sample.

Sodium levels in the August 2002 samples ranged from 60 to 64 mg/l in the upper water layers. Comparable data from 2001 was not available, but the sodium levels in the make–up water was 9.1 mg/l in the August 2002 sample (Table 1).

There were only minor variations in the concentrations of the above parameters from site to site in the upper water layers. Sulfates and TDS were slightly higher at the discharge (Site 2) end of the cooling pond. Levels for alkalinity, sulfates, TDS, and total hardness were slightly lower near the bottom at the 10 and 11-meter depths at Site 4 and Site 7 respectively.

Phosphorus and nitrogen are essential nutrients for aquatic plants. Concentrations in the water are typically low since phytoplankton or macrophytes quickly assimilate these nutrients. Total phosphate levels in the August 2002 samples were at 1.5 mg/l throughout the cooling pond (Table1). Samples collected on April 2002 ranged from 1.3 to 1.6 mg/l (Table 3). Total phosphates at two sites in the June 2002 samples were 1.8 mg/l (Table 4) in the upper water layers and 4.9 mg/l at a well stratified, 10-meter depth at Site 4. The Test America data for 2001 had total phosphate levels from 0.16 to 5.5 mg/l (Table 2). The 5.5 mg/l occurred at the discharge on May 18 of 2001 and levels dropped to 0.77mg/l at the plant intake on the same date. This suggests the Station was the source of the phosphate. Although the levels were slightly lower in 2002, they were consistent throughout the cooling pond suggesting that phosphates are in excess and not a limiting factor for phytoplankton. The total phosphate levels in the make- up water were 0.12 mg/l and 0.19mg/l in June (Table 4) and August of 2002 respectively.

Relative to most lakes the phosphate level in BCP is quite high. Since BCP is a cooling pond and not a lake, it is not subject to the Section 302.205 regulation that limits phosphorus in a lake of 20 acres or more to < 0.05mg/l. The high phosphate level is of concern since these levels support phytoplankton blooms and the breakdown of the phosphorus compounds can also contribute to increased pH.

Ortho-phosphate is the form that is most readily available to aquatic plants. These levels are usually very low in lakes since plants normally take it up within minutes. Ortho-phosphate levels were consistent throughout the lake in the August 2002 samples and ranged from 0.38 to 0.44mg/l. Like the total phosphate levels, the ortho-phosphate levels are consistently high suggesting it is in excess of the needs of the phytoplankton. The August 2002 levels were significantly higher than the <0.06mg/l reported by Test America in 2001(Table 2). Ortho-phosphate level in the make-up water was 0.19 and although lower than the lake levels is relatively high.

Nitrate-nitrites are the other essential or potentially limiting nutrient for phytoplankton. The August 2002 nitrate-nitrate levels were rather low in most of BCP with the highest level of 0.1mg/l at the discharge. The rest of the cooling pond ranged for <0.01mg/l (below detection limit) to 0.08 mg/l in the upper waters. Unlike most other parameters, the nitrate-nitrite level in the make-up water was significantly higher at 2 mg/l (Table 1). Nitrate-nitrite data could not be compared to the 2001 Test America data because the detection limit of 1.0 mg/l was too high for a meaningful assessment.

The ratios of phosphates to nitrates-nitrites suggest BCP would be described as a nitrate-nitrites limited water rather than phosphate limited with respect to phytoplankton growth. However the limited phytoplankton data that SEA Inc. has collected on BCP suggests that bluegreen algae dominate BCP for much of the summer. Bluegreen algae have the unique ability to utilize atmospheric nitrogen and are not as limited by low nitrate-nitrite levels. Bluegreen algae made up 88.5 % and 76.4% of the algae at Sites 3 and 7 respectively in the August 2002 sample. The dominant bluegreen algae were *Lynabya* and *Oscillatoria*. Bluegreen algae are the least desirable algae and are favored by high pH and warmer temperatures. Bluegreen blooms can impart a smell or taste to water, deplete dissolved oxygen, and in some cases generate toxins that may impact aquatic life.

The ammonia levels appear reasonable relative to the high productivity in BCP. As productivity increases and oxygen is reduced at deeper depths there may be increases in ammonia. The abnormally high level at 5 meters at Site 9 (Table 1 may have resulted from the water sampler disturbing the bottom sediments where ammonia is likely to be higher.

The aquatic plant community in BCP appears to have undergone a change in the last two years. SEA Inc.'s first investigation of BCP on May 29, 2001 was to assess the impact of the extensive growth of macrophytes (rooted aquatic plants) on the pond's increasing pH. That investigation found an extensive phytoplankton bloom and the few macrophytes that remained were being shaded out by the phytoplankton bloom. SEA Inc. projected that BCP was changing from a macrophyte dominated water to a phytoplankton-dominated water and that would see more plankton blooms. The phosphate levels from the 2001 Test America data suggested there was an excess of phosphorus to support those blooms. Based upon SEA Inc.'s 2002 observations, BCP has transformed into a phytoplankton dominated water and is experiencing regular plankton blooms. This change not only reflects an increasing load of nutrients in BCP but also creates a higher risk to the fishery. As plankton blooms come and go they can create oxygen depletion problems that impact fishes and other aquatic life.

SEA Inc. has measured the primary production rates as an index to the activity of the plankton community. The rate of oxygen production by the plankton

community is measured in a light (clear) bottle and the plankton respiration (oxygen depletion) is measured in a dark bottle. In the first measurement in May of 2001, there was so much oxygen production in the normal 24 hr measurement period that the oxygen was super saturated and only a portion could be measured (Table 5). Subsequent measurements were limited to shorter time periods and provided a more useful index. The highest primary production rate was 1.525 mg/l of O_2/hr at Site 9 (Intake) on June 28, 2002. This correlated well with the highest chlorophyll a level provided by the Braidwood Station (Figure 2). In the August 2002 measurement, the rate at Site 9 had dropped to 0.653 mg/l of O_2/hr. This rate correlated with lower chlorophyll levels that occurred throughout most of August. Temperatures during the August 28,2002 measurements were high enough at the discharge (Site 2) to suppress photosynthetic activity. The temperature at the discharge was 115.1° F (Table 5) and the intake (Site 9) temperature was 92.2°F and the corresponding production rates were 0.142 and 0.653 mg/l of O_2/hr respectively. The temperature suppression of photosynthesis and an apparent die off of a phytoplankton bloom may account for the low dissolved oxygen levels observed during the August 2002 sampling.

All of sampling by SEA Inc. has involved in-situ sampling with a HydroLab for temperature, dissolved oxygen, pH, and specific conductivity. The data from all 2002 HydroLab sampling is presented in Tables 1,3,4,6, and 7.

The dissolved oxygen (DO) levels on August 28 of 2002 were notably lower than the same date in 2001(Table 6). As lakes undergo eutrophication and productivity increases, the DO level can exhibit wide diurnal changes that may stress aquatic life. Afternoon DO levels may rise to supersaturated levels, but during the night and early morning hours respiration demands may nearly deplete the DO and can result in fish kills. There also becomes a more pronounced difference in DO levels between the upper and lower layers of the water column due to increased oxygen demand from decomposition.

Dissolved oxygen levels at the same four sites in August 2001 and 2002 are compared in Figure 3. These comparisons indicate that the DO levels were generally lower at the same sites in 2002, were slower to rise during the day, and there was a greater differences between depths. Site 2 and Site 2.5 illustrate the lower DO levels in 2002 even later in the day when it should rise. Oxygen levels were less than 1ppm at 2 meters and below. Site 4, 2002 levels reflect the increase in DO later in the day compared to earlier in the day in 2001. The consistent drop in DO at 4 meters is typical of a stratified site. At Site 7 the higher DO in 2002 reflect the later time of day than the 2001 sample. However the more significant difference is the drop in DO with increasing depth in 2002. This drop suggests a more productive system that has a higher demand for oxygen in 2002. Site 7 has good flow and in 2001 had a nearly constant DO level down to the bottom and provided a good thermal refuge for fish. In 2002 the area below 6 meters would be stressful for most fish. The Site 9 AM chart again demonstrates the 2002 DO level was lower even when taken later in the morning than the 2001

sample. The Site 9 PM chart shows some recovery of DO level in the mid afternoon but levels are still below 4ppm. The more rapid drop in deeper samples from the 2001 most likely reflects the loss of late afternoon light to the deeper depths.

The 2002 DO curves appear to reflect a more eutrophic environment that may place additional oxygen stress on the fishery. During the August 2002 sampling there were dead and dying gizzard shad from Site 2 to Site 4. The combinations of stress from the low DO and warmer temperatures were the most likely explanation for the loss of these fish. This loss was not extensive enough to have a significant impact on the fishery. No other species were involved in the kill but small bluegills were exhibiting some signs of DO stress. As BCP continues to become more eutrophic the DO stress may be a greater problem for the fishery.

The increasing pH levels have been a concern in BCP. Comparison of HydroLab data from August 28 in 2001 (Table 6) and 2002 (Table 1) indicated only a little variation in pH. During the summer of 2002 the Station was adding H_2SO_4 into the circulating water. The impact was only apparent at Site 2 (discharge canal) and Site 3. The 2002 samples collected in the morning hours at Site 2 ranged from 8.34 to 8.38 compared to 8.5 in 2001 (Table 2). At Site 3 the 2002 levels ranged from 8.35 in the morning to 8.54 at midday compared to a range of 8.4 to 8.6 in 2001. The pH levels at Sites 4,7 and 9 had slight variations depending upon time of day but had similar ranges in 2001 and 2002. With the high alkalinity levels in BCP, it is not surprising that the addition of H_2SO_4 did not result in larger changes. This assessment is also based on only a few data points. Correlating H_2SO_4 feed rates with continuous pH monitoring at the intake would provide more reliable information on the effects of the acid additions.

Questions have been raised on the impact of the phytoplankton on the increasing pH levels. As phytoplankton carries on photosynthesis and extract CO_2 from the water it increases the pH. This however may not be as apparent in BCP due to the high buffering capacity (alkalinity). In general the higher pH levels in the afternoon reflect the photosynthetic activity. Conversely the lower pH levels in the early morning samples reflect the increase in CO_2 resulting from respiration during the night. The role of phytoplankton in increasing pH is quantified in the measurement of primary productivity. A comparison of the starting pH with the ending pH in the light bottles illustrates the change due to photosynthesis. The pH during the 24-hour measurement on May 29, 2001at Site 2 went from 9.22 to 9.52 (Table 5).

Summary and Conclusions:

Braidwood Cooling Pond has high levels of alkalinity, total hardness, TDS, sulfates, magnesium, calcium and total phosphates. These parameters are of concern since they have the potential for increased problems with scaling, increasing pH, compliance with blow down limits, and maintaining a recreational

fishery. The additional of treatment chemicals and evaporative loss of the recycled cooling water with limited blown down rates are most likely the primary factor in the increased levels of these parameters. The make-up water does not have elevated levels of the above-mentioned parameters. With increasing capacity factors and increasing concentrations for these parameters in the cooling water, water treatment costs and operational concerns are likely to increase.

Baseline water quality data is important in evaluating options and solutions to address water quality in the cooling pond. The comparison of the August 2002 sampling to the 2001 Test America data indicated significant increases in total hardness, sulfates, and calcium in the past year. Increases of this magnitude can be important predictors of future problems. Critical assessments of the impact of H_2SO_4 additions and other treatment changes are dependent upon having pretreatment and post treatment data. The plan to increase the blow down rate from BCP is a good long-term solution to the continued viability of the cooling pond. The effectiveness of increasing the blown down rate from BCP can be quantified by continued monitoring of the cooling lake concentrations.

The high nutrient levels in BCP will continue to cause plankton blooms. Unlike many waters, phosphates appear to be in excess and nitrates are more of a limiting factor. However, bluegreen algae appear to be the dominant summer form and are not as limited by low nitrates as other algae. The primary production measurements did correlate fairly well with chlorophyll a levels and were a good index to the productivity of BCP. The primary production measurements also illustrated how much of an influence phytoplankton have on diurnal increases in pH.

Algal blooms are occurring in the pond and based on two comparable samplings, appear to be influencing the DO levels. The DO levels in the early hours were generally lower in 2002 than in 2001 and the DO at a deep site experienced a decline with depth that did not occur in 2001. These changes suggest a trend toward an increasing rate of eutrophication. If nutrient levels continue to increase the potential for fish kills associated with oxygen depletion resulting from the blooms would also increase.

Jim Smithson
SEA Inc.
11/04/02

APPENDIX REPORT B-4.

Fish Kill Reports Going Back to 2003

john.petro@exeloncorp.com [john.petro@exeloncorp.com]

Sent: Wednesday, September 23, 2009 2:42 PM

To: Jeremiah.Haas@exeloncorp.com

2003

There were no fish kills in Braidwood Lake in 2003.

~~June~~ July 30, 2004

Investigated a fish mortality on July 30, 2004. Most fish were in the advanced state of decay by the time the kill was investigated. Gizzard shad were the dominant species involved although channel catfish were observed as well. During this investigation, the shallow water near shore was teaming with plankton which under magnification proved to be daphnia as well as Cypris, which is an Ostacod resembling a small clam.

Temperature/dissolved oxygen profiles were conducted in early October. Water temperature just north of the south boat access was 29.2-^{0}C/84.5-^{0}F at a depth of one foot with a dissolved oxygen reading of 3.8 ppm, a pH of 8.03 and a secchi disk reading of 2.1 feet. Readings were somewhat improved in the area near the rearing cove. In a location several hundred feet from the lake make-up, more favorable dissolved oxygen levels were found. At one foot, a water temperature of 26.5 ^{0}C/79.7 ^{0}F with a dissolved oxygen reading of 7.6 and a pH of 8.47 were observed. Water temperature showed minimal decrease to 40 feet while the dissolved oxygen declined to 5.3 ppm.

June 28, 2005 Fish Kill

An on the water inspection of a thermal fish kill was conducted on June 28, 2005. No formal counts were made however field assessments indicate a fairly significant kill that involved a variety of species including (in no specific order) gizzard shad, threadfin shad, common carp, channel catfish, quillback carpsucker, black bass. Gizzard shad were the most numerous species effected by this kill and fish carcases were observed at most all areas of the lake that were checked.

August 27-28, 2007 Fish Kill

· Rob Miller, IDNR investigated a thermal kill on August 27 and 28, 2007 and conducted temperature/dissolved oxygen evaluations. The majority of the dead fish which were observed were large gizzard shad and threadfin shad up to 5 inches in length. Channel catfish were also prevalent. Only a few common carp and black bass were observed and no bluegills were noted. Due to moderate prevailing south winds, many dead fish were wind-rowed along the north shore in close proximity of the boat ramp and the bank fishing area. The number of dead fish observed decreased towards the south (hot) side of the lake. At a point several hundred yards from the south ramp surface water temperature was 35.3 C/95.9 F and dissolved oxygen was near 3ppm.

· The following are data which were collected at the north ramp at the time the fish kill was being

investigated:

Time	Temperature (^0C)	Dissolved Oxygen (ppm)
12:10	30.3	3.1
14:25	33.1	5.4
15:30	33.5	6.7
16:58	33.9	5.9

Investigation of Fish Kill on Braidwood Cooling Pond (August 27-28, 2007)

· Strategic Environmental Actions Inc. (SEA Inc.) conducted an investigation of an on-going fish kill on Braidwood Cooling Pond on August 27 & 28, 2007. The investigation consisted of surveying the shoreline to determine the extent of the kill and the species involved, and water quality analyses for pH, temperature, and dissolved oxygen.

· Most of the fish appeared to have been dead for about 24 hours and more than 95% were gizzard shad. The other species involved in descending order of relative abundance were freshwater drum, quillback, carp, largemouth bass, channel catfish, redhorse, smallmouth bass and bluegill. Other than gizzard shad most of the dead fish were located between the mid -point in the cooling loop to the intake. Throughout most of the cooling pond, dissolved oxygen levels were at or below the minimum levels necessary to support most fish and was the most likely cause of the kill. Water clarity was very high and suggested a recent die off of much of the phytoplankton, which is usually followed by oxygen depletion. This is a natural phenomenon that can occur in highly productive lakes during summer months. Temperatures throughout most of the lake were within the tolerance limits of the species involved in the kill. It does not appear that operations of the power station had a direct impact on the fish kill.

APPENDIX REPORT B-5.

FW: Braidwood Lake Fish Kill

john.petro@exeloncorp.com [john.petro@exeloncorp.com]

Sent: Wednesday, September 23, 2009 2:31 PM

To: Jeremiah.Haas@exeloncorp.com

-----Original Message-----
From: ROB MILLER [mailto:ROB.MILLER@illinois.gov]
Sent: Tuesday, August 21, 2007 8:26 PM
To: JOE FERENCAK; STEVE PALLO
Cc: Petro, John R.; CHRIS MCCLOUD; LARRY DUNHAM; MIKE CONLIN
Subject: Re: Braidwood Lake Fish Kill

I was contacted by John Petro and Tim Meents (Braidwood Station) this morning at 11:20 but due to bad accident on I-55 was somewhat delayed in arriving at the lake. When I got there (3:00) I met with Exelon biologist Jeremiah Haas. Jeremiah had arrived earlier and had taken dissolved oxygen/temperature readings. He and I toured the lake via his boat to assess the extent of the kill. Due to moderate prevailing south winds, many dead fish were wind-rowed along the north shore in close proximity of the boat ramp and the bank fishing area. The number of dead fish we observed decreased as we traveled towards the south (hot) side of the lake. At a point several hundred yards from the south ramp, we took a reading and returned to the north ramp to meet up with John Petro. At this location water temperature was 35.3C and dissolved oxygen was near 3ppm. The following are data which were collected at the north ramp:

Time	Temp. (C)	Dissolved Oxygen (ppm)
12:10	30.3	3.1
14:25	33.1	5.4
15:30	33.5	6.7
16:58	33.9	5.9

Based on the declining trend in d.o., it is possible that more fish could succumb throughout the night.

The majority of the dead fish which were observed were large gizzard shad and threadfin shad up to 5 inches. Channel catfish were also prevalent. Only a few common carp and black bass were observed and no bluegills were noted. SET Environmental had arrived at the north ramp and were conducting clean-up operations at 5:00. I will be attended the AFS Continuing Education course in Monticello tomorrow and thursday. If you need any further information, or if there are any further developments, please contact me at 815/409-2426. Thanks.
Rob
Rob Miller

District Fisheries Biologist
Illinois Department of Natural Resources
13608 Fox Road
Yorkville, Illinois 60560
630/553-6680
rob.miller@illinois.gov
>>> STEVE PALLO 08/21/07 12:10 PM >>>
Just got off phone with John Petro, Environmental Manager for Exelon.

John wanted to report a moderate gizzard shad kill at Braidwood Cooling Lake, and a minor kill of catfish. Rob Miller, District Fisheries Manager was already notified. Water temps in the lake had dropped some 12F recently, there are no obvious power plant operational changes or permit exceedances. Exelon is arranging to have the fish picked up.

APPENDIX REPORT B-6.

FW: Braidwood Fish Kill 8-21-07

john.petro@exeloncorp.com [john.petro@exeloncorp.com]

Sent: Wednesday, September 23, 2009 2:28 PM

To: Jeremiah.Haas@exeloncorp.com

-----Original Message-----

From: Haas, Jeremiah J.

Sent: Tuesday, August 21, 2007 9:02 PM

To: Petro, John R.; Tidmore, Joseph W.; Meents, Timothy P.

Cc: Hebeler, Ronald L.; Neels, Vicki J.; Steve Pallo (E-mail); Haas, Jeremiah J.

Subject: Braidwood Fish Kill 8-21-07

All,

Here's the quick and dirty of the incident. I'll right something more formal in the morning.

I arrived at Braidwood Lake at 12:00 and took a dissolved oxygen (DO) reading from the ramp dock which extends about 30 feet into the lake. The DO was 3.1 ppm w/ a temp of 30.3 C. Several thousand gizzard and threadfin shad were floating across most all visible areas of the lake. The currents within the lake were visible with the dead fish movement. Also seen were dozens of channel catfish, most of which were adults from 3-15 lbs. Shad ranged from 4 - 13 inches with the shorter fish being predominately threadfin and the larger ones being gizzard. At this time I informed John P. of the DO situation and began setting up the boat for additional surveys. During the entire day, no other species was observed that counted more than 2 individuals.

I took several water readings throughout the afternoon before Rob Miller (IDNR biologist responsible for Braidwood Lake) arrived. We did a quick boat survey throughout the lake, including the pockets that are not part of the cooling loop. These areas showed the same readings as the rest of the lake. During this time we had a few hours of direct sunshine and DO reading rose as high as 6.7 ppm @ 15:30.

Rob and I determined that the DO crash was a result of the past several days cloud cover and subsequent die-off of phytoplankton. The decay of the phytoplankton would have been sufficient to lower the DO available to the fish during the overnight hours. We also observed the DO beginning to lower @ 16:58 (5.9 ppm) and believe that there is an opportunity to see similar results tomorrow and possibly a few more days depending on the weather conditions.

A local newspaper reporter did arrive on site, took photos, and asked questions. She was familiar with Braidwood Station's Site Communicator and said she would be in contact with them. Rob explained the cycle that was occurring in the lake several times to the reporter.

All in all, I believe that Rob and I are both comfortable with the explanation for the action that occurred to cause the fish kill. This is similar to the "annual" fish kill seen at Braidwood, but the densities were higher than the past few years. There is a survey of the lake scheduled for October and, if possible, I will be at the site for that.

Exelon
Jeremiah J Haas
Principal Aquatic Biologist
Quad Cities Nuclear Station
309.227.2867
jeremiah.haas@exeloncorp.com

APPENDIX REPORT B-7.

Braidwood Fish Kill Clean up
8/22&23/07

I worked with SET Environmental to clean up a fish kill.
This was a major kill and our clean up efforts were confined to the area near North boat ramp on the intake end of the lake. SET had been working on the kill for one or two days when I was called to provide assistance. A total of about 24 cubic yards of fish were removed in this clean up. The species involved in decreasing order of abundance were: gizzard shad (large fish), channel catfish, bluegill, green sunfish, flathead catfish, bigmouth buffalo, quillback and largemouth bass.

I went up in the restricted arm toward the intake and found huge masses of fish in the back of several coves. There were areas 50 to 75 ft by 100 ft of solid floating mats of fish in these coves. We picked up 12 flathead catfish that would have averaged near 50 lb. each. On the second day when we returned to these coves we counted as many large flathead catfish that we had picked up the previous day. They were in a state of decomposition that prevented up from picking them up.

We did not take any water quality measurements or examine other parts of the lake in this clean up effort. From my past work on this cooling pond, I would suspect a combination of DO depletion and high water temperatures caused this fish kill. The plant did not report any abnormal operation conditions prior to the kill. Since 2001 when we first worked on this cooling pond we have seen a switch from macrophytes to phytoplankton with blue green dominating. We have measured wide diurnal swings in DO levels even in the upper part of the water column in late summers. Even with the strong circulation from the circulating water pumps there is mid summer stratification and DO depletion in the deeper areas.

Jim Smithson
SEA Inc.

RAI #: AQ-12b **Category: Aquatic Resources**

Statement of Question:

Section 2.2.5, Page 2-16 of the ER states that "HDR [HDR Engineering] assessed water quality and fish populations in the cooling pond in late summer 2009 and 2010 to develop a better understanding of the factors contributing to fish kills and design a water quality or fish monitoring program that could be used to predict (and conceivably mitigate) fish kills in the pond."

b. Has Exelon designed a water quality or fish monitoring program for the cooling pond, as mentioned in the ER? If so, provide a brief description of the program and any associated monitoring reports for available data years.

Response:

Summer monitoring of fish populations and water quality in the Braidwood cooling pond for the purpose of developing a better understanding of the factors contributing to fish kills has been ongoing since 2009. Monitoring reports for 2009 and 2010 are attached to the response for RAI # AQ-12a, above. Monitoring reports for 2011 and 2012 are attached to this response.

Based on the annual summer aquatic sampling results since 2009, HDR Engineering has not been able identify a practical way to prevent fish kills or reduce their effects in the Braidwood cooling pond. In fact, each annual summer sampling report notes that fish die-offs should be anticipated to occur on a fairly regular basis. Accordingly, HDR has recommended that routine sampling of dissolved oxygen levels be implemented as an indicator of conditions that could cause fish kills so that plant personnel can better prepare for fish kill events.

Consistent with HDR's recommendation, Braidwood has incorporated weekly sampling for chlorophyll a and dissolved oxygen into a plan for managing macrobiological challenges in the cooling pond. The sampling data are reviewed against established criteria to identify abnormal results at the time of collection. If chlorophyll a, an indicator of the water's oxygen-producing capacity, is showing a decreasing trend, the dissolved oxygen sampling frequency may be increased. If dissolved oxygen trends indicate potential for a large fish loss to exist (i.e., dissolved oxygen concentrations are trending below three parts per million), then plant personnel are placed on standby to initiate actions that would mitigate potential adverse operational effects of a fish kill, should one occur. Such actions could include increasing the speed of the Lake Screen House traveling screens and/or the frequency with which the trash basket is dumped to deal with higher numbers of accumulating dead fish.

No monitoring reports containing sampling results for chlorophyll a and dissolved oxygen are created.

List of Attachments Provided:

1. (Exelon Nuclear 2012) Exelon Nuclear. 2012. Braidwood Station - Braidwood Lake Additional Biological Sampling Program, 2011. Prepared by HDR Engineering, Inc. Copyright by Exelon Corporation.
2. (Exelon Nuclear 2013) Exelon Nuclear, 2013. Braidwood Station – Braidwood Lake Additional Biological Sampling Program, 2012. Prepared by HDR Engineering, Inc. Copyright by Exelon Corporation.

Attachment #1 to Response -- RAI # AQ-12b

BRAIDWOOD STATION

BRAIDWOOD LAKE ADDITIONAL BIOLOGICAL SAMPLING PROGRAM, 2011

Prepared for
EXELON NUCLEAR

February 2012

HDR Engineering, Inc.
Environmental Science & Engineering Consultants
10207 Lucas Road
Woodstock, Illinois 60098

BRAIDWOOD STATION

BRAIDWOOD LAKE ADDITIONAL BIOLOGICAL SAMPLING PROGRAM, 2011

Prepared for

EXELON NUCLEAR
Warrenville, Illinois

HDR Engineering, Inc.
Environmental Science & Engineering Consultants
10207 Lucas Road
Woodstock, Illinois 60098

ACKNOWLEDGMENTS

The field work and data analysis for this project was conducted by HDR Engineering, Inc. (HDR). Particular appreciation is extended to Rob Miller of the Illinois Department of Natural Resources (IDNR), Jim Smithson of Strategic Environmental Actions, Inc. (SEA), and John Petro of Exelon Nuclear for providing historical fisheries and water quality data.

This report was prepared by HDR and reviewed by Exelon Nuclear. A special debt of gratitude is owed to the environmental staff at Braidwood Station and in particular Mr. Jeremiah Haas of Exelon Nuclear for his technical assistance, cooperation, and guidance during the preparation of this document and the study plan. Mr. Haas's experience and insight has been invaluable and is greatly appreciated by the authors.

ABSTRACT

HDR Engineering, Inc. (HDR) was contacted on March 12, 2009 by Braidwood Nuclear Generating Station, requesting HDR to design and conduct a fish sampling program at Braidwood Lake. The information gathered during that study was to be used by Exelon to develop an effective sampling program and set of procedures that could potentially predict fish die-offs in the cooling lake. That same sampling program was conducted again in 2010 and 2011 with only minor changes to the original program design.

Large die-offs of fish at Braidwood Lake could potentially challenge the integrity of the traveling screens at the Station. With advanced warning, the Station could be informed of a potential reportable event; regulatory agencies could be notified in advance; and crews responsible for fish cleanup and disposal could be put on alert to help manage the risk associated with a substantial fish die-off. Currently, there are no practical or simple methods that can be used to predict or prevent the occurrence of fish die-offs at Braidwood Lake.

Sampling has been conducted at Braidwood Lake by the IDNR since 1980. From 1980 through 2009 IDNR (Illinois Department of Natural Resources) collected 49 taxa of fish. In comparison, thirty-one taxa representing eight families have been included among the 6873 fish collected by HDR since 2009. Several taxa listed as collected by IDNR from 1980 to 2009 have not been captured by HDR. Many of the species listed by IDNR were only rarely captured, have not been captured during recent years, or represent taxa that were stocked. However, five species have been captured by HDR that have not been collected during IDNR sampling efforts. They included shortnose gar, smallmouth buffalo, bigmouth buffalo, fathead minnow, and rosyface shiner.

In 2011, 18 taxa of fish representing six families were included among the 2298 fish captured by electrofishing, hoop netting, gill netting, and trap netting. The relative abundance of species collected during the course of these studies is similar to those reported by IDNR in recent years. Braidwood Lake is dominated by warmwater species including gizzard shad, threadfin shad, carp,

channel catfish, flathead catfish, largemouth bass, bluegill, and spotfin shiner. No threatened or endangered species have been collected by HDR since these studies were initiated in 2009.

Water quality data recorded in conjunction with fish sampling was measured at each location prior to every sample collection. Water temperature (°C), dissolved oxygen (ppm), pH, and conductivity (µmhos/cm) measurements were taken 0.5 m below the water surface at each sampling location. In addition, water quality was also measured approximately 0.5 m off the bottom at all three of the deep water collection sites (Location GN-1, HN-1, and HN-2).

Water temperatures during the early August sampling period were warmer (34.8 to 41.0 °C) than those observed during the late August sampling period (30.1 to 35.3°C) in 2011 because of the unusually hot and humid conditions that existed throughout the Midwest during late July and early August. Diurnal swings in dissolved oxygen (DO) were observed at the lake with DO ranging from 3.1 to 13.5 ppm in early August and from 5.6 to 14.0 ppm in late August. Dissolved oxygen readings were typically slightly higher during the second sampling effort in late August. Cursory observations by the field crew indicated that the water color appeared greener during the late August sampling dates. This suggests that an increase in the phytoplankton population occurred within the lake between the first and second sampling period, which would explain (coupled with slightly cooler water temperatures) the slight increase in oxygen levels noted in Braidwood Lake during late August.

Examination of pH data collected during these studies show pH ranged from 8.3 to 8.7 during the first sampling effort and from 8.5 to 8.6 during the second sampling effort. Conductivity ranged from 928 to 993 µmhos/cm in early August and from 988 to 1036 µmhos/cm in late August.

Review of historical water quality data reported in 2002 by Strategic Environmental Actions, Inc. (SEA Inc.) at Braidwood Lake indicates that abnormally high levels of total dissolved solids (TDS), alkalinity, hardness, sulfates, magnesium, calcium, and total phosphorus exist throughout the entire cooling loop. This is not unexpected based upon the evaporation that takes place within the cooling loop coupled with the relatively low make-up and blow-down flows associated with the operation of Braidwood Station. These elevated levels within the lake were measured at two to nearly eight times higher than those of the make-up water from the Kankakee River. Elevated levels of water hardness are of concern to the Station because high levels have the potential to increase problems associated with scaling at the Station.

Phosphorus and nitrogen are two essential nutrients required by aquatic plants. Studies conducted by SEA in 2002 indicated that nutrients within the cooling lake were at levels sufficiently high to cause problems associated with phytoplankton blooms. These blooms result in oxygen production via photosynthesis during daylight and oxygen depletion through respiration during darkness. When algal populations crash and decompose they can produce severe oxygen depletion within the water column. Diurnal swings in oxygen readings have been routinely observed at Braidwood Lake during the past several years. In addition, DO levels of less than 3 ppm have been recorded at the lake immediately following fish die-offs. Deeper portions of the lake were also reported to stratify in 2002. In the deeper zones of the lake, DO levels approaching 0 ppm and reduced water temperatures have been measured below the thermocline. This is noteworthy because dissolved oxygen levels of 3 ppm and less cannot be tolerated over an extended period of time by most fish species. Piper et al. (1983) states that dissolved oxygen levels below 5 ppm will reduce growth and survival for most species of fish cultured in raceways or ponds. Dissolved oxygen requirements are dependent upon species and other factors including water temperature and acclimation period.

Review of historical fisheries information that was provided to HDR indicated that five separate fish kills were reported from 2001 to 2007. Numerically, the majority of fish observed during these events were either gizzard shad or threadfin shad. These two species have typically comprised over 90% to 95% of all fish observed. Remaining species included carp, freshwater drum, bluegill, channel catfish, flathead catfish, quillback and largemouth bass. Each of the reported fish die-offs was attributed to oxygen depletion at the lake and not the result of specific Station operations.

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1.0 INTRODUCTION

The Braidwood Lake Fish and Wildlife Areas are comprised of approximately 2640 acres of terrestrial and aquatic habitat that is located in Will County, Illinois. Braidwood Lake is owned by Exelon and is a partially perched, cooling lake that was constructed in the late 1970s. The lake was filled during 1980 and 1981 with water pumped from the Kankakee River. Several surface mined pits existed at the site prior to the filling of the impoundment. Fisheries management activities began in those surface mine pits in 1978, prior to the creation of Braidwood Cooling Lake. Originally the lake was considered a semi-private area used by employees of Commonwealth Edison Company until the end of 1981 when the Department of Conservation (now the Illinois Department of Natural Resources) acquired a long-term lease agreement from the company, which allowed for general public access to the area. Braidwood Lake is currently used for fishing, waterfowl hunting, and fossil hunting. From the late 1970's to the present time, Braidwood Lake has been stocked with a variety of warm- and coolwater fish species. These stockings include largemouth and smallmouth bass, blue catfish, striped bass, crappie, walleye, and tiger muskie. Monitoring programs have documented the failure of the coolwater stockings to create a meaningful fishery. This is attributed to the extreme water temperatures that occur within the cooling lake during the warm summer months.

Construction of the Braidwood Nuclear Generating Station and its associated riverside intake and discharge structures provided an opportunity to gather fisheries information from the Kankakee River and Braidwood Lake. These studies were initiated to determine the effects of construction and plant operation on the river and the lake. Units I and II began commercial operation on 29 July and 17 October, 1988, respectively. Fisheries surveys at Braidwood Lake were conducted annually by the Illinois Department of Natural Resources (IDNR) from 1980 through 1992. Since 1992, fishery surveys have been conducted by IDNR every other year except 1995 and 1996. Fishery surveys on the Kankakee River near the Station's intake have also been conducted annually since the late 1970's by the Illinois Natural History Survey (1977-1979 and 1981-1990), LMS Engineers (1991-1992 and 1994-2004), Environmental Research and Technology (1993), HDR/LMS (2005-2007), and HDR (2008-2011).

The objectives of the 2011 Braidwood Lake Additional Sampling Program were to:

1. Conduct fish surveys at Braidwood Lake for comparison with historical data that has been collected by IDNR and HDR Engineering, Inc.

2. Summarize any existing data related to fish kills that have occurred at Braidwood Lake.

3. Develop a sampling procedure or protocol that will help anticipate fish die-offs in the cooling lake that could potentially effect Station operations.

2.0 METHODS

2.1 Electrofishing

Electrofishing was conducted using a boat-mounted boom-type electrofisher utilizing a 5000 watt, 230 volt AC, 10 amp, three-phase Model GDP-5000 Multiquip generator equipped with volt/amp meters and a safety-mat cutoff switch. The electrode array consisted of three pairs of stainless steel cables (1.5 m long, 6.5 mm in diameter) arranged 1.5 m apart and suspended perpendicular to the longitudinal axis of the boat 1.5 m off the bow. Each of the three electrodes was powered by one of the phases. Electrofishing samples were collected on 4 August during the first sampling effort and on 31 August and 1 September during the final survey period (Appendix Table A-1). The first sampling event that was scheduled for late July was rescheduled for the first week of August due to extremely warm air and water temperatures that existed throughout the Midwest. Heat indexes of 110 to 120 °F were recorded during late July. Therefore, sampling was delayed until the first week of August to avoid unnecessary stress to the fish, field equipment, and the sampling crew.

Eight locations around the dike and islands at Braidwood Lake were electrofished during both the first and second sampling periods (Figure 2-1). Electrofishing was conducted near the shoreline at each location to collect fish utilizing shallow water habitats. Voltage and amperage of the electrofishing unit was recorded at each location at the beginning and end of each sampling effort. Sampling was restricted to the period of time ranging from one-half hour after sunrise to one-half hour before sunset. Each electrofishing location was sampled for 20 minutes. Electrofishing effort was reduced from 30 minutes per sample in 2009 and 2010 to 20 minutes per sample in 2011. This reduced the stress and handling mortality of fish associated with the field collection process with minimal impact on the data that was used to evaluate the fish assemblage at Braidwood Lake.

The electrofishing crew consisted of two people. One crew member operated the boat while the second crew member dipped fish from the bow of the boat. The boat operator also dipped fish

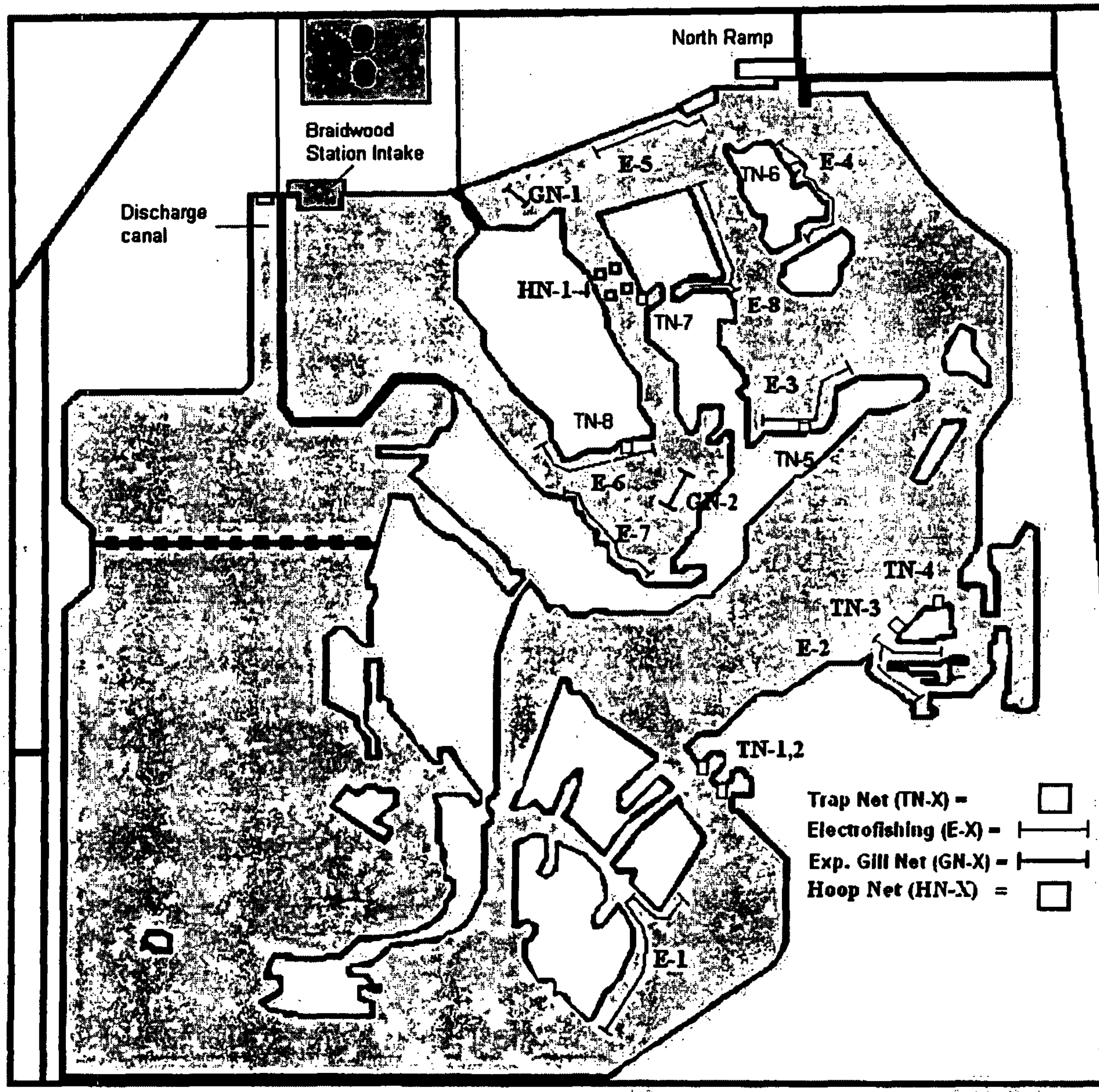

FIGURE 2-1. SAMPLING LOCATIONS AT BRAIDWOOD LAKE.

whenever necessary. When fish surfaced behind the boat the boat operator backed up to retrieve all stunned fish. All stunned fish were collected without bias of size or species.

