EXHIBIT 1

Quad Cities Nuclear Station

316a Demonstration

Prepared for

Exelon Nuclear

QUAD CITIES NUCLEAR STATION
316(a) Demonstration

September 2012

Prepared by

HDR

QUAD CITIES NUCLEAR STATION

316(a) Demonstration Summary

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1.0 OVERVIEW OF THE SUMMARY AND APPENDICES

1.1 Roadmap to the Summary and Appendices

This Demonstration in support of Exelon's request for a thermal variance for Quad Cities Nuclear Station (QCNS) under Section 316(a) of the Clean Water Act represents the culmination of years of extensive studies and analyses of Pool 14 of the Mississippi River and the Station's operations. These studies and analyses are discussed in detail in the documents that comprise this Demonstration. The Demonstration presents both retrospective (Appendix C) and prospective (Appendix B) analyses which show that the requested thermal variance will assure the protection and propagation of a balanced, indigenous community of shellfish, fish, and wildlife in and on Pool 14, thereby meeting the 316(a) standard for granting of the requested thermal variance.

While each of the appended documents contains important information supporting Exelon's request, this Summary and Appendices B and C are likely to be of particular interest to most readers. This Summary describes the extensive body of technical information supporting the requested thermal variance and explains the historical and legal context for the variance request. Section 1 of the Summary provides important background material, and a brief overview of the hydrothermal, biothermal, and other biological studies that were performed. Section 2 describes current and past operations at Quad Cities Nuclear Station. Section 3 discusses the legal framework applicable to determinations under Section 316(a) and identifies the biological and technical data supporting Exelon's request for a variance. Section 4 discusses the criteria used in a 316(a) Demonstration to assess whether a balanced indigenous community of shellfish, fish, and wildlife has been and will be maintained in and on the receiving water body despite the Station's thermal discharge.

Appendix A describes in detail the Mississippi River in the vicinity of Pool 14 while Appendix B and C provide prospective and retrospective biothermal assessments, respectively. Appendix D describes the operations at QCNS while Appendix E summarizes the Station's data collection programs.

1.2 Background of Proposed Alternate Thermal Standards

Construction of Quad Cities Nuclear Station began in 1967. Both units began commercial operation in early 1973, a few months after promulgation of the Clean Water Act ("CWA") National Pollutant Discharge Elimination System ("NPDES") permit program. Since the NPDES program took effect, Quad Cities Nuclear Station has held an NPDES permit. Beginning in the early 1970s and continuing through the present day, the Station has worked closely with a Technical Advisory Committee ("TAC"), called the Quad Cities Steering Committee on matters related to the Station's NPDES permit.[1]

Thermal limits in the current NPDES Permit are based on Illinois environmental regulations, and studies and demonstrations performed under Section 316(a) of the Clean Water Act. The NPDES Permit defines the mixing zone boundary as a straight line across the Mississippi River, 500 feet downstream of the diffuser pipes, and compliance with the temperature standards in the NPDES Permit is measured at the end of this mixing zone boundary. The existing thermal standards and the proposed standards under the 316(a) variance are summarized in Table 1 and described in detail on pages B-2 and B-3 of Appendix B.

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[1] The TAC is comprised of: USEPA Region V, ILEPA, USACE, USF&WS, ILDNR, IADNR, Office of IL Attorney General, Southern Illinois U. Carbondale, IL Natural History Survey, Isaac Walton League of America, United Autoworkers Union, , Mensinger Aquatic Resources, Exelon Corp., MidAmerica Energy, Dr. Roy Heidinger, Mr. James Mayhew, and Mr. Larry LaJeone.

Table 1. Existing and Proposed Alternative Thermal Standards for Quad Cities Nuclear Station

End of Mixing Zone Temperature Criterion[1]			
Month	**Excursion Threshold Temperature[2]**	**Current Maximum Excursion Temperature**	**Proposed Maximum Excursion Temperature**
January	45°F	48°F	No Change
February	45°F	48°F	No Change
March	57°F	60°F	No Change
April	68°F	71°F	No Change
May	78°F	81°F	No Change
June	85°F	88°F	No Change
July	86°F	89°F	91°F
August	86°F	89°F	91°F
September	85°F	88°F	90°F
October	75°F	78°F	No Change
November	65°F	68°F	No Change
December	52°F	55°F	No Change

Temperature Tacking Method		Allowable Excursion Hours	
Current	**Proposed**	**Current**	**Proposed**
Rolling 12-month basis	Calendar year basis (January to December)	1% (87.6 hours)	2.5% (219 hours) of which 1.5% (131.4 hours) may cause 5 °F increases in July, August and September.