Fish at each location were put into barrels of water in the front of the boat for analysis at the end of each 20 minute collection period. All fish were processed in the field immediately following collection at each location. Special emphasis was placed on the return of all game fish species to the water as quickly as possible following field analysis. Catches were standardized to catch-per-effort (CPE) from actual fishing time (20 min/sample) to numbers caught per hour by dividing the total numbers of fish collected by the actual fishing time in hours.

2.2 Trap Netting

Trap nets were set at eight separate locations in Braidwood Lake (Figure 2-1). Each trap net consisted of a 25-ft. lead that was 4-ft. deep and attached to a series of rectangular frames. The last rectangular frame was attached to a hoop net constructed of 1.5-in. (bar) mesh nylon webbing on hoops 3.5 ft in diameter. Two separate throats were contained within each net. One was located in the series of rectangular frames at the front of the net, while the second throat was located toward the back of the net inside the 3.5 ft diameter hoop net. Trap nets were set during late afternoon or early evening and were allowed to fish overnight for approximately 12 hrs before being retrieved the following morning. Trap nets were set on 1 August and retrieved on 2 August during the first sampling period and set on 30 August and retrieved on 31 August during the second sampling period (Appendix Table A-2).

Fish at each location were put into barrels of water in the front of the boat for analysis at the end of each collection period. All fish were processed in the field immediately following removal from the net. Special emphasis was placed on the return of all game fish species to the water as quickly as possible following field analysis. Catches were standardized to catch-per-effort by dividing the total number of fish caught by the total number of hours the nets were allowed to fish (fish/12-hr set).

2.3 Gill Netting

Two 125-ft. long and 6-ft. deep monofilament experimental gill nets were used to collect fish from two locations in Braidwood Lake (Figure 2-1). Each net consisted of five separate panels that were 25-ft long by 6-ft deep. Bar mesh sizes of each panel were 0.5, 0.75, 1.0, 2.0, and 3.0 inches, respectively. One of the two gill nets (GN-1) was set in deep water at a depth of approximately 10-13 m, while the second gill net was set in shallow water (GN-2) at a depth of approximately 2-3 m. During the first sampling period, the deep water gill net sample (GN-1) and the shallow water gill net sample (GN-2) were set and retrieved during the late afternoon of 1 August. Both nets were allowed to fish for 0.5 hrs before they were retrieved. During the second sampling period, both the deep and shallow water gill net were set and retrieved 15 minutes later during the late afternoon of 30 August (Appendix Table A-3). Gill net set times were reduced from previous years based on the number of fish that were being captured coupled with concerns expressed by Illinois Department of Natural Resources. Elevated water temperatures in the cooling lake prohibited longer set times due to the high mortality that occurred shortly after the fish became entangled in the monofilament netting.

All fish were processed in the field as they were removed from the net. Special emphasis was placed on the return of game fish species to the water as quickly as possible. Catches were standardized to catch-per-effort (CPE) from actual fishing time the nets were in the water to numbers caught per hour by dividing the total numbers of fish collected by the actual fishing time in hours.

2.4 Hoop Netting

Hoop nets used to collect fish at Braidwood Lake were constructed of 1.25-in. (bar) mesh nylon webbing on hoops 3.5 ft in diameter. Four separate nets were sampled during each sampling period (Figure 2-1). Two of the four nets were set in deep water (7.5 m), while the remaining two nets were set in shallow water (2.0 m). In addition, one of the deep (HN-1) and shallow water (HN-3) hoop nets were baited with dead gizzard shad, while the remaining deep (HN-2) and shallow water (HN-4) nets were allowed to fish without bait. All four nets during the first sampling period in early August were set during the late afternoon of 1 August and retrieved the following morning on 2 August. During the second sampling period in late August the hoop nets were set during the late afternoon of 30 August and retrieved the following morning on 31 August (Appendix Table A-4).

Captured fish from each net were put into a barrel of water in the front of the boat for analysis at the end of each collection period. All fish were processed in the field immediately following removal from the net. Special emphasis was placed on the return of all game fish species to the water as quickly as possible following field analysis. Catches were standardized to catch-per-effort by dividing the total number of fish caught by the total number of overnight sets conducted (fish/overnight set). Hoop nets were set and retrieved over a 16 to 18 hour period of time during both the first and second sampling periods.

2.5 Sample Processing

All fish were identified to the lowest positive taxonomic level and enumerated. For each gear type, up to 25 individuals of a species were measured for total length (mm) and weight (g) at each location. Any remaining individuals of that species were counted and weighed en masse. Minnow species (excluding carp) were counted and weighed en masse. Specimens that could not be positively identified in the field were either photographed in the field or returned to the laboratory for identification. References used to facilitate identification included Pflieger (1975), Smith (1979), and Trautman (1981).

2.6 Water Quality Measurements

Four physicochemical parameters (temperature, dissolved oxygen [DO], pH, and conductivity) were measured in conjunction with the sampling program. These data were collected at each station prior to each sampling effort. Physicochemical measurements were taken a half meter below the water surface at all locations prior to sample collection. At deeper locations, temperature, conductivity, and DO were measured 0.5 m below the surface and 0.5 m off the bottom. Temperature (°C), dissolved oxygen (ppm), and conductivity (μmhos) were measured using an YSI Model 85 handheld oxygen, conductivity, salinity, and temperature meter. A Cole-Parmer pH Tester1 was used to determine pH. All instruments were calibrated prior to each monthly sampling event.

3.0 RESULTS AND DISCUSSION

3.1 Species occurrence.

Fish surveys have been conducted at Braidwood Lake by the Illinois Department of Natural Resources (IDNR) since 1980 when the cooling lake was first impounded with water pumped from the Kankakee River. Sampling was conducted annually from 1980-1992, again in 1994, and every other year from 1997-2011 (Table 3-1). During these 22 years of sampling, 49 taxa of fish have been collected including 47 species and two hybrids (hybrid sunfish and tiger muskie). Gizzard shad (32.6%), bluegill (21.7), common carp (18.5%), largemouth bass (8.7%), and channel catfish (5.8%) have been the dominate species collected during these surveys. The total number of taxa collected by the IDNR has ranged from 12 in 1980 to 27 in 1989. Several species have been rarely collected or only occasionally observed during this 32 year period. These include yellow bass, rock bass, redear sunfish, orangespotted sunfish, tiger muskie, grass pickerel, longnose gar, goldfish, highfin carpsucker, silver redhorse, river redhorse, blackstripe topminnow, emerald shiner, common shiner, striped shiner, redfin shiner, slenderhead darter, johnny darter, bullhead minnow, blue catfish and mosquito fish that were captured for the first time in 2009. All of these taxa have been collected in five or fewer of the 22 years of sampling conducted by the IDNR from 1980 through 2009. Sampling was collected by the IDNR in 2011; however, the data had not been tabulated in time for inclusion in this report.

The only protected species (one fish collected in 1999) collected during these surveys has been river redhorse (*Moxostoma carinatum*), which is currently listed as threatened in Illinois (Illinois Endangered Species Protection Board 2009). River redhorse have been collected from the Kankakee River during several years during past sampling programs (HDR 2011). Eighteen of the taxa identified by the IDNR have not been captured since 1999.

Braidwood Lake has been stocked with a variety of warmwater and coolwater fish species since the late 1970's. Some of these species, such as striped bass, tiger muskie, and walleye, have not been collected in recent years following the discontinuance of those stocking programs. Currently, the fish community is dominated by warmwater species that are more tolerant of the elevated water temperatures that exist in the cooling lake during summer months.

TABLE 3-1

SPECIES OCCURRENCE OF FISH COLLECTED BY THE ILLINOIS DEPARTMENT OF NATURAL RESOURCES[a] AT BRAIDWOOD LAKE FROM 1980 THROUGH 2009[a].

Taxa	SAMPLING YEARS														
	80-85	86-90	91	92	94	97	99	01	03	05	07	09	11[b]	TOTAL	%
Longnose gar	3					13								16	<0.1
Threadfin shad	564								11	230	122	770		1697	2.7
Gizzard shad	4012	6712	1382	3018	412	925	925	786	1031	872	195	543		20.813	32.6
Grass pickerel	39													39	0.1
Tiger muskie	11			5		12								28	<0 1
Goldfish					2	3	1	1						7	<0 1
Carp	2987	4393	108	227	285	853	385	929	620	204	405	403		11,799	18.5
Golden shiner	88			1	1			1	1		1	2		95	0.1
Emerald shiner	1	3	1					48						53	0.1
Common shiner	31	4												35	0.1
Striped shiner	14													14	<0.1
Spotfin shiner	1	124	5	4	1	1		198	3	27	249	959		1572	2.5
Sand shiner	5	39	2	1					5		75	10		137	0.2
Redfin shiner									1					1	<0.1
Bluntnose minnow	6	78	6	3			3	13		1	6	49		165	0.3
Bullhead minnow											11	5		16	<0.1
Quillback	189	183	26	66	20	37	5	3						529	0.8
Highfin carpsucker	2													2	<0.1
Silver redhorse	1	1			1									3	<0.1
Golden redhorse		7	2		1									10	<0.1
Shorthead redhorse		20	3	3		4	3							33	0.1
River redhorse							1							1	<0.1
Black bullhead	319													319	0.5
Yellow bullhead	46	14	1	1	1		3	3		1	1	4		75	0.1
Blue catfish												3		3	<0.1
Channel catfish	39	318	362	357	463	136	364	866	384	129	228	90		3736	5.8
Flathead catfish						1	2	10		1	1	3		18	<0.1

TABLE 3-1 (Continued).

Taxa	SAMPLING YEARS														
	80-85	86-90	91	92	94	97	99	01	03	05	07	09	11[b]	TOTAL	%
Blackstripe topminnow		6												6	<0.1
Mosquito												2		2	<0.1
Brook silverside	150	192	8	9	13	6	12	50	3	5	1	1		450	0.7
Yellow bass	1	1												2	<0.1
Striped bass		9	4	1	1	15								30	<0.1
Rock bass		2	1		2									5	<0.1
Green sunfish	436	36	10	8	23	13	37	139	26	10	77	49		864	1.4
Orangespotted sunfish			1				1				1			3	<0.1
Bluegill	1432	459	698	247	252	241	998	1754	1393	1369	2758	2280		13,881	21.7
Longear sunfish					25	1	7		3		1	5		42	0.1
Redear sunfish					1			3				13		17	<0.1
Hybrid sunfish	55	18	2	1	4		9	13	8	5	7	7		129	0.2
Smallmouth bass		4	42	24	17	42	17	9	3	5		3		166	0.3
Largemouth bass	1834	867	175	91	337	202	711	351	334	88	263	315		5568	8.7
White crappie	107	24	10	2			3							146	0.2
Black crappie	57	22	6	1			20	2	2	1	1			112	0.2
Johnny darter	2													2	<0.1
Yellow perch	234	241												475	0.7
Logperch		130	11	72	6	7								226	0.4
Slenderhead darter		4	1											5	<0.1
Walleye	68	220	7	8	1	3								307	0.5
Freshwater drum	19	113	8	15	6	21	14	14	34	9	1	1		255	0.4
Total fish	12,753	14,244	2882	4165	1875	2536	3521	5193	3862	2957	4404	5517		63,909	
Total taxa	31	30	26	23	23	20	21	20	17	16	20	22		49	
Total species	29	28	25	21	22	19	20	19	16	15	19	21		47	

[a]Table was reformatted from data provided by the Illinois Department of Natural Resources.
[b]Data was collected in 2011 but not tabulated prior to the preparation of this report.

3.2 Relative Abundance and CPE.

In 2011, 18 taxa representing six families were included among the 2298 fish collected by electrofishing, trap netting, hoop netting, and gill netting. Thirty-one taxa representing eight families have been included among the 6873 fish collected by HDR since 2009 (Table 3-2). Several species that were listed as collected by the IDNR during surveys conducted between 1980 and 2009 have not been captured by HDR. Each of these taxa were either rarely encountered during previous years, represent taxa that were stocked, or have not been captured during recent years. However, five species have been captured that have not been collected by IDNR. They included shortnose gar, bigmouth buffalo, smallmouth buffalo, fathead minnow, and rosyface shiner. No threatened or endangered species were collected in 2011.

Species that numerically dominated the catch in 2011 (all sampling methods combined) included threadfin shad at 24.2%, bluegill at 23.5%, channel catfish at 17.8%, carp at 12.6%, spotfin shiner at 5.2%, largemouth bass at 4.6%, and gizzard shad at 4.1% (Table 3-2). All of these species have been commonly collected by the IDNR during recent sampling efforts (Table 3-1). Biomass of fish captured by electrofishing, trap netting, gill netting, and hoop netting was dominated by carp (56.5%), channel catfish (28.3%), flathead catfish (5.0%), largemouth bass (3.4%), bluegill (2.9%), and gizzard shad (1.6%). These results are similar to data collected during previous years and indicate that Braidwood Lake is best suited to support warmwater species.

3.2.1 Electrofishing

In 2011, electrofishing resulted in the collection of 1480 individuals representing 15 taxa (Table 3-3). The catch was dominated numerically by bluegill, which comprised 33.4% of all fish captured. Threadfin shad (29.0%), spotfin shiner (8.0%), largemouth bass (6.4%), carp (5.4%), gizzard shad (4.5%), longear sunfish (3.6%), channel catfish (3.1%), and bullhead minnow (3.1%) were the only other species to individually comprise greater than 3% of the total catch by number. The total number of fish collected by location ranged from 407 at Location E-3 to 61 at Location E-1 (Table 3-4). The total number of taxa collected ranged from seven at Location E-1 to 11 at Locations E-3, E6, and E8. The fewest number fish and taxa were collected at Location E-1 located closest to the Braidwood Station discharge. In general, more fish and greater

TABLE 3-2

TOTAL NUMBER, WEIGHT (g) AND PERCENT CONTRIBUTION OF FISH COLLECTED BY ALL SAMPLING GEARS FROM BRAIDWOOD STATION COOLING LAKE DURING 2011 AND 2009 THROUGH 2011.

	2011				2009-2011			
	NUMBER		WEIGHT		NUMBER		WEIGHT	
TAXON	No.	%	(g)	%	No.	%	(g)	%
Threadfin shad	556	24.2	5166	0.7	953	13.9	9685	0.5
Gizzard shad	95	4.1	11,347	1.6	383	5.6	58,594	3.1
Shortnose gar					1	<0.1	1750	0.1
Longnose gar					9	0.1	26,900	1.4
Carp	290	12.6	404,018	56.5	671	9.8	979,777	52.2
Common shiner					1	<0.1	17	<0.1
Striped shiner					34	0.5	59	<0.1
Rosyface shiner					21	0.3	51	<0.1
Spotfin shiner	119	5.2	336	<0.1	546	7.9	1314	0.1
Sand shiner					41	0.6	68	<0.1
Fathead minnow					1	<0.1	2	<0.1
Bluntnose minnow					261	3.8	535	<0.1
Bullhead minnow	46	2.0	128	<0.1	245	3.6	566	<0.1
Smallmouth buffalo	2	0.1	3240	0.5	3	<0.1	6590	0.4
Bigmouth buffalo					1	<0.1	2550	0.1
Yellow bullhead	1	<0.1	60	<0.1	3	<0.1	137	<0.1
Blue catfish	26	1.1	3094	0.4	66	1.0	15,830	0.8
Channel catfish	409	17.8	202,472	28.3	1117	16.3	488,899	26.1
Flathead catfish	3	0.1	36,000	5.0	7	0.1	88,750	4.7
Brook silverside					24	0.3	27	<0.1
Sunfish spp.	1	<0.1	1	<0.1	2	<0.1	2	<0.1
Green sunfish	43	1.9	1017	0.1	100	1.5	2793	0.1
Orangespotted sunfish					3	<0.1	29	<0.1
Redear sunfish	3	0.1	231	<0.1	21	0.3	832	<0.1
Bluegill	539	23.5	20,452	2.9	1949	28.4	110,869	5.9

TABLE 3-2 (Continued).

TAXON	2011 NUMBER No.	2011 NUMBER %	2011 WEIGHT (g)	2011 WEIGHT %	2009-2011 NUMBER No.	2009-2011 NUMBER %	2009-2011 WEIGHT (g)	2009-2011 WEIGHT %
Longear sunfish	53	2.3	975	0.1	126	1.8	2307	0.1
Hybrid sunfish	3	0.1	88	< 0.1	17	0.2	325	< 0.1
Smallmouth bass					5	0.1	3327	0.2
Largemouth bass	105	4.6	24,025	3.4	253	3.7	69,351	3.7
Black crappie					1	< 0.1	147	< 0.1
Freshwater drum	4	0.2	2357	0.3	8	0.1	3430	0.2
Totals	2298		715,007		6873		1,875,513	
Total taxa	18				31			
Total species	16				29			

[a]Sampling methods included electrofishing, trap netting, gill netting and hoop netting.

TABLE 3-3

TOTAL CATCH BY METHOD FOR FISH SPECIES COLLECTED FROM THE BRAIDWOOD STATION COOLING LAKE, 2011.

TAXON	ELECTROFISHING				TRAP NETTING				GILL NETTING				HOOP NETTING			
	NUMBER		WEIGHT		NUMBER		WEIGHT		NUMBER		WEIGHT		NUMBER		WEIGHT	
	No.	%	(g)	%	No.	%	(g)	%	No.	%	(g)	%	No.	%	(g)	%
Threadfin shad	429	29.0	3990	2.0					127	46.9	1176	10.9				
Gizzard shad	66	4.5	3662	1.9	22	4.5	5586	1.2	6	2.2	1920	17.7	1	1.9	179	0.5
Carp	80	5.4	123,773	63.4	207	42.0	274,765	57.9					3	5.6	5480	15.6
Spotfin shiner	119	8.0	336	0.2												
Bullhead minnow	46	3.1	128	0.1												
Smallmouth buffalo	1	0.1	40	< 0.1	1	0.2	3200	0.7								
Yellow bullhead	1	0.1	60	< 0.1												
Blue catfish					1	0.2	663	0.1	25	9.2	2431	22.4				
Channel catfish	46	3.1	26,084	13.4	227	46.0	158,551	33.4	113	41.7	5308	49.0	23	42.6	12,529	36.5
Flathead catfish					2	0.4	21,500	4.5					1	1.9	14,500	42.2
Hybrid sunfish	3	0.2	88	< 0.1												
Sunfish spp.	1	0.1	1	< 0.1												
Green sunfish	43	2.9	1017	0.5												
Redear sunfish	3	0.2	231	0.1												
Bluegill	494	33.4	17,061	8.7	19	3.9	1730	0.4					26	48.1	1661	4.8
Longear sunfish	53	3.6	975	0.5												
Largemouth bass	95	6.4	17,899	9.2	10	2.0	6126	1.3								
Freshwater drum					4	0.8	2357	0.5								
Totals	1480		195,345		493		474,478		271		10,835		54		34,349	
Total taxa	15				9				4				5			
Total species	13				9				4				5			

TABLE 3-4

NUMBERS OF FISH CAPTURED BY ELECTROFISHING AT EACH SAMPLING LOCATION IN BRAIDWOOD LAKE, 2011.

TAXON	SAMPLING LOCATIONS								TOTAL	%%
	E-1	E-2	E-3	E-4	E-5	E-6	E-7	E-8		
Threadfin shad	11	22	224	1	7	40	105	19	429	29.0
Gizzard shad	35	17	2			6	5	1	66	4.5
Carp	7	8	16	11	6	5	10	17	80	5.4
Spotfin shiner	2	2	52	6	13	11	8	25	119	8.0
Bullhead minnow			25	8		8	5		46	3.1
Smallmouth buffalo						1			1	0.1
Yellow bullhead					1				1	0.1
Channel catfish	2	16	6		2	2	8	10	46	3.1
Lepomis spp.								1	1	0.1
Green sunfish			1	5	27	3	6	1	43	2.9
Redear sunfish			2					1	3	0.2
Bluegill	2	55	55	85	214	16	35	32	494	33.4
Longear sunfish		4	9	6	9	11	11	3	53	3.6
Hybrid sunfish					3				3	0.2
Largemouth bass	2	24	15	13	7	10	14	10	95	6.4
Total fish	61	148	407	135	289	113	207	120	1480	
Total Taxa	7	8	11	8	10	11	10	11	15	
CPE (fish/hr)	91.0	220.9	607.5	201.5	431.3	168.7	309.0	179.1	277.7	

[a] Based on 0.67 hrs electrofishing effort.
[b] Based on 5.33 hrs electrofishing effort.

numbers of taxa were collected at sampling areas located toward the middle and cooler end of the Braidwood Lake cooling loop (Locations E-3, E-5, and E-7). Electrofishing biomass was dominated by carp, which constituted 63.4% of the 195.3 kg collected (Table 3-3). Other species that individually contributed more than 5% of the total biomass included channel catfish (13.4%), largemouth bass (9.2%), and bluegill (8.7%).

The mean electrofishing catch-per-effort (CPE) for all locations combined in 2011 was 277.7 fish/hr (Table 3-4). This value is higher then the mean electrofishing CPE of 177.5 and 167.6 fish/hr for all locations combined in 2009 and 2010, respectively (HDR 2010, 2011). Some of this increase may be the result of reducing the sampling effort from 30 minutes per location in 2009 and 2010 to 20 minutes per location in 2011. This was done to minimize the stress on fish that were being held in the holding tank before they could be processed in the field. Due to the relatively small size of the sampling areas that have been electrofished during each annual effort, the majority of the collected fish have been captured during the first 15 to 20 minutes of sampling. Toward the end of each sampling run in 2009 and 2010 some of the areas had to be electrofished again in order to make the 30 minute sampling period. Fewer fish were collected during the second runs through each of these areas.

In 2011, CPE ranged from 91.0 fish/hr at Location E-1 to 607.5 fish/hr at Location E-3. The second highest CPE occurred at Location E-5 (431.3 fish/hr). Location E-5 exhibited the highest CPE's in 2009 and 2010. This site includes the area around the make-up water discharge into the lake from the Kankakee River. Five species, threadfin shad, common carp, spotfin shiner, bluegill, and largemouth bass, were collected at each of the eight electrofishing locations.

3.2.2 Trap Netting

A total of 493 fish including nine species was collected by trap net (Table 3-5). Channel catfish was the dominant species captured, comprising 46.0% of all fish taken. The second most abundant species collected was carp (42.0%), followed by gizzard shad (4.5%), bluegill (3.9%), and largemouth bass (2.0%). The total number of fish collected by location ranged from 27 at Location TN-2 and TN-4 to 102 at Locations TN-8. The total number of species collected by location ranged from two at Location TN-2 to six at Locations TN-3, TN-5, and TN-6. The total biomass of fish captured by trap netting was 474.5 kg (Table 3-3). Carp (57.9%), channel catfish

TABLE 3-5

NUMBER OF FISH CAPTURED BY TRAP NETTING AT EACH SAMPLING LOCATION IN BRAIDWOOD LAKE, 2011.

TAXON	SAMPLING LOCATIONS TN-1	TN-2	TN-3	TN-4	TN-5	TN-6	TN-7	TN-8	TOTAL	%
Gizzard shad			1	3	15		2	1	22	4.5
Carp	5	8	9	6	10	75	44	50	207	42.0
Smallmouth buffalo						1			1	0.2
Blue catfish					1				1	0.2
Channel catfish	36	19	56	17	43	14	5	37	227	46.0
Flathead catfish						1	1		2	0.4
Bluegill	1		1	1	1	1	2	12	19	3.9
Largemouth bass	2		5		2	1			10	2.0
Freshwater drum	1		1					2	4	0.8
Total fish	45	27	73	27	72	93	54	102	493	
Total Taxa	5	2	6	4	6	6	5	5	9	
CPE (fish/trap net set)	22.5[a]	13.5[a]	36.5[a]	13.5[a]	36.0[a]	46.5[a]	27.0[a]	51.0[a]	30.8[b]	

[a]Based on two over night sets of approximately 12 hr duration.
[b]Based on 16 over night sets of approximately 12 hr duration.

(33.4%), flathead catfish (4.5%), largemouth bass (1.3%), and gizzard shad (1.2%) were the only species to individually comprise more than 1% of the total biomass collected.

During the two August sampling periods, mean trap netting CPE for all locations combined was 30.8 fish/net (overnight sets of approximately 12-hrs), which is similar to the 28.5 fish/net reported in 2009 (HDR 2010) and the 40.8 fish/net reported in 2010 (HDR 2011). CPE by location ranged from 13.5 fish/net at Locations TN-2 and TN-4 to 51.0 fish/net at Location TN-8. Carp and channel catfish were the only species collected at each of the eight sampling locations.

3.2.3 Gill Netting

Gill netting resulted in the collection of 271 individuals representing four species (Table 3-6). Threadfin shad dominated the catch by comprising 127 (46.9%) of the 271 total fish collected. Channel catfish was the second most abundant species collected (41.7%). The only other species to individually contribute more than 5% of the total catch was blue catfish (9.2%). Channel catfish comprised 5.3 kg (49.0%) of the 10.8 kg of fish collected by gill netting (Table 3-3), followed by blue catfish at 2.4 kg (22.4%), gizzard shad at 1.9 kg (17.7%), and threadfin shad 1.2 kg (10.9%).

A total of 252 fish representing four species was collected from the two deep water sets conducted at Location GN-1 (Table 3-6). Gill nets at this location were set in a deep hole at a depth of approximately 10-13 m. At the shallow water sampling Location GN-2 the gill nets were set at a depth of approximately 2 m. Nineteen fish and two species were collected from this sampling location during the two combined August sampling dates.

Gill net CPE at the deep water Location GN-1 was 336.0 fish/hr based on 252 fish collected during 0.75 hours of sampling effort during the two combined August sampling efforts. CPE at the shallow water Location GN-2 was substantially lower at 25.3 fish/hr based upon the 19 fish collected during 0.75 hours of total sampling effort in August. Mean CPE for the two sampling locations was 180.7 fish/hr, which is higher than 73.5 fish/hr in 2010 (HDR 2011) and the 53.4 fish/hr reported in 2009 (HDR 2010). Threadfin shad and channel catfish were the only species collected at both sampling locations.

TABLE 3-6

NUMBERS OF FISH CAPTURED BY DEEP (GN-1) AND SHALLOW WATER (GN-2) GILL NETS IN BRAIDWOOD LAKE, 2011.

	SAMPLING LOCATION			
TAXA	GN-1[a]	GN-2[b]	TOTAL	%
Threadfin shad	122	5	127	46.9
Gizzard shad	6		6	2.2
Blue catfish	25		25	9.2
Channel catfish	99	14	113	41.7
Total fish	252	19	271	
Total taxa	4	2	4	
CPE (fish/hr)	336.0[c]	25.3[c]	180.7[d]	

[a]GN-1 was a deep water set in approximately 10-13 meters of water.
[b]GN-2 was a shallow water set in approximately 2 meters of water.
[c]Based on 0.75 hours of total effort.
[d]Based on 1.50 hours of total effort.

3.2.4 *Hoop Netting*

A total of 54 fish including five species was collected by hoop nets (Table 3-7). Bluegill was the most abundant species captured, comprising 48.1% of all fish taken. The second and third most abundant species captured were channel catfish (42.6%) and carp (5.6%). The only other species collected included one individual each of gizzard shad and flathead catfish. A total of 34.3 kg of fish was collected by hoop net (Table 3-3). Flathead catfish (42.2%), channel catfish (36.5%), and carp (15.6%) were the only species that individually comprised greater than 5% of the total hoop net catch by weight.

The greatest number of fish (23 individuals) was collected at Location HN-3, which was a shallow water set baited with dead gizzard shad (Table 3-7). Twenty fish were collected at Location HN-4, which was also a shallow water set, but the net was not baited. Similar numbers of fish were collected at the two shallow water locations. Only three individuals were collected in the deep water baited net at Location HN-1, while eight fish were collected in the deep water net without bait at Location HN-2. The total number of species collected by location ranged from two at Locations HN-3 and HN-4 to four at Location HN-2. A total of 26 fish was collected from the two baited net locations compared to 28 fish captured from the two nets that were not baited at Braidwood Lake in 2011.

Hoop netting CPE ranged from 1.5 fish/overnight set at Location HN-1 (deep water with bait) to 11.5 fish/overnight set at Location HN-3 (deep water with bait). CPE for the two deep water sets (HN-1 and HN-2) averaged 2.8 fish/overnight set compared to 10.8 fish/overnight set at the shallow water locations (HN-3 and HN-4). The two baited net sets (HN-1 and HN-3) had an average CPE of 6.5 fish/overnight set compared to 7.0 fish/overnight set for the two nets (HN-2 and HN-4) that were not baited. Mean CPE for all nets combined was 6.8 fish/overnight set.

3.3 *Length-Frequecy Distributions*

Length-frequency distributions of six selected species (bluegill, largemouth bass, channel catfish, blue catfish, threadfin shad, and gizzard shad) captured by all sampling gears in 2011 were compiled and are presented graphically (Figure 3-1 through Figure 3-5). With the exception of electrofishing, the sampling gears used in these studies are biased toward larger fish. Therefore,

TABLE 3-7

NUMBERS OF FISH CAPTURED IN BAITED AND UNBAITED DEEP AND SHALLOW WATER HOOP NETS IN BRAIDWOOD LAKE, 2011.

TAXA	SAMPLING LOCATION: DEEP WATER[a] HN-1 (BAITED)	HN-2 (UNBAITED)	SHALLOW WATER[b] HN-3 (BAITED)	HN-4 (UNBAITED)	TOTAL	%
Gizzard shad	1				1	1.9
Carp	1	2			3	5.6
Channel catfish	1	4	17	1	23	42.6
Flathead catfish		1			1	1.9
Bluegill		1	6	19	26	48.1
Total fish	3	8	23	20	54	
Total taxa	3	4	2	2	5	
CPE (fish/overnight set)	1.5[c]	4.0[c]	11.5[c]	10.0[c]	6.8[d]	

[a]Deep water hoop nets HN-1 and HN-2 were set in 7.5 meters of water.

[b]Shallow water hoop nets HN-3 and HN-4 were set in approximately 2.0 meters of water.

[c]CPE was based on two overnight sets of approximately 12 hours duration.

[d]CPE was based on eight overnight sets of approximately 12 hours duration.

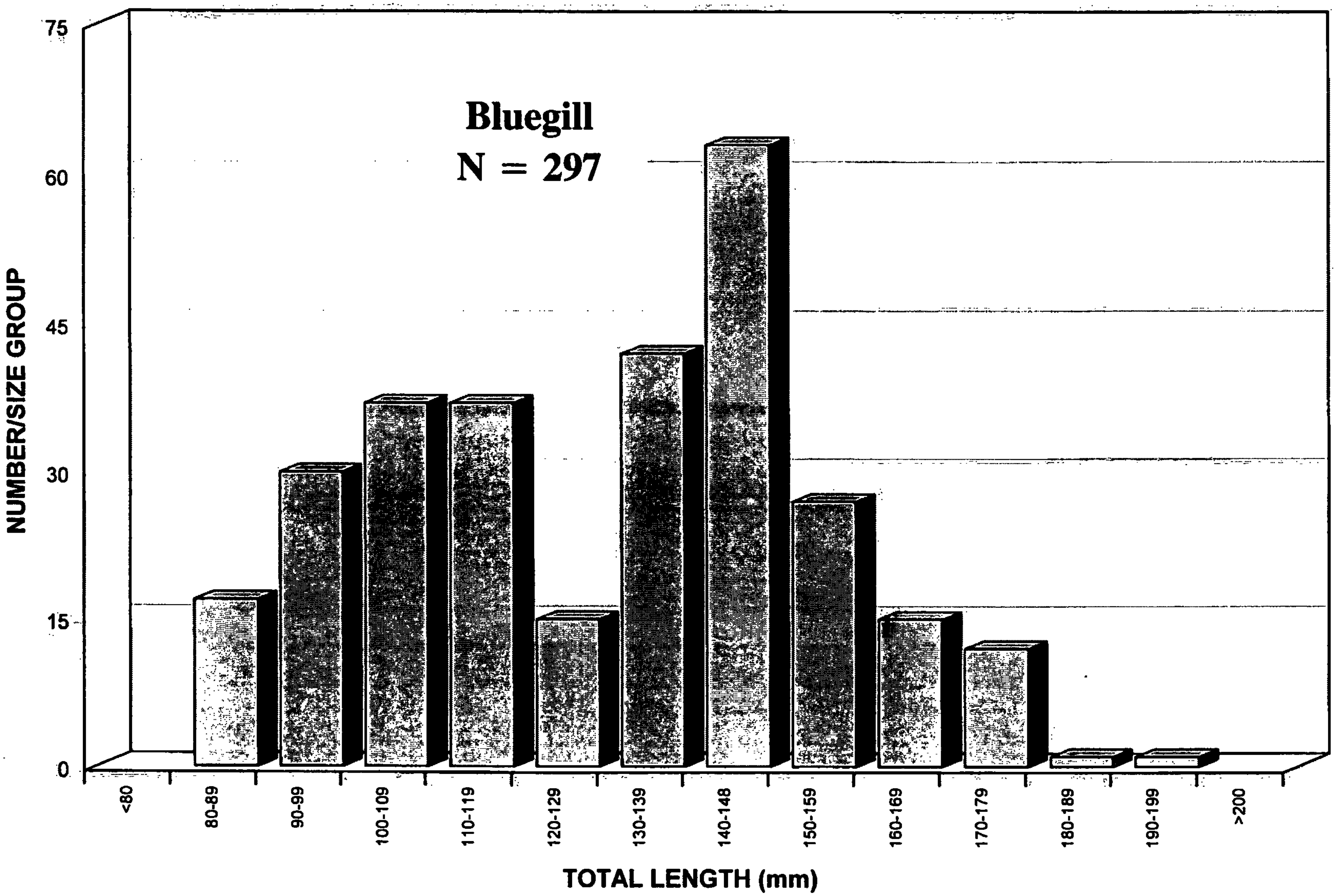

FIGURE 3-1. LENGTH-FREQUENCY DISTRIBUTION OF BLUEGILL COLLECTED FROM BRAIDWOOD LAKE DURING AUGUST, 2011.

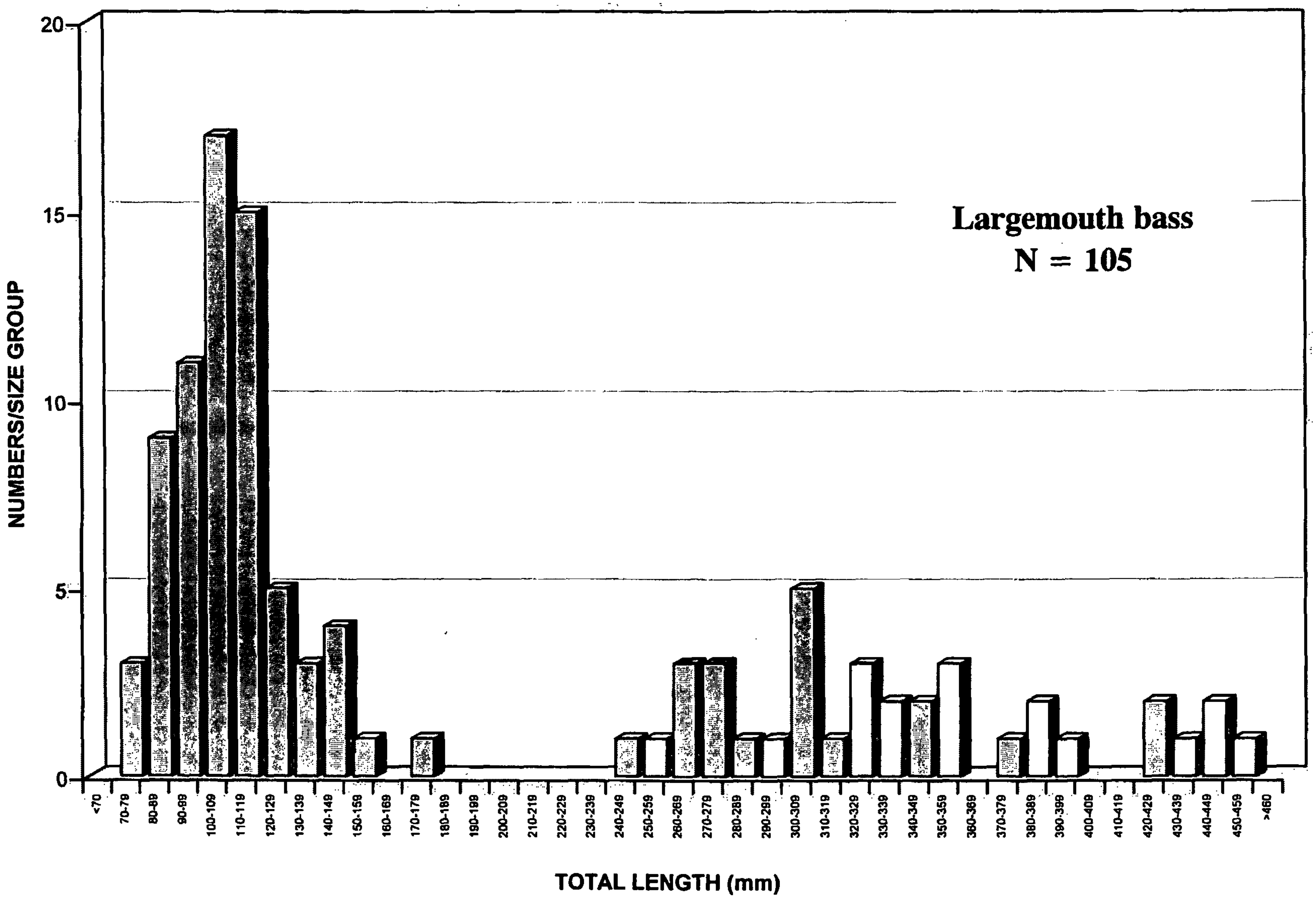

FIGURE 3-2. LENGTH-FREQUENCY DISTRIBUTION OF LARGEMOUTH BASS COLLECTED FROM BRAIDWOOD LAKE DURING AUGUST, 2011.

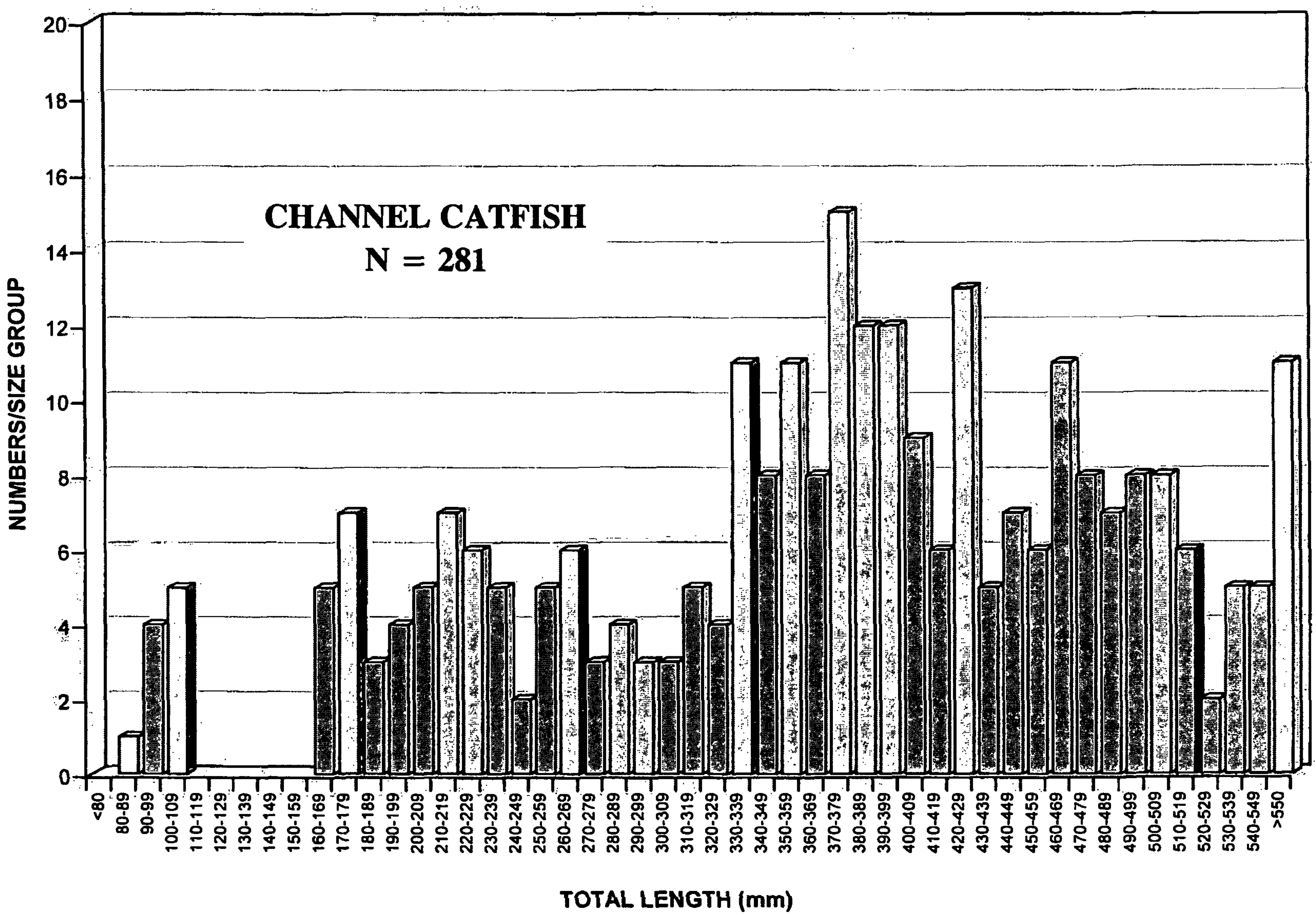

FIGURE 3-3. LENGTH-FREQUENCY DISTRIBUTION OF CHANNEL CATFISH COLLECTED FROM BRAIDWOOD LAKE DURING AUGUST, 2011.

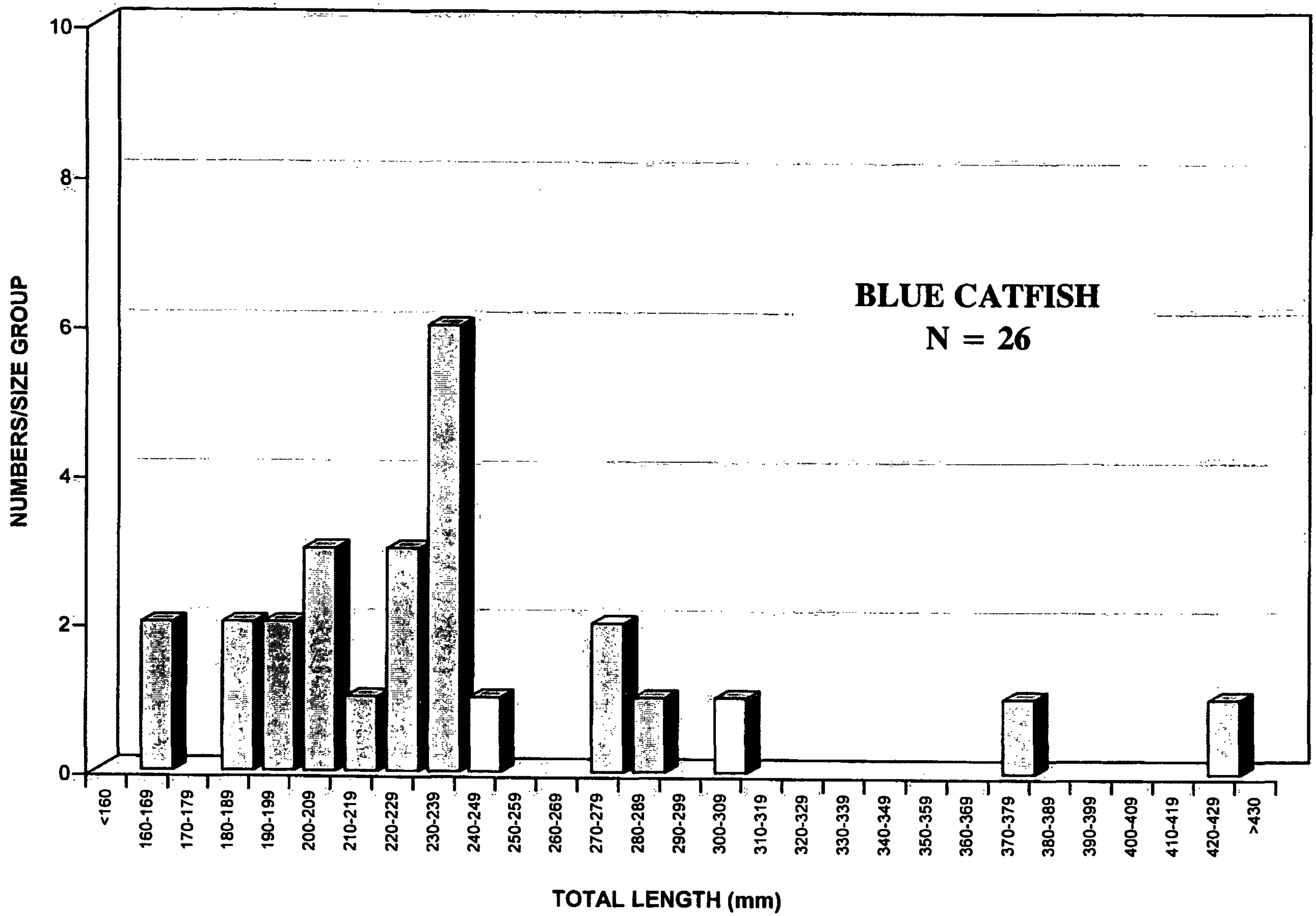

FIGURE 3-4. LENGTH-FREQUENCY DISTRIBUTION OF BLUE CATFISH COLLECTED FROM BRAIDWOOD LAKE DURING AUGUST, 2011.

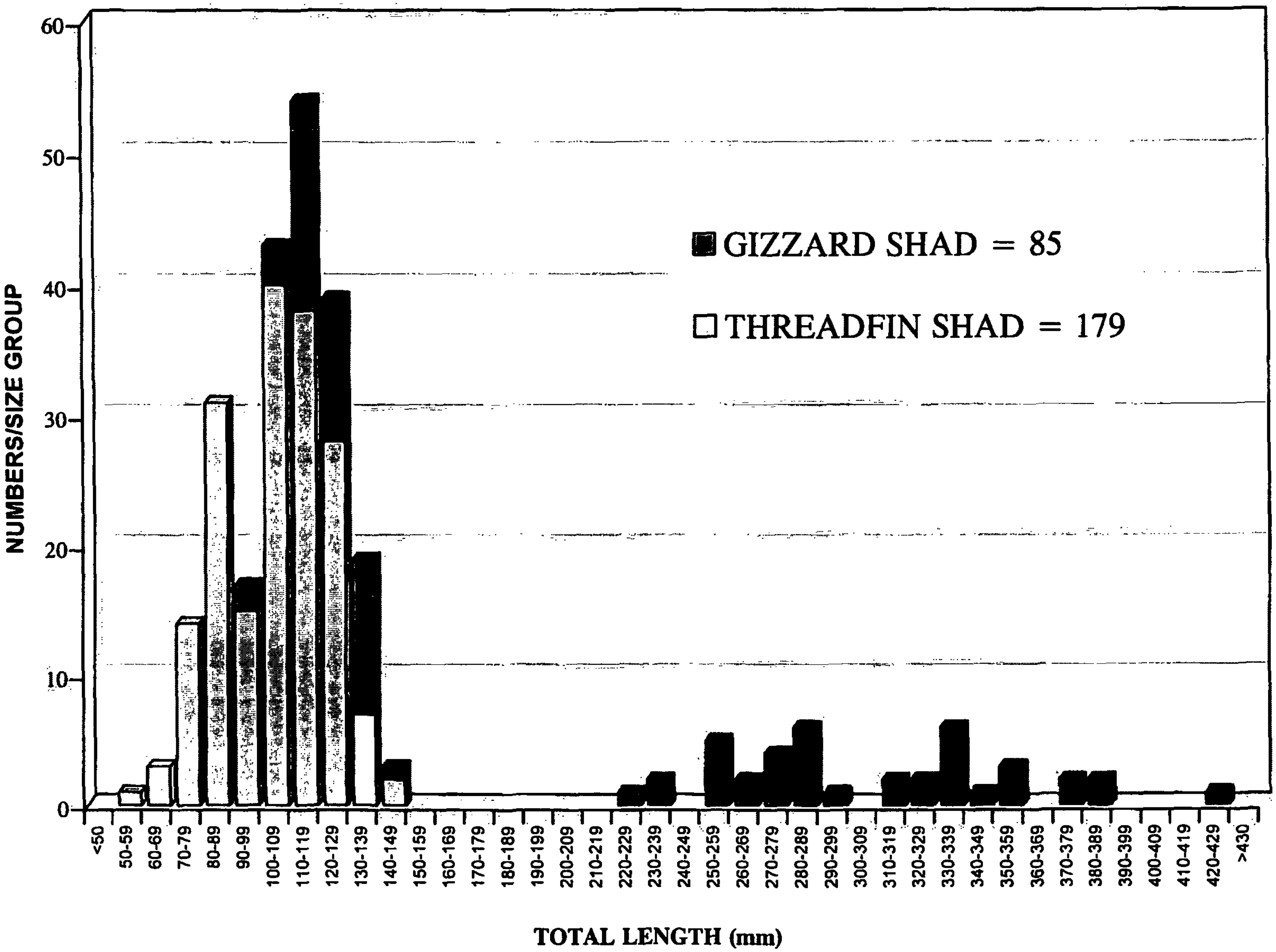

FIGURE 3-5. LENGTH-FREQUENCY DISTRIBUTION OF THREADFIN AND GIZZARD SHAD COLLECTED FROM BRAIDWOOD LAKE DURING AUGUST, 2011.

smaller fish, especially young-of-year and yearlings, were not collected in numbers that would most accurately represent their true abundance in Braidwood Lake.

Bluegill is one of the most abundant species found in Braidwood Lake. Two hundred ninety-seven individuals measuring from 80 to 194 mm in total length are included in the length-frequency histogram of bluegill that were captured in 2011 (Figure 3-1). Two major peaks in the length-frequency distribution representing at least two different age classes were noted. The first major group of fish includes bluegill measuring from 80 to 130 mm, while the second major group includes fish measuring from 130 to 180 mm. The age of these fish, as well as other species, in thermally enhanced bodies of water, such as Braidwood Lake, is impossible to determine without hard-part (scales, spines, and otoliths) analysis because the growing season extends throughout the winter months. Regardless of age, Braidwood Lake supports a large population of bluegill that is large enough to support a quality sport fishery.

The length-frequency distribution of 105 largemouth bass measuring from 70 to 453 mm in total length were collected from Braidwood Lake during 2011 (Figure 3-2). The length-frequency distribution indicates that several age classes of fish were included among the catch. The largest peak in the length-frequency histogram occurs from 100 to 120 mm and likely represents either YOY or Age 1 fish. Thirteen (12.4%) of the 105 fish collected exceeded 350 mm (14 in.). The largest individual that measured 454 mm was likely Age 4 or 5. Again, the age of fish in cooling lakes is difficult to ascertain based on length-frequency analysis because of the extended growing season that exist in these thermally enhanced bodies of water. Only three fish were collected that measured between 150 and 250 mm in TL. This may represent a weak or missing year class in the length-frequency histogram for largemouth bass as illustrated in Figure 3-2. It should also be noted that the IDNR stocked 46,160 four inch fingerlings into Braidwood Lake in 2010. This was equivalent to 20.6 fish/acre (HDR 2011). The authors of this report are uncertain if any additional stocking activities were conducted for this or any other species in 2011.

Channel catfish is an abundant species that is targeted by recreational anglers at Braidwood Lake. A total of 281 fish measuring from 84 to 686 mm are included in the length frequency analysis for channel catfish captured in 2011 (Figure 3-3). Several age classes of channel catfish are included among the 281 fish observed in the length-frequency analysis. Recruitment of this species appears to be very good based on Figure 3-3, which illustrates that there are not any missing or obvious weak year classes in the catch.

Braidwood Lake has been stocked with a variety of warm- and coolwater fish specie since the 1970's to the present time. Those efforts have included the introduction of blue catfish to the cooling lake. Because of those stocking efforts, and because of the number of blue catfish that were collected in 2011, a length-frequency histogram was also created for this species (Figure 3-4). The length-frequency distribution of 26 fish measuring from 164 to 423 mm indicates that as many as four or perhaps five year classes of blue catfish were included in the catch at Braidwood Lake during 2011. Twenty (76.9%) of the 26 fish collected measured less than 270 mm in total length, while the remaining six (23.1%) individuals ranged from 277 to 423 mm in total length. Blue catfish were stocked in Braidwood Lake by IDNR in 2010. This stocking effort included 9,812 blue catfish fingerlings (5.3 inches) equivalent to 4.3 fish/acre (HDR 2011). The authors of this report are uncertain if any of these species were stocked again in 2011.

Two additional species, threadfin shad and gizzard shad, were also analyzed (Figure 3-5). Both of these abundant forage species reside in Braidwood Lake. They are important to the ecology of the system because they have the potential to pose a treat to the operation and maintenance of Braidwood Nuclear Station when fish kills occur at the cooling lake. Large numbers of dead gizzard and threadfin shad could accumulate on the bar grills, traveling water screens, and other systems at the Stations intake, which could potentially interfere with water flow used to cool the reactors and other support systems.

A total of 85 gizzard shad and 179 threadfin shad are included in the length-frequency histogram for these two species (Figure 3-5). All of the threadfin shad collected during the current study measured from 57 to 147 mm in total length, while 50 (58.8%) of the 85 gizzard shad captured exceeded 150 mm in total length. Gizzard shad ranged in length from 92 to 426 mm. At least three or four year classes of gizzard shad were collected during 2011. In contrast, threadfin shad rarely exceed 150 mm in total length and individuals spawned early in the year commonly mature and spawn late in their first summer of life. Few threadfin shad live for more than two or three years.

3.4 Physicochemical Data

Water quality data recorded in conjunction with fish sampling was measured at each location prior to every sample collection (Appendix Tables A-1 to A-4). During August 1-4, water temperature at Braidwood Lake ranged from 34.8 °C at Location E-3 on 4 August to 41.0 °C at Location TN-2 on 1 August. Water temperatures during the second sampling period (30 August through 1 September) were cooler than those measured in early August. Temperatures during this period ranged from 30.1 °C at Location TN-5 (where make-up water is pumped into the lake from the Kankakee River) on 31 August to 35.3 °C at Location TN-2 on 30 August. As expected, the temperature gradient generally declined as the cooling water in the lake moved from the Station's discharge toward the Braidwood Station intake.

During the first sampling period (August 1-4), dissolved oxygen (DO) ranged from 3.1 ppm at Locations TN-2 during the early morning of 2 August to 13.5 ppm at Location TN-5 during the late afternoon of 1 August. Oxygen levels were generally higher during the second sampling period in late August and early September. Dissolved oxygen levels ranged from 5.6 ppm at Location TN-3 during the morning of 31 August to 14.0 ppm at Location E-3 during the afternoon of 31 August.

Dissolved oxygen measurements increased each day in the lake from early morning to late afternoon during both the first and second sampling periods. Similar conditions were also observed in 2009 and 2010 (HDR 2010, 2011). The increase in dissolved oxygen measurements from early morning to late afternoon can be attributed to photosynthesis by the extensive phytoplankton population in the lake that produces oxygen throughout the daylight hours.

Surface and bottom water temperature, DO, and conductivity readings were taken at deep water gill net set Location GN-1and the deep water hoop net set Locations HN-1 and HN-2. Similar surface and bottom readings were recorded at the deep water Locations HN-1 and HN-2. At Location GN-1, the bottom temperatures were slightly cooler (0.3 to 0.8 °C) than the surface reading, while the DO levels measured near the bottom were more variable ranging from 1.4 to 2.7 ppm less than the surface readings during the two August sampling periods.

Braidwood Lake is a very productive system with heavy oxygen demand (respiration and decomposition) occurring during the night and intense oxygen production (photosynthesis) occurring during clear sunny days. Currently, the majority of the photosynthetic activity within Braidwood Lake is attributable to phytoplankton, which has decreased the water clarity and replaced aquatic macrophtyes as the primary producer. In a report submitted to Exelon by SEA in 2001 (Appendix Report B-1); it states that "Several perched cooling ponds in the Midwest have had high macrophyte densities in their earlier years but usually become dominated by phytoplankton if they have heavy thermal loading. A switch to phytoplankton dominance is usually accompanied by a reduction in water transparency."

Braidwood Lake appears to be relatively well buffered with only minor diurnal variation in pH readings. Examination of pH data collected during the present surveys show that pH ranged from 8.3 to 8.7 during the first August sampling period and from 8.5 to 8.6 during the second August sampling period. The pH of water typically increases with increased photosynthetic activity and the resulting oxygen production can explain upward shifts in pH during the course of bright sunny days.

During the early August sampling period, conductivity ranged from 928 μmhos at Location TN-1 on 1 August to 993 μmhos at Location E-3 on 4 August. Conductivity during the late August sampling period ranged from 988 μmhos at Location E-3 on 31 August to 1036 μmhos at Locations TN-1 and TN-2 on 31 August. Conductivity and pH readings were similar throughout the entire length of Braidwood Lake. Surface to bottom readings were also similar, suggesting that the water throughout the cooling loop was well mixed during early and late August.

Make-up water is pumped into Braidwood Lake on an irregular basis from the Kankakee River throughout most of the year. As a result, water quality parameters can be expected to be generally more favorable near the make-up water discharge (Location E-5) compared to the remainder of the sampling locations. However, the affects of the make-up water discharge is quickly dissipated because of the relatively low volume of make-up flow being pumped into the lake. Make-up water was pumped into Braidwood Lake during portions of the first sampling period in early August. Make-up flow was not observed being pumped into Braidwood Lake during the late August sampling dates.

During the early August sampling period, water temperatures were at the upper limits of the range of values acceptable for some warmwater fish species. Air temperatures during late July and early August were unusually high throughout the Midwest in 2011, which accounted for most of the increase in the water temperatures at Braidwood Lake during early August. Conductivity and dissolved oxygen readings were slightly higher during the second sampling period, while pH measurements were similar during both sampling periods. The early morning dissolved oxygen readings that were measured on 2 August (3 ppm at Location TN-1 and TN-2) were approaching values that adversely affect most fish species. As previously noted, these diurnal oxygen fluctuations are common at Braidwood Lake during the summer months and can be attributed to oxygen depletion (respiration and decomposition) during the night and oxygen production (photosynthesis) during the day. On cloudy calm days, photosynthesis and oxygen production can be slowed to levels that cannot compensate for oxygen depletion that occurs throughout the night. When this occurs over an extended period of time (days), an oxygen deficit can develop and cause substantial fish die-offs if suitable refuges within the system are not available.

3.5 Historical Information

3.5.1 Water Quality

Water quality parameters were measured on seven separate occasions at Braidwood Lake from May 29, 2001 through August 27-28, 2002 (Appendix Reports B-1 through B-7). The purpose and scope of these investigations varied, but the most intensive sampling was conducted during the August 27-28, 2002 sampling event. Results of these investigations indicated that abnormally high levels of total dissolved solids (TDS), alkalinity, hardness, sulfates, magnesium, calcium, and total phosphorus existed throughout the cooling loop. This data was not unexpected based on the evaporation that occurs within the cooling loop coupled with the relative low make-up and blow-down flows associated with the operation of the Station. The cooling lake exhibited elevated values for these parameters at levels of two to nearly eight times higher than those of the make-up water from the Kankakee River. These elevated levels of water hardness can be of concern to the Station because they have the potential to intensify problems associated with scaling.

Phosphorus and nitrogen are two essential nutrients required by aquatic plants. Concentrations of these nutrients are typically low in water because phytoplankton and aquatic macrophytes quickly assimilate and utilize these nutrients for growth and reproduction. The studies conducted by SEA in 2002 indicated that the high levels of these nutrients within the cooling lake would continue to cause problems associated with phytoplankton blooms. Unlike most water bodies, phosphorus levels within Braidwood Lake were in excess and nitrates were the limiting factor. Bluegreen algae appeared to be the dominant summer form of algae within Braidwood Lake because they are not as limited by low nitrate levels as other algal species.

Water quality analysis has indicated that dissolved oxygen levels within the cooling lake can exhibit large diurnal variation in response to algal blooms that are most problematic during the summer months (June through August). The nutrient rich water of Braidwood Lake is ideal for the development of algal blooms that produce large amounts of oxygen during the day (photosynthesis) and oxygen depletion in the dark (respiration and decomposition). As oxygen is produced through photosynthesis, pH tends to increase if the water is not well buffered. Dissolved oxygen levels of 4-5 ppm (levels that most fish species become stressed) and lower have been recorded throughout the cooling loop 0.5 m below the waters surface. The lowest DO readings generally occur during the early morning period and typically increase throughout the day. Increases in DO of 4 to 5 ppm or more have been observed from morning to late afternoon at Braidwood Lake. In addition, stratification of the water column has also been reported during the same period of time when DO readings are measured at less than 3 ppm. During these events, DO readings in the hypolimnion (the zone below the thermocline to the bottom of the lake) can approach zero. When this occurs, it further limits the refuge available for fish and other aquatic organisms.

3.5.2 Fish Kills

Historical fisheries data summarizing fish kills that have occurred at Braidwood Lake was provided to HDR by Exelon Nuclear, IDNR, and SEA (Appendix Reports B-2 through B-7). Five fish kills that occurred from 2001 through 2007 were identified in the information provided to HDR. Each of these events occurred during June, July, or August. Two of the kills occurred in 2001. The first took place in late July and the second on August 27-28. A third kill was reported on July 30, 2004, the fourth on June 28, 2005, and the fifth occurred over an extended period of time during August 21-28, 2007. No additional information regarding fish kills has been provided to HDR since 2009. Therefore, it is assumed that no reportable fish kills have been observed at Braidwood Lake since August, 2007.

Little information was provided for the fish kills that occurred in late July and August, 2001. The species involved and the extent of dead fish observed during the first event in July were not included in the information received by HDR. The second fish die-off in late August was dominated primarily by gizzard shad that comprised more than 95% of all fish observed. The remaining species involved in the die-off in decreasing order of relative abundance included, freshwater drum, quillback, carp, largemouth bass, channel catfish, redhorse spp., smallmouth bass, and bluegill. With the exception of gizzard shad, the majority of the fish were located from the mid-point of the cooling loop to the intake. A report submitted by SEA indicated that warm water temperatures and/or low dissolved oxygen levels were the most likely factors that contributed to the fish die-off in July. SEA also indicated that the die-off in late August was most likely the result of depleted dissolved oxygen levels that occurred in the lake following an extensive phytoplankton bloom collapse, which is a natural phenomenon that can occur in highly productive waters during summer months. Dissolved oxygen measurements throughout the majority of the lake were at or below minimum levels necessary to support most fish species.

A third fish die-off at Braidwood Lake was investigated on July 30, 2004. Gizzard shad was the dominant species involved, although channel catfish were also observed. The gizzard shad appeared to be in an advanced state of decay suggesting that the actual die-off occurred earlier in the week. Water quality parameters at the time of the incident were not included in the brief summary report provided to HDR, which suggests they were not measured concurrent with the fish die-off. Water quality measurements were taken in early October following the fish die-off. During this period of time, DO levels of 3.8 ppm and a water temperature of 29.2 °C were recorded at a depth of one foot below the surface, just north of the south boat ramp. At a location several hundred feet from the lake make-up discharge from the Kankakee River, more favorable dissolved oxygen (7.6 ppm) and water temperatures (26.5 °C) were measured. DO readings at this location were stratified exhibiting a decline to 5.3 ppm at 40 feet, while water temperature showed minimal decrease with water depth.

In 2005, an inspection of a fish die-off was conducted on 28 June. Formal counts of fish were not conducted at this time, but field assessments indicated that a fairly substantial die-off involving several species had occurred. Gizzard shad was again the most numerous species affected and fish carcasses were observed throughout the majority of the lake. Additional species observed included threadfin shad, quillback, largemouth and smallmouth bass, carp, and channel catfish. Water quality measurements during this event were not provided to HDR and are assumed to be unavailable.

Rob Miller of IDNR and Jeremiah Haas of Exelon Nuclear investigated another fish die-off that was first reported at Braidwood Lake on August 21, 2007. The majority of the dead fish observed were either large gizzard shad or threadfin shad up to five inches in length. Channel catfish were also prevalent, with only a few carp, largemouth bass, and flathead catfish being observed. Most of the fish were distributed in close proximity to the north boat ramp due to prevailing south winds. The number of dead fish observed decreased towards the south (hot) end of the cooling loop. During the afternoon of 21 August, surface water temperature was 35.3 °C and DO was near 3 ppm at a sampling point several hundred yards from the south ramp. Four separate water temperature and DO readings were also conducted at the north ramp between 1210 hrs and 1658 hrs. Water temperature increased from 30.3 to 33.9 °C over the course of that time interval. Dissolved oxygen was measured at 3.1 ppm at 1210 hrs and increased to 6.7 ppm during the third reading at 1530 hrs. DO levels decreased during the last reading at 1658 hrs to 5.9 ppm. Oxygen depletion appeared to be the factor responsible for the August fish kill that occurred at Braidwood Lake in 2007.

4.0 SUMMARY AND RECOMMENDATIONS

4.1 Summary. Braidwood Lake is a 2640 acre, partially perched cooling lake that was first impounded in 1980-1981 after several old strip-mine pits were inundated with water from the Kankakee River. The lake has received supplemental stockings of both warmwater and coolwater fish species since the late 1970's. However, stocking efforts of species including walleye, tiger muskie, smallmouth bass, and hybrid striped bass have not produced a sustainable quality fishery, which is due to the warm temperatures that are currently common in the cooling lake throughout the summer months. Water quality, particularly water temperature, improves as the water moves from the southern (hot) end of the cooling loop toward the northern (cool) end of the lake.

Fisheries surveys have been conducted by IDNR at Braidwood Lake annually from 1980 through 1992, in 1994, and at two year intervals from 1997 through 2011. Forty-seven species of fish and two hybrid taxa (tiger muskie and hybrid sunfish) have been included among the 13 families of fish collected. Several of these species were rarely collected, were the result of supplemental stocking efforts, or have not been collected during the past ten years of sampling. Two species, mosquitofish and blue catfish, were collected for the first time in 2009 by the IDNR. River redhorse (one individual captured in 1999) is the only species that has been collected which is currently listed as protected in Illinois. Fisheries surveys were again conducted by the IDNR in 2011, but the data had not been compiled prior to the preparation of this report.

In 2009, HDR collected 24 species and two taxa (hybrid sunfish and small unidentified young-of-year sunfish species) among the 2143 fish collected. Similar results were observed in 2010 when 25 taxa representing eight families were included among the 2432 fish collected by electrofishing, trap netting, gill netting, and hoop netting. In 2011, 18 taxa representing 16 species were included among the 2298 fish collected by HDR. Several taxa that were collected by IDNR from 1980 to 2009 were not collected by HDR during 2009-2011. However, five species (shortnose gar, smallmouth buffalo, bigmouth buffalo, fathead minnow, and rosyface shiner) that have been captured by HDR have not been captured by IDNR. No threatened or endangered species have been encountered by HDR during any of the three years of sampling. Since 1980, 52 species of fish and two hybrids (tiger muskie and hybrid sunfish) have been collected at Braidwood Lake by the IDNR and HDR.

The Braidwood Lake Fish and Wildlife Area evolved through three distinct phases since its inception prior to the 1980's. Originally, several surface mined pits existed at the site until the lake was impounded with water from the Kankakee River during 1980 and 1981. The lake continued to function in this capacity until July 29 and November 17, 1988 when Braidwood Station began commercial operation of Units I and Unit II, respectively. From 1980 through July 1988, Braidwood Lake did not receive any thermal loading from Braidwood Station. Since 1988, the lake has functioned as a cooling loop for the operation of the Station. Currently, the lake is best suited to support a warmwater fishery due to the warm temperatures prevalent in the lake throughout the summer months. Dominant species currently found at Braidwood Lake include gizzard shad, threadfin shad, bluegill, channel catfish, and carp. Additional species such as largemouth bass, green sunfish, flathead catfish, spotfin shiner, bluntnose minnow, and sand shiner have also been commonly encountered. Excluding the stocked fish that have been introduced into the Braidwood Lake, the taxa encountered have also been collected from the Kankakee River, which is the source of make-up water for the lake. With the possible exception of common carp and channel catfish, these species are better suited to conditions that exist within the river. Survival of individuals that are introduced into the lake with the make-up water is limited by the elevated water temperatures that exist within the cooling loop during summer months.

Braidwood Lake can be currently described as a well buffered body of water with elevated water temperatures, high levels of total dissolved solids (TDS), phosphates, and nitrates. Primary productivity in the lake can be very high in conjunction with algal blooms that occur throughout the lake, especially during the June through August period. These blooms are driven by the high nutrient levels that exist within the lake. In recent years, phytoplankton has replaced aquatic macrophytes as the principal source of primary production. The lake can also display relatively large diurnal fluctuations in dissolved oxygen measurements, particularly during the summer when oxygen is produced in large quantities by photosynthesis during the day and used in large quantities by respiration and decomposition during the night. In addition, Braidwood Lake can stratify during certain portions of the year, which has led to anoxic (oxygen depletion) or near anoxic conditions throughout the hypolimnion (stratified bottom layer of water below the thermocline) as a result of respiration and decomposition from a collapsing algal bloom. Even in the surface waters of the epilimnion, dissolved oxygen readings of less than 4 ppm have been reported following an extensive and rapid die-off of an existing phytoplankton bloom. It is during these periods of time when water temperatures are elevated and dissolved oxygen levels are low that the fish die-offs are observed at the lake. The conditions described in this paragraph should not be expected to change at Braidwood Lake in the foreseeable future.

4.2 Recommedations. Five separate fish die-offs attributed to low DO levels were observed at Braidwood Lake between 2001 and 2007. It is expected that the conditions which led to those five events will not change or improve in the foreseeable future. Therefore, it should be assumed that fish die-offs will continue to occur when algal blooms crash and oxygen depletion occurs. Substantial fish die-offs within the cooling loop could adversely affect both the operation and maintenance of Braidwood Nuclear Station.

Currently, there are no practical or simple solutions that could prevent the occurrence of fish die-offs at Braidwood Lake. It should be anticipated that fish die-offs will continue to occur at the lake on a fairly regular basis. Therefore, it would be advantageous if a reliable sampling protocol or set of procedures were developed that would reasonably predict fish die-offs that may adversely affect the operation and/or maintenance of the Station. With advanced warning the Station could be informed of a potential reportable incident, regulatory agencies could be notified, and crews responsible for fish disposal could be put on alert to help manage the risk associated with a substantial fish die-off. HDR believes this can be accomplished by conducting routine visual inspections of the lake, monitoring dissolved oxygen levels, and by having a basic understanding of environmental conditions that may trigger these events, especially weather conditions.

HDR recommends a two tier sampling procedure that may be utilized to help predict the onset of a possible reportable fish die-off. We recommend that visual inspections of the lake and water quality measurements be conducted routinely throughout the year, particularly during the warm weather months, if budget and staff is available to monitor the lake. The frequency of observations and the intensity of the water quality measurements should be discussed by the management who would analyze risk management at Braidwood Station. Historically, all the fish die-offs at Braidwood Lake have occurred during the warm weather period of June through August. This is the period of time when water in the cooling loop is the warmest and dissolved oxygen levels can fall substantially following die-offs of extensive phytoplankton booms. Therefore, this is the most critical time to monitor existing conditions that could result in a potential problem (May through September). Sampling on a less frequent basis throughout the remainder of the year may provide additional information that could be useful to the Station and possibly alert the Station to an impending problem that may not have been identified in the past.

Water quality measurements should include dissolved oxygen readings at a minimum because fisheries biologists that have investigated these events in the past have concluded that the mortality of fish was the result of oxygen depletion. The most effective way to monitor dissolved oxygen levels within the lake would be through the use of permanently fixed continuous water quality samplers and data loggers installed at several depths that could be programmed to take measurements at predetermined time intervals. The number of water quality samplers purchased or the type of sampler utilized would be dependent upon the desired results and cost of the equipment. Ideally, the best system would allow the sampling unit to take measurements at programmed time interval (perhaps every 15 minutes to daily), would measure at least DO, water temperature, and pH, could provide instantaneous readouts to Braidwood staff without having to manually go into the field to download data, and would require minimal maintenance or calibration to operate. The price range of this type of equipment is highly variable depending on the unit selected, the anchoring mechanism for the unit if required, battery life, the number of parameters measured, etc. An alternative to this approach would be to utilize a technician to manually take these measurements. The disadvantage of this approach is the number of readings that could be taken on a daily basis and the time involved to conduct the water quality analysis in the field.

Water quality at Braidwood Lake should be monitored on some predetermined routine basis. That could be at least weekly throughout the year or perhaps only through the more critical time period of approximately June through August. The two tiered sampling approach would be initiated when dissolved oxygen readings hit a pre-determined trigger point (perhaps 5 to 6 ppm). Once DO readings decrease to the trigger point, sampling frequency should be increased. If automatic samplers are not used, field technicians should be in the field by sunrise when DO readings are typically the lowest. If automatic samplers were utilized, dissolved oxygen, temperature and other water quality parameters could be tracked throughout the day. This would become important if DO readings ranged from 4 or 5 ppm in the morning to 7 or 8 ppm in the afternoon. This information would indicate that photosynthesis is still occurring during the daylight period, which would replenish DO levels in the water and reduce the risk of a fish die-off. However, if DO levels were 4 or 5 ppm in the morning and only increased slightly throughout the day, this would indicate very little oxygen production due to photosynthesis. This condition would lead to a greater oxygen deficit during the evening, and could indicate the onset of a phytoplankton bloom die-off that could trigger a fish kill. Once DO levels approach 3 ppm, Station management could be notified of a potential problem, increased visual inspections of the lake could be conducted, and fish cleanup and disposal crews could be notified and put on standby status.

Additionally, Braidwood staff should be aware of weather patterns that can influence these events. When phytoplankton blooms are prevalent and several cloudy days with little or no wind are forecast, massive dies offs of the bloom and subsequent oxygen depletion throughout the water column should be anticipated. Increased sampling of DO during these weather patterns is advisable in conjunction with an increase in the frequency of visual inspections at the lake for moribund or dead fish. An increase in water clarity or transparency within the lake would also be expected to occur as the phytoplankton population crash is in progress.

Visual inspections for fish die-offs should be conducted around the entire cooling loop as prevailing winds may push most of the fish toward one end of the lake. HDR recommends water quality measurements be conducted at a depth of approximately one meter, if multiple depths are not sampled. If only one sampling location is selected, that location should be located near the approximate mid-point of the cooling loop. The number of water quality stations sampled should be determined by Exelon management or an advisory staff. It is further recommended that an advisory team should be formed to devise an effective sampling program and set of procedures that can effectively monitor conditions within the lake. HDR is willing to participate and interact with the advisory team to provide expertise in the development of an effective sampling program.

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APPENDIX A

PHYSICOCHEMICAL DATA

LIST OF TABLES

TABLE A-1

PHYSICOCHEMICAL MEASUREMENTS RECORDED CONCURRENTLY WITH ELECTROFISHING SAMPLES COLLECTED FROM BRAIDWOOD LAKE

Braidwood Station - 2011

PARAMETER	E-1	E-2	E-3	E-4	E-5	E-6	E-7	E-8
Date (First Sample Period)	**AUG 4**	**AUG 4**	**AUG 4**	**AUG 4**	**AUG 4**	**AUG 4**	**AUG 4**	**AUG 4**
Time	1120	1030	0925	0840	0710	1200	1245	0755
Temperature (°C)	39.0	36.6	34.8	35.5	35.5	35.4	35.0	35.0
Dissolved oxygen (ppm)	5.15	6.34	6.31	4.90	4.42	7.14	10.6	4.65
pH	8.4	8.5	8.6	8.5	8.6	8.5	8.7	8.4
Conductivity (μmhos/cm)	972	987	993	990	988	969	954	983
Date (Second Sample Period)	**AUG 31**	**AUG 31**	**AUG 31**	**AUG 31**	**SEP 1**	**SEP 1**	**SEP 1**	**AUG 31**
Time	1300	1350	1440	1330	0740	0845	0915	1612
Temperature (°C)	34.1	33.6	32.1	33.1	32.8	32.4	31.8	32.8
Dissolved oxygen (ppm)	12.2	13.4	14.0	12.4	7.27	8.44	7.56	9.74
pH	8.6	8.6	8.6	8.6	8.6	8.5	8.6	8.6
Conductivity (μmhos/cm)	1009	1001	988	1003	1031	1024	1015	1023

TABLE A-2

PHYSICOCHEMICAL MEASUREMENTS RECORDED CONCURRENTLY WITH TRAP NETTING SAMPLES COLLECTED FROM BRAIDWOOD LAKE

Braidwood Station – 2011

PARAMETER	TN-1	TN-2	TN-3	TN-4	TN-5	TN-6	TN-7	TN-8
Date (First Sample Period)	**AUG 1-2**	**AUG 1-2**	**AUG 1-2**	**AUG 1-2**	**AUG 1-2**	**AUG 1-2**	**AUG 1-2**	**AUG 1-2**
Time	1910[a] 0645[b]	1902 0650	1854 0658	1751 0705	1742 0715	1736 0740	1702 0805	1650 0825
Temperature (° C)	40.8 39.7	41.0 39.8	39.2 38.4	38.9 38.3	37.9 35.7	38.5 37.7	37.1 36.7	37.0 36.8
Dissolved oxygen (ppm)	9.17 3.18	9.30 3.07	12.0 3.84	12.55 3.87	13.5 6.02	12.08 4.73	9.04 5.19	10.90 6.25
pH	8.6 8.3	8.6 8.3	8.7 8.4	8.7 8.5	8.6 8.6	8.5 8.6	8.5 8.6	8.4 8.6
Conductivity (μmhos/cm)	928 991	971 993	966 989	957 988	955 983	958 986	946 974	941 969
Date (Second Sample Period)	**AUG 30-31**	**AUG 30-31**	**AUG 30-31**	**AUG 30-31**	**AUG 30-31**	**AUG 30-31**	**AUG 30-31**	**AUG 30-31**
Time	1715 0700	1710 0725	1700 0745	1650 0800	1620 0830	1610 0845	1552 0930	1548 0910
Temperature (° C)	35.2 33.3	35.3 33.3	34.6 31.8	34.3 31.8	32.8 30.1	34.2 31.2	32.6 31.3	32.5 30.7
Dissolved oxygen (ppm)	11.21 5.76	11.34 5.76	12.52 5.58	13.93 5.73	13.40 7.61	12.40 6.52	9.80 6.99	9.33 7.99
pH	8.6 8.5	8.6 8.5	8.6 8.5	8.6 8.5	8.5 8.6	8.5 8.6	8.5 8.6	8.5 8.6
Conductivity (μmhos/cm)	1013 1036	1014 1036	1010 1030	1007 1031	1009 1024	1008 1028	1004 1020	1001 1011

[a]Top number represents subsurface readings taken 0.5 meter below the surface when the nets were set in the evening.

[b]Bottom number represent subsurface readings taken 0.5 meter below the surface when the nets were retrieved the next morning approximately 12 hours later.

TABLE A-3

PHYSICOCHEMICAL MEASUREMENTS RECORDED CONCURRENTLY WITH GILL NETTING SAMPLES COLLECTED FROM BRAIDWOOD LAKE

Braidwood Station – 2011

PARAMETER	GN-1 in Deep water (10-13 m)		GN-2 in shallow water (2 m)	
	Surface	**Bottom**	**Surface**	**Bottom**
Date (First Sample Period)	**AUG 1**		**AUG 1**	
Time	1725	1725	1640	a
Temperature (° C)	37.9	37.1	37.0	a
Dissolved oxygen (ppm)	12.0	9.3	10.9	a
pH	8.5	a	8.4	a
Conductivity (μmhos/cm)	955	957	941	a
Date (Second Sample Period)	**AUG 30**		**AUG 30**	
Time	1610	1610	1540	a
Temperature (° C)	33.1	32.9	32.5	a
Dissolved oxygen (ppm)	12.7	11.3	9.33	a
pH	8.6	a	8.6	a
Conductivity (μmhos/cm)	1005	1009	1001	a

[a] Water quality measurement not taken.

TABLE A-4

PHYSICOCHEMICAL MEASUREMENTS RECORDED CONCURRENTLY WITH TRAP NETTING SAMPLES COLLECTED FROM BRAIDWOOD LAKE

Braidwood Station - 2011

PARAMETER	HN-1 DEEP WATER BAITED (7.5 m)		HN-2 DEEP WATER UNBAITED (7.5 m)		HN-3 SHALLOW WATER BAITED (2.0 m)		HN-4 SHALLOW WATER UNBAITED (2.0 m)	
Date (First Sample Period)	**AUG 1 (SET)**	**AUG 2 (LIFT)**	**AUG 1 (SET)**	**AUG 2 (LIFT)**	**AUG 1 (SET)**	**AUG 2 (LIFT)**	**AUG 1 (SET)**	**AUG 2 (LIFT)**
Time	1623	0845	1638	0900	1640	0905	1642	0910
Temperature (° C)	37.1[a] 37.1[b]	36.8 36.2	37.1 37.1	36.8 36.5	37.1	36.9	37.1	36.9
Dissolved oxygen (ppm)	9.04 8.44	5.39 5.34	9.04 8.44	5.44 5.33	9.04	5.88	9.04	5.88
pH	8.5	8.6	8.5	8.6	8.5	8.6	8.5	8.6
Conductivity (μmhos/cm)	946 945	976 975	946 945	976 975	946	970	946	970
Date (Second Sample Period)	**AUG 30 (SET)**	**AUG 31 (LIFT)**	**AUG 30 (SET)**	**AUG 31 (LIFT)**	**AUG 30 (SET)**	**AUG 31 (LIFT)**	**AUG 30 (SET)**	**AUG 31 (LIFT)**
Time	1525	0937	1530	1002	1535	1007	1538	1012
Temperature (° C)	32.6 32.5	31.3 31.3	32.6 32.5	31.3 31.3	32.6	31.3	32.6	31.3
Dissolved oxygen (ppm)	9.8 9.0	6.99 6.89	9.8 9.0	6.99 6.89	9.80	6.99	9.80	6.99
pH	8.5	8.6	8.6	8.6	8.5	8.6	8.5	8.6
Conductivity (μmhos/cm)	1004 1002	1020 1020	1004 1002	1020 1020	1004	1020	1004	1020

[a]Top number represents subsurface readings taken 0.5 meter below the surface.

[b]Bottom number represent deep water readings taken 0.5 meter off the bottom.

APPENDIX B

HISTORICAL WATER QUALITY AND FISHERIES DATA

LIST OF TABLES

APPENDIX REPORT B-1.

Results of Initial Braidwood Cooling Pond Survey by SEA Inc.

SEA Inc. was asked to conduct an initial water quality and ecological assessment of Braidwood Cooling Pond. The objective was to determine if the dense macrophytes were contributing to an increasing trend toward a higher pH in the pond. The results and discussion presented in this report are primarily based upon the samples taken and observations made on May 29 and 30, 2001, and on a preliminary review of water quality data from three sites taken on May 18, and June 14, 2001. SEA Inc. was also asked to investigate a fish kill on Braidwood Cooling Pond on August 27 and 28. The results of that investigation are in a separate report but some of that information is referenced in this report.

Overview of Methods and Results Presentation.

SEA's initial survey (May 29-30) consisted of:
- water quality parameters at several key sites with a Hydrolab Surveyor III, during both daylight and night conditions,
- measuring phytoplankton community respiration (light & dark bottle method),
- identification of macrophytes and observations on their distribution and abundance, and
- monitoring temperatures throughout the cooling loop.

The survey results are summarized in Tables 1,2, 3, and 4. Table 1 provides the results from key sampling sites that were selected to characterize the cooling pond. These sites were sampled three to four times over a 36-hour period. Parameters sampled with the Hydrolab included: Depth, Temperature, Dissolved Oxygen (D.O.), pH, Specific Conductance, and Redox Potential. Sample times included midday, just before sunset, and prior to sunrise.

Table 2. includes results from two sites for depth profiles, 24 hour duration light & dark bottles, and the SX discharge. Table 3. provides D.O. and temperatures sequentially around the cooling loop at midday. Table 4. lists the D.O. levels and % saturation at four sites prior to sunrise. Table 5 list the water quality analysis preformed by Test America at three locations on two dates. Figure 1. is a map identifying the sample locations listed in the tables.

Discussion of Results and Observations:

Braidwood Cooling Pond was characterized to SEA Inc. as a pond that was dominated or choked by macrophytes. Based on this characterization, we feel that Braidwood Cooling Pond has undergone a transformation to a system dominated by phytoplankton. Although we were not prepared to sample the phytoplankton for densities and identification, it was very obvious that an

intensive phytoplankton bloom was in progress. Secchi disc readings were only 0.30 to 0.35 m throughout the pond. Although we were unable sample the phytoplankton, we would suspect it is dominated by Blue-Green algae (Cyanophyta), based on the water temperatures, total phosphorous levels, high pH and apparent high densities.

Braidwood Cooling Pond appears to be a very dynamic system that receives energy subsidies in the form of heat, pumped circulation and make-up water from the Kankakee River. Several perched cooling ponds in the Midwest have had high macrophyte densities in their earlier years but usually become dominated by phytoplankton if they have heavy thermal loading. A switch to phytoplankton dominance is usually accompanied by a reduction in water transparency. Our Secchi disc readings were about 0.3 m which is about one half of the 2 ft or 0.6m)value listed in a privately produced fishing guide (Sportsman' Connection) published in 2000. Although we did not examine many of the isolated coves, we found Milfoil (*Myriophyllum verticillatum*) only in the last 1/3 of the cooling loop(Figure 1. sites7,8,9) and its abundance was spotty. The Sportsman' Connection fishing guide map had a much wider distribution of submerged, emergent and floating vegetation and appeared to be more in line with earlier descriptions SEA Inc. were given of Braidwood. Nutrients that were previously tied up by the macrophytes are now likely being taken up by the phytoplankton. The reduced water transparency due to the phytoplankton bloom will limit light to the submerged macrophytes and likely cause further reductions.

The intensive phytoplankton bloom that Braidwood is currently experiencing may have more potential for adverse impacts to the biological community than on operational impacts to the station. The water seems to be fairly well buffered and diurnal swings in pH were insignificant. Analysis of the water for alkalinity could confirm the buffering capacity. Blue-Green algae blooms may present problems with D.O. levels and in some rare cases may release toxins with impact other aquatic life.

The light & dark bottle (Table 2.) and the pre-sunrise D. O. levels (Table 4.) illustrated the intensity of the bloom. The light and dark bottles were at a 0.5 m depth at end of the discharge canal for 24 hours. Respiration in the dark bottled depleted the initial D.O. from 10.8 mg/l (158% saturation) to 1.37 mg/l (20 % saturation). The light bottle was supersaturated to the point the entire inside surface was coated with oxygen bubbles and the D.O. was 11.8 (174% saturation). The photosynthetic rate was much higher than could be measured due to the extensive formation of oxygen bubbles in the light bottle. The photosynthetic rate was so high that the light bottle should have been limited to 6 hours to obtain a better measurement of the gross plankton photosynthetic rate.

The pre-sunrise D.O. measurements (Table 4.) also reflect the high respiration rate of the plankton community. Most notable was Site #3 where D.O. levels dropped to 4.1 mg/l. The midday sampling on the first day (Table 1.) was conducted during bright and sunny conditions and D.O. levels at most sites were higher than midday samples on the following day when it was overcast. This

plankton community is so productive that D.O. levels can be expected to swing rapidly. During our survey, air temperatures were mild (high 65 F) and it was windy both days. Under a scenario of several hot summer days, with little wind, full operation of the station, followed by a cloudy day, D.O. levels could drop to the point that fish kills could occur. Some fish species will be already stressed by heat, saturation levels for D.O. will be lower, and high, predawn respiration rates could create a significant problem. Unfortunately, there are no operational changes the station can make to reduce this risk. The fish kill that did occur in late August was apparently a result of depleted DO that most likely resulted from the phytoplankton bloom die off.

Thermal refuges are critical to the survival of fish in heavily loaded cooling ponds. The deeper areas in the warmer end of the lake will not be refuges since adequate levels of oxygen are already absent from depths below 4 meters (Table 2.). However, the flow and slightly cooler temperatures at site 7 (figure1.) have maintained oxygen levels down to nearly 10 meters. If these refuges are eroded away during the summer, fishes will be stressed. Of the three key species listed in the Sportsman's Connection for Braidwood, both the walleye and crappie would be sensitive to D.O. at higher temperatures. Two fish kills occurred in Braidwood this summer, the first in late July was likely related to temperature, the second in lake August resulted from DO depletion.

Although our expertise is not in water chemistry, Braidwood Cooling Pond may be facing some water quality issues. One of the objectives of the survey was to determine if macrophytes were contributing to the increasing pH. A chart of pH values from 1989 to 1998 provided by the Braidwood Station indicated the increasing trend in pH has become more pronounced since 1997. Since this survey indicated macrophytes abundance was in a sharp decline, it is clear they are not contributing to the elevated pH of 9.1 to 9.2 (Table 1). The intensive phytoplankton boom present during the survey could have contributed to the elevated pH. The phytoplankton bloom had crashed by August 27 and 28 (fish kill investigation) and the pH had dropped to 8.6. It was not possible from this limited data to determine to what extent several factors may be contributing to the elevated pH. The cooling pond's buffering capacity, photosynthetic activity, blowndown rate, and plant operations are all potential factors to be investigated.

The Test America analytical results from three sites on 5/18/01 and 6/14/01 provides some information on water quality (Table 5). Orthro phosphate is a readily available form for plants and is quickly taken up. The detection limit listed by the lab was 0.06 ppm, which was too high to show any differences between sites or sample dates. Orthro phosphate levels in many Illinois lakes would be below 0.025 ppm. Total phosphate at the plant discharge on 5/18/01 was 5.5 ppm, which is very high. The Illinois General Use Water Quality standard is not to exceed 0.05 ppm in lakes or reservoirs over 20 acres. The plant appears to be the phosphate source and one possible explanation may be scale inhibitors commonly used by power plants. Scale inhibitors are typically high in phosphates but it is generally in a form not available to aquatic plants. Total phosphate levels on 6/14/01 were lower (0.18 to 0.28 ppm) but still elevated relative to other lakes.

Phosphates are a major concern as elevated levels can contribute to nuisance phytoplankton blooms.

Total Suspended Solids (TSS) on 5/18/01 were high (164 ppm) at the discharge and generally higher than expected throughout the pond. It is suspected that the plankton bloom may have been responsible for much of that elevation. This could have been confirmed by comparing the volatile to the non-volatile portion of the TSS.

Total Dissolved Substances (TDS), total hardness, calcium, sulfates and specific conductance are all correlated and generally exhibited increases from 5/18/01 to 6/14/01. The high evaporation rates in the cooling pond during the summer probably contributed to this increase. These parameters are of concern since they are indicators of potential scaling in heat exchangers. Lowering these levels would require an increase in make-up and blow-down rates. However it is recognized there are restrictions on make up withdraws and blow-down concentrations are regulated.

<u>Summary</u>

It appears that the Braidwood Cooling Pond plant community is changing from one dominated by macrophytes to phytoplankton. The phytoplankton bloom in May was very rich and has the potential to deplete D.O. to the point that fish kills could occur. There are few operational changes that the plant can take to prevent these potential events. Monitoring the cooling pond and preparing regulatory agencies for these potential changes may be a way to help manage these risks. Unfortunately the fish kill in late August confirmed the potential for these kills. The phytoplankton bloom may a contributor to the increasing pH. The high total phosphate level that appears to be coming from the plant may be fueling the phytoplankton bloom. Further investigation of the factors that may be contributing

APPENDIX REPORT B-2.

DRAFT

Investigation of Fish Kill on Braidwood Cooling Pond August 27-28, 2001

Executive Summary:
Strategic Environmental Actions Inc. (SEA Inc.) conducted an investigation of an on-going fish kill on Braidwood Cooling Pond on August 27 & 28, 2001. The investigation consisted of surveying the shoreline to determine the extent of the kill and the species involved, and water quality analyses for pH, temperature, and dissolved oxygen.

Most of the fish appeared to have been dead for about 24 hours and more than 95% were gizzard shad. The other species involved in descending order of relative abundance were freshwater drum, quillback, carp, largemouth bass, channel catfish, redhorse, smallmouth bass and bluegill. Other than gizzard shad most of the dead fish were located between the mid –point in the cooling loop to the intake. Throughout most of the cooling pond, dissolved oxygen levels were at or below the minimum levels necessary to support most fish and was the most likely cause of the kill. Water clarity was very high and suggested a recent die off of much of the phytoplankton, which is usually followed by oxygen depletion. This is a natural phenomenon that can occur in highly productive lakes during summer months. Temperatures throughout most of the lake were within the tolerance limits of the species involved in the kill. It does not appear that operations of the power station had a direct impact on the fish kill.

Methods Overview and Results Presentation:

SEA Inc. arrived at 5:00 PM on August 27 and conducted an initial survey of the main portion of the cooling loop and checked temperature, dissolved oxygen (DO), and pH at two locations. The investigation continued at sunrise on August 28, and included investigation of many of the coves on the lake and water quality analyses at sixteen sites. Water quality analysis was conducted with a Hydrolab Surveyor III. Measurements were for depth, temperature, DO, pH, specific conductance, and redox potential at the surface (0.5 Meters) and then at one-meter intervals to the bottom.

The water quality sampling locations are shown on Figure 1. Dissolved oxygen profiles from selected sites are illustrated in Figure 2. Figure 3 illustrates DO concentrations at one-meter depth at all sites. The results of the water quality analyses are presented in Table 1. The station hourly inlet and outlet water temperatures for August 24 through August 27 are listed in Table 2.

Discussion of Results and Observations:

Upon arrival the investigation began at the south access boat ramp near Site 3 (Figure 1.) and proceeded around the cooling loop toward the plant intake. Near Site 3 several gizzard shad in the 170 to 220 mm were observed. They appeared to have been dead for 12 to 24 hours. In the portion of the pond between sites 5.5 and 5.75 there were greater numbers of gizzard shad along the shoreline and a few largemouth bass. The largemouth bass appeared to have been dead for more than 36 hours. The number of fish appeared to increase as the investigation progressed around the cooling loop. The largest concentrations of dead fish were in several coves on the East side of the lake near Site 8. The back 20 to 35 ft. of the cover were covered solid with dead fish. Gizzard shad comprised more than 95% of the fish in these coves and were represented by three size classes. The other species involved in descending order of relative abundance were freshwater drum, quillback, carp, largemouth bass, channel catfish, redhorse, smallmouth bass and bluegill.

There are two factors that may have influenced the distribution of dead fish. First, the temperature gradient becomes more favorable for fish toward the intake end of the cooling loop. Second, the circulation of water around the cooping loop would tend to concentrate dead fish in the intake area of the cooling pond. The concentration of fish in coves at Sites 8 and 8.5 was most likely an accumulation resulting the above mention factors and wind direction. However DO levels at Site 8.5 were only 2 ppm (Table 1, page 3) at a time of day when they should have been much higher. This level of DO is not adequate to support most fishes. Several YOY freshwater drum were observed at the surface which had recently died or were about to. This kill did involve many fish, but during this survey many live fish were observed on sonar in the cooler end on the lake. Bluegills exhibiting normal behaviors were observed in the cove just East of Site 2.5.

Dissolved oxygen levels at the plant intake were 3.5 ppm at the surface and 1.2 ppm at 3 meters (Table 3) during the evening of August 27. Percent DO saturation was 49% and 17% respectively. Surface DO level taken on May 29 by SEA Inc. at this same location, at the same time of day was 9.3 ppm and 117% saturation. The DO levels at Site 3 were 3.8 ppm on August 27 which was much lower than the 8.0 ppm taken at sunset on May 29. On August 28 just prior to sunrise the DO at Site 3 was 3.2 ppm only slightly lower than the previous evening indicating little diurnal variation. On May 29 the overnight drop in DO at Site 3 was 50%.

The surface DO level at Site 4 on August 28 was 2.9 ppm and dropped to 0.7 ppm at 4 meters. Surface DO levels Sites 4.5, 5, 5.5, and 5.7 were even lower

ranging from 2.4 to 2.1 ppm. Site 6 had one of the higher DO levels at 4.4 ppm. Site 8 and 9 had the highest surface DO levels at 4.8-ppm (Table 1).

Temperatures throughout most of the cooling pond were within the tolerance limits of most fish species and there had been no major temperature changes in the last few days (Table 2). The oxygen levels throughout most of the lake suggest that depleted oxygen levels were the most likely cause for the fish kill. Such kills can naturally occur in highly productive lakes or ponds that may exhibit large diurnal swings in DO levels due to high daytime photosynthetic rates and high respiration during the night. The survey SEA Inc. conducted on May 28 and 29 suggested Braidwood Cooling Pond was a very productive and the potential existed for an oxygen depletion fish kill. This survey noted several changes in the cooling pond that suggested such a kill had occurred. There was no indication that the fish kill was directly related to the operation of the power station.

SEA Inc.'s initial investigation in May was to assess if the historically high abundance of macrophytes (rooted aquatic vegetation) was contributing an increasing trend in pH. What was observed was an intensive phytoplankton bloom that limited light penetration and almost no healthy macrophytes remained. Water transparency measured with a Secchi Disc was only 0.3 meters. Diurnal swings in DO levels were very pronounced and at some locations dropped to 4 ppm just prior to sunrise and reached supersaturation levels by mid day. Under these conditions any major change in nutrients, reduced light intensity, increase in biological oxygen demand, or other factors could result in oxygen depletion. Braidwood Cooling Pond appeared to be undergoing a transition from a system dominated by macrophytes to one dominated by phytoplankton.

One of the most notable changes during this investigation was the dramatic change in water transparency. There was no phytoplankton bloom and Secchi Disc readings had increased up to 2.7 meters. Plankton samples indicated very low levels of phytoplankton but high abundance of zooplanktors (primarily Rotifers and Cladocera). Oxygen levels were typically from 29% to 66% of saturation as opposed to May when most midday levels were at or above saturation. As discussed earlier, there were only minor differences in diurnal oxygen levels. All the above factors suggest the phytoplankton bloom had recently crashed. There were no remaining macrophytes to fill the niche as primary producers. Not only was there a reduction in photosynthetic activity to produce oxygen, there was an increased oxygen demand from decomposition and respiration of the abundant consumers. It is suspected that oxygen levels a day or two prior to this investigation may have been even lower than observed.

The one-meter DO levels were lowest toward the center portion of the cooling loop (Figure 2). From Site 3 to Site 6.5 (with the exception of Site 6) DO levels were 3.1ppm or less. A similar pattern of low DO was noted at Sites 3 and 4 in early morning samples taken in the May survey. Factors contributing to lower DO

levels were not clear, but it suggest this may be one of the most sensitive areas of the cooling pond to oxygen depletion. Additional sampling would be required to attempt to identify the cause and to eliminate any data bias associated with the time of day samples were taken.

The unique changes in water depths and flow velocities in Braidwood Cooling Pond have a major influence on DO levels and temperature stratification. Areas of the cooling pond which were deep and not in a high velocity areas exhibited a more normal DO curve from top to bottom (Figure 3). At Site 2.5, DO declined quickly between 6 and 8 meters and coincided with thermal stratification. At Site 4, the DO declined rapidly between 2 and 3 meters where thermal stratification was apparent (Table 1). In contrast, Sites 5.5 and 7 were located in areas with high velocities and had fairly consistent DO levels and temperatures from top to bottom (Figure 3). This is quite different from the DO and temperature profiles in more typical perched cooling ponds and better utilizes the entire volume for cooling and may also provide for better thermal refuges for fish. During this last incident it is unlikely Site 5.5 was an effective refuge for DO since levels were below 2.5 ppm. These DO levels were however due to lower DO levels throughout the cooling pond rather than depletion at this site.

Braidwood Cooling Pond appears to be undergoing a transition from a pond dominated by marcophytes to one dominated by phytoplankton. During such a transition major swings may be expected as different components of this ecosystem adapt to this change. Over time one would expect the amplitude of these changes to moderate. During the May survey the intense phytoplankton bloom appeared to eliminate the macrophytes. There were major differences in diurnal DO levels suggesting a very productive system with heavy respiration and decomposition demands at night and supersaturation from photosynthesis during the day. This survey indicated a major loss of the phytoplankton, no remaining macrophytes to carry on primary production and enough respiration and decomposition to reduce oxygen below the levels to maintain many fishes. Additional studies on nutrients and the dynamics of the plankton would be needed to better identify the changes that may be taking place in this cooling pond. Decisions on the operational management of this cooling pond as well as the fishery management need to consider that this pond may be going through transitional changes.

APPENDIX REPORT B-3.

Results of Braidwood Cooling Pond Water Quality Analysis from August 27 & 28, 2002

SEA Inc. was asked to sample Braidwood Cooling Pond for a number of water quality parameters on August 27, 2002. This sampling effort was to provide data to address operational concerns related to a trend toward an increasing pH and increased scaling at the plant intake. This report provides the results of the August 27and 28, 2002 sampling and makes comparisons with data from previous sampling efforts by SEA Inc. and with other data provided by the Braidwood Station to SEA Inc.

Executive Summary:

Braidwood Cooling Pond has high levels of alkalinity, total hardness, TDS, sulfates, magnesium, calcium and total phosphates. These parameters are of concern since they have the potential for increased problems with scaling, increasing pH, compliance with cooling pond blow down limits, and maintaining a recreational fishery. Several of these parameters had significant increases in the past year and could lead to greater operational costs and problems in the near future.

The excess of nutrients in the water has contributed to plankton blooms that have eliminated the submerged aquatic plants, contributed to diurnal increases in pH, and lowered dissolved oxygen levels. Swings in the dissolved oxygen level associated with the plankton blooms could lead to fish kills.

The plan to increase the blow down rate from the cooling pond is a good long-term solution to the continued viability of the cooling pond. Continued monitoring of the cooling lake water quality would be important in evaluating the effectiveness of the increased blown down rate, the impacts of H2SO4 additions, and other water treatment changes.

Overview of Methods and Scope of the Sampling Effort.

The investigation on August 27 and 28 of 2002 consisted of collection of water samples from various depths at six sites around Braidwood Cooling Pond (BCP), as well as in-situ profile measurements for temperature, conductivity, pH, and dissolved oxygen. A contract laboratory analyzed the water samples for the eleven chemical parameters as listed in Table 1. In addition to chemical samples, the primary production rate of the phytoplankton community was determined at two sites by the light/dark bottle method, and plankton samples were taken for

qualitative analysis. Water transparency was measured with a Secchi disc at each site. The sampling sites used in this investigation are identified on Figure 1.

Additional investigations by SEA Inc. referenced in this report include June 28, 2002, April 29,2002, March 6, 2002, January 10, 2002, August 28, 2001 and May 29, 2001. The purpose and scope of each of these investigations varied but none were as extensive for water quality as the August 2002 investigation. In several cases SEA Inc. collected the water samples for Betz and the results were not made available to SEA Inc. Data from the above referenced studies is included to help identify trends and provide a single summary of data for ongoing investigations. The discussion of results is based on and limited to the studies referenced in this report and those provided to SEA Inc.

Presentation of Results and Related Discussion:

The analytical results of the water quality analysis are presented in Table 1. The eleven parameters were selected to provide input to the water quality issues that were described to SEA Inc. These issues include increasing trends for rising pH, scaling, algal blooms, and recent fish kills.

Table 1 indicates abnormally high levels for TDS, alkalinity, hardness, sulfates, magnesium, calcium, and total phosphorus throughout the cooling pond. These values were not unexpected and support the ongoing program to increase the blow down rate from the cooling pond. These values can be put into perspective by comparing the cooling lake sites to the same values for the make –up water pond (Site 7P in Table 1), which is the source water. The cooling pond values for the above mentioned parameters ranged from 2X to nearly 9X higher than the make-up water.

The alkalinity is a measure of water's capacity to neutralize acids and is a result of the quantity of compounds in the water that shift the pH to the alkaline side. Bicarbonate and carbonate ions normally make up most of the alkalinity. However in waters with a pH of greater than 8.3, carbonate alkalinity is the primary form. Alkalinity is very high throughout the cooling pond and ranged from 340 to 360 mg/l in the upper water layers (Table 1). In contrast, the make-up water pond alkalinity was 150mg/l. Other comparisons include a 14-year average for Clinton Lake of 168 mg/l and an IEPA survey of 63 lakes around the state with alkalinity ranging from 20 to 270 mg/l. The high alkalinity gives Braidwood Cooling Pond has a great capacity to neutralize acids.

Hardness is a measure of the divalent metallic cations present in water (such as calcium, magnesium, ferrous iron, and manganous manganese). Calcium reacts with bicarbonate ions in water to form calcium carbonate

scale. Magnesium typically reacts with sulfate; the ferrous ion with nitrate; and the manganous ion with silicates.

Hardness and alkalinity in water are related. Carbonate hardness is the part of total hardness that is chemically equivalent to the bicarbonate plus carbonate alkalinities present in the water. If alkalinity is greater than total hardness then total hardness is equal to the carbonate hardness. In cases such as in BCP where alkalinity is less than the total hardness then alkalinity equals carbonate hardness (as $CaCO_3$) and the remaining part of hardness is the noncarbonate compounds such as magnesium sulfate.

The total hardness in the upper layers of August 2002 samples ranged from 680 to 720 mg/l (nearly twice the alkalinity level) so other ions are contributing significantly to the hardness. The total hardness levels in 2002 were significantly higher than the 435 to 531mg/l range reported for two dates in 2001 by Test America (Table 2). This increase in hardness is a reason for concern.

Sulfate levels in the August 2002 samples ranged from 330 to 390 mg/l (Table 1). These levels are much higher than the make up water (58 mg/l) and to some extent may reflect the history of portions of the cooling pond as strip mine lakes that are characteristically high in sulfates. However there seems to be a significant increase in sulfates in the past year. In the Test America data from two dates in 2001, sulfates ranged from 230 to 270 mg/l (Table 2). Sulfate levels in samples collected by SEA Inc. on April 29, 2002 were 250 mg/l (Table 3). Samples collected by SEA Inc. on June 28,2002 had levels ranging from 320 to 340 mg/l (Table 4). The sulfate increase noted in the summer of 2002 may reflect the use of H_2SO_4 to reduce pH levels in the cooling pond. This level of sulfates may be a concern since it significantly contributes to the non-carbonate hardness and can be a factor in scaling.

Calcium levels in the August 2002 samples were about twice the levels in 2001and ranged from 130 to 140 mg/l (Table 1). The 2001 Test America data ranged from 41 to 58 mg/l (Table 2) and the make-up water in August 2002 was 57 mg/l. The increase in calcium may be a major concern since with the high carbonate alkalinity there is a high potential for scaling.

Magnesium levels in the August 2002 sampling ranged from 84 to 93 mg/l. These levels were essentially the same as the 81 to 91 mg/l reported by Test America in 2001. Magnesium levels are however elevated compared to the make-up water that had only 20mg/l or when compared to the 14-year average for Clinton Lake of 32.2 mg/l. Magnesium levels are also a concern due to their potential for scaling.

Total dissolved solids include all of the above parameters and other dissolved solids in the water. As would be expected, the August 2002 samples are elevated and are higher than the previous year. The August 2002 TDS ranged from 930 to

1100 mg/l (Table 1) compared to a range of 684 to 788 in the 2001 Test America data (Table 2). The make-up water was 280 mg/l in the August 2002 sample.

Sodium levels in the August 2002 samples ranged from 60 to 64 mg/l in the upper water layers. Comparable data from 2001 was not available, but the sodium levels in the make–up water was 9.1 mg/l in the August 2002 sample (Table 1).

There were only minor variations in the concentrations of the above parameters from site to site in the upper water layers. Sulfates and TDS were slightly higher at the discharge (Site 2) end of the cooling pond. Levels for alkalinity, sulfates, TDS, and total hardness were slightly lower near the bottom at the 10 and 11-meter depths at Site 4 and Site 7 respectively.

Phosphorus and nitrogen are essential nutrients for aquatic plants. Concentrations in the water are typically low since phytoplankton or macrophytes quickly assimilate these nutrients. Total phosphate levels in the August 2002 samples were at 1.5 mg/l throughout the cooling pond (Table1). Samples collected on April 2002 ranged from 1.3 to 1.6 mg/l (Table 3). Total phosphates at two sites in the June 2002 samples were 1.8 mg/l (Table 4) in the upper water layers and 4.9 mg/l at a well stratified, 10-meter depth at Site 4. The Test America data for 2001 had total phosphate levels from 0.16 to 5.5 mg/l (Table 2). The 5.5 mg/l occurred at the discharge on May 18 of 2001 and levels dropped to 0.77mg/l at the plant intake on the same date. This suggests the Station was the source of the phosphate. Although the levels were slightly lower in 2002, they were consistent throughout the cooling pond suggesting that phosphates are in excess and not a limiting factor for phytoplankton. The total phosphate levels in the make- up water were 0.12 mg/l and 0.19mg/l in June (Table 4) and August of 2002 respectively.

Relative to most lakes the phosphate level in BCP is quite high. Since BCP is a cooling pond and not a lake, it is not subject to the Section 302.205 regulation that limits phosphorus in a lake of 20 acres or more to < 0.05mg/l. The high phosphate level is of concern since these levels support phytoplankton blooms and the breakdown of the phosphorus compounds can also contribute to increased pH.

Ortho-phosphate is the form that is most readily available to aquatic plants. These levels are usually very low in lakes since plants normally take it up within minutes. Ortho-phosphate levels were consistent throughout the lake in the August 2002 samples and ranged from 0.38 to 0.44mg/l. Like the total phosphate levels, the ortho-phosphate levels are consistently high suggesting it is in excess of the needs of the phytoplankton. The August 2002 levels were significantly higher than the <0.06mg/l reported by Test America in 2001(Table 2). Ortho-phosphate level in the make-up water was 0.19 and although lower than the lake levels is relatively high.

Nitrate-nitrites are the other essential or potentially limiting nutrient for phytoplankton. The August 2002 nitrate-nitrate levels were rather low in most of BCP with the highest level of 0.1mg/l at the discharge. The rest of the cooling pond ranged for <0.01mg/l (below detection limit) to 0.08 mg/l in the upper waters. Unlike most other parameters, the nitrate-nitrite level in the make-up water was significantly higher at 2 mg/l (Table 1). Nitrate-nitrite data could not be compared to the 2001 Test America data because the detection limit of 1.0 mg/l was too high for a meaningful assessment.

The ratios of phosphates to nitrates-nitrites suggest BCP would be described as a nitrate-nitrites limited water rather than phosphate limited with respect to phytoplankton growth. However the limited phytoplankton data that SEA Inc. has collected on BCP suggests that bluegreen algae dominate BCP for much of the summer. Bluegreen algae have the unique ability to utilize atmospheric nitrogen and are not as limited by low nitrate-nitrite levels. Bluegreen algae made up 88.5 % and 76.4% of the algae at Sites 3 and 7 respectively in the August 2002 sample. The dominant bluegreen algae were *Lynabya* and *Oscillatoria*. Bluegreen algae are the least desirable algae and are favored by high pH and warmer temperatures. Bluegreen blooms can impart a smell or taste to water, deplete dissolved oxygen, and in some cases generate toxins that may impact aquatic life.

The ammonia levels appear reasonable relative to the high productivity in BCP. As productivity increases and oxygen is reduced at deeper depths there may be increases in ammonia. The abnormally high level at 5 meters at Site 9 (Table 1 may have resulted from the water sampler disturbing the bottom sediments where ammonia is likely to be higher.

The aquatic plant community in BCP appears to have undergone a change in the last two years. SEA Inc.'s first investigation of BCP on May 29, 2001 was to assess the impact of the extensive growth of macrophytes (rooted aquatic plants) on the pond's increasing pH. That investigation found an extensive phytoplankton bloom and the few macrophytes that remained were being shaded out by the phytoplankton bloom. SEA Inc. projected that BCP was changing from a macrophyte dominated water to a phytoplankton-dominated water and that would see more plankton blooms. The phosphate levels from the 2001 Test America data suggested there was an excess of phosphorus to support those blooms. Based upon SEA Inc.'s 2002 observations, BCP has transformed into a phytoplankton dominated water and is experiencing regular plankton blooms. This change not only reflects an increasing load of nutrients in BCP but also creates a higher risk to the fishery. As plankton blooms come and go they can create oxygen depletion problems that impact fishes and other aquatic life.

SEA Inc. has measured the primary production rates as an index to the activity of the plankton community. The rate of oxygen production by the plankton

community is measured in a light (clear) bottle and the plankton respiration (oxygen depletion) is measured in a dark bottle. In the first measurement in May of 2001, there was so much oxygen production in the normal 24 hr measurement period that the oxygen was super saturated and only a portion could be measured (Table 5). Subsequent measurements were limited to shorter time periods and provided a more useful index. The highest primary production rate was 1.525 mg/l of O2/hr at Site 9 (Intake) on June 28, 2002. This correlated well with the highest chlorophyll a level provided by the Braidwood Station (Figure 2). In the August 2002 measurement, the rate at Site 9 had dropped to 0.653 mg/l of O2/hr. This rate correlated with lower chlorophyll levels that occurred throughout most of August. Temperatures during the August 28,2002 measurements were high enough at the discharge (Site 2) to suppress photosynthetic activity. The temperature at the discharge was 115.1° F (Table 5) and the intake (Site 9) temperature was 92.2°F and the corresponding production rates were 0.142 and 0.653 mg/l of O2/hr respectively. The temperature suppression of photosynthesis and an apparent die off of a phytoplankton bloom may account for the low dissolved oxygen levels observed during the August 2002 sampling.

All of sampling by SEA Inc. has involved in-situ sampling with a HydroLab for temperature, dissolved oxygen, pH, and specific conductivity. The data from all 2002 HydroLab sampling is presented in Tables 1,3,4,6, and 7.

The dissolved oxygen (DO) levels on August 28 of 2002 were notably lower than the same date in 2001(Table 6). As lakes undergo eutrophication and productivity increases, the DO level can exhibit wide diurnal changes that may stress aquatic life. Afternoon DO levels may rise to supersaturated levels, but during the night and early morning hours respiration demands may nearly deplete the DO and can result in fish kills. There also becomes a more pronounced difference in DO levels between the upper and lower layers of the water column due to increased oxygen demand from decomposition.

Dissolved oxygen levels at the same four sites in August 2001 and 2002 are compared in Figure 3. These comparisons indicate that the DO levels were generally lower at the same sites in 2002, were slower to rise during the day, and there was a greater differences between depths. Site 2 and Site 2.5 illustrate the lower DO levels in 2002 even later in the day when it should rise. Oxygen levels were less than 1ppm at 2 meters and below. Site 4, 2002 levels reflect the increase in DO later in the day compared to earlier in the day in 2001. The consistent drop in DO at 4 meters is typical of a stratified site. At Site 7 the higher DO in 2002 reflect the later time of day than the 2001 sample. However the more significant difference is the drop in DO with increasing depth in 2002. This drop suggests a more productive system that has a higher demand for oxygen in 2002. Site 7 has good flow and in 2001 had a nearly constant DO level down to the bottom and provided a good thermal refuge for fish. In 2002 the area below 6 meters would be stressful for most fish. The Site 9 AM chart again demonstrates the 2002 DO level was lower even when taken later in the morning than the 2001

sample. The Site 9 PM chart shows some recovery of DO level in the mid afternoon but levels are still below 4ppm. The more rapid drop in deeper samples from the 2001 most likely reflects the loss of late afternoon light to the deeper depths.

The 2002 DO curves appear to reflect a more eutrophic environment that may place additional oxygen stress on the fishery. During the August 2002 sampling there were dead and dying gizzard shad from Site 2 to Site 4. The combinations of stress from the low DO and warmer temperatures were the most likely explanation for the loss of these fish. This loss was not extensive enough to have a significant impact on the fishery. No other species were involved in the kill but small bluegills were exhibiting some signs of DO stress. As BCP continues to become more eutrophic the DO stress may be a greater problem for the fishery.

The increasing pH levels have been a concern in BCP. Comparison of HydroLab data from August 28 in 2001 (Table 6) and 2002 (Table 1) indicated only a little variation in pH. During the summer of 2002 the Station was adding H_2SO_4 into the circulating water. The impact was only apparent at Site 2 (discharge canal) and Site 3. The 2002 samples collected in the morning hours at Site 2 ranged from 8.34 to 8.38 compared to 8.5 in 2001 (Table 2). At Site 3 the 2002 levels ranged from 8.35 in the morning to 8.54 at midday compared to a range of 8.4 to 8.6 in 2001. The pH levels at Sites 4,7 and 9 had slight variations depending upon time of day but had similar ranges in 2001 and 2002. With the high alkalinity levels in BCP, it is not surprising that the addition of H_2SO_4 did not result in larger changes. This assessment is also based on only a few data points. Correlating H_2SO_4 feed rates with continuous pH monitoring at the intake would provide more reliable information on the effects of the acid additions.

Questions have been raised on the impact of the phytoplankton on the increasing pH levels. As phytoplankton carries on photosynthesis and extract CO_2 from the water it increases the pH. This however may not be as apparent in BCP due to the high buffering capacity (alkalinity). In general the higher pH levels in the afternoon reflect the photosynthetic activity. Conversely the lower pH levels in the early morning samples reflect the increase in CO_2 resulting from respiration during the night. The role of phytoplankton in increasing pH is quantified in the measurement of primary productivity. A comparison of the starting pH with the ending pH in the light bottles illustrates the change due to photosynthesis. The pH during the 24-hour measurement on May 29, 2001at Site 2 went from 9.22 to 9.52 (Table 5).

Summary and Conclusions:

Braidwood Cooling Pond has high levels of alkalinity, total hardness, TDS, sulfates, magnesium, calcium and total phosphates. These parameters are of concern since they have the potential for increased problems with scaling, increasing pH, compliance with blow down limits, and maintaining a recreational

fishery. The additional of treatment chemicals and evaporative loss of the recycled cooling water with limited blown down rates are most likely the primary factor in the increased levels of these parameters. The make-up water does not have elevated levels of the above-mentioned parameters. With increasing capacity factors and increasing concentrations for these parameters in the cooling water, water treatment costs and operational concerns are likely to increase.

Baseline water quality data is important in evaluating options and solutions to address water quality in the cooling pond. The comparison of the August 2002 sampling to the 2001 Test America data indicated significant increases in total hardness, sulfates, and calcium in the past year. Increases of this magnitude can be important predictors of future problems. Critical assessments of the impact of H_2SO_4 additions and other treatment changes are dependent upon having pretreatment and post treatment data. The plan to increase the blow down rate from BCP is a good long-term solution to the continued viability of the cooling pond. The effectiveness of increasing the blown down rate from BCP can be quantified by continued monitoring of the cooling lake concentrations.

The high nutrient levels in BCP will continue to cause plankton blooms. Unlike many waters, phosphates appear to be in excess and nitrates are more of a limiting factor. However, bluegreen algae appear to be the dominant summer form and are not as limited by low nitrates as other algae. The primary production measurements did correlate fairly well with chlorophyll a levels and were a good index to the productivity of BCP. The primary production measurements also illustrated how much of an influence phytoplankton have on diurnal increases in pH.

Algal blooms are occurring in the pond and based on two comparable samplings, appear to be influencing the DO levels. The DO levels in the early hours were generally lower in 2002 than in 2001 and the DO at a deep site experienced a decline with depth that did not occur in 2001. These changes suggest a trend toward an increasing rate of eutrophication. If nutrient levels continue to increase the potential for fish kills associated with oxygen depletion resulting from the blooms would also increase.

Jim Smithson
SEA Inc.
11/04/02

APPENDIX REPORT B-4.

Fish Kill Reports Going Back to 2003

john.petro@exeloncorp.com [john.petro@exeloncorp.com]

Sent: Wednesday, September 23, 2009 2:42 PM

To: Jeremlah.Haas@exeloncorp.com

2003

There were no fish kills in Braidwood Lake in 2003.

~~June~~ July 30, 2004

Investigated a fish mortality on July 30, 2004. Most fish were in the advanced state of decay by the time the kill was investigated. Gizzard shad were the dominant species involved although channel catfish were observed as well. During this investigation, the shallow water near shore was teaming with plankton which under magnification proved to be daphnia as well as Cypris, which is an Ostacod resembling a small clam.

Temperature/dissolved oxygen profiles were conducted in early October. Water temperature just north of the south boat access was 29.2-^{0}C/84.5-^{0}F at a depth of one foot with a dissolved oxygen reading of 3.8 ppm, a pH of 8.03 and a secchi disk reading of 2.1 feet. Readings were somewhat improved in the area near the rearing cove. In a location several hundred feet from the lake make-up, more favorable dissolved oxygen levels were found. At one foot, a water temperature of 26.5 ^{0}C/79.7 ^{0}F with a dissolved oxygen reading of 7.6 and a pH of 8.47 were observed. Water temperature showed minimal decrease to 40 feet while the dissolved oxygen declined to 5.3 ppm.

June 28, 2005 Fish Kill

An on the water inspection of a thermal fish kill was conducted on June 28, 2005. No formal counts were made however field assessments indicate a fairly significant kill that involved a variety of species including (in no specific order) gizzard shad, threadfin shad, common carp, channel catfish, quillback carpsucker, black bass. Gizzard shad were the most numerous species effected by this kill and fish carcases were observed at most all areas of the lake that were checked.

August 27-28, 2007 Fish Kill

· Rob Miller, IDNR investigated a thermal kill on August 27 and 28, 2007 and conducted temperature/dissolved oxygen evaluations. The majority of the dead fish which were observed were large gizzard shad and threadfin shad up to 5 inches in length. Channel catfish were also prevalent. Only a few common carp and black bass were observed and no bluegills were noted. Due to moderate prevailing south winds, many dead fish were wind-rowed along the north shore in close proximity of the boat ramp and the bank fishing area. The number of dead fish observed decreased towards the south (hot) side of the lake. At a point several hundred yards from the south ramp surface water temperature was 35.3 C/95.9 F and dissolved oxygen was near 3ppm.

· The following are data which were collected at the north ramp at the time the fish kill was being

investigated:

Time	Temperature (^0C)	Dissolved Oxygen (ppm)
12:10	30.3	3.1
14:25	33.1	5.4
15:30	33.5	6.7
16:58	33.9	5.9

Investigation of Fish Kill on Braidwood Cooling Pond (August 27-28, 2007)

· Strategic Environmental Actions Inc. (SEA Inc.) conducted an investigation of an on-going fish kill on Braidwood Cooling Pond on August 27 & 28, 2007. The investigation consisted of surveying the shoreline to determine the extent of the kill and the species involved, and water quality analyses for pH, temperature, and dissolved oxygen.

· Most of the fish appeared to have been dead for about 24 hours and more than 95% were gizzard shad. The other species involved in descending order of relative abundance were freshwater drum, quillback, carp, largemouth bass, channel catfish, redhorse, smallmouth bass and bluegill. Other than gizzard shad most of the dead fish were located between the mid -point in the cooling loop to the intake. Throughout most of the cooling pond, dissolved oxygen levels were at or below the minimum levels necessary to support most fish and was the most likely cause of the kill. Water clarity was very high and suggested a recent die off of much of the phytoplankton, which is usually followed by oxygen depletion. This is a natural phenomenon that can occur in highly productive lakes during summer months. Temperatures throughout most of the lake were within the tolerance limits of the species involved in the kill. It does not appear that operations of the power station had a direct impact on the fish kill.

APPENDIX REPORT B-5.

FW: Braidwood Lake Fish Kill

john.petro@exeloncorp.com [john.petro@exeloncorp.com]

Sent: Wednesday, September 23, 2009 2:31 PM

To: Jeremiah.Haas@exeloncorp.com

-----Original Message-----
From: ROB MILLER [mailto:ROB.MILLER@illinois.gov]
Sent: Tuesday, August 21, 2007 8:26 PM
To: JOE FERENCAK; STEVE PALLO
Cc: Petro, John R.; CHRIS MCCLOUD; LARRY DUNHAM; MIKE CONLIN
Subject: Re: Braidwood Lake Fish Kill

I was contacted by John Petro and Tim Meents (Braidwood Station) this morning at 11:20 but due to bad accident on I-55 was somewhat delayed in arriving at the lake. When I got there (3:00) I met with Exelon biologist Jeremiah Haas. Jeremiah had arrived earlier and had taken dissolved oxygen/temperature readings. He and I toured the lake via his boat to assess the extent of the kill. Due to moderate prevailing south winds, many dead fish were wind-rowed along the north shore in close proximity of the boat ramp and the bank fishing area. The number of dead fish we observed decreased as we traveled towards the south (hot) side of the lake. At a point several hundred yards from the south ramp, we took a reading and returned to the north ramp to meet up with John Petro. At this location water temperature was 35.3C and dissolved oxygen was near 3ppm. The following are data which were collected at the north ramp:

Time	Temp. (C)	Dissolved Oxygen (ppm)
12:10	30.3	3.1
14:25	33.1	5.4
15:30	33.5	6.7
16:58	33.9	5.9

Based on the declining trend in d.o., it is possible that more fish could succumb throughout the night.

The majority of the dead fish which were observed were large gizzard shad and threadfin shad up to 5 inches. Channel catfish were also prevalent. Only a few common carp and black bass were observed and no bluegills were noted. SET Environmental had arrived at the north ramp and were conducting clean-up operations at 5:00. I will be attended the AFS Continuing Education course in Monticello tomorrow and thursday. If you need any further information, or if there are any further developments, please contact me at 815/409-2426. Thanks.
Rob
Rob Miller

District Fisheries Biologist
Illinois Department of Natural Resources
13608 Fox Road
Yorkville, Illinois 60560
630/553-6680
rob.miller@illinois.gov
>>> STEVE PALLO 08/21/07 12:10 PM >>>
Just got off phone with John Petro, Environmental Manager for Exelon.

John wanted to report a moderate gizzard shad kill at Braidwood Cooling Lake, and a minor kill of catfish. Rob Miller, District Fisheries Manager was already notified. Water temps in the lake had dropped some 12F recently, there are no obvious power plant operational changes or permit exceedances. Exelon is arranging to have the fish picked up.

APPENDIX REPORT B-6.

FW: Braidwood Fish Kill 8-21-07

john.petro@exeloncorp.com [john.petro@exeloncorp.com]

Sent: Wednesday, September 23, 2009 2:28 PM

To: Jeremiah.Haas@exeloncorp.com

-----Original Message-----
From: Haas, Jeremiah J.
Sent: Tuesday, August 21, 2007 9:02 PM
To: Petro, John R.; Tidmore, Joseph W.; Meents, Timothy P.
Cc: Hebeler, Ronald L.; Neels, Vicki J.; Steve Pallo (E-mail); Haas, Jeremiah J.
Subject: Braidwood Fish Kill 8-21-07

All,

Here's the quick and dirty of the incident. I'll right something more formal in the morning.

I arrived at Braidwood Lake at 12:00 and took a dissolved oxygen (DO) reading from the ramp dock which extends about 30 feet into the lake. The DO was 3.1 ppm w/ a temp of 30.3 C. Several thousand gizzard and threadfin shad were floating across most all visible areas of the lake. The currents within the lake were visible with the dead fish movement. Also seen were dozens of channel catfish, most of which were adults from 3-15 lbs. Shad ranged from 4 - 13 inches with the shorter fish being predominately threadfin and the larger ones being gizzard. At this time I informed John P. of the DO situation and began setting up the boat for additional surveys. During the entire day, no other species was observed that counted more than 2 individuals.

I took several water readings throughout the afternoon before Rob Miller (IDNR biologist responsible for Braidwood Lake) arrived. We did a quick boat survey throughout the lake, including the pockets that are not part of the cooling loop. These areas showed the same readings as the rest of the lake. During this time we had a few hours of direct sunshine and DO reading rose as high as 6.7 ppm @ 15:30.

Rob and I determined that the DO crash was a result of the past several days cloud cover and subsequent die-off of phytoplankton. The decay of the phytoplankton would have been sufficient to lower the DO available to the fish during the overnight hours. We also observed the DO beginning to lower @ 16:58 (5.9 ppm) and believe that there is an opportunity to see similar results tomorrow and possibly a few more days depending on the weather conditions.

A local newspaper reporter did arrive on site, took photos, and asked questions. She was familiar with Braidwood Station's Site Communicator and said she would be in contact with them. Rob explained the cycle that was occurring in the lake several times to the reporter.

All in all, I believe that Rob and I are both comfortable with the explanation for the action that occurred to cause the fish kill. This is similar to the "annual" fish kill seen at Braidwood, but the densities were higher than the past few years. There is a survey of the lake scheduled for October and, if possible, I will be at the site for that.

Exelon
Jeremiah J Haas
Principal Aquatic Biologist
Quad Cities Nuclear Station
309.227.2867
jeremiah.haas@exeloncorp.com

APPENDIX REPORT B-7.

Braidwood Fish Kill Clean up
8/22&23/07

I worked with SET Environmental to clean up a fish kill.
This was a major kill and our clean up efforts were confined to the area near North boat ramp on the intake end of the lake. SET had been working on the kill for one or two days when I was called to provide assistance. A total of about 24 cubic yards of fish were removed in this clean up. The species involved in decreasing order of abundance were: gizzard shad (large fish), channel catfish, bluegill, green sunfish, flathead catfish, bigmouth buffalo, quillback and largemouth bass.

I went up in the restricted arm toward the intake and found huge masses of fish in the back of several coves. There were areas 50 to 75 ft by 100 ft of solid floating mats of fish in these coves. We picked up 12 flathead catfish that would have averaged near 50 lb. each. On the second day when we returned to these coves we counted as many large flathead catfish that we had picked up the previous day. They were in a state of decomposition that prevented up from picking them up.

We did not take any water quality measurements or examine other parts of the lake in this clean up effort. From my past work on this cooling pond, I would suspect a combination of DO depletion and high water temperatures caused this fish kill. The plant did not report any abnormal operation conditions prior to the kill. Since 2001 when we first worked on this cooling pond we have seen a switch from macrophytes to phytoplankton with blue green dominating. We have measured wide diurnal swings in DO levels even in the upper part of the water column in late summers. Even with the strong circulation from the circulating water pumps there is mid summer stratification and DO depletion in the deeper areas.

Jim Smithson
SEA Inc.

Attachment #2 to Response -- RAI # AQ-12b

BRAIDWOOD STATION

BRAIDWOOD LAKE ADDITIONAL BIOLOGICAL SAMPLING PROGRAM, 2012

Prepared for
EXELON NUCLEAR

February 2013

HDR Engineering, Inc.
Environmental Science & Engineering Consultants
10207 Lucas Road
Woodstock, Illinois 60098

BRAIDWOOD STATION

BRAIDWOOD LAKE ADDITIONAL BIOLOGICAL SAMPLING PROGRAM, 2012

Prepared for

EXELON NUCLEAR
Warrenville, Illinois

HDR Engineering, Inc.
Environmental Science & Engineering Consultants
10207 Lucas Road
Woodstock, Illinois 60098

ACKNOWLEDGMENTS

The field work and data analysis for this project was conducted by HDR Engineering, Inc. (HDR). Particular appreciation is extended to Rob Miller of the Illinois Department of Natural Resources (IDNR), Jim Smithson of Strategic Environmental Actions, Inc. (SEA), and John Petro of Exelon Nuclear for providing historical fisheries and water quality data.

This report was prepared by HDR and reviewed by Exelon Nuclear. A special debt of gratitude is owed to the environmental staff at Braidwood Station and in particular Mr. Jeremiah Haas of Exelon Nuclear for his technical assistance, cooperation, and guidance during the preparation of this document and the study plan. Mr. Haas's experience and insight has been invaluable and is greatly appreciated by the authors.

ABSTRACT

HDR Engineering, Inc. (HDR) was contacted on March 12, 2009 by Braidwood Nuclear Generating Station, requesting HDR to design and conduct a fish sampling program at Braidwood Lake. The information gathered during that study was to be used by Exelon to develop an effective sampling program and set of procedures that could potentially predict fish die-offs in the cooling lake. That same sampling program was conducted again in 2010, 2011, and 2012 with only minor changes to the original program design.

Large die-offs of fish at Braidwood Lake could potentially challenge the integrity of the traveling screens at the Station. With advanced warning, the Station could be informed of a potential reportable event; regulatory agencies could be notified in advance; and crews responsible for fish cleanup and disposal could be put on alert to manage the risk associated with a substantial fish die-off. Currently, there are no practical or simple methods that can be used to predict or prevent the occurrence of fish die-offs at Braidwood Lake.

Sampling has been conducted at Braidwood Lake by the IDNR since 1980. From 1980 through 2009 IDNR (Illinois Department of Natural Resources) collected 49 taxa of fish. In comparison, thirty-four taxa representing ten families have been included among the 8787 fish collected by HDR since 2009. Several taxa listed as collected by IDNR from 1980 to 2009 have not been captured by HDR. Many of the species listed by IDNR were only rarely captured, have not been captured during recent years, or represent taxa that were stocked. However, six species and one hybrid have been captured by HDR that have not been collected during IDNR sampling efforts. They included shortnose gar, smallmouth buffalo, bigmouth buffalo, fathead minnow, rosyface shiner, shovelnose tiger catfish, and hybrid striped bass.

In 2012, 23 taxa of fish representing eight families were included among the 1914 fish captured by electrofishing, hoop netting, gill netting, and trap netting. The relative abundance of species collected during the course of these studies is similar to those reported by IDNR in recent years. Braidwood Lake is dominated by warmwater species including gizzard shad, threadfin shad, carp,

channel catfish, flathead catfish, largemouth bass, bluegill, and spotfin shiner. No threatened or endangered species have been collected by HDR since these studies were initiated in 2009.

Water quality data recorded in conjunction with fish sampling was measured at each location prior to every sample collection. Water temperature (℃), dissolved oxygen (ppm), pH, and conductivity (μmhos/cm) measurements were taken 0.5 m below the water surface at each sampling location. In addition, water quality was also measured approximately 0.5 m off the bottom at all three of the deep water collection sites (Location GN-1, HN-1, and HN-2).

Water temperatures during the August sampling period were warmer (30.3 to 35.1 ℃) than those observed during the September sampling period (27.4 to 33.6℃) in 2012 because of the unusually hot and humid conditions that existed throughout the Midwest during July and early August. Diurnal swings in dissolved oxygen (DO) were observed at the lake with DO ranging from 4.6 to 11.5 ppm in August and from 4.3 to 13.2 ppm in September. Dissolved oxygen readings were generally slightly higher during the second sampling effort in September. Cursory observations by the field crew indicated that the water color appeared greener during the September sampling dates. This suggests that an increase in the phytoplankton population occurred within the lake between the first and second sampling period, which would explain (coupled with cooler water temperatures) the slight increase in oxygen levels noted in Braidwood Lake during September.

Examination of pH data collected during these studies show pH ranged from 8.5 to 8.8 during the first sampling effort and from 8.7 to 9.0 during the second sampling effort. Conductivity ranged from 1081 to 1114 μmhos/cm in August and from 1160 to 1275 μmhos/cm in September.

Review of historical water quality data reported in 2002 by Strategic Environmental Actions, Inc. (SEA Inc.) at Braidwood Lake indicates that abnormally high levels of total dissolved solids (TDS), alkalinity, hardness, sulfates, magnesium, calcium, and total phosphorus exist throughout the entire cooling loop. This is not unexpected based upon the evaporation that takes place within the cooling loop coupled with the relatively low make-up and blow-down flows associated with the operation of Braidwood Station. These elevated levels within the lake were measured at two to nearly eight times higher than those of the make-up water from the Kankakee River. Elevated levels of water hardness are of concern to the Station because high levels have the potential to increase problems associated with scaling at the Station.

Phosphorus and nitrogen are two essential nutrients required by aquatic plants. Studies conducted by SEA in 2002 indicated that nutrients within the cooling lake were at levels sufficiently high to cause problems associated with phytoplankton blooms. These blooms result in oxygen production via photosynthesis during daylight and oxygen depletion through respiration during darkness. When algal populations crash and decompose they can produce severe oxygen depletion within the water column. Diurnal swings in oxygen readings have been routinely observed at Braidwood Lake during the past several years. In addition, DO levels of less than 3 ppm have been recorded at the lake immediately following fish die-offs. Deeper portions of the lake were also reported to stratify in 2002. In the deeper zones of the lake, DO levels approaching 0 ppm and reduced water temperatures have been measured below the thermocline. This is noteworthy because dissolved oxygen levels of 3 ppm and less cannot be tolerated over an extended period of time by most fish species. Piper et al. (1983) states that dissolved oxygen levels below 5 ppm will reduce growth and survival for most species of fish cultured in raceways or ponds. Dissolved oxygen requirements are dependent upon species and other factors including water temperature and acclimation period.

Review of historical fisheries information that was provided to HDR indicated that five separate fish kills were reported from 2001 to 2007. Numerically, the majority of fish observed during these events were either gizzard shad or threadfin shad. These two species have typically comprised over 90% to 95% of all dead fish observed. Remaining species included carp, freshwater drum, bluegill, channel catfish, flathead catfish, quillback and largemouth bass. Each of the reported fish die-offs was attributed to oxygen depletion at the lake and not the result of specific Station operations.

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1.0 INTRODUCTION

The Braidwood Lake Fish and Wildlife Areas are comprised of approximately 2640 acres of terrestrial and aquatic habitat that is located in Will County, Illinois. Braidwood Lake is owned by Exelon and is a partially perched, cooling lake that was constructed in the late 1970s. The lake was filled during 1980 and 1981 with water pumped from the Kankakee River. Several surface mined pits existed at the site prior to the filling of the impoundment. Fisheries management activities began in those surface mine pits in 1978, prior to the creation of Braidwood Cooling Lake. Originally the lake was considered a semi-private area used by employees of Commonwealth Edison Company until the end of 1981 when the Department of Conservation (now the Illinois Department of Natural Resources) acquired a long-term lease agreement from the company, which allowed for general public access to the area. Braidwood Lake is currently used for fishing, waterfowl hunting, and fossil hunting. From the late 1970's to the present time, Braidwood Lake has been stocked with a variety of warm- and coolwater fish species. These stockings include largemouth and smallmouth bass, blue catfish, striped bass, crappie, walleye, and tiger muskie. Monitoring programs have documented the failure of the coolwater stockings to create a meaningful fishery. This is attributed to the extreme water temperatures that occur within the cooling lake during the warm summer months.

Construction of the Braidwood Nuclear Generating Station and its associated riverside intake and discharge structures provided an opportunity to gather fisheries information from the Kankakee River and Braidwood Lake. These studies were initiated to determine the effects of construction and plant operation on the river and the lake. Units I and II began commercial operation on 29 July and 17 October, 1988, respectively. Fisheries surveys at Braidwood Lake were conducted annually by the Illinois Department of Natural Resources (IDNR) from 1980 through 1992. Since 1992, fishery surveys have been conducted by IDNR every other year except 1995 and 1996. Fishery surveys on the Kankakee River near the Station's intake have also been conducted annually since the late 1970's by the Illinois Natural History Survey (1977-1979 and 1981-1990), LMS Engineers (1991-1992 and 1994-2004), Environmental Research and Technology (1993), HDR/LMS (2005-2007), and HDR (2008-2012).

The objectives of the 2012 Braidwood Lake Additional Sampling Program were to:

1. Conduct fish surveys at Braidwood Lake for comparison with historical data that has been collected by IDNR and HDR Engineering, Inc.

2. Summarize any existing data related to fish kills that have occurred at Braidwood Lake.

3. Develop a sampling procedure or protocol that will help anticipate fish die-offs in the cooling lake that could potentially effect Station operations.

2.0 METHODS

2.1 Electrofishing

Electrofishing was conducted using a boat-mounted boom-type electrofisher utilizing a 5000 watt, 230 volt AC, 10 amp, three-phase Model GDP-5000 Multiquip generator equipped with volt/amp meters and a safety-mat cutoff switch. The electrode array consisted of three pairs of stainless steel cables (1.5 m long, 6.5 mm in diameter) arranged 1.5 m apart and suspended perpendicular to the longitudinal axis of the boat 1.5 m off the bow. Each of the three electrodes was powered by one of the phases. Electrofishing samples were collected on 23 August during the first sampling effort and on 11 and 12 September during the final survey period (Appendix Table A-1). The first sampling event that was scheduled for late July was rescheduled for September due to extremely warm air and water temperatures that existed throughout the Midwest in July. Therefore, the first sampling period was delayed until the third week of August to avoid unnecessary stress to the fish, field equipment, and the sampling crew. The second sampling period was then moved to the second week of September at the recommendation of the Illinois DNR and Exelon.

Eight locations around the dike and islands at Braidwood Lake were electrofished during both the first and second sampling periods (Figure 2-1). Electrofishing was conducted near the shoreline at each location to collect fish utilizing shallow water habitats. Voltage and amperage of the electrofishing unit was recorded at each location at the beginning and end of each sampling effort. Sampling was restricted to the period of time ranging from one-half hour after sunrise to one-half hour before sunset. Each electrofishing location was sampled for 20 minutes. Electrofishing effort was reduced from 30 minutes per sample in 2009 and 2010 to 20 minutes per sample in 2011 and 2012. This reduced the stress and handling mortality of fish associated with the field collection process with minimal impact on the data that was collected to evaluate the fish assemblage at Braidwood Lake.

The electrofishing crew consisted of two people. One crew member operated the boat while the second crew member dipped fish from the bow of the boat. The boat operator also dipped fish

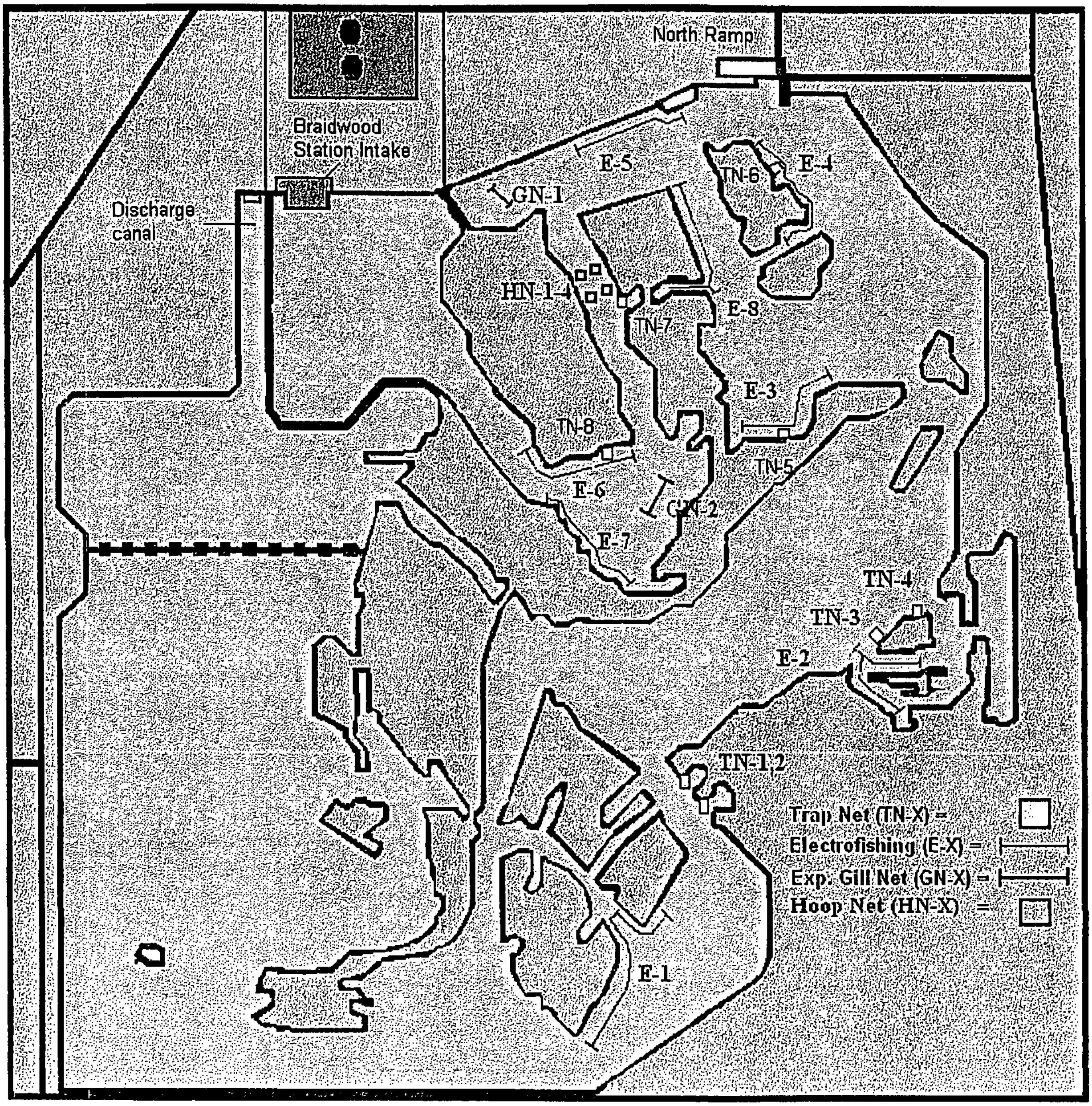

FIGURE 2-1. SAMPLING LOCATIONS AT BRAIDWOOD LAKE DURING AUGUST AND SEPTEMBER, 2012 .

whenever necessary. When fish surfaced behind the boat the boat operator backed up to retrieve all stunned fish. All stunned fish were collected without bias of size or species.

Fish at each location were put into large tubs of water in the front of the boat for analysis at the end of each 20 minute collection period. All fish were processed in the field immediately following collection at each location. Special emphasis was placed on the return of all game fish species to the water as quickly as possible following field analysis. Catches were standardized to catch-per-effort (CPE) from actual fishing time (20 min/sample) to numbers caught per hour by dividing the total numbers of fish collected by the actual fishing time in hours.

2.2 Trap Netting

Trap nets were set at eight separate locations in Braidwood Lake (Figure 2-1). Each trap net consisted of a 25-ft. lead that was 4-ft. deep and attached to a series of rectangular frames. The last rectangular frame was attached to a hoop net constructed of 1.5-in. (bar) mesh nylon webbing on hoops 3.5 ft in diameter. Two separate throats were contained within each net. One was located in the series of rectangular frames at the front of the net, while the second throat was located toward the back of the net inside the 3.5 ft diameter hoop net. Trap nets were set during late afternoon or early evening and were allowed to fish overnight for approximately 12 hrs before being retrieved the following morning. Trap nets were set on 20 August and retrieved on 21 August during the first sampling period and set on 10 September and retrieved on 11 September during the second sampling period (Appendix Table A-2).

Fish at each location were put into large tubs of water in the front of the boat for analysis at the end of each collection period. All fish were processed in the field immediately following removal from the net. Special emphasis was placed on the return of all game fish species to the water as quickly as possible following field analysis. Catches were standardized to catch-per-effort by dividing the total number of fish caught by the total number of hours the nets were allowed to fish (fish/12-hr set).

2.3 Gill Netting

Two 125-ft. long and 6-ft. deep monofilament experimental gill nets were used to collect fish from two locations in Braidwood Lake (Figure 2-1). Each net consisted of five separate panels that were 25-ft long by 6-ft deep. Bar mesh sizes of each panel were 0.5, 0.75, 1.0, 2.0, and 3.0 inches, respectively. One of the two gill nets (GN-1) was set in deep water at a depth of approximately 8-10 m, while the second gill net was set in shallow water (GN-2) at a depth of approximately 2-3 m. During the first sampling period, the shallow water gill net sample (GN-1) and the deep water gill net sample (GN-2) were set and retrieved during the late afternoon of 20 August. Both nets were allowed to fish for 15 minutes before they were retrieved. During the second sampling period, both the shallow and deep water gill net were set and retrieved during the late morning of 11 September. The shallow water gill net was allowed to fish for 20 minutes, while the deep water gill net was allowed to fish for 15 minutes (Appendix Table A-3). Gill net set times were reduced from previous years based on the number of fish that were being captured coupled with concerns expressed by Illinois Department of Natural Resources. Elevated water temperatures in the cooling lake prohibited longer set times due to the high mortality that occurred shortly after the fish became entangled in the monofilament netting.

All fish were processed in the field as they were removed from the net. Special emphasis was placed on the return of game fish species to the water as quickly as possible. Catches were standardized to catch-per-effort (CPE) from actual fishing time the nets were in the water to numbers caught per hour by dividing the total numbers of fish collected by the actual fishing time in hours.

2.4 Hoop Netting

Hoop nets used to collect fish at Braidwood Lake were constructed of 1:25-in. (bar) mesh nylon webbing on hoops 3.5 ft in diameter. Four separate nets were sampled during each sampling period (Figure 2-1). Two of the four nets were set in deep water (8-10 m), while the remaining two nets were set in shallow water (1-2 m). In addition, one of the deep (HN-1) and shallow water (HN-3) hoop nets were baited with dead gizzard shad, while the remaining deep (HN-2) and shallow water (HN-4) hoop nets were allowed to fish without bait. All four nets during the first sampling period in August were set during the late afternoon of 20 August and retrieved the following morning on 21 August. During the second sampling period the hoop nets were set during the late afternoon of 10 September and retrieved the following morning on 11 September (Appendix Table A-4).

Captured fish from each net were put into large tubs of water in the front of the boat for analysis at the end of each collection period. All fish were processed in the field immediately following removal from the net. Special emphasis was placed on the return of all game fish species to the water as quickly as possible following field analysis. Catches were standardized to catch-per-effort by dividing the total number of fish caught by the total number of overnight sets conducted (fish/overnight set). Hoop nets were set and retrieved over a 16 to 18 hour period of time during both the first and second sampling periods.

2.5 Sample Processing

All fish were identified to the lowest positive taxonomic level and enumerated. For each gear type, up to 25 individuals of a species were measured for total length (mm) and weight (g) at each location. Any remaining individuals of that species were counted and weighed en masse. Minnow species (excluding carp) were counted and weighed en masse. Specimens that could not be positively identified in the field were either photographed in the field or returned to the laboratory for identification. References used to facilitate identification included Pflieger (1975), Smith (1979), and Trautman (1981).

2.6 Water Quality Measurements

Four physicochemical parameters (temperature, dissolved oxygen [DO], pH, and conductivity) were measured in conjunction with the sampling program. These data were collected at each station prior to each sampling effort. Physicochemical measurements were taken a half meter below the water surface at all locations prior to sample collection. At deeper locations, temperature, conductivity, and DO were measured 0.5 m below the surface and 0.5 m off the bottom. Temperature (°C) and dissolved oxygen (ppm) were measured using a YSI Model 55 handheld meter. Conductivity (μmhos) was measured using an YSI Model 30 handheld conductivity, salinity, and temperature meter. A Cole-Parmer pH Tester1 was used to determine pH. All instruments were calibrated prior to each monthly sampling event.

3.0 RESULTS AND DISCUSSION

3.1 Species occurrence.

Fish surveys have been conducted at Braidwood Lake by the Illinois Department of Natural Resources (IDNR) since 1980 when the cooling lake was first impounded with water pumped from the Kankakee River. Sampling was conducted annually from 1980-1992, again in 1994, and every other year from 1997-2011 (Table 3-1). During this 33 year period (21 years of actual sample collection), 49 taxa of fish including 47 species and two hybrids (hybrid sunfish and tiger muskie) were collected by IDNR. Gizzard shad (32.6%), bluegill (21.7%), common carp (18.5%), largemouth bass (8.7%), and channel catfish (5.8%) have been the dominate species collected during these surveys. The total number of taxa collected by the IDNR has ranged from 12 in 1980 to 27 in 1989. Several species have been rarely collected or only occasionally observed during this 32 year period. These include yellow bass, rock bass, redear sunfish, orangespotted sunfish, tiger muskie, grass pickerel, longnose gar, goldfish, highfin carpsucker, silver redhorse, river redhorse, blackstripe topminnow, emerald shiner, common shiner, striped shiner, redfin shiner, slenderhead darter, johnny darter, bullhead minnow, blue catfish and mosquitofish. All of these taxa have been collected in five or fewer of the 21 years of sampling conducted by the IDNR from 1980 through 2009. Sampling was conducted by the IDNR in 2011; however, the data were not available to the authors at the time this report was prepared.

The only protected species (one fish collected in 1999) collected during these surveys has been river redhorse (*Moxostoma carinatum*), which is currently listed as threatened in Illinois (Illinois Endangered Species Protection Board 2009). River redhorse have been collected from the Kankakee River during past sampling programs (HDR 2011 and 2012). Eighteen of the taxa identified by the IDNR have not been captured since 1999.

Braidwood Lake has been stocked with a variety of warmwater and coolwater fish species since the late 1970's. Some of these species, such as striped bass, tiger muskie, and walleye, have not been collected in recent years following the discontinuance of those stocking programs. Currently, the fish community is dominated by warmwater species that are more tolerant of the elevated water temperatures that exist in the cooling lake during summer months.

TABLE 3-1

SPECIES OCCURRENCE OF FISH COLLECTED BY THE ILLINOIS DEPARTMENT OF NATURAL RESOURCES[a] AT BRAIDWOOD LAKE FROM 1980 THROUGH 2009[a].

Taxa	SAMPLING YEARS														
	80-85	86-90	91	92	94	97	99	01	03	05	07	09	11[b]	TOTAL	%
Longnose gar	3					13								16	<0.1
Threadfin shad	564								11	230	122	770		1697	2.7
Gizzard shad	4012	6712	1382	3018	412	925	925	786	1031	872	195	543		20,813	32.6
Grass pickerel	39													39	0.1
Tiger muskie	11			5		12								28	<0.1
Goldfish					2	3	1	1						7	<0.1
Carp	2987	4393	108	227	285	853	385	929	620	204	405	403		11,799	18.5
Golden shiner	88			1	1			1	1		1	2		95	0.1
Emerald shiner	1	3	1					48						53	0.1
Common shiner	31	4												35	0.1
Striped shiner	14													14	<0.1
Spotfin shiner	1	124	5	4	1	1		198	3	27	249	959		1572	2.5
Sand shiner	5	39	2	1					5		75	10		137	0.2
Redfin shiner									1					1	<0.1
Bluntnose minnow	6	78	6	3			3	13		1	6	49		165	0.3
Bullhead minnow											11	5		16	<0.1
Quillback	189	183	26	66	20	37	5	3						529	0.8
Highfin carpsucker	2													2	<0.1
Silver redhorse	1	1			1									3	<0.1
Golden redhorse		7	2		1									10	<0.1
Shorthead redhorse		20	3	3		4	3							33	0.1
River redhorse							1							1	<0.1
Black bullhead	319													319	0.5
Yellow bullhead	46	14	1	1	1		3	3		1	1	4		75	0.1
Blue catfish												3		3	<0.1
Channel catfish	39	318	362	357	463	136	364	866	384	129	228	90		3736	5.8
Flathead catfish						1	2	10		1	1	3		18	<0.1

TABLE 3-1 (Continued).

Taxa	80-85	86-90	91	92	94	97	99	01	03	05	07	09	11[b]	TOTAL	%
	SAMPLING YEARS														
Blackstripe topminnow		6												6	<0.1
Mosquito												2		2	<0.1
Brook silverside	150	192	8	9	13	6	12	50	3	5	1	1		450	0.7
Yellow bass	1	1												2	<0.1
Striped bass		9	4	1	1	15								30	<0.1
Rock bass		2	1		2									5	<0.1
Green sunfish	436	36	10	8	23	13	37	139	26	10	77	49		864	1.4
Orangespotted sunfish			1				1				1			3	<0.1
Bluegill	1432	459	698	247	252	241	998	1754	1393	1369	2758	2280		13,881	21.7
Longear sunfish					25	1	7		3		1	5		42	0.1
Redear sunfish					1			3				13		17	<0.1
Hybrid sunfish	55	18	2	1	4		9	13	8	5	7	7		129	0.2
Smallmouth bass		4	42	24	17	42	17	9	3	5		3		166	0.3
Largemouth bass	1834	867	175	91	337	202	711	351	334	88	263	315		5568	8.7
White crappie	107	24	10	2			3							146	0.2
Black crappie	57	22	6	1			20	2	2	1	1			112	0.2
Johnny darter	2													2	<0.1
Yellow perch	234	241												475	0.7
Logperch		130	11	72	6	7								226	0.4
Slenderhead darter		4	1											5	<0.1
Walleye	68	220	7	8	1	3								307	0.5
Freshwater drum	19	113	8	15	6	21	14	14	34	9	1	1		255	0.4
Total fish	12,753	14,244	2882	4165	1875	2536	3521	5193	3862	2957	4404	5517		63,909	
Total taxa	31	30	26	23	23	20	21	20	17	16	20	22		49	
Total species	29	28	25	21	22	19	20	19	16	15	19	21		47	

[a]Table was reformatted from data provided by the Illinois Department of Natural Resources.
[b]Data was collected in 2011, but the data was not available to the authors prior to the preparation of this report.

3.2 *Relative Abundance and CPE.*

In 2012, 23 taxa representing eight families were included among the 1914 fish collected by electrofishing, trap netting, hoop netting, and gill netting. Thirty-four taxa representing ten families have been included among the 8787 fish collected by HDR since 2009 (Table 3-2). Several species that were listed as collected by the IDNR during surveys conducted between 1980 and 2009 have not been captured by HDR. Each of these taxa were either rarely encountered during previous years, represent taxa that were stocked, or have not been captured during recent years. However, six species have been captured by HDR that have not been collected by IDNR. They included shortnose gar, bigmouth buffalo, smallmouth buffalo, fathead minnow, rosyface shiner, and a shovelnose tiger catfish, which was collected for the first time in 2012. This exotic species was collected in a trap net and almost certainly was an unwanted aquarium fish that was released into Braidwood Lake. The shovelnose tiger catfish measure 490 mm in total length and weighed 862 grams. In addition, a single hybrid striped bass was also collected for the first time in 2012. This fish was also captured in a trap net and measure 342 mm in total length and weighed 408 grams. It is assumed that this fish was the result of a recent stocking effort in 2011 by IDNR. With the exception of these two fish, no threatened, endangered, or new species were collected in 2012.

Species that numerically dominated the catch in 2012 (all sampling methods combined) included bluegill at 28.7%, bullhead minnow at 16.2%, channel catfish at 14.1%, threadfin shad at 9.2%, carp at 6.8%, spotfin shiner at 5.1%, bluntnose minnow at 5.0%, largemouth bass at 4.3%, and gizzard shad at 2.7% (Table 3-2). All of these species have been commonly collected by the IDNR during recent sampling efforts (Table 3-1). Biomass of fish captured by electrofishing, trap netting, gill netting, and hoop netting was dominated by carp (40.6%), channel catfish (34.3%), bluegill (10.3%), largemouth bass (8.3%), flathead catfish (2.1%), and gizzard shad (1.9%). These results are similar to data collected during previous years and indicate that Braidwood Lake is best suited to support warmwater species.

3.2.1 *Electrofishing*

In 2012, electrofishing resulted in the collection of 1271 individuals representing 18 taxa (Table 3-3). The catch was dominated numerically by bullhead minnow (310 individuals), which

TABLE 3-2

TOTAL NUMBER, WEIGHT (g) AND PERCENT CONTRIBUTION OF FISH COLLECTED BY ALL SAMPLING GEARS FROM BRAIDWOOD STATION COOLING LAKE DURING 2012 AND 2009 THROUGH 2012.

	2012				2009-2012			
	NUMBER		WEIGHT		NUMBER		WEIGHT	
TAXON	No.	%	(g)	%	No.	%	(g)	%
Threadfin shad	177	9.2	1224	0.3	1130	12.9	10,909	0.5
Gizzard shad	52	2.7	7106	1.9	435	5.0	65,700	2.9
Shortnose gar					1	< 0.1	1750	0.1
Longnose gar					9	0.1	26,900	1.2
Carp	130	6.8	150,918	40.6	801	9.1	1,130,695	50.3
Common shiner					1	< 0.1	17	< 0.1
Striped shiner					34	0.4	59	< 0.1
Rosyface shiner					21	0.2	51	< 0.1
Spotfin shiner	98	5.1	242	0.1	644	7.3	1556	0.1
Sand shiner	5	0.3	10	< 0.1	46	0.5	78	< 0.1
Fathead minnow	6	0.3	18	< 0.1	7	0.1	20	< 0.1
Bluntnose minnow	96	5.0	228	0.1	357	4.1	763	< 0.1
Bullhead minnow	310	16.2	746	0.2	555	6.3	1312	0.1
Smallmouth buffalo					3	< 0.1	6590	0.3
Bigmouth buffalo					1	< 0.1	2550	0.1
Yellow bullhead					3	< 0.1	137	< 0.1
Blue catfish	8	0.4	1005	0.3	74	0.8	16,835	0.7
Channel catfish	270	14.1	127,482	34.3	1387	15.8	616,381	27.4
Flathead catfish	1	0.1	7800	2.1	8	0.1	96,550	4.3
Shovelnose tiger catfish	1	0.1	862	0.2	1	< 0.1	862	< 0.1
Mosquitofish	2	0.1	5	< 0.1	2	< 0.1	5	< 0.1
Brook silverside	2	0.1	5	< 0.1	26	0.3	32	< 0.1
Hybrid striped bass	1	0.1	408	0.1	1	< 0.1	408	< 0.1
Sunfish spp.	3	0.2	3	< 0.1	5	0.1	5	< 0.1
Green sunfish	45	2.4	1143	0.3	145	1.7	3936	0.2

TABLE 3-2 (Continued).

TAXON	2012 NUMBER No.	2012 NUMBER %	2012 WEIGHT (g)	2012 WEIGHT %	2009-2012 NUMBER No.	2009-2012 NUMBER %	2009-2012 WEIGHT (g)	2009-2012 WEIGHT %
Orangespotted sunfish					3	< 0.1	29	< 0.1
Redear sunfish	30	1.6	1815	0.5	51	0.6	2647	0.1
Bluegill	550	28.7	38,160	10.3	2499	28.4	149,029	6.6
Longear sunfish	39	2.0	936	0.3	165	1.9	3243	0.1
Hybrid sunfish					17	0.2	325	< 0.1
Smallmouth bass	4	0.2	134	< 0.1	9	0.1	3461	0.2
Largemouth bass	83	4.3	30,988	8.3	336	3.8	100,339	4.5
Black crappie					1	< 0.1	147	< 0.1
Freshwater drum	1	0.1	246	0.1	9	0.1	3676	0.2
Totals	1914		371,484		8787		2,246,997	
Total taxa	23				34			
Total species	21				31			

[a]Sampling methods included electrofishing, trap netting, gill netting and hoop netting.

TABLE 3-3

TOTAL CATCH BY METHOD FOR FISH SPECIES COLLECTED FROM THE BRAIDWOOD STATION COOLING LAKE, 2012.

TAXON	ELECTROFISHING				TRAP NETTING				GILL NETTING				HOOP NETTING			
	NUMBER		WEIGHT		NUMBER		WEIGHT		NUMBER		WEIGHT		NUMBER		WEIGHT	
	No.	%	(g)	%	No.	%	(g)	%	No.	%	(g)	%	No.	%	(g)	%
Threadfin shad	111	8.7	627	0.3					66	60.6	597	15.5				
Gizzard shad	46	3.6	5620	2.9	2	0.5	619	0.4	4	3.7	867	22.6				
Carp	65	5.1	99,249	50.9	64	15.1	51,591	35.8	1	0.9	78	2.0				
Spotfin shiner	98	7.7	242	0.1												
Sand shiner	5	0.4	10	< 0.1												
Fathead minnow	6	0.5	18	< 0.1												
Bluntnose minnow	96	7.6	228	0.1												
Bullhead minnow	310	24.4	746	0.4												
Blue catfish					1	0.2	518	0.4	7	6.4	487	12.7				
Channel catfish	63	5.0	51,658	26.5	72	16.9	45,954	31.8	31	28.4	1815	47.2	104	95.4	28,055	98.9
Flathead catfish					1	0.2	7800	5.4								
Shovelnose tiger catfish					1	0.2	862	0.6								
Mosquitofish	2	0.2	5	< 0.1												
Brook silverside	2	0.2	5	< 0.1												
Hybrid striped bass					1	0.2	408	0.3								
Sunfish spp.	3	0.2	3	< 0.1												
Green sunfish	45	3.5	1143	0.6												
Redear sunfish	29	2.3	1673	0.9	1	0.2	142	0.1								
Bluegill	280	22.0	12,362	6.3	265	62.4	25,488	17.7					5	4.6	310	1.1
Longear sunfish	39	3.1	936	0.5												
Smallmouth bass	4	0.3	134	0.1												
Largemouth bass	67	5.3	20,310	10.4	16	3.8	10,678	7.4								
Freshwater drum					1	0.2	246	0.2								
Totals	1271		194,969		425		144,306		109		3844		109		28,365	
Total taxa	18				11				5				2			
Total species	17				10				5				2			

comprised 24.4% of all fish captured. Bluegill (22.0%), threadfin shad (8.7%), spotfin shiner (7.7%), bluntnose minnow (7.6%), largemouth bass (5.3%), carp (5.1%), channel catfish (5.0%), gizzard shad (3.6%), green sunfish (3.5%), longear sunfish (3.1%), and redear sunfish (2.3%) were the only other species to individually comprise greater than 2% of the total catch by number. The total number of fish collected by location ranged from 69 at Location E-3 to 254 at Location E-5 (Table 3-4). The total number of taxa collected ranged from nine at Location E-3 to 15 at Locations E-5 and E8. The fewest number fish and taxa were collected at Location E-1 located closest to the Braidwood Station discharge. In general, more fish and greater numbers of taxa were collected at sampling areas located toward the middle and cooler end of the Braidwood Lake cooling loop (Locations E-4, E-5, E6, E7, and E-8). Electrofishing biomass was dominated by carp, which constituted 50.9% of the 195.0 kg collected (Table 3-3). Other species that individually contributed more than 2% of the total biomass included channel catfish (26.5%), largemouth bass (10.4%), bluegill (6.3%), and gizzard shad (2.9%).

The mean electrofishing catch-per-effort (CPE) for all locations combined in 2012 was 238.3 fish/hr (Table 3-4). This value is higher then the mean electrofishing CPE of 177.5 and 167.6 fish/hr for all locations combined in 2009 and 2010, and slightly less than the 277.7 fish/hr that was reported in 2011 (HDR 2010, 2011, and 2012). Some of the increase in CPE during the last two years is indirectly the result of reducing the sampling effort from 30 minutes per location in 2009 and 2010 to 20 minutes per location in 2011 and 2012. This was done to minimize the stress on fish that were being held in the holding tank before they could be processed in the field. Due to the relatively small size of the sampling areas that have been electrofished during each annual effort, the majority of the collected fish that were captured in 2009 and 2010 were collected during the first 15 to 20 minutes of sampling. Toward the end of each sampling effort in 2009 and 2010 some of the areas had to be electrofished a second time in order to make the 30 minute sampling period requirement. Fewer fish and lower CPE's were observed during the second runs through each of these re-sampled areas.

In 2012, CPE ranged from 103.5 fish/hr at Location E-3 to 381.0 fish/hr at Location E-5. Location E-5 also exhibited the highest CPE's in 2009 and 2010, and the second highest CPE in 2011. This site includes the area around the make-up water discharge into the lake from the Kankakee River. Four species, common carp, bullhead minnow, bluegill, and largemouth bass, were collected at each of the eight electrofishing locations.

TABLE 3-4

NUMBERS OF FISH CAPTURED BY ELECTROFISHING AT EACH SAMPLING LOCATION IN BRAIDWOOD LAKE, 2012.

	SAMPLING LOCATIONS									
TAXON	E-1	E-2	E-3	E-4	E-5	E-6	E-7	E-8	TOTAL	%%
Threadfin shad	1	1		1	98	9	1		111	8.7
Gizzard shad	29	7		3	3		4		46	3.6
Carp	16	11	7	6	4	2	8	11	65	5.1
Spotfin shiner	30		4	7	8	27	5	17	98	7.7
Sand shiner			1	2		1		1	5	0.4
Fathead minnow				1	2	1	1	1	6	0.5
Bluntnose minnow	3	1		20	22	14	7	29	96	7.6
Bullhead minnow	24	2	9	50	15	39	33	138	310	24.4
Channel catfish	7	29	8		4	4	10	1	63	5.0
Mosquitofish								2	2	0.2
Brook silverside								2	2	0.2
Lepomis spp.					3				3	0.2
Green sunfish	1	1			27		6	10	45	3.5
Redear sunfish		1	12	1	4	2	3	6	29	2.3
Bluegill	1	40	20	33	53	21	59	53	280	22.0
Longear sunfish		2	2	4	3	10	11	7	39	3.1
Smallmouth bass					2			2	4	0.3
Largemouth bass	1	10	6	6	6	9	24	5	67	5.3
Total fish	113	105	69	134	254	139	172	205	1271	
Total Taxa	10	11	9	12	15	12	13	15	18	
CPE (fish/hr)	169.5[a]	157.5[a]	103.5[a]	201.0[a]	381.0[a]	208.5[a]	258.5[a]	307.5[a]	238.3[b]	

[a] Based on 0.67 hrs electrofishing effort.
[b] Based on 5.33 hrs electrofishing effort.

3.2.2 Trap Netting

A total of 425 fish including ten species and one hybrid striped bass was collected by trap net (Table 3-5). Bluegill was the dominant species captured, comprising 62.4% of all fish taken. The second most abundant species collected was channel catfish (16.9%), followed by carp (15.1%), and largemouth bass (3.8%). The total number of fish collected by location ranged from one at Location TN-7 to 99 at Locations TN-4. The trap net at Location TN-7 collapsed in the current sometime during each of the two 12-hr sets during both sampling events in 2012, which did not allow the net to fish properly. The total number of species collected by location ranged from one at Location TN-7 to six at Locations TN-4 and TN-8. The total biomass of fish captured by trap netting was 144.3 kg (Table 3-3). Carp (35.8%), channel catfish (31.8%), bluegill (17.7%), largemouth bass (7.4%), and flathead catfish (5.4%) were the only species to individually comprise more than 1% of the total biomass collected.

During the August and September sampling periods, mean trap netting CPE for all locations combined was 26.6 fish/net (overnight sets of approximately 12-hrs), which is similar to, but slightly less than, the 28.5, 40.8, and 30.8 fish/net reported from 2009-2011 (HDR 2010, 2011, and 2012). CPE by location ranged from 0.5 fish/net at Locations TN-7 to 49.5 fish/net at Location TN-4. Channel catfish was the only species collected at each of the eight sampling locations.

3.2.3 Gill Netting

Gill netting resulted in the collection of 109 individuals representing five species (Table 3-6). Threadfin shad dominated the catch by comprising 66 (60.6%) of the 109 total fish collected. Channel catfish was the second most abundant species collected (28.4%). The only other species to individually contribute more than 5% of the total catch was blue catfish (6.4%). Channel catfish comprised 1.8 kg (47.2%) of the 3.8 kg of fish collected by gill netting (Table 3-3), followed by gizzard shad at 0.9 kg (22.6%), threadfin shad at 0.6 kg (15.5%), and blue catfish at 0.5 kg (12.7%).

A total of 91 fish representing five species was collected from the two deep water sets conducted at Location GN-2 (Table 3-6). Gill nets at this location were set in a deep hole at a depth of

TABLE 3-5

NUMBER OF FISH CAPTURED BY TRAP NETTING AT EACH SAMPLING LOCATION IN BRAIDWOOD LAKE, 2012.

	SAMPLING LOCATIONS									
TAXON	TN-1	TN-2	TN-3	TN-4	TN-5	TN-6	TN-7	TN-8	TOTAL	%
Gizzard shad				1				1	2	0.5
Carp	15	11	10	10	10	1		7	64	15.1
Blue catfish	1								1	0.2
Channel catfish	11	15	16	12	4	8	1	5	72	16.9
Flathead catfish					1				1	0.2
Shovelnose tiger catfish								1	1	0.2
Hybrid striped bass				1					1	0.2
Redear sunfish					1				1	0.2
Bluegill	24	8	39	72	15	82		25	265	62.4
Largemouth bass	8		5	3					16	3.8
Freshwater drum								1	1	0.2
Total fish	59	34	70	99	31	91	1	40	425	
Total Taxa	5	3	4	6	5	3	1	6	11	
CPE (fish/trap net set)	29.5[a]	17.0[a]	35.0[a]	49.5[a]	15.5[a]	45.5[a]	0.5[a]	20.0[a]	26.6[b]	

[a]Based on two over night sets of approximately 12 hr duration.
[b]Based on 16 over night sets of approximately 12 hr duration.

TABLE 3-6

NUMBERS OF FISH CAPTURED BY DEEP (GN-1) AND SHALLOW WATER (GN-2) GILL NETS IN BRAIDWOOD LAKE, 2012.

	SAMPLING LOCATION			
TAXA	GN-1[a]	GN-2[b]	TOTAL	%
Threadfin shad	13	53	66	60.6
Gizzard shad	2	2	4	3.7
Carp		1	1	0.9
Blue catfish		7	7	6.4
Channel catfish	3	28	31	28.4
Total fish	18	91	109	
Total taxa	3	5	5	
CPE (fish/hr)	31.0[c]	182.0[d]	100.9[e]	

[a]GN-1 was a shallow water set in approximately 2-3 meters of water.
[b]GN-2 was a deep water set in approximately 8-10 meters of water.
[c]Based on 0.58 hours of total effort.
[d]Based on 0.50 hours of total effort.
[e]Based on 1.08 hours of total effort.

approximately 8-10 m. Gill nets at the shallow water sampling Location GN-1 were set at a depth of approximately 2-3 m. Eighteen fish and three species were collected from this sampling location during the August and September sampling dates.

Gill net CPE at the deep water Location GN-2 was 182.0 fish/hr based on 91 fish collected during 0.5 hours of sampling effort during the two combined sampling dates. CPE at the shallow water Location GN-1 was substantially lower at 31.0 fish/hr based upon the 18 fish collected during 0.58 hours of total sampling effort in August and September. Mean CPE for the two sampling locations in 2012 was 100.9 fish/hr, which is higher than 73.5 fish/hr in 2010 (HDR 2011) and the 53.4 fish/hr reported in 2009 (HDR 2010), but lower than the 180.7 fish/hr reported in 2011 (HDR 2012). Threadfin shad, gizzard shad, and channel catfish were the only species collected at both sampling locations.

3.2.4 Hoop Netting

A total of 108 fish including two species was collected by hoop nets (Table 3-7). Channel catfish dominated the catch by comprising 95.4% of all fish taken. The only other species collected was bluegill (4.6%), which was represented by five individuals. A total of 28.4 kg of fish was collected by hoop net (Table 3-3). Channel catfish comprised 98.9% of the catch by weight, while bluegill constituted the remaining 1.1% of the biomass collected by hoop net.

The greatest number of fish (58 individuals) was collected at Location HN-2, which was a deep water set that was not baited with dead gizzard shad (Table 3-7). Eighteen fish were collected at Location HN-1, which was also a deep water set that was baited with dead gizzard shad. Twenty-five fish were captured at Location HN-3, which was a shallow water set baited with gizzard shad. Only three channel catfish were collected at Location HN-4, which was a shallow water set that was not baited with dead gizzard shad. A total of 43 fish was collected from the two baited net locations compared to 66 fish captured from the two nets that were not baited at Braidwood Lake in 2012. Baiting hoop nets with dead gizzard shad has provided inconsistent results during the course of this four year study period (2009-2012).

Hoop netting CPE ranged from 4.0 fish/overnight set at Location HN-4 (shallow water without bait) to 29.0 fish/overnight set at Location HN-2 (deep water without bait). CPE for the two deep

TABLE 3-7

NUMBERS OF FISH CAPTURED IN BAITED AND UNBAITED DEEP AND SHALLOW WATER HOOP NETS IN BRAIDWOOD LAKE, 2012.

	SAMPLING LOCATION					
	DEEP WATER[a]		SHALLOW WATER[b]			
TAXA	HN-1 (BAITED)	HN-2 (UNBAITED)	HN-3 (BAITED)	HN-4 (UNBAITED)	TOTAL	%
Channel catfish	18	58	25	3	104	95.4
Bluegill				5	5	4.6
Total fish	18	58	25	8	108	
Total taxa	1	1	1	2	2	
CPE (fish/overnight set)	9.0[c]	29.0[c]	11.5[c]	4.0[c]	13.5[d]	

[a]Deep water hoop nets HN-1 and HN-2 were set in 8.0 - 10.0 meters of water.
[b]Shallow water hoop nets HN-3 and HN-4 were set in approximately 1.0 – 2.0 meters of water.
[c]CPE was based on two overnight sets of approximately 12 hours duration.
[d]CPE was based on eight overnight sets of approximately 12 hours duration.

water sets (HN-1 and HN-2) averaged 19.0 fish/overnight set compared to 7.8 fish/overnight set at the shallow water locations (HN-3 and HN-4). The two baited net sets (HN-1 and HN-3) had an average CPE of 10.2 fish/overnight set compared to 16.5 fish/overnight set for the two nets (HN-2 and HN-4) that were not baited. Mean CPE for all nets combined was 13.5 fish/overnight set.

3.3 Length-Frequecy Distributions

Length-frequency distributions of six selected species (bluegill, largemouth bass, channel catfish, blue catfish, threadfin shad, and gizzard shad) captured by all sampling gears in 2012 were compiled and are presented graphically (Figure 3-1 through Figure 3-5). With the exception of electrofishing, the sampling gears used in these studies are biased toward larger individuals. Therefore, smaller fish, especially young-of-year and yearlings, were not collected in numbers that would most accurately represent their true abundance in Braidwood Lake.

Bluegill is one of the most abundant species found in Braidwood Lake. Four hundred forty-eight individuals measuring from 34 to 190 mm in total length are included in the length-frequency histogram of bluegill that were captured in 2012 (Figure 3-1). A major peak in the length-frequency distribution representing one or two age classes was observed from 140 to 180 mm in total length. A second minor peak in the length-frequency histogram occurred at 80-90 mm in total length. The age of these fish, as well as all other species, in thermally enhanced bodies of water like Braidwood Lake, is difficult to determine without hard-part (scales, spines, and otoliths) analysis because the growing season extends throughout the winter months. Regardless of age, Braidwood Lake supports a substantial population of bluegill that are large enough to support a quality sport fishery.

The length-frequency distribution of 83 largemouth bass measuring from 98 to 495 mm in total length were collected from Braidwood Lake during 2012 (Figure 3-2). The length-frequency distribution indicates that several age classes of fish were included among the catch. The largest peak in the length-frequency histogram occurs from 120 to 170 mm and likely represents either YOY or Age 1 fish. Eighteen (21.7%) of the 83 fish collected exceeded 350 mm (14 in.). The largest individual that measured 495 mm was likely Age 4 or older. Again, the age of fish in cooling lakes is difficult to ascertain based on length-frequency analysis because of the extended

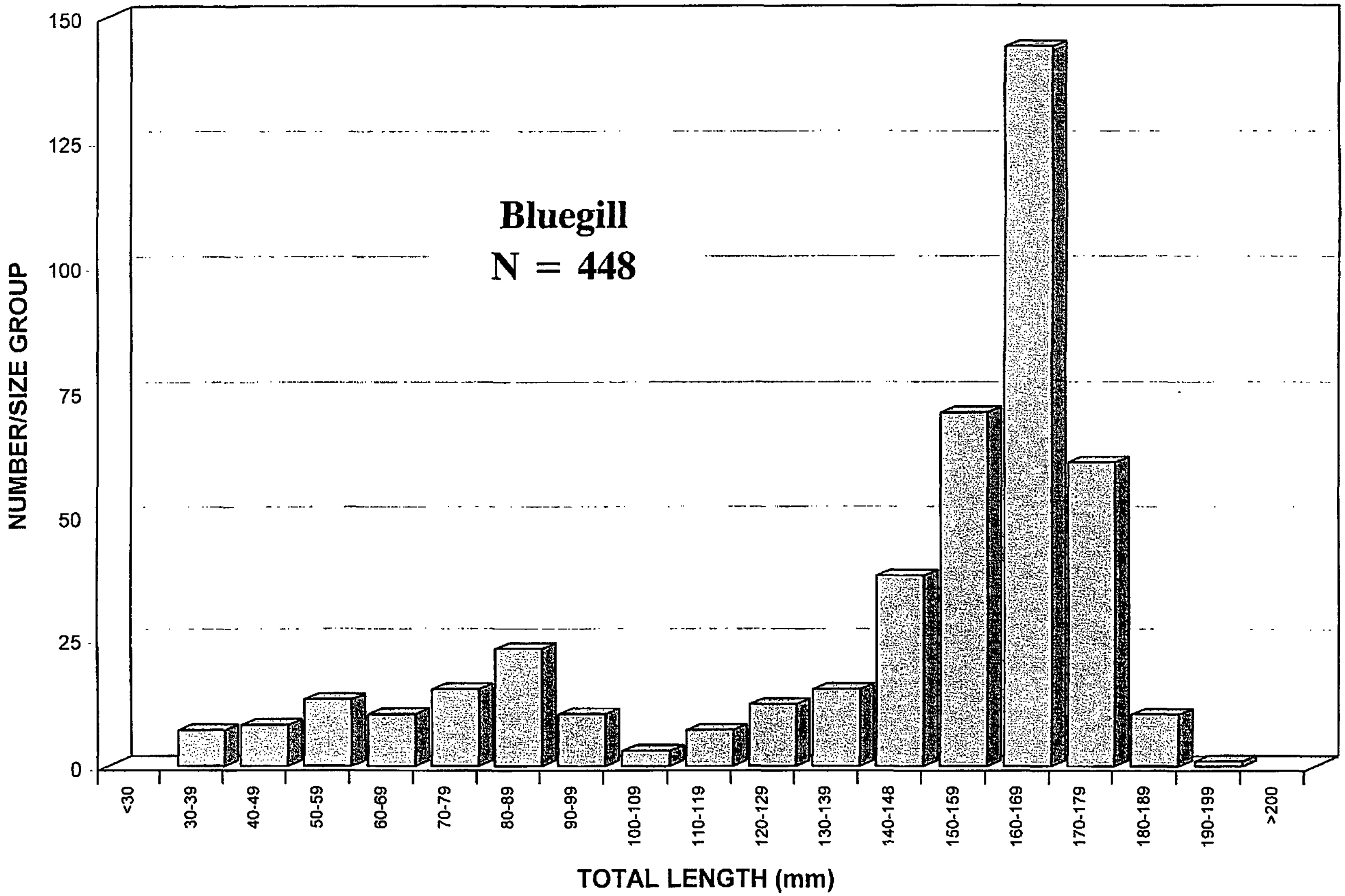

FIGURE 3-1. LENGTH-FREQUENCY DISTRIBUTION OF BLUEGILL COLLECTED FROM BRAIDWOOD LAKE DURING AUGUST AND SEPTEMBER, 2012.

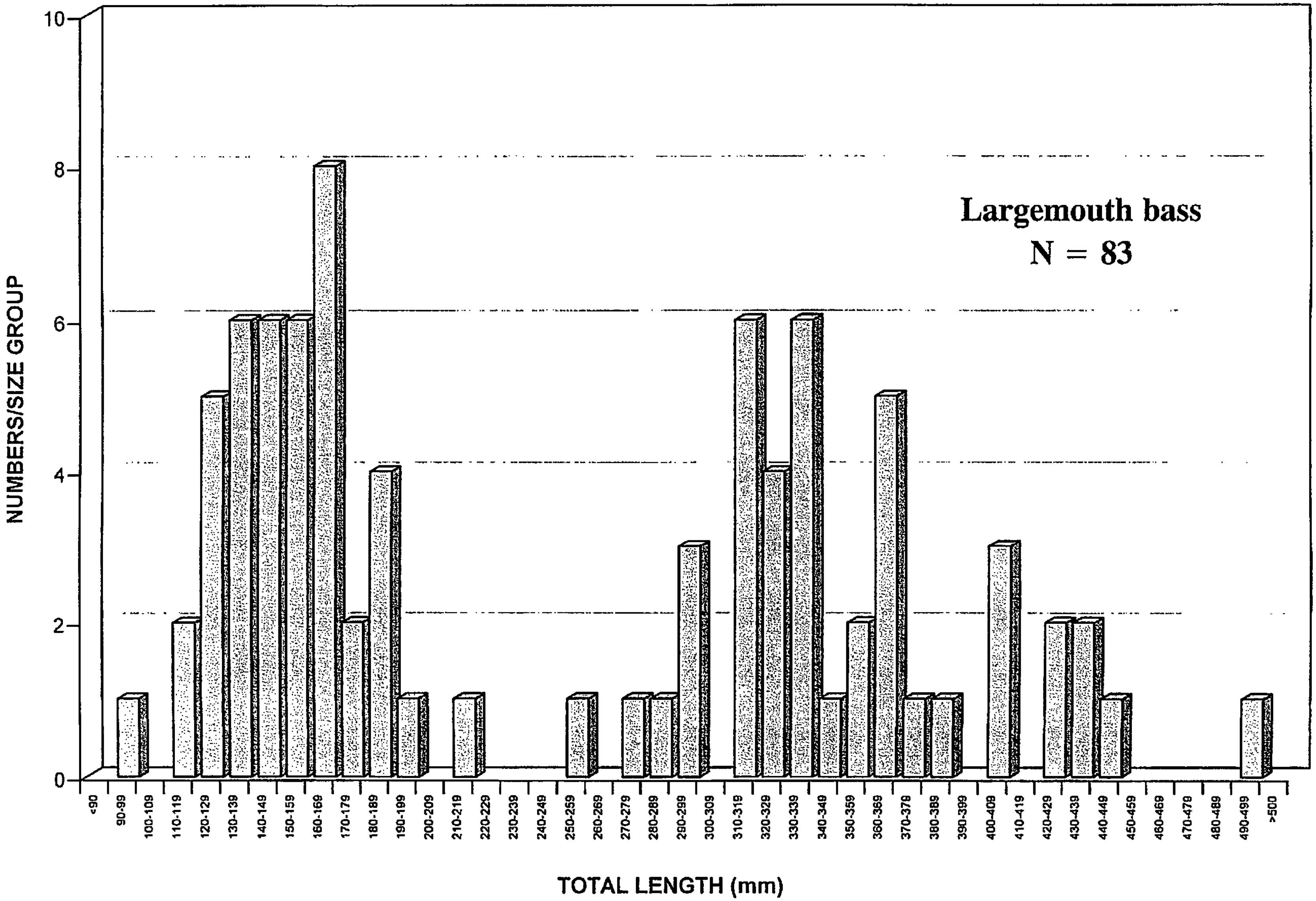

FIGURE 3-2. LENGTH-FREQUENCY DISTRIBUTION OF LARGEMOUTH BASS COLLECTED FROM BRAIDWOOD LAKE DURING AUGUST AND SEPTEMBER, 2012.

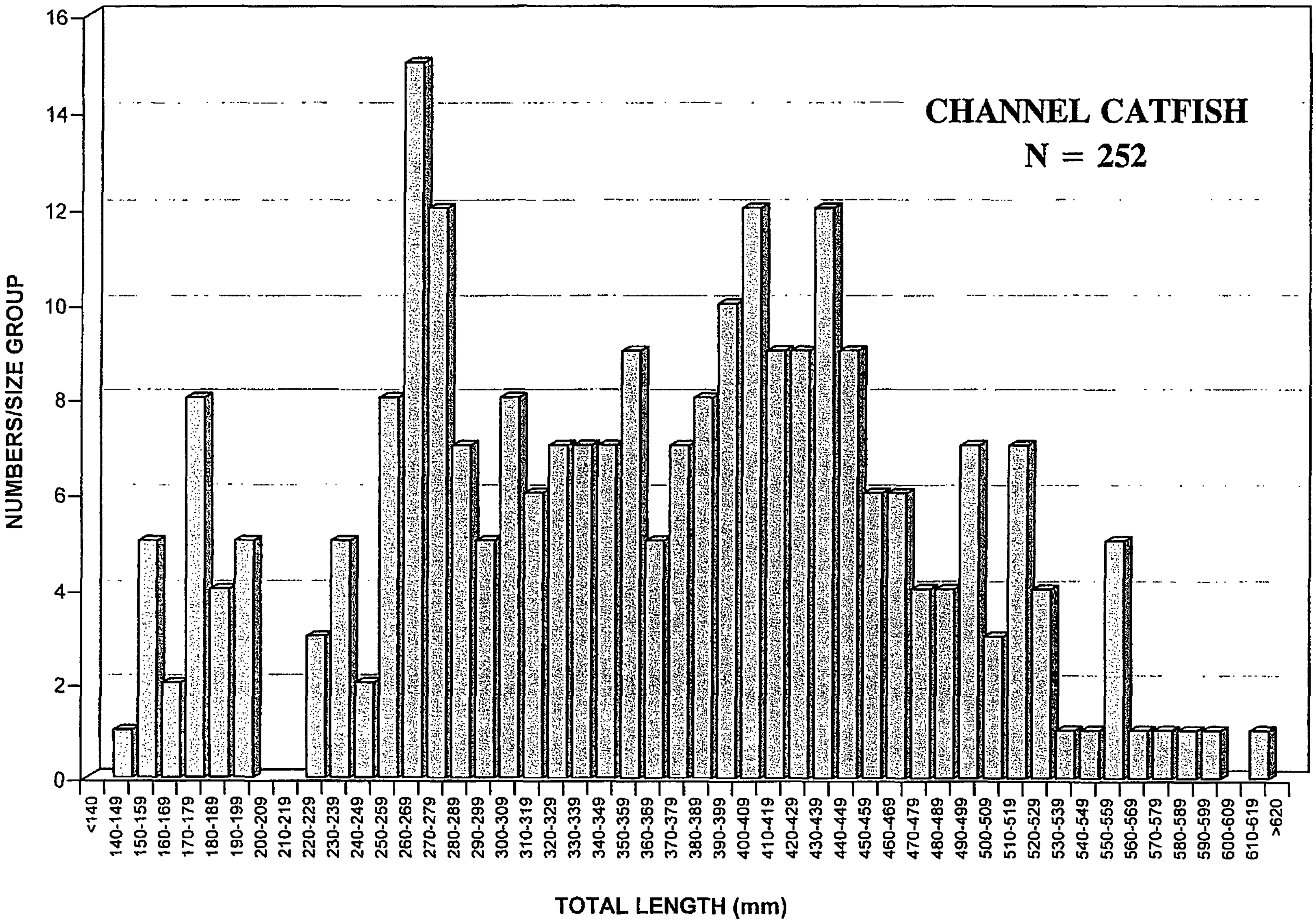

FIGURE 3-3. LENGTH-FREQUENCY DISTRIBUTION OF CHANNEL CATFISH COLLECTED FROM BRAIDWOOD LAKE DURING AUGUST AND SEPTEMBER, 2012.

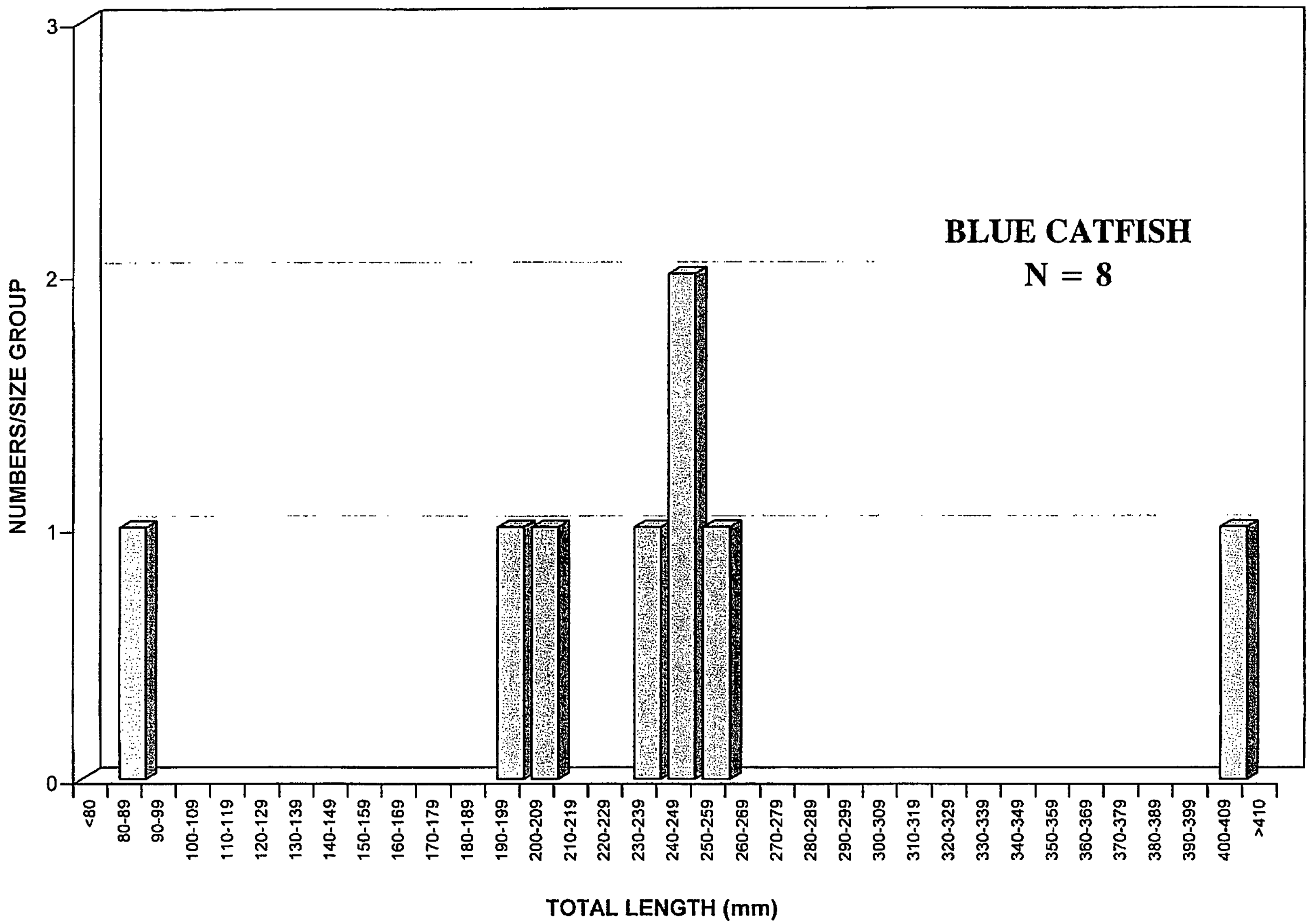

FIGURE 3-4. LENGTH-FREQUENCY DISTRIBUTION OF BLUE CATFISH COLLECTED FROM BRAIDWOOD LAKE DURING AUGUST AND SEPTEMBER, 2012.

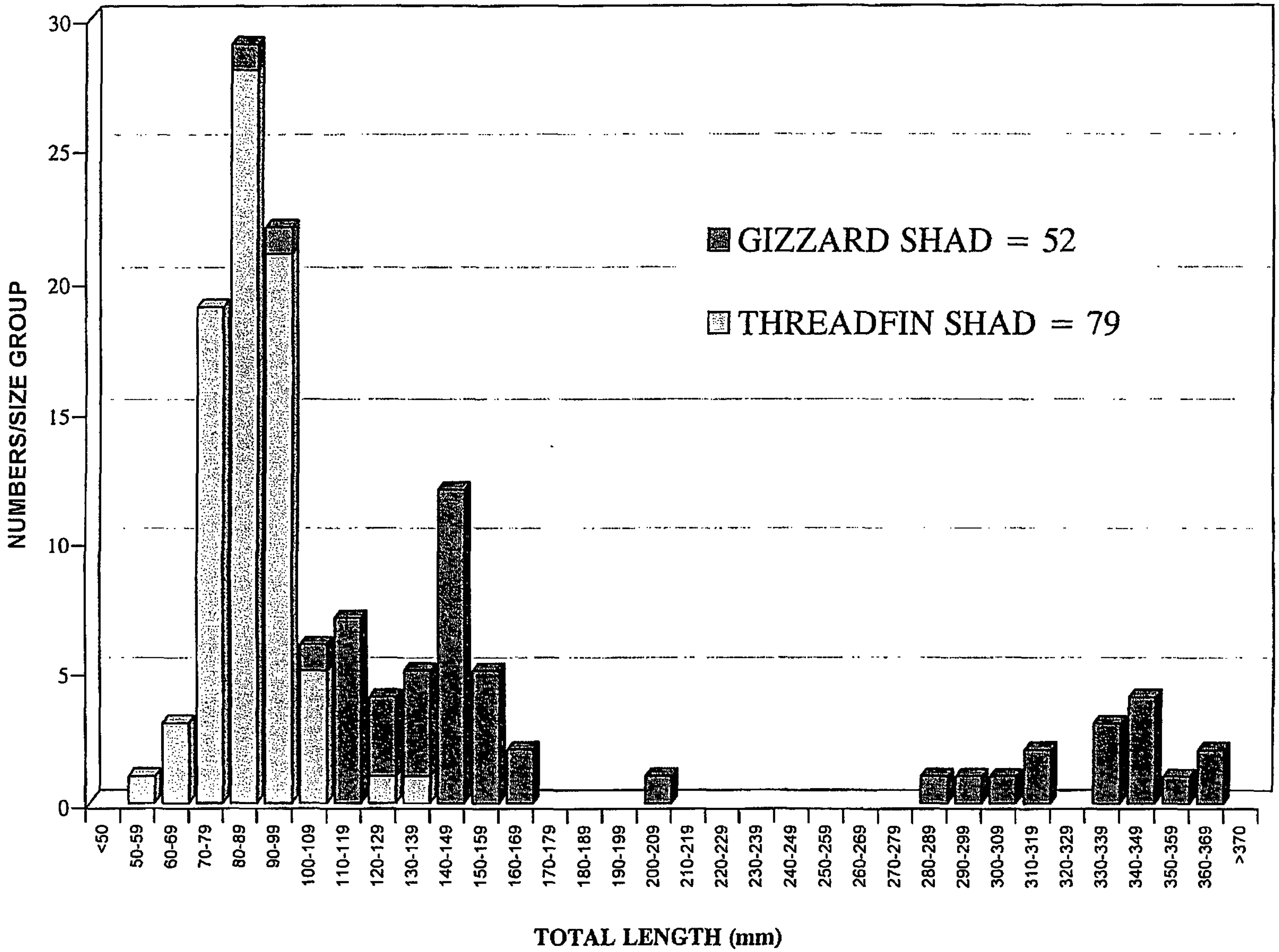

FIGURE 3-5. LENGTH-FREQUENCY DISTRIBUTION OF THREADFIN AND GIZZARD SHAD COLLECTED FROM BRAIDWOOD LAKE DURING AUGUST AND SEPTEMBER, 2012.

growing season that exist in these thermally enhanced bodies of water. Only eight fish were collected that measured between 190 and 310 mm in TL. This may represent a weak year class in the length-frequency histogram for largemouth bass as illustrated in Figure 3-2. It should also be noted that the IDNR stocked 46,160 four inch fingerlings into Braidwood Lake in 2010. This was equivalent to 20.6 fish/acre (HDR 2011). Stocking activities conducted by IDNR at Braidwood Lake in 2012 were not available at the time this report was prepared.

Channel catfish is an abundant species that is targeted by recreational anglers at Braidwood Lake. A total of 252 fish measuring from 147 to 610 mm are included in the length frequency analysis for channel catfish (Figure 3-3). Several age classes of channel catfish are included among the 252 fish observed in the length-frequency analysis. Recruitment of this species appears to be very good based on Figure 3-3, which illustrates that there are not any missing or obvious weak year classes in the catch.

Braidwood Lake has been stocked with a variety of warm- and coolwater fish species since the 1970's to the present time. Those efforts have included the introduction of blue catfish to the cooling lake. Because of those stocking efforts, and because of the number of blue catfish that were collected during recent years, a length-frequency histogram was also created for this species (Figure 3-4). The length-frequency distribution of eight fish measuring from 84 to 400 mm indicates that as many as three or perhaps four year classes of blue catfish were included in the catch at Braidwood Lake during 2012. Six (75.0%) of the eight fish collected measured from 190 to 260 mm in total length. Blue catfish were stocked in Braidwood Lake by IDNR in 2010. This stocking effort included 9,812 blue catfish fingerlings (5.3 inches) equivalent to 4.3 fish/acre (HDR 2011). The authors of this report do not know if any of these individuals were stocked in Braidwood Lake by IDNR in 2012.

Two additional species, threadfin shad and gizzard shad, were also analyzed (Figure 3-5). Both of these abundant forage species reside in Braidwood Lake. They are important to the ecology of the system and they have the potential to pose a threat to the operation and maintenance of Braidwood Nuclear Station when fish kills occur at the cooling lake. Large numbers of dead gizzard and threadfin shad could accumulate on the bar grills, traveling water screens, and other systems at the Stations intake, which could potentially interfere with water flow used to cool the reactors and other support systems.

A total of 52 gizzard shad and 79 threadfin shad are included in the length-frequency histogram for these two species (Figure 3-5). All of the threadfin shad collected during the current study measured from 52 to 130 mm in total length, while 50 (96.2%) of the 52 gizzard shad captured exceeded 100 mm in total length. Gizzard shad ranged in length from 89 to 369 mm in total length. At least three or four year classes of gizzard shad were collected during 2012. In contrast, threadfin shad rarely exceed 150 mm in total length and individuals spawned early in the year commonly mature and spawn late in their first summer of life. Few threadfin shad live for more than two or three years.

3.4 Physicochemical Data

Water quality data recorded in conjunction with fish sampling was measured at each location prior to every sample collection (Appendix Tables A-1 to A-4). During August 20-23, water temperature at Braidwood Lake ranged from 30.3 °C at Location E-3 on 23 August to 35.1 °C at Locations TN-1 and TN-2 on 20 August. Water temperatures during the second sampling period (September 10-12) were slightly cooler than those measured in August. Temperatures during this period ranged from 27.4 °C at Location TN-8 on 11 September to 33.6 °C at Locations TN-1 and TN-2 on 10 September. As expected, the temperature gradient generally declined as the cooling water in the lake moved from the Station's discharge toward the Braidwood Station intake.

During the first sampling period (August 20-23), dissolved oxygen (DO) ranged from 4.6 ppm at Locations E-1 during the early morning of 23 August to 11.5 ppm at Location TN-4 during the late afternoon of 20 August. Oxygen levels were generally slightly higher during the second sampling period in September. Dissolved oxygen levels ranged from 4.3 ppm at Location TN-1 during the morning of 11 September to 13.2 ppm at Location TN-5 during the afternoon of 10 September.

Dissolved oxygen measurements increased each day in the lake from early morning to late afternoon during both the first and second sampling periods. Similar conditions were also observed in previous years. The increase in dissolved oxygen measurements from early morning to late afternoon can be attributed to photosynthesis by the phytoplankton population in the lake that produces oxygen throughout the daylight hours.

Surface and bottom water temperature, DO, and conductivity readings were taken at deep water gill net set Location GN-1 and the two deep water hoop net set Locations HN-1 and HN-2 (Appendix Tables A-3 and A-4). At all three of these locations, slightly cooler water temperatures (0.1 to 0.3 °C) and slightly lower DO readings (0.19 to 1.38 ppm) were measured 0.5 meters off the bottom when compared to the surface readings. Conductivity measurements at the surface and bottom in Braidwood Lake were very similar (1-11 µmhos/cm) at all three of these sampling locations.

Braidwood Lake is a very productive system with heavy oxygen demand (respiration and decomposition) occurring during the night and intense oxygen production (photosynthesis) occurring during clear sunny days. Currently, the majority of the photosynthetic activity within Braidwood Lake is attributable to phytoplankton, which has decreased the water clarity and replaced aquatic macrophtyes as the primary producer. In a report submitted to Exelon by SEA in 2001 (Appendix Report B-1); it states that "Several perched cooling ponds in the Midwest have had high macrophyte densities in their earlier years but usually become dominated by phytoplankton if they have heavy thermal loading. A switch to phytoplankton dominance is usually accompanied by a reduction in water transparency."

Braidwood Lake appears to be relatively well buffered with only minor diurnal variation in pH readings. Examination of pH data collected during the present surveys show that pH ranged from 8.5 to 8.8 during the first August sampling period and from 8.7 to 9.0 during the second September sampling period. The pH of water typically increases with increased photosynthetic activity and the resulting oxygen production can explain upward shifts in pH during the course of bright sunny days.

During the August sampling period, conductivity ranged from 1081 µmhos at Location E-6 on 23 August to 1114 µmhos at Location TN-1 on 21 August. Conductivity during the September sampling period ranged from 1160 µmhos at Location TN-5 on 11 September to 1275 µmhos at Locations TN-1 and TN-2 on 10 September. Conductivity readings were generally slightly higher near the Braidwood Station discharge compared to the Stations intake, while pH readings were similar throughout the entire length of Braidwood Lake. Surface to bottom readings were also generally similar, suggesting that the water throughout the cooling loop was well mixed during both the August and September sampling periods.

Make-up water is pumped into Braidwood Lake on an irregular basis from the Kankakee River throughout most of the year. As a result, water quality parameters can be expected to be generally more favorable near the make-up water discharge (Location E-5) compared to the remainder of the sampling locations. However, the affects of the make-up water discharge is quickly dissipated because of the relatively low volume of make-up flow being pumped into the lake. Make-up flow was not observed being pumped into Braidwood Lake during either the first or the second sampling periods in August and September.

During the August sampling period, water temperatures were approaching the upper limits acceptable for some warmwater fish species. Air temperatures during July and early August were unusually high throughout the Midwest in 2012, which accounted for most of the increase in the water temperatures at Braidwood Lake during July and early August. Water temperatures were typically 1-4 °C cooler during the September sampling period as air temperatures decrease notably from those observed in July and early August. Conductivity measurements were slightly higher during the September sampling period, while DO and pH measurements were similar during both sampling periods. The early morning dissolved oxygen reading that was measured on 11 September (4.3 ppm) at Location TN-1 was beginning to approach values that adversely affect most fish species. As previously noted, these diurnal oxygen fluctuations are common at Braidwood Lake during the summer months and can be attributed to oxygen depletion (respiration and decomposition) during the night and oxygen production (photosynthesis) during the day. On cloudy calm days, photosynthesis and oxygen production can be slowed to levels that cannot compensate for oxygen depletion that occurs throughout the night. When this occurs over an extended period of time (days), an oxygen deficit can develop and cause substantial fish die-offs if suitable refuges within the system are not available.

3.5 Historical Information

3.5.1 Water Quality

Water quality parameters were measured on seven separate occasions at Braidwood Lake from May 29, 2001 through August 27-28, 2002 (Appendix Reports B-1 through B-7). The purpose and scope of these investigations varied, but the most intensive sampling was conducted during the August 27-28, 2002 sampling event. Results of these investigations indicated that abnormally high levels of total dissolved solids (TDS), alkalinity, hardness, sulfates, magnesium, calcium, and total phosphorus existed throughout the cooling loop. These data were not unexpected based on the evaporation that occurs within the cooling loop coupled with the relative low make-up and blow-down flows associated with the operation of the Station. The cooling lake exhibited elevated values for these parameters at levels of two to nearly eight times higher than those of the make-up water from the Kankakee River. These elevated levels of water hardness can be of concern to the Station because they have the potential to intensify problems associated with scaling.

Phosphorus and nitrogen are two essential nutrients required by aquatic plants. Concentrations of these nutrients are typically low in water because phytoplankton and aquatic macrophytes quickly assimilate and utilize these nutrients for growth and reproduction. The studies conducted by SEA in 2002 indicated that the high levels of these nutrients within the cooling lake would continue to cause problems associated with phytoplankton blooms. Unlike most water bodies, phosphorus levels within Braidwood Lake were in excess and nitrates were the limiting factor. Bluegreen algae appeared to be the dominant summer form of algae within Braidwood Lake because they are not as limited by low nitrate levels as other algal species.

Water quality analysis has indicated that dissolved oxygen levels within the cooling lake can exhibit large diurnal variation in response to algal blooms that are most problematic during the summer months (June through August). The nutrient rich water of Braidwood Lake is ideal for the development of algal blooms that produce large amounts of oxygen during the day (photosynthesis) and oxygen depletion in the dark (respiration and decomposition). As oxygen is produced through photosynthesis, pH tends to increase if the water is not well buffered. Dissolved oxygen levels of 4-5 ppm (levels that most fish species become stressed) and lower have been recorded throughout the cooling loop 0.5 m below the waters surface. The lowest DO readings occur during the early morning period and typically increase throughout the day. Increases in DO of 4 to 5 ppm or more have been observed from morning to late afternoon at Braidwood Lake. In addition, stratification of the water column has also occasionally been reported during the same period of time when DO readings are measured at less than 3 ppm. During these events, DO readings in the hypolimnion (the zone below the thermocline to the bottom of the lake) can approach zero. When this occurs, it further limits the refuge available for fish and other aquatic organisms.

3.5.2 Fish Kills

Historical fisheries data summarizing fish kills that have occurred at Braidwood Lake was provided to HDR by Exelon Nuclear, IDNR, and SEA (Appendix Reports B-2 through B-7). Five fish kills that occurred from 2001 through 2007 were identified in the information provided to HDR. Each of these events occurred during June, July, or August. Two of the kills occurred in 2001. The first took place in late July and the second on August 27-28. A third kill was reported on July 30, 2004, the fourth on June 28, 2005, and the fifth occurred over an extended period of time during August 21-28, 2007. No additional information regarding fish kills has been provided to HDR since 2009. Therefore, it is assumed that no reportable fish kills have been observed at Braidwood Lake since August, 2007.

Little information was provided for the fish kills that occurred in late July and August, 2001. The species involved and the extent of dead fish observed during the first event in July were not included in the information received by HDR. The second fish die-off in late August was dominated primarily by gizzard shad that comprised more than 95% of all fish observed. The remaining species involved in the die-off in decreasing order of relative abundance included, freshwater drum, quillback, carp, largemouth bass, channel catfish, redhorse spp., smallmouth bass, and bluegill. With the exception of gizzard shad, the majority of the fish were located from the mid-point of the cooling loop to the intake. A report submitted by SEA indicated that warm water temperatures and/or low dissolved oxygen levels were the most likely factors that contributed to the fish die-off in July. SEA also indicated that the die-off in late August was most likely the result of depleted dissolved oxygen levels that occurred in the lake following an extensive phytoplankton bloom collapse, which is a natural phenomenon that can occur in highly productive waters during summer months. Dissolved oxygen measurements throughout the majority of the lake were at or below minimum levels necessary to support most fish species.

A third fish die-off at Braidwood Lake was investigated on July 30, 2004. Gizzard shad was the dominant species involved, although channel catfish were also observed. The gizzard shad appeared to be in an advanced state of decay suggesting that the actual die-off occurred earlier in the week. Water quality parameters at the time of the incident were not included in the brief summary report provided to HDR, which suggests they were not measured concurrent with the fish die-off. Water quality measurements were taken in early October following the fish die-off. During this period of time, DO levels of 3.8 ppm and a water temperature of 29.2 °C were recorded at a depth of one foot below the surface, just north of the south boat ramp. At a location several hundred feet from the lake make-up discharge from the Kankakee River, more favorable dissolved oxygen (7.6 ppm) and water temperatures (26.5 °C) were measured. DO readings at this location were stratified exhibiting a decline to 5.3 ppm at 40 feet, while water temperature showed minimal decrease with water depth.

In 2005, an inspection of a fish die-off was conducted on 28 June. Formal counts of fish were not conducted at this time, but field assessments indicated that a fairly substantial die-off involving several species had occurred. Gizzard shad was again the most numerous species affected and fish carcasses were observed throughout the majority of the lake. Additional species observed included threadfin shad, quillback, largemouth and smallmouth bass, carp, and channel catfish. Water quality measurements during this event were not provided to HDR and are assumed to be unavailable.

Rob Miller of IDNR and Jeremiah Haas of Exelon Nuclear investigated another fish die-off that was first reported at Braidwood Lake on August 21, 2007. The majority of the dead fish observed were either large gizzard shad or threadfin shad up to five inches in length. Channel catfish were also prevalent, with only a few carp, largemouth bass, and flathead catfish being observed. Most of the fish were distributed in close proximity to the north boat ramp due to prevailing south winds. The number of dead fish observed decreased towards the south (hot) end of the cooling loop. During the afternoon of 21 August, surface water temperature was 35.3 °C and DO was near 3 ppm at a sampling point several hundred yards from the south ramp. Four separate water temperature and DO readings were also conducted at the north ramp between 1210 hrs and 1658 hrs. Water temperature increased from 30.3 to 33.9 °C over the course of that time interval. Dissolved oxygen was measured at 3.1 ppm at 1210 hrs and increased to 6.7 ppm during the third reading at 1530 hrs. DO levels decreased during the last reading at 1658 hrs to 5.9 ppm. Oxygen depletion appeared to be the factor responsible for the August fish kill that occurred at Braidwood Lake in 2007.

4.0 SUMMARY AND RECOMMENDATIONS

4.1 Summary. Braidwood Lake is a 2640 acre, partially perched cooling lake that was first impounded in 1980-1981 after several old strip-mine pits were inundated with water from the Kankakee River. The lake has received supplemental stockings of both warmwater and coolwater fish species since the late 1970's. However, stocking efforts of species including walleye, tiger muskie, smallmouth bass, and hybrid striped bass have not produced a sustainable quality fishery, which is due to the warm temperatures that are currently common in the cooling lake throughout the summer months. Water quality, particularly water temperature, improves as the water moves from the southern (hot) end of the cooling loop toward the northern (cool) end of the lake.

Fisheries surveys have been conducted by IDNR at Braidwood Lake annually from 1980 through 1992, in 1994, and at two year intervals from 1997 through 2011. Forty-seven species of fish and two hybrid taxa (tiger muskie and hybrid sunfish) have been included among the 13 families of fish collected. Several of these species were rarely collected, were the result of supplemental stocking efforts, or have not been collected during the past ten years of sampling. Two species, mosquitofish and blue catfish, were collected for the first time in 2009 by the IDNR. River redhorse (one individual captured in 1999) is the only species that has been collected which is currently listed as protected in Illinois. Fisheries surveys were again conducted by the IDNR in 2011, but the data were not available prior to the preparation of this report.

In 2009, HDR collected 24 species and two taxa (hybrid sunfish and small unidentified young-of-year sunfish species) among the 2143 fish collected. Similar results were observed in 2010 when 25 taxa representing eight families were included among the 2432 fish collected by electrofishing, trap netting, gill netting, and hoop netting. In 2011, 18 taxa representing 16 species were included among the 2298 fish collected by HDR. In 2012, 23 taxa and two hybrids were included among the 1914 fish that were collected by HDR. From 2009-2012, a total of 8787 fish representing 34 taxa and 31 species were collected by HDR. Several taxa that were collected by IDNR from 1980 to 2009 were not collected by HDR during 2009-2012. However, six species (shortnose gar, smallmouth buffalo, bigmouth buffalo, fathead minnow, rosyface shiner, shovelnose tiger catfish) and one taxa (hybrid striped bass) that have been captured by HDR have not been captured by IDNR. No threatened or endangered species have been encountered by HDR during any of the three years of sampling. Since 1980, 53 species of fish and three hybrids (tiger muskie, hybrid sunfish, and hybrid striped bass) have been collected at Braidwood Lake by the IDNR and HDR. Two new taxa were collected by HDR in 2012. One was a shovelnose tiger catfish, an exotic species that can be purchased at pet stores, and the second individual was a hybrid striped bass that was recovered after a fish stocking of this taxa by IDNR into Braidwood Lake in 2011.

The Braidwood Lake Fish and Wildlife Area evolved through three distinct phases since its inception prior to the 1980's. Originally, several surface mined pits existed at the site until the lake was impounded with water from the Kankakee River during 1980 and 1981. The lake continued to function in this capacity until July 29 and November 17, 1988 when Braidwood Station began commercial operation of Units I and Unit II, respectively. From 1980 through July 1988, Braidwood Lake did not receive any thermal loading from Braidwood Station. Since 1988, the lake has functioned as a cooling loop for the operation of the Station. Currently, the lake is best suited to support a warmwater fishery due to the warm temperatures prevalent in the lake throughout the summer months. Dominant species currently found at Braidwood Lake include gizzard shad, threadfin shad, bluegill, channel catfish, and carp. Additional species such as largemouth bass, green sunfish, flathead catfish, spotfin shiner, bluntnose minnow, and sand shiner have also been commonly encountered. Excluding the stocked fish that have been introduced into the Braidwood Lake, the taxa encountered have also been collected from the Kankakee River, which is the source of make-up water for the lake. With the possible exception of common carp and channel catfish, these species are better suited to conditions that exist within the river. Survival of individuals that are introduced into the lake with the make-up water is limited by the elevated water temperatures that exist within the cooling loop during summer months.

Braidwood Lake can be currently described as a well buffered body of water with elevated water temperatures, high levels of total dissolved solids (TDS), phosphates, and nitrates. Phosphate and nitrate levels have declined in recent years, but these levels are still high compared to a natural system. Primary productivity in the lake can be very high in conjunction with algal blooms that occur throughout the lake, especially during the June through August period. These blooms are driven by the high nutrient levels that exist within the lake. In recent years, phytoplankton has replaced aquatic macrophytes as the principal source of primary production. The lake can also display relatively large diurnal fluctuations in dissolved oxygen measurements, particularly during the summer when oxygen is produced in large quantities by photosynthesis during the day and used in large quantities by respiration and decomposition during the night. In addition, Braidwood Lake can stratify during certain portions of the year, which has led to anoxic (oxygen depletion) or near anoxic conditions throughout the hypolimnion (stratified bottom layer of water below the thermocline) as a result of respiration and decomposition from a collapsing algal bloom. Even in the surface waters of the epilimnion, dissolved oxygen readings of less than 4 ppm have been reported following an extensive and rapid die-off of an existing phytoplankton bloom. It is during these periods of time when water temperatures are elevated and dissolved oxygen levels are low that the fish die-offs are observed at the lake. The conditions described in this paragraph should not be expected to change at Braidwood Lake in the foreseeable future.

4.2 Recommedations. Five separate fish die-offs attributed to low DO levels were observed at Braidwood Lake between 2001 and 2007. It is expected that the conditions which led to those five events will not change or improve in the foreseeable future. Therefore, it should be assumed that fish die-offs will continue to occur when algal blooms crash and oxygen depletion occurs. Substantial fish die-offs within the cooling loop could adversely affect both the operation and maintenance of Braidwood Nuclear Station.

Currently, there are no practical or simple solutions that could prevent the occurrence of fish die-offs at Braidwood Lake. It should be anticipated that fish die-offs will continue to occur at the lake on a fairly regular basis. Therefore, it would be advantageous if a reliable sampling protocol or set of procedures were developed that would reasonably predict fish die-offs that may adversely affect the operation and/or maintenance of the Station. With advanced warning the Station could be informed of a potential reportable incident, regulatory agencies could be notified, and crews responsible for fish disposal could be put on alert to help manage the risk associated with a substantial fish die-off. HDR believes this can be accomplished by conducting routine visual inspections of the lake, monitoring dissolved oxygen levels, and by having a basic understanding of environmental conditions that may trigger these events, especially weather conditions.

HDR recommends a two tier sampling procedure that may be utilized to help predict the onset of a possible reportable fish die-off. We recommend that visual inspections of the lake and water quality measurements be conducted routinely throughout the year, particularly during the warm weather months, if budget and staff is available to monitor the lake. The frequency of observations and the intensity of the water quality measurements should be discussed by the management who would analyze risk management at Braidwood Station. Historically, all the fish die-offs at Braidwood Lake have occurred during the warm weather period of June through August. This is the period of time when water in the cooling loop is the warmest and dissolved oxygen levels can fall substantially following die-offs of extensive phytoplankton blooms. Therefore, this is the most critical time to monitor existing conditions that could result in a potential problem (May through September). Sampling on a less frequent basis throughout the remainder of the year may provide additional information that could be useful to the Station and possibly alert the Station to an impending problem that may not have been identified in the past.

Water quality measurements should include dissolved oxygen readings at a minimum because fisheries biologists that have investigated these events in the past have concluded that the mortality of fish was the result of oxygen depletion. The most effective way to monitor dissolved oxygen levels within the lake would be through the use of permanently fixed continuous water quality samplers and data loggers installed at several depths that could be programmed to take measurements at predetermined time intervals. The number of water quality samplers purchased or the type of sampler utilized would be dependent upon the desired results and cost of the equipment. Ideally, the best system would allow the sampling unit to take measurements at programmed time interval (perhaps every 15 minutes to daily), would measure at least DO, water temperature, and pH, could provide instantaneous readouts to Braidwood staff without having to manually go into the field to download data, and would require minimal maintenance or calibration to operate. The price range of this type of equipment is highly variable depending on the unit selected, the anchoring mechanism for the unit if required, battery life, the number of parameters measured, etc. An alternative to this approach would be to utilize a technician to manually take these measurements. The disadvantage of this approach is the number of readings that could be taken on a daily basis and the time involved to conduct the water quality analysis in the field.

Water quality and weather at Braidwood Lake should be monitored on a predetermined routine basis. That could be at least weekly throughout the year or perhaps only through the more critical time period of approximately June through August. The two tiered sampling approach would be initiated when dissolved oxygen readings hit a pre-determined trigger point (perhaps 5 to 6 ppm). Once DO readings decrease to the trigger point, sampling frequency should be increased. If automatic samplers are not used, field technicians should be in the field by sunrise when DO readings are the lowest. If automatic samplers were utilized, dissolved oxygen, temperature and other water quality parameters could be tracked throughout the day. This would become important if DO readings ranged from 4 or 5 ppm in the morning to 7 or 8 ppm in the afternoon. This information would indicate that photosynthesis is still occurring during the daylight period, which would replenish DO levels in the water and reduce the risk of a fish die-off. However, if DO levels were 4 or 5 ppm in the morning and only increased slightly throughout the day, this would indicate very little oxygen production due to photosynthesis. This condition would lead to a greater oxygen deficit during the evening, and could indicate the onset of a phytoplankton die-off that could trigger a fish kill. Once DO levels approach 3 ppm, Station management could be notified of a potential problem, increased visual inspections of the lake could be conducted, and fish cleanup and disposal crews could be notified and put on standby status.

Additionally, Braidwood staff should be aware of weather patterns that can influence these events. When phytoplankton blooms are prevalent and several cloudy days with little or no wind are forecast, massive dies offs of the bloom and subsequent oxygen depletion throughout the water column should be anticipated. Increased sampling of DO during these weather patterns is advisable in conjunction with an increase in the frequency of visual inspections at the lake for moribund or dead fish. An increase in water clarity or transparency within the lake would also be expected to occur as the phytoplankton population crash is in progress.

Visual inspections for fish die-offs should be conducted around the entire cooling loop as prevailing winds may push most of the fish toward one end of the lake. HDR recommends water quality measurements be conducted at a depth of approximately one meter, if multiple depths are not sampled. If only one sampling location is selected, that location should be located near the approximate mid-point of the cooling loop. The number of water quality stations sampled should be determined by Exelon management or an advisory staff. It is further recommended that an advisory team should be formed to devise an effective sampling program and set of procedures that can effectively monitor conditions within the lake. HDR is willing to participate and interact with the advisory team to provide expertise in the development of an effective sampling program.

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APPENDIX A

PHYSICOCHEMICAL DATA

LIST OF TABLES

TABLE A-1

PHYSICOCHEMICAL MEASUREMENTS RECORDED CONCURRENTLY WITH ELECTROFISHING SAMPLES COLLECTED FROM BRAIDWOOD LAKE

Braidwood Station – 2012

PARAMETER	E-1	E-2	E-3	E-4	E-5	E-6	E-7	E-8
Date (First Sample Period)	**AUG 23**	**AUG 23**	**AUG 23**	**AUG 23**	**AUG 23**	**AUG 23**	**AUG 23**	**AUG 23**
Time	0725	0815	0900	0945	0620	1210	1120	1030
Temperature (° C)	32.7	31.6	30.3	32.0	31.7	32.0	31.4	32.1
Dissolved oxygen (ppm)	4.60	6.38	7.31	6.82	6.86	7.50	8.32	7.16
pH	8.6	8.7	8.8	8.8	8.7	8.6	8.6	8.6
Conductivity (μmhos/cm)	1112	1109	1106	1102	1106	1081	1097	1086
Date (Second Sample Period)	**SEP 12**	**SEP 12**	**SEP 11**	**SEP 11**	**SEP 12**	**SEP 12**	**SEP 11**	**SEP 11**
Time	0825	0915	1425	1350	0725	1015	1610	1505
Temperature (° C)	28.7	28.3	29.3	30.2	29.5	28.7	29.6	30.1
Dissolved oxygen (ppm)	6.37	7.40	10.54	9.86	6.81	8.09	10.14	10.22
pH	8.8	8.8	8.9	8.9	8.8	8.9	8.9	8.9
Conductivity (μmhos/cm)	1198	1178	1181	1210	1186	1184	1191	1190

TABLE A-2

PHYSICOCHEMICAL MEASUREMENTS RECORDED CONCURRENTLY WITH TRAP NETTING SAMPLES COLLECTED FROM BRAIDWOOD LAKE

Braidwood Station – 2012

PARAMETER	TN-1	TN-2	TN-3	TN-4	TN-5	TN-6	TN-7	TN-8
Date (First Sample Period)	**AUG 20-21**	**AUG 20-21**	**AUG 20-21**	**AUG 20-21**	**AUG 20-21**	**AUG 20-21**	**AUG 20-21**	**AUG 20-21**
Time	1820[a] 0742[b]	1815 0755	1805 0710	1755 0650	1750 0820	1830 0620	1703 0852	1640 0845
Temperature (° C)	35.1 33.8	35.1 33.8	33.7 32.6	33.6 32.4	32.0 30.5	32.7 31.3	31.8 31.2	31.4 30.7
Dissolved oxygen (ppm)	11.15 5.59	11.11 5.62	11.38 6.42	11.46 6.65	10.64 6.36	10.95 7.21	9.45 7.26	10.20 7.47
pH	8.8 8.7	8.8 8.7	8.7 8.7	8.7 8.7	8.6 8.8	8.8 8.6	8.6 8.8	8.6 8.8
Conductivity (μmhos/cm)	1105 1114	1102 1112.	1099 1112	1100 1100	1096 1108	1100 1104	1097 1106	1094 1107
Date (Second Sample Period)	**SEP 10-11**	**SEP 10-11**	**SEP 10-11**	**SEP 10-11**	**SEP 10-11**	**SEP 10-11**	**SEP 10-11**	**SEP 10-11**
Time	1715 0755	1705 0745	1730 0725	1715 0710	1650 0815	1745 0832	1615 0845	1605 0855
Temperature (° C)	33.6 31.1	33.6 31.2	32.2 30.3	32.3 30.4	30.9 27.6	31.2 29.5	29.7 29.0	29.7 27.4
Dissolved oxygen (ppm)	11.87 4.31	11.87 4.73	12.17 6.23	12.25 6.85	13.20 7.36	11.94 7.60	9.29 7.56	11.80 7.36
pH	8.8 8.8	8.8 8.8	9.0 8.8	9.0 8.7	8.9 8.9	9.0 8.9	8.8 8.9	8.8 8.9
Conductivity (μmhos/cm)	1275 1245	1275 1245	1242 1221	1240 1224	1203 1160	1219 1202	1185 1190	1185 1164

[a]Top number represents subsurface readings taken 0.5 meter below the surface when the nets were set in the evening.

[b]Bottom number represent subsurface readings taken 0.5 meter below the surface when the nets were retrieved the next morning approximately 12 hours later.

TABLE A-3

PHYSICOCHEMICAL MEASUREMENTS RECORDED CONCURRENTLY WITH GILL NETTING SAMPLES COLLECTED FROM BRAIDWOOD LAKE

Braidwood Station – 2012

	GN-1 in Shallow Water (1-2 m)		GN-2 in Deep Water (8-10 m)	
PARAMETER	**Surface**	**Bottom**	**Surface**	**Bottom**
Date (First Sample Period)	**AUG 20**			
Time	1630	a	1845	1845
Temperature (° C)	31.4	a	32.2	31.9
Dissolved oxygen (ppm)	9.30	a	10.84	10.53
pH	8.7	a	8.7	a
Conductivity (μmhos/cm)	1094	a	1098	1095
Date (Second Sample Period)	**SEP 11**			
Time	1020	a	1045	1045
Temperature (° C)	29.3	a	29.5	29.3
Dissolved oxygen (ppm)	8.15	a	8.65	7.27
pH	8.9	a	9.0	a
Conductivity (μmhos/cm)	1192	a	1193	1192

[a] Water quality measurement not taken.

TABLE A-4

PHYSICOCHEMICAL MEASUREMENTS RECORDED CONCURRENTLY WITH TRAP NETTING SAMPLES COLLECTED FROM BRAIDWOOD LAKE

Braidwood Station – 2012

PARAMETER	HN-1 DEEP WATER BAITED (8-10 m)		HN-2 DEEP WATER UNBAITED (8-10 m)		HN-3 SHALLOW WATER BAITED (1-2 m)		HN-4 SHALLOW WATER UNBAITED (1-2 m)	
Date (First Sample Period)	**AUG 20 (SET)**	**AUG 21 (LIFT)**	**AUG 20 (SET)**	**AUG 21 (LIFT)**	**AUG 20 (SET)**	**AUG 21 (LIFT)**	**AUG 20 (SET)**	**AUG 21 (LIFT)**
Time	1715	0905	1705	0915	1745	0925	1735	0935
Temperature (° C)	31.8[a] 31.8[b]	31.3 31.2	31.8 31.8	31.3 31.2	31.9	31.3	31.9	31.3
Dissolved oxygen (ppm)	9.45 9.22	7.35 7.16	9.45 8.22	7.35 7.16	9.45	7.54	9.45	7.54
pH	8.5	8.7	8.5	8.7	8.5	8.8	8.5	8.8
Conductivity (μmhos/cm)	1097 1097	1108 1108	1097 1097	1108 1108	1095	1104	1095	1104
Date (Second Sample Period)	**SEP 10 (SET)**	**SEP 11 (LIFT)**	**SEP 10 (SET)**	**SEP 11 (LIFT)**	**SEP 10 (SET)**	**SEP 11 (LIFT)**	**SEP 10 (SET)**	**SEP 11 (LIFT)**
Time	1640	0920	1640	930	1630	0945	1630	1000
Temperature (° C)	30.0 29.8	29.2 29.2	30.0 29.8	29.2 29.2	30.1	29.4	30.1	29.4
Dissolved oxygen (ppm)	10.55 9.95	7.64 7.42	10.55 9.55	7.64 7.42	10.90	8.17	10.90	8.17
pH	8.8	8.9	8.8	8.9	8.9	8.9	8.9	8.9
Conductivity (μmhos/cm)	1188 1188	1192 1192	1188 1188	1192 1192	1191	1190	1191	1194

[a]Top number represents subsurface readings taken 0.5 meter below the surface.

[b]Bottom number represent deep water readings taken 0.5 meter off the bottom.

APPENDIX B

HISTORICAL WATER QUALITY AND FISHERIES DATA

LIST OF TABLES

APPENDIX REPORT B-1.

Results of Initial Braidwood Cooling Pond Survey by SEA Inc.

SEA Inc. was asked to conduct an initial water quality and ecological assessment of Braidwood Cooling Pond. The objective was to determine if the dense macrophytes were contributing to an increasing trend toward a higher pH in the pond. The results and discussion presented in this report are primarily based upon the samples taken and observations made on May 29 and 30, 2001, and on a preliminary review of water quality data from three sites taken on May 18, and June 14, 2001. SEA Inc. was also asked to investigate a fish kill on Braidwood Cooling Pond on August 27 and 28. The results of that investigation are in a separate report but some of that information is referenced in this report.

Overview of Methods and Results Presentation.

SEA's initial survey (May 29-30) consisted of:

- water quality parameters at several key sites with a Hydrolab Surveyor III, during both daylight and night conditions,
- measuring phytoplankton community respiration (light & dark bottle method),
- identification of macrophytes and observations on their distribution and abundance, and
- monitoring temperatures throughout the cooling loop.

The survey results are summarized in Tables 1,2, 3, and 4. Table 1 provides the results from key sampling sites that were selected to characterize the cooling pond. These sites were sampled three to four times over a 36-hour period. Parameters sampled with the Hydrolab included: Depth, Temperature, Dissolved Oxygen (D.O.), pH, Specific Conductance, and Redox Potential. Sample times included midday, just before sunset, and prior to sunrise.

Table 2. includes results from two sites for depth profiles, 24 hour duration light & dark bottles, and the SX discharge. Table 3. provides D.O. and temperatures sequentially around the cooling loop at midday. Table 4. lists the D.O. levels and % saturation at four sites prior to sunrise. Table 5 list the water quality analysis preformed by Test America at three locations on two dates. Figure 1. is a map identifying the sample locations listed in the tables.

Discussion of Results and Observations:

Braidwood Cooling Pond was characterized to SEA Inc. as a pond that was dominated or choked by macrophytes. Based on this characterization, we feel that Braidwood Cooling Pond has undergone a transformation to a system dominated by phytoplankton. Although we were not prepared to sample the phytoplankton for densities and identification, it was very obvious that an

intensive phytoplankton bloom was in progress. Secchi disc readings were only 0.30 to 0.35 m throughout the pond. Although we were unable sample the phytoplankton, we would suspect it is dominated by Blue-Green algae (Cyanophyta), based on the water temperatures, total phosphorous levels, high pH and apparent high densities.

Braidwood Cooling Pond appears to be a very dynamic system that receives energy subsidies in the form of heat, pumped circulation and make-up water from the Kankakee River. Several perched cooling ponds in the Midwest have had high macrophyte densities in their earlier years but usually become dominated by phytoplankton if they have heavy thermal loading. A switch to phytoplankton dominance is usually accompanied by a reduction in water transparency. Our Secchi disc readings were about 0.3 m which is about one half of the 2 ft or 0.6m)value listed in a privately produced fishing guide (Sportsman' Connection) published in 2000. Although we did not examine many of the isolated coves, we found Milfoil (*Myriophyllum verticillatum*) only in the last 1/3 of the cooling loop(Figure 1. sites7,8,9) and its abundance was spotty. The Sportsman' Connection fishing guide map had a much wider distribution of submerged, emergent and floating vegetation and appeared to be more in line with earlier descriptions SEA Inc. were given of Braidwood. Nutrients that were previously tied up by the macrophytes are now likely being taken up by the phytoplankton. The reduced water transparency due to the phytoplankton bloom will limit light to the submerged macrophytes and likely cause further reductions.

The intensive phytoplankton bloom that Braidwood is currently experiencing may have more potential for adverse impacts to the biological community than on operational impacts to the station. The water seems to be fairly well buffered and diurnal swings in pH were insignificant. Analysis of the water for alkalinity could confirm the buffering capacity. Blue-Green algae blooms may present problems with D.O. levels and in some rare cases may release toxins with impact other aquatic life.

The light & dark bottle (Table 2.) and the pre-sunrise D. O. levels (Table 4.) illustrated the intensity of the bloom. The light and dark bottles were at a 0.5 m depth at end of the discharge canal for 24 hours. Respiration in the dark bottled depleted the initial D.O. from 10.8 mg/l (158% saturation) to 1.37 mg/l (20 % saturation). The light bottle was supersaturated to the point the entire inside surface was coated with oxygen bubbles and the D.O. was 11.8 (174% saturation). The photosynthetic rate was much higher than could be measured due to the extensive formation of oxygen bubbles in the light bottle. The photosynthetic rate was so high that the light bottle should have been limited to 6 hours to obtain a better measurement of the gross plankton photosynthetic rate.

The pre-sunrise D.O. measurements (Table 4.) also reflect the high respiration rate of the plankton community. Most notable was Site #3 where D.O. levels dropped to 4.1 mg/l. The midday sampling on the first day (Table 1.) was conducted during bright and sunny conditions and D.O. levels at most sites were higher than midday samples on the following day when it was overcast. This

plankton community is so productive that D.O. levels can be expected to swing rapidly. During our survey, air temperatures were mild (high 65 F) and it was windy both days. Under a scenario of several hot summer days, with little wind, full operation of the station, followed by a cloudy day, D.O. levels could drop to the point that fish kills could occur. Some fish species will be already stressed by heat, saturation levels for D.O. will be lower, and high, predawn respiration rates could create a significant problem. Unfortunately, there are no operational changes the station can make to reduce this risk. The fish kill that did occur in late August was apparently a result of depleted DO that most likely resulted from the phytoplankton bloom die off.

Thermal refuges are critical to the survival of fish in heavily loaded cooling ponds. The deeper areas in the warmer end of the lake will not be refuges since adequate levels of oxygen are already absent from depths below 4 meters (Table 2.). However, the flow and slightly cooler temperatures at site 7 (figure1.) have maintained oxygen levels down to nearly 10 meters. If these refuges are eroded away during the summer, fishes will be stressed. Of the three key species listed in the Sportsman's Connection for Braidwood, both the walleye and crappie would be sensitive to D.O. at higher temperatures. Two fish kills occurred in Braidwood this summer, the first in late July was likely related to temperature, the second in lake August resulted from DO depletion.

Although our expertise is not in water chemistry, Braidwood Cooling Pond may be facing some water quality issues. One of the objectives of the survey was to determine if macrophytes were contributing to the increasing pH. A chart of pH values from 1989 to 1998 provided by the Braidwood Station indicated the increasing trend in pH has become more pronounced since 1997. Since this survey indicated macrophytes abundance was in a sharp decline, it is clear they are not contributing to the elevated pH of 9.1 to 9.2 (Table 1). The intensive phytoplankton boom present during the survey could have contributed to the elevated pH. The phytoplankton bloom had crashed by August 27 and 28 (fish kill investigation) and the pH had dropped to 8.6. It was not possible from this limited data to determine to what extent several factors may be contributing to the elevated pH. The cooling pond's buffering capacity, photosynthetic activity, blowndown rate, and plant operations are all potential factors to be investigated.

The Test America analytical results from three sites on 5/18/01 and 6/14/01 provides some information on water quality (Table 5). Orthro phosphate is a readily available form for plants and is quickly taken up. The detection limit listed by the lab was 0.06 ppm, which was too high to show any differences between sites or sample dates. Orthro phosphate levels in many Illinois lakes would be below 0.025 ppm. Total phosphate at the plant discharge on 5/18/01 was 5.5 ppm, which is very high. The Illinois General Use Water Quality standard is not to exceed 0.05 ppm in lakes or reservoirs over 20 acres. The plant appears to be the phosphate source and one possible explanation may be scale inhibitors commonly used by power plants. Scale inhibitors are typically high in phosphates but it is generally in a form not available to aquatic plants. Total phosphate levels on 6/14/01 were lower (0.18 to 0.28 ppm) but still elevated relative to other lakes.

Phosphates are a major concern as elevated levels can contribute to nuisance phytoplankton blooms.

Total Suspended Solids (TSS) on 5/18/01 were high (164 ppm) at the discharge and generally higher than expected throughout the pond. It is suspected that the plankton bloom may have been responsible for much of that elevation. This could have been confirmed by comparing the volatile to the non-volatile portion of the TSS.

Total Dissolved Substances (TDS), total hardness, calcium, sulfates and specific conductance are all correlated and generally exhibited increases from 5/18/01 to 6/14/01. The high evaporation rates in the cooling pond during the summer probably contributed to this increase. These parameters are of concern since they are indicators of potential scaling in heat exchangers. Lowering these levels would require an increase in make-up and blow-down rates. However it is recognized there are restrictions on make up withdraws and blow-down concentrations are regulated.

<u>Summary</u>

It appears that the Braidwood Cooling Pond plant community is changing from one dominated by macrophytes to phytoplankton. The phytoplankton bloom in May was very rich and has the potential to deplete D.O. to the point that fish kills could occur. There are few operational changes that the plant can take to prevent these potential events. Monitoring the cooling pond and preparing regulatory agencies for these potential changes may be a way to help manage these risks. Unfortunately the fish kill in late August confirmed the potential for these kills. The phytoplankton bloom may a contributor to the increasing pH. The high total phosphate level that appears to be coming from the plant may be fueling the phytoplankton bloom. Further investigation of the factors that may be contributing

APPENDIX REPORT B-2.

DRAFT

Investigation of Fish Kill on Braidwood Cooling Pond August 27-28, 2001

Executive Summary:
Strategic Environmental Actions Inc. (SEA Inc.) conducted an investigation of an on-going fish kill on Braidwood Cooling Pond on August 27 & 28, 2001. The investigation consisted of surveying the shoreline to determine the extent of the kill and the species involved, and water quality analyses for pH, temperature, and dissolved oxygen.

Most of the fish appeared to have been dead for about 24 hours and more than 95% were gizzard shad. The other species involved in descending order of relative abundance were freshwater drum, quillback, carp, largemouth bass, channel catfish, redhorse, smallmouth bass and bluegill. Other than gizzard shad most of the dead fish were located between the mid –point in the cooling loop to the intake. Throughout most of the cooling pond, dissolved oxygen levels were at or below the minimum levels necessary to support most fish and was the most likely cause of the kill. Water clarity was very high and suggested a recent die off of much of the phytoplankton, which is usually followed by oxygen depletion. This is a natural phenomenon that can occur in highly productive lakes during summer months. Temperatures throughout most of the lake were within the tolerance limits of the species involved in the kill. It does not appear that operations of the power station had a direct impact on the fish kill.

Methods Overview and Results Presentation:

SEA Inc. arrived at 5:00 PM on August 27 and conducted an initial survey of the main portion of the cooling loop and checked temperature, dissolved oxygen (DO), and pH at two locations. The investigation continued at sunrise on August 28, and included investigation of many of the coves on the lake and water quality analyses at sixteen sites. Water quality analysis was conducted with a Hydrolab Surveyor III. Measurements were for depth, temperature, DO, pH, specific conductance, and redox potential at the surface (0.5 Meters) and then at one-meter intervals to the bottom.

The water quality sampling locations are shown on Figure 1. Dissolved oxygen profiles from selected sites are illustrated in Figure 2. Figure 3 illustrates DO concentrations at one-meter depth at all sites. The results of the water quality analyses are presented in Table 1. The station hourly inlet and outlet water temperatures for August 24 through August 27 are listed in Table 2.

Discussion of Results and Observations:

Upon arrival the investigation began at the south access boat ramp near Site 3 (Figure 1.) and proceeded around the cooling loop toward the plant intake. Near Site 3 several gizzard shad in the 170 to 220 mm were observed. They appeared to have been dead for 12 to 24 hours. In the portion of the pond between sites 5.5 and 5.75 there were greater numbers of gizzard shad along the shoreline and a few largemouth bass. The largemouth bass appeared to have been dead for more than 36 hours. The number of fish appeared to increase as the investigation progressed around the cooling loop. The largest concentrations of dead fish were in several coves on the East side of the lake near Site 8. The back 20 to 35 ft. of the cover were covered solid with dead fish. Gizzard shad comprised more than 95% of the fish in these coves and were represented by three size classes. The other species involved in descending order of relative abundance were freshwater drum, quillback, carp, largemouth bass, channel catfish, redhorse, smallmouth bass and bluegill.

There are two factors that may have influenced the distribution of dead fish. First, the temperature gradient becomes more favorable for fish toward the intake end of the cooling loop. Second, the circulation of water around the cooping loop would tend to concentrate dead fish in the intake area of the cooling pond. The concentration of fish in coves at Sites 8 and 8.5 was most likely an accumulation resulting the above mention factors and wind direction. However DO levels at Site 8.5 were only 2 ppm (Table 1, page 3) at a time of day when they should have been much higher. This level of DO is not adequate to support most fishes. Several YOY freshwater drum were observed at the surface which had recently died or were about to. This kill did involve many fish, but during this survey many live fish were observed on sonar in the cooler end on the lake. Bluegills exhibiting normal behaviors were observed in the cove just East of Site 2.5.

Dissolved oxygen levels at the plant intake were 3.5 ppm at the surface and 1.2 ppm at 3 meters (Table 3) during the evening of August 27. Percent DO saturation was 49% and 17% respectively. Surface DO level taken on May 29 by SEA Inc. at this same location, at the same time of day was 9.3 ppm and 117% saturation. The DO levels at Site 3 were 3.8 ppm on August 27 which was much lower than the 8.0 ppm taken at sunset on May 29. On August 28 just prior to sunrise the DO at Site 3 was 3.2 ppm only slightly lower than the previous evening indicating little diurnal variation. On May 29 the overnight drop in DO at Site 3 was 50%.

The surface DO level at Site 4 on August 28 was 2.9 ppm and dropped to 0.7 ppm at 4 meters. Surface DO levels Sites 4.5, 5, 5.5, and 5.7 were even lower

ranging from 2.4 to 2.1 ppm. Site 6 had one of the higher DO levels at 4.4 ppm. Site 8 and 9 had the highest surface DO levels at 4.8-ppm (Table 1).

Temperatures throughout most of the cooling pond were within the tolerance limits of most fish species and there had been no major temperature changes in the last few days (Table 2). The oxygen levels throughout most of the lake suggest that depleted oxygen levels were the most likely cause for the fish kill. Such kills can naturally occur in highly productive lakes or ponds that may exhibit large diurnal swings in DO levels due to high daytime photosynthetic rates and high respiration during the night. The survey SEA Inc. conducted on May 28 and 29 suggested Braidwood Cooling Pond was a very productive and the potential existed for an oxygen depletion fish kill. This survey noted several changes in the cooling pond that suggested such a kill had occurred. There was no indication that the fish kill was directly related to the operation of the power station.

SEA Inc.'s initial investigation in May was to assess if the historically high abundance of macrophytes (rooted aquatic vegetation) was contributing an increasing trend in pH. What was observed was an intensive phytoplankton bloom that limited light penetration and almost no healthy macrophytes remained. Water transparency measured with a Secchi Disc was only 0.3 meters. Diurnal swings in DO levels were very pronounced and at some locations dropped to 4 ppm just prior to sunrise and reached supersaturation levels by mid day. Under these conditions any major change in nutrients, reduced light intensity, increase in biological oxygen demand, or other factors could result in oxygen depletion. Braidwood Cooling Pond appeared to be undergoing a transition from a system dominated by macrophytes to one dominated by phytoplankton.

One of the most notable changes during this investigation was the dramatic change in water transparency. There was no phytoplankton bloom and Secchi Disc readings had increased up to 2.7 meters. Plankton samples indicated very low levels of phytoplankton but high abundance of zooplanktors (primarily Rotifers and Cladocera). Oxygen levels were typically from 29% to 66% of saturation as opposed to May when most midday levels were at or above saturation. As discussed earlier, there were only minor differences in diurnal oxygen levels. All the above factors suggest the phytoplankton bloom had recently crashed. There were no remaining macrophytes to fill the niche as primary producers. Not only was there a reduction in photosynthetic activity to produce oxygen, there was an increased oxygen demand from decomposition and respiration of the abundant consumers. It is suspected that oxygen levels a day or two prior to this investigation may have been even lower than observed.

The one-meter DO levels were lowest toward the center portion of the cooling loop (Figure 2). From Site 3 to Site 6.5 (with the exception of Site 6) DO levels were 3.1ppm or less. A similar pattern of low DO was noted at Sites 3 and 4 in early morning samples taken in the May survey. Factors contributing to lower DO

levels were not clear, but it suggest this may be one of the most sensitive areas of the cooling pond to oxygen depletion. Additional sampling would be required to attempt to identify the cause and to eliminate any data bias associated with the time of day samples were taken.

The unique changes in water depths and flow velocities in Braidwood Cooling Pond have a major influence on DO levels and temperature stratification. Areas of the cooling pond which were deep and not in a high velocity areas exhibited a more normal DO curve from top to bottom (Figure 3). At Site 2.5, DO declined quickly between 6 and 8 meters and coincided with thermal stratification. At Site 4, the DO declined rapidly between 2 and 3 meters where thermal stratification was apparent (Table 1). In contrast, Sites 5.5 and 7 were located in areas with high velocities and had fairly consistent DO levels and temperatures from top to bottom (Figure 3). This is quite different from the DO and temperature profiles in more typical perched cooling ponds and better utilizes the entire volume for cooling and may also provide for better thermal refuges for fish. During this last incident it is unlikely Site 5.5 was an effective refuge for DO since levels were below 2.5 ppm. These DO levels were however due to lower DO levels throughout the cooling pond rather than depletion at this site.

Braidwood Cooling Pond appears to be undergoing a transition from a pond dominated by marcophytes to one dominated by phytoplankton. During such a transition major swings may be expected as different components of this ecosystem adapt to this change. Over time one would expect the amplitude of these changes to moderate. During the May survey the intense phytoplankton bloom appeared to eliminate the macrophytes. There were major differences in diurnal DO levels suggesting a very productive system with heavy respiration and decomposition demands at night and supersaturation from photosynthesis during the day. This survey indicated a major loss of the phytoplankton, no remaining macrophytes to carry on primary production and enough respiration and decomposition to reduce oxygen below the levels to maintain many fishes. Additional studies on nutrients and the dynamics of the plankton would be needed to better identify the changes that may be taking place in this cooling pond. Decisions on the operational management of this cooling pond as well as the fishery management need to consider that this pond may be going through transitional changes.

APPENDIX REPORT B-3.

Results of Braidwood Cooling Pond Water Quality Analysis from August 27 & 28, 2002

SEA Inc. was asked to sample Braidwood Cooling Pond for a number of water quality parameters on August 27, 2002. This sampling effort was to provide data to address operational concerns related to a trend toward an increasing pH and increased scaling at the plant intake. This report provides the results of the August 27and 28, 2002 sampling and makes comparisons with data from previous sampling efforts by SEA Inc. and with other data provided by the Braidwood Station to SEA Inc.

Executive Summary:

Braidwood Cooling Pond has high levels of alkalinity, total hardness, TDS, sulfates, magnesium, calcium and total phosphates. These parameters are of concern since they have the potential for increased problems with scaling, increasing pH, compliance with cooling pond blow down limits, and maintaining a recreational fishery. Several of these parameters had significant increases in the past year and could lead to greater operational costs and problems in the near future.

The excess of nutrients in the water has contributed to plankton blooms that have eliminated the submerged aquatic plants, contributed to diurnal increases in pH, and lowered dissolved oxygen levels. Swings in the dissolved oxygen level associated with the plankton blooms could lead to fish kills.

The plan to increase the blow down rate from the cooling pond is a good long-term solution to the continued viability of the cooling pond. Continued monitoring of the cooling lake water quality would be important in evaluating the effectiveness of the increased blown down rate, the impacts of H2SO4 additions, and other water treatment changes.

Overview of Methods and Scope of the Sampling Effort.

The investigation on August 27 and 28 of 2002 consisted of collection of water samples from various depths at six sites around Braidwood Cooling Pond (BCP), as well as in-situ profile measurements for temperature, conductivity, pH, and dissolved oxygen. A contract laboratory analyzed the water samples for the eleven chemical parameters as listed in Table 1. In addition to chemical samples, the primary production rate of the phytoplankton community was determined at two sites by the light/dark bottle method, and plankton samples were taken for

qualitative analysis. Water transparency was measured with a Secchi disc at each site. The sampling sites used in this investigation are identified on Figure 1.

Additional investigations by SEA Inc. referenced in this report include June 28, 2002, April 29,2002, March 6, 2002, January 10, 2002, August 28, 2001 and May 29, 2001. The purpose and scope of each of these investigations varied but none were as extensive for water quality as the August 2002 investigation. In several cases SEA Inc. collected the water samples for Betz and the results were not made available to SEA Inc. Data from the above referenced studies is included to help identify trends and provide a single summary of data for ongoing investigations. The discussion of results is based on and limited to the studies referenced in this report and those provided to SEA Inc.

Presentation of Results and Related Discussion:

The analytical results of the water quality analysis are presented in Table 1. The eleven parameters were selected to provide input to the water quality issues that were described to SEA Inc. These issues include increasing trends for rising pH, scaling, algal blooms, and recent fish kills.

Table 1 indicates abnormally high levels for TDS, alkalinity, hardness, sulfates, magnesium, calcium, and total phosphorus throughout the cooling pond. These values were not unexpected and support the ongoing program to increase the blow down rate from the cooling pond. These values can be put into perspective by comparing the cooling lake sites to the same values for the make –up water pond (Site 7P in Table 1), which is the source water. The cooling pond values for the above mentioned parameters ranged from 2X to nearly 9X higher than the make-up water.

The alkalinity is a measure of water's capacity to neutralize acids and is a result of the quantity of compounds in the water that shift the pH to the alkaline side. Bicarbonate and carbonate ions normally make up most of the alkalinity. However in waters with a pH of greater than 8.3, carbonate alkalinity is the primary form. Alkalinity is very high throughout the cooling pond and ranged from 340 to 360 mg/l in the upper water layers (Table 1). In contrast, the make-up water pond alkalinity was 150mg/l. Other comparisons include a 14-year average for Clinton Lake of 168 mg/l and an IEPA survey of 63 lakes around the state with alkalinity ranging from 20 to 270 mg/l. The high alkalinity gives Braidwood Cooling Pond has a great capacity to neutralize acids.

Hardness is a measure of the divalent metallic cations present in water (such as calcium, magnesium, ferrous iron, and manganous manganese). Calcium reacts with bicarbonate ions in water to form calcium carbonate

scale. Magnesium typically reacts with sulfate; the ferrous ion with nitrate; and the manganous ion with silicates.

Hardness and alkalinity in water are related. Carbonate hardness is the part of total hardness that is chemically equivalent to the bicarbonate plus carbonate alkalinities present in the water. If alkalinity is greater than total hardness then total hardness is equal to the carbonate hardness. In cases such as in BCP where alkalinity is less than the total hardness then alkalinity equals carbonate hardness (as $CaCO_3$) and the remaining part of hardness is the noncarbonate compounds such as magnesium sulfate.

The total hardness in the upper layers of August 2002 samples ranged from 680 to 720 mg/l (nearly twice the alkalinity level) so other ions are contributing significantly to the hardness. The total hardness levels in 2002 were significantly higher than the 435 to 531mg/l range reported for two dates in 2001 by Test America (Table 2). This increase in hardness is a reason for concern.

Sulfate levels in the August 2002 samples ranged from 330 to 390 mg/l (Table 1). These levels are much higher than the make up water (58 mg/l) and to some extent may reflect the history of portions of the cooling pond as strip mine lakes that are characteristically high in sulfates. However there seems to be a significant increase in sulfates in the past year. In the Test America data from two dates in 2001, sulfates ranged from 230 to 270 mg/l (Table 2). Sulfate levels in samples collected by SEA Inc. on April 29, 2002 were 250 mg/l (Table 3). Samples collected by SEA Inc. on June 28,2002 had levels ranging from 320 to 340 mg/l (Table 4). The sulfate increase noted in the summer of 2002 may reflect the use of H_2SO_4 to reduce pH levels in the cooling pond. This level of sulfates may be a concern since it significantly contributes to the non-carbonate hardness and can be a factor in scaling.

Calcium levels in the August 2002 samples were about twice the levels in 2001and ranged from 130 to 140 mg/l (Table 1). The 2001 Test America data ranged from 41 to 58 mg/l (Table 2) and the make-up water in August 2002 was 57 mg/l. The increase in calcium may be a major concern since with the high carbonate alkalinity there is a high potential for scaling.

Magnesium levels in the August 2002 sampling ranged from 84 to 93 mg/l. These levels were essentially the same as the 81 to 91 mg/l reported by Test America in 2001. Magnesium levels are however elevated compared to the make-up water that had only 20mg/l or when compared to the 14-year average for Clinton Lake of 32.2 mg/l. Magnesium levels are also a concern due to their potential for scaling.

Total dissolved solids include all of the above parameters and other dissolved solids in the water. As would be expected, the August 2002 samples are elevated and are higher than the previous year. The August 2002 TDS ranged from 930 to

1100 mg/l (Table 1) compared to a range of 684 to 788 in the 2001 Test America data (Table 2). The make-up water was 280 mg/l in the August 2002 sample.

Sodium levels in the August 2002 samples ranged from 60 to 64 mg/l in the upper water layers. Comparable data from 2001 was not available, but the sodium levels in the make–up water was 9.1 mg/l in the August 2002 sample (Table 1).

There were only minor variations in the concentrations of the above parameters from site to site in the upper water layers. Sulfates and TDS were slightly higher at the discharge (Site 2) end of the cooling pond. Levels for alkalinity, sulfates, TDS, and total hardness were slightly lower near the bottom at the 10 and 11-meter depths at Site 4 and Site 7 respectively.

Phosphorus and nitrogen are essential nutrients for aquatic plants. Concentrations in the water are typically low since phytoplankton or macrophytes quickly assimilate these nutrients. Total phosphate levels in the August 2002 samples were at 1.5 mg/l throughout the cooling pond (Table1). Samples collected on April 2002 ranged from 1.3 to 1.6 mg/l (Table 3). Total phosphates at two sites in the June 2002 samples were 1.8 mg/l (Table 4) in the upper water layers and 4.9 mg/l at a well stratified, 10-meter depth at Site 4. The Test America data for 2001 had total phosphate levels from 0.16 to 5.5 mg/l (Table 2). The 5.5 mg/l occurred at the discharge on May 18 of 2001 and levels dropped to 0.77mg/l at the plant intake on the same date. This suggests the Station was the source of the phosphate. Although the levels were slightly lower in 2002, they were consistent throughout the cooling pond suggesting that phosphates are in excess and not a limiting factor for phytoplankton. The total phosphate levels in the make- up water were 0.12 mg/l and 0.19mg/l in June (Table 4) and August of 2002 respectively.

Relative to most lakes the phosphate level in BCP is quite high. Since BCP is a cooling pond and not a lake, it is not subject to the Section 302.205 regulation that limits phosphorus in a lake of 20 acres or more to < 0.05mg/l. The high phosphate level is of concern since these levels support phytoplankton blooms and the breakdown of the phosphorus compounds can also contribute to increased pH.

Ortho-phosphate is the form that is most readily available to aquatic plants. These levels are usually very low in lakes since plants normally take it up within minutes. Ortho-phosphate levels were consistent throughout the lake in the August 2002 samples and ranged from 0.38 to 0.44mg/l. Like the total phosphate levels, the ortho-phosphate levels are consistently high suggesting it is in excess of the needs of the phytoplankton. The August 2002 levels were significantly higher than the <0.06mg/l reported by Test America in 2001(Table 2). Ortho-phosphate level in the make-up water was 0.19 and although lower than the lake levels is relatively high.

Nitrate-nitrites are the other essential or potentially limiting nutrient for phytoplankton. The August 2002 nitrate-nitrate levels were rather low in most of BCP with the highest level of 0.1mg/l at the discharge. The rest of the cooling pond ranged for <0.01mg/l (below detection limit) to 0.08 mg/l in the upper waters. Unlike most other parameters, the nitrate-nitrite level in the make-up water was significantly higher at 2 mg/l (Table 1). Nitrate-nitrite data could not be compared to the 2001 Test America data because the detection limit of 1.0 mg/l was too high for a meaningful assessment.

The ratios of phosphates to nitrates-nitrites suggest BCP would be described as a nitrate-nitrites limited water rather than phosphate limited with respect to phytoplankton growth. However the limited phytoplankton data that SEA Inc. has collected on BCP suggests that bluegreen algae dominate BCP for much of the summer. Bluegreen algae have the unique ability to utilize atmospheric nitrogen and are not as limited by low nitrate-nitrite levels. Bluegreen algae made up 88.5 % and 76.4% of the algae at Sites 3 and 7 respectively in the August 2002 sample. The dominant bluegreen algae were *Lynabya* and *Oscillatoria*. Bluegreen algae are the least desirable algae and are favored by high pH and warmer temperatures. Bluegreen blooms can impart a smell or taste to water, deplete dissolved oxygen, and in some cases generate toxins that may impact aquatic life.

The ammonia levels appear reasonable relative to the high productivity in BCP. As productivity increases and oxygen is reduced at deeper depths there may be increases in ammonia. The abnormally high level at 5 meters at Site 9 (Table 1 may have resulted from the water sampler disturbing the bottom sediments where ammonia is likely to be higher.

The aquatic plant community in BCP appears to have undergone a change in the last two years. SEA Inc.'s first investigation of BCP on May 29, 2001 was to assess the impact of the extensive growth of macrophytes (rooted aquatic plants) on the pond's increasing pH. That investigation found an extensive phytoplankton bloom and the few macrophytes that remained were being shaded out by the phytoplankton bloom. SEA Inc. projected that BCP was changing from a macrophyte dominated water to a phytoplankton-dominated water and that would see more plankton blooms. The phosphate levels from the 2001 Test America data suggested there was an excess of phosphorus to support those blooms. Based upon SEA Inc.'s 2002 observations, BCP has transformed into a phytoplankton dominated water and is experiencing regular plankton blooms. This change not only reflects an increasing load of nutrients in BCP but also creates a higher risk to the fishery. As plankton blooms come and go they can create oxygen depletion problems that impact fishes and other aquatic life.

SEA Inc. has measured the primary production rates as an index to the activity of the plankton community. The rate of oxygen production by the plankton

community is measured in a light (clear) bottle and the plankton respiration (oxygen depletion) is measured in a dark bottle. In the first measurement in May of 2001, there was so much oxygen production in the normal 24 hr measurement period that the oxygen was super saturated and only a portion could be measured (Table 5). Subsequent measurements were limited to shorter time periods and provided a more useful index. The highest primary production rate was 1.525 mg/l of O2/hr at Site 9 (Intake) on June 28, 2002. This correlated well with the highest chlorophyll a level provided by the Braidwood Station (Figure 2). In the August 2002 measurement, the rate at Site 9 had dropped to 0.653 mg/l of O2/hr. This rate correlated with lower chlorophyll levels that occurred throughout most of August. Temperatures during the August 28,2002 measurements were high enough at the discharge (Site 2) to suppress photosynthetic activity. The temperature at the discharge was 115.1° F (Table 5) and the intake (Site 9) temperature was 92.2°F and the corresponding production rates were 0.142 and 0.653 mg/l of O2/hr respectively. The temperature suppression of photosynthesis and an apparent die off of a phytoplankton bloom may account for the low dissolved oxygen levels observed during the August 2002 sampling.

All of sampling by SEA Inc. has involved in-situ sampling with a HydroLab for temperature, dissolved oxygen, pH, and specific conductivity. The data from all 2002 HydroLab sampling is presented in Tables 1,3,4,6, and 7.

The dissolved oxygen (DO) levels on August 28 of 2002 were notably lower than the same date in 2001(Table 6). As lakes undergo eutrophication and productivity increases, the DO level can exhibit wide diurnal changes that may stress aquatic life. Afternoon DO levels may rise to supersaturated levels, but during the night and early morning hours respiration demands may nearly deplete the DO and can result in fish kills. There also becomes a more pronounced difference in DO levels between the upper and lower layers of the water column due to increased oxygen demand from decomposition.

Dissolved oxygen levels at the same four sites in August 2001 and 2002 are compared in Figure 3. These comparisons indicate that the DO levels were generally lower at the same sites in 2002, were slower to rise during the day, and there was a greater differences between depths. Site 2 and Site 2.5 illustrate the lower DO levels in 2002 even later in the day when it should rise. Oxygen levels were less than 1ppm at 2 meters and below. Site 4, 2002 levels reflect the increase in DO later in the day compared to earlier in the day in 2001. The consistent drop in DO at 4 meters is typical of a stratified site. At Site 7 the higher DO in 2002 reflect the later time of day than the 2001 sample. However the more significant difference is the drop in DO with increasing depth in 2002. This drop suggests a more productive system that has a higher demand for oxygen in 2002. Site 7 has good flow and in 2001 had a nearly constant DO level down to the bottom and provided a good thermal refuge for fish. In 2002 the area below 6 meters would be stressful for most fish. The Site 9 AM chart again demonstrates the 2002 DO level was lower even when taken later in the morning than the 2001

sample. The Site 9 PM chart shows some recovery of DO level in the mid afternoon but levels are still below 4ppm. The more rapid drop in deeper samples from the 2001 most likely reflects the loss of late afternoon light to the deeper depths.

The 2002 DO curves appear to reflect a more eutrophic environment that may place additional oxygen stress on the fishery. During the August 2002 sampling there were dead and dying gizzard shad from Site 2 to Site 4. The combinations of stress from the low DO and warmer temperatures were the most likely explanation for the loss of these fish. This loss was not extensive enough to have a significant impact on the fishery. No other species were involved in the kill but small bluegills were exhibiting some signs of DO stress. As BCP continues to become more eutrophic the DO stress may be a greater problem for the fishery.

The increasing pH levels have been a concern in BCP. Comparison of HydroLab data from August 28 in 2001 (Table 6) and 2002 (Table 1) indicated only a little variation in pH. During the summer of 2002 the Station was adding H_2SO_4 into the circulating water. The impact was only apparent at Site 2 (discharge canal) and Site 3. The 2002 samples collected in the morning hours at Site 2 ranged from 8.34 to 8.38 compared to 8.5 in 2001 (Table 2). At Site 3 the 2002 levels ranged from 8.35 in the morning to 8.54 at midday compared to a range of 8.4 to 8.6 in 2001. The pH levels at Sites 4,7 and 9 had slight variations depending upon time of day but had similar ranges in 2001 and 2002. With the high alkalinity levels in BCP, it is not surprising that the addition of H_2SO_4 did not result in larger changes. This assessment is also based on only a few data points. Correlating H_2SO_4 feed rates with continuous pH monitoring at the intake would provide more reliable information on the effects of the acid additions.

Questions have been raised on the impact of the phytoplankton on the increasing pH levels. As phytoplankton carries on photosynthesis and extract CO_2 from the water it increases the pH. This however may not be as apparent in BCP due to the high buffering capacity (alkalinity). In general the higher pH levels in the afternoon reflect the photosynthetic activity. Conversely the lower pH levels in the early morning samples reflect the increase in CO_2 resulting from respiration during the night. The role of phytoplankton in increasing pH is quantified in the measurement of primary productivity. A comparison of the starting pH with the ending pH in the light bottles illustrates the change due to photosynthesis. The pH during the 24-hour measurement on May 29, 2001at Site 2 went from 9.22 to 9.52 (Table 5).

Summary and Conclusions:

Braidwood Cooling Pond has high levels of alkalinity, total hardness, TDS, sulfates, magnesium, calcium and total phosphates. These parameters are of concern since they have the potential for increased problems with scaling, increasing pH, compliance with blow down limits, and maintaining a recreational

fishery. The additional of treatment chemicals and evaporative loss of the recycled cooling water with limited blown down rates are most likely the primary factor in the increased levels of these parameters. The make-up water does not have elevated levels of the above-mentioned parameters. With increasing capacity factors and increasing concentrations for these parameters in the cooling water, water treatment costs and operational concerns are likely to increase.

Baseline water quality data is important in evaluating options and solutions to address water quality in the cooling pond. The comparison of the August 2002 sampling to the 2001 Test America data indicated significant increases in total hardness, sulfates, and calcium in the past year. Increases of this magnitude can be important predictors of future problems. Critical assessments of the impact of H_2SO_4 additions and other treatment changes are dependent upon having pretreatment and post treatment data. The plan to increase the blow down rate from BCP is a good long-term solution to the continued viability of the cooling pond. The effectiveness of increasing the blown down rate from BCP can be quantified by continued monitoring of the cooling lake concentrations.

The high nutrient levels in BCP will continue to cause plankton blooms. Unlike many waters, phosphates appear to be in excess and nitrates are more of a limiting factor. However, bluegreen algae appear to be the dominant summer form and are not as limited by low nitrates as other algae. The primary production measurements did correlate fairly well with chlorophyll a levels and were a good index to the productivity of BCP. The primary production measurements also illustrated how much of an influence phytoplankton have on diurnal increases in pH.

Algal blooms are occurring in the pond and based on two comparable samplings, appear to be influencing the DO levels. The DO levels in the early hours were generally lower in 2002 than in 2001 and the DO at a deep site experienced a decline with depth that did not occur in 2001. These changes suggest a trend toward an increasing rate of eutrophication. If nutrient levels continue to increase the potential for fish kills associated with oxygen depletion resulting from the blooms would also increase.

Jim Smithson
SEA Inc.
11/04/02

APPENDIX REPORT B-4.

Fish Kill Reports Going Back to 2003

john.petro@exeloncorp.com [john.petro@exeloncorp.com]

Sent: Wednesday, September 23, 2009 2:42 PM

To: Jeremiah.Haas@exeloncorp.com

2003

There were no fish kills in Braidwood Lake in 2003.

July
~~June~~ 30, 2004

Investigated a fish mortality on July 30, 2004. Most fish were in the advanced state of decay by the time the kill was investigated. Gizzard shad were the dominant species involved although channel catfish were observed as well. During this investigation, the shallow water near shore was teaming with plankton which under magnification proved to be daphnia as well as Cypris, which is an Ostacod resembling a small clam.

Temperature/dissolved oxygen profiles were conducted in early October. Water temperature just north of the south boat access was 29.2-^{0}C/84.5-^{0}F at a depth of one foot with a dissolved oxygen reading of 3.8 ppm, a pH of 8.03 and a secchi disk reading of 2.1 feet. Readings were somewhat improved in the area near the rearing cove. In a location several hundred feet from the lake make-up, more favorable dissolved oxygen levels were found. At one foot, a water temperature of 26.5 ^{0}C/79.7 ^{0}F with a dissolved oxygen reading of 7.6 and a pH of 8.47 were observed. Water temperature showed minimal decrease to 40 feet while the dissolved oxygen declined to 5.3 ppm.

June 28, 2005 Fish Kill

An on the water inspection of a thermal fish kill was conducted on June 28, 2005. No formal counts were made however field assessments indicate a fairly significant kill that involved a variety of species including (in no specific order) gizzard shad, threadfin shad, common carp, channel catfish, quillback carpsucker, black bass. Gizzard shad were the most numerous species effected by this kill and fish carcases were observed at most all areas of the lake that were checked.

August 27-28, 2007 Fish Kill

· Rob Miller, IDNR investigated a thermal kill on August 27 and 28, 2007 and conducted temperature/dissolved oxygen evaluations. The majority of the dead fish which were observed were large gizzard shad and threadfin shad up to 5 inches in length. Channel catfish were also prevalent. Only a few common carp and black bass were observed and no bluegills were noted. Due to moderate prevailing south winds, many dead fish were wind-rowed along the north shore in close proximity of the boat ramp and the bank fishing area. The number of dead fish observed decreased towards the south (hot) side of the lake. At a point several hundred yards from the south ramp surface water temperature was 35.3 C/95.9 F and dissolved oxygen was near 3ppm.

· The following are data which were collected at the north ramp at the time the fish kill was being

investigated:

Time	Temperature (^0C)	Dissolved Oxygen (ppm)
12:10	30.3	3.1
14:25	33.1	5.4
15:30	33.5	6.7
16:58	33.9	5.9

Investigation of Fish Kill on Braidwood Cooling Pond (August 27-28, 2007)

· Strategic Environmental Actions Inc. (SEA Inc.) conducted an investigation of an on-going fish kill on Braidwood Cooling Pond on August 27 & 28, 2007. The investigation consisted of surveying the shoreline to determine the extent of the kill and the species involved, and water quality analyses for pH, temperature, and dissolved oxygen.

· Most of the fish appeared to have been dead for about 24 hours and more than 95% were gizzard shad. The other species involved in descending order of relative abundance were freshwater drum, quillback, carp, largemouth bass, channel catfish, redhorse, smallmouth bass and bluegill. Other than gizzard shad most of the dead fish were located between the mid -point in the cooling loop to the intake. Throughout most of the cooling pond, dissolved oxygen levels were at or below the minimum levels necessary to support most fish and was the most likely cause of the kill. Water clarity was very high and suggested a recent die off of much of the phytoplankton, which is usually followed by oxygen depletion. This is a natural phenomenon that can occur in highly productive lakes during summer months. Temperatures throughout most of the lake were within the tolerance limits of the species involved in the kill. It does not appear that operations of the power station had a direct impact on the fish kill.

APPENDIX REPORT B-5.

FW: Braidwood Lake Fish Kill

john.petro@exeloncorp.com [john.petro@exeloncorp.com]

Sent: Wednesday, September 23, 2009 2:31 PM

To: Jeremiah.Haas@exeloncorp.com

-----Original Message-----
From: ROB MILLER [mailto:ROB.MILLER@illinois.gov]
Sent: Tuesday, August 21, 2007 8:26 PM
To: JOE FERENCAK; STEVE PALLO
Cc: Petro, John R.; CHRIS MCCLOUD; LARRY DUNHAM; MIKE CONLIN
Subject: Re: Braidwood Lake Fish Kill

I was contacted by John Petro and Tim Meents (Braidwood Station) this morning at 11:20 but due to bad accident on I-55 was somewhat delayed in arriving at the lake. When I got there (3:00) I met with Exelon biologist Jeremiah Haas. Jeremiah had arrived earlier and had taken dissolved oxygen/temperature readings. He and I toured the lake via his boat to assess the extent of the kill. Due to moderate prevailing south winds, many dead fish were wind-rowed along the north shore in close proximity of the boat ramp and the bank fishing area. The number of dead fish we observed decreased as we traveled towards the south (hot) side of the lake. At a point several hundred yards from the south ramp, we took a reading and returned to the north ramp to meet up with John Petro. At this location water temperature was 35.3C and dissolved oxygen was near 3ppm. The following are data which were collected at the north ramp:

Time	Temp. (C)	Dissolved Oxygen (ppm)
12:10	30.3	3.1
14:25	33.1	5.4
15:30	33.5	6.7
16:58	33.9	5.9

Based on the declining trend in d.o., it is possible that more fish could succumb throughout the night.

The majority of the dead fish which were observed were large gizzard shad and threadfin shad up to 5 inches. Channel catfish were also prevalent. Only a few common carp and black bass were observed and no bluegills were noted. SET Environmental had arrived at the north ramp and were conducting clean-up operations at 5:00. I will be attended the AFS Continuing Education course in Monticello tomorrow and thursday. If you need any further information, or if there are any further developments, please contact me at 815/409-2426. Thanks.
Rob
Rob Miller

District Fisheries Biologist
Illinois Department of Natural Resources
13608 Fox Road
Yorkville, Illinois 60560
630/553-6680
rob.miller@illinois.gov
>>> STEVE PALLO 08/21/07 12:10 PM >>>
Just got off phone with John Petro, Environmental Manager for Exelon.

John wanted to report a moderate gizzard shad kill at Braidwood Cooling Lake, and a minor kill of catfish. Rob Miller, District Fisheries Manager was already notified. Water temps in the lake had dropped some 12F recently, there are no obvious power plant operational changes or permit exceedances. Exelon is arranging to have the fish picked up.

APPENDIX REPORT B-6.

FW: Braidwood Fish Kill 8-21-07

john.petro@exeloncorp.com [john.petro@exeloncorp.com]

Sent: Wednesday, September 23, 2009 2:28 PM

To: Jeremiah.Haas@exeloncorp.com

-----Original Message-----
From: Haas, Jeremiah J.
Sent: Tuesday, August 21, 2007 9:02 PM
To: Petro, John R.; Tidmore, Joseph W.; Meents, Timothy P.
Cc: Hebeler, Ronald L.; Neels, Vicki J.; Steve Pallo (E-mail); Haas, Jeremiah J.
Subject: Braidwood Fish Kill 8-21-07

All,

Here's the quick and dirty of the incident. I'll right something more formal in the morning.

I arrived at Braidwood Lake at 12:00 and took a dissolved oxygen (DO) reading from the ramp dock which extends about 30 feet into the lake. The DO was 3.1 ppm w/ a temp of 30.3 C. Several thousand gizzard and threadfin shad were floating across most all visible areas of the lake. The currents within the lake were visible with the dead fish movement. Also seen were dozens of channel catfish, most of which were adults from 3-15 lbs. Shad ranged from 4 - 13 inches with the shorter fish being predominately threadfin and the larger ones being gizzard. At this time I informed John P. of the DO situation and began setting up the boat for additional surveys. During the entire day, no other species was observed that counted more than 2 individuals.

I took several water readings throughout the afternoon before Rob Miller (IDNR biologist responsible for Braidwood Lake) arrived. We did a quick boat survey throughout the lake, including the pockets that are not part of the cooling loop. These areas showed the same readings as the rest of the lake. During this time we had a few hours of direct sunshine and DO reading rose as high as 6.7 ppm @ 15:30.

Rob and I determined that the DO crash was a result of the past several days cloud cover and subsequent die-off of phytoplankton. The decay of the phytoplankton would have been sufficient to lower the DO available to the fish during the overnight hours. We also observed the DO beginning to lower @ 16:58 (5.9 ppm) and believe that there is an opportunity to see similar results tomorrow and possibly a few more days depending on the weather conditions.

A local newspaper reporter did arrive on site, took photos, and asked questions. She was familiar with Braidwood Station's Site Communicator and said she would be in contact with them. Rob explained the cycle that was occurring in the lake several times to the reporter.

All in all, I believe that Rob and I are both comfortable with the explanation for the action that occurred to cause the fish kill. This is similar to the "annual" fish kill seen at Braidwood, but the densities were higher than the past few years. There is a survey of the lake scheduled for October and, if possible, I will be at the site for that.

Exelon
Jeremiah J Haas
Principal Aquatic Biologist
Quad Cities Nuclear Station
309.227.2867
jeremiah.haas@exeloncorp.com

APPENDIX REPORT B-7.

Braidwood Fish Kill Clean up
8/22&23/07

I worked with SET Environmental to clean up a fish kill.
This was a major kill and our clean up efforts were confined to the area near North boat ramp on the intake end of the lake. SET had been working on the kill for one or two days when I was called to provide assistance. A total of about 24 cubic yards of fish were removed in this clean up. The species involved in decreasing order of abundance were: gizzard shad (large fish), channel catfish, bluegill, green sunfish, flathead catfish, bigmouth buffalo, quillback and largemouth bass.

I went up in the restricted arm toward the intake and found huge masses of fish in the back of several coves. There were areas 50 to 75 ft by 100 ft of solid floating mats of fish in these coves. We picked up 12 flathead catfish that would have averaged near 50 lb. each. On the second day when we returned to these coves we counted as many large flathead catfish that we had picked up the previous day. They were in a state of decomposition that prevented up from picking them up.

We did not take any water quality measurements or examine other parts of the lake in this clean up effort. From my past work on this cooling pond, I would suspect a combination of DO depletion and high water temperatures caused this fish kill. The plant did not report any abnormal operation conditions prior to the kill. Since 2001 when we first worked on this cooling pond we have seen a switch from macrophytes to phytoplankton with blue green dominating. We have measured wide diurnal swings in DO levels even in the upper part of the water column in late summers. Even with the strong circulation from the circulating water pumps there is mid summer stratification and DO depletion in the deeper areas.

Jim Smithson
SEA Inc.

RAI #: AQ-12c **Category: Aquatic Resources**

Statement of Question:

Section 2.2.5, Page 2-16 of the ER states that "HDR [HDR Engineering] assessed water quality and fish populations in the cooling pond in late summer 2009 and 2010 to develop a better understanding of the factors contributing to fish kills and design a water quality or fish monitoring program that could be used to predict (and conceivably mitigate) fish kills in the pond."

c. Has Exelon implemented any mitigation to reduce the number of fish kills in the cooling pond? If so, describe such mitigation.

Response:

As the response to RAI # AQ-12b explains, based on the annual summer aquatic sampling results since 2009, Exelon Generation has not been able to identify a practical way to prevent fish kills or reduce their effects in the Braidwood cooling pond. Therefore, mitigation measures to reduce the number of fish killed during such events have not been implemented.

List of Attachments Provided:

None.

RAI #: AQ-13 **Category: Aquatic Resources**

Statement of Question:

Sections 4.2 and 4.3 of the ER discuss the effects resulting from entrainment and impingement of Kankakee River aquatic biota at the makeup water intake or associated river screen house. In its analysis of entrainment and impingement, the NRC will consider the effects of entrainment and impingement that occurs at both the river screen house and the lake screen house. To support this analysis, please provide any studies that assess entrainment or impingement at the cooling pond's lake screen house.

Response:

The Braidwood cooling pond is a wastewater treatment system, and as such it is not classified as "waters of the United States" under the Clean Water Act. As a result, assessment of entrainment or impingement effects at the cooling pond's lake screen house is not required, and no studies of such effects have been performed.

List of Attachments Provided:

None.

RAI #: AQ-14 **Category: Aquatic Resources**

Statement of Question:

Section 4.4 of the ER considers the effects of heat shock on aquatic biota in the Kankakee River. In its analysis, the NRC will consider the effects of heat shock on aquatic biota in both the Kankakee River and the cooling pond. To support this analysis, please provide any thermal studies that have been conducted on the cooling pond.

Response:

The Braidwood cooling pond is a wastewater treatment system, and as such it is not classified as "waters of the United States" under the Clean Water Act. As a result, assessment of thermal effects in the cooling pond is not required, and no studies of such effects have been performed.

List of Attachments Provided:

None.

RAI #: AQ-15 **Category: Aquatic Resources**

Statement of Question:

Submit the following ER references for docketing:

a. (Exelon Nuclear 2011c) Exelon Nuclear. 2011. Braidwood Station - Braidwood Lake Additional Biological Sampling Program, 2010.

Response:

The requested document is attached to the response for RAI # AQ-12a,

above.

List of Attachments Provided:

None.