[1] The NPDES Permit defines the mixing zone boundary as a straight line across the Mississippi River, 500 feet downstream of the diffuser pipes.

[2] No change in these values is proposed.

1.2.1 Excursion Hours

The Clean Water Act requires that an applicant for a thermal variance (or alternate thermal standards) demonstrate that the generally applicable standards are more stringent than necessary to assure the protection and propagation of a balanced indigenous population [community] of shellfish, fish, and wildlife in and on the body of water into which the discharge is to be made. Many of the studies that comprise this Demonstration were conducted to evaluate increasing the number of excursion hours available to QCNS on an annual basis from 1% (87.6 hours) to 3% (262.8 hours). As shown in this Demonstration (based on comprehensive biological, historical, and hydrothermal evaluations), the fish and shellfish populations in Pool 14 will be adequately protected if the Station is allowed an increase of excursion hours from 1% to 3%.

However, during the 28-year QCNS open cycle operating history the Station never utilized more than approximately 2.5% excursion hours during a summer season.[2] That occurred during the summers of 2006 and 2012. For that reason, rather than seeking an excursion hour increase to 3%, Exelon is limiting its request to 2.5% excursion hours (219 hours). It follows that a 2.5% standard, being more stringent than the 3% standard on which many of the analyses in this Demonstration are based, will also "assure the protection and propagation of a balanced indigenous community of shellfish and fish" in Pool 14.

1.2.2 Zone of Passage

The portions of cross-sectional area or volume of flow of the receiving steam not included in a mixing zone is termed the zone of passage (ZOP). Illinois regulation provides that the ZOP contain at least 75% of the cross-sectional area or volume of flow. In 1978, the Illinois Pollution Control Board determined that Station discharges were not reasonably expected to cause significant ecological damage to the river. As a result, the Station has not restricted plant operations for ZOP purposes.

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[2] During March 2012, record breaking air temperatures caused the upstream water temperature at Lock and Dam 13 to reach and exceed the monthly excursion temperature threshold of 57 ºF. As a result, during the period March 18 through March 29, 2012 QCNS used a total of 223.5 excursion hours, 168.9 of which were accumulated under a provisional variance. During the summer of 2012 (June – September) 219 (2.5%) excursion hours were used.

Modeling studies (Jain, 2002) have quantified the relationship between river flow and the zone of passage. Table C-1 (Appendix C) shows that based on Jain's modeling studies, with the plant operating at full capacity, the ZOP will be less than 75% at a river flow of 16,400 cfs. Flow records indicate that over the past 26 years, river flows have been less than 16,400 cfs on 209 days with only 25 of those days occurring during March, April, May, or October, the biologically important months in terms of fish movement (Haas, 2011). The retrospective analysis in Appendix C demonstrates that these historical episodes when ZOP has been less than 75% have not caused appreciable harm to the biological indigenous community in Pool 14. The prospective analysis (Appendix B Section 1.1) demonstrates that a ZOP of 66% will be protective of the BIC in the future. To assure that a ZOP of 66% or higher will be maintained, Exelon has committed to derating of QCNS when river flows reach levels that are predicted to result in ZOP values of 66% or less (Section 2.9.3 of Appendix C).

1.2.3 Twelve –month Tracking of Excursion Hours

Exelon is requesting that it be allowed to track excursion hours on a calendar year basis instead of over a 12-month rolling period. This change in the way in which excursion hours are tracked should have no biological consequence or impact. Excursion hours have been tracked at QCNS for the past 28 years (1983-2011). During that time, excursion hours have occurred exclusively during the March-August period. There is virtually no possibility that Exelon would use excursion hours in December or January, that is, at the end of one calendar year and the beginning of another. Thus, there should be no concern that tracking excursion hours at QCNS would result in allowing the plant to use two years of allotted hours over a two or three month contiguous period.

1.3 Exelon's Contributions to the Well-Being of Pool 14

Recognizing the value of the Mississippi River Pool 14 ecosystem, Exelon is committed to maintaining and improving the health of the Pool. Some of the specific actions Exelon has taken and is taking to address the health of Pool 14 include:

- Operation of Fish Hatchery/Stocking Program
- Long-Term Aquatic Monitoring Program
- Freshwater Mussel Monitoring Program
- Zebra Mussel Monitoring Program.

1.4 Summary of data collection and analyses

The Station, a team of distinguished scientists[3], and the TAC have worked together to identify and implement the data collection, study, and analysis requirements for considering possible impacts on Pool 14 from Station operations. The focus of the work regarding Pool 14 has been to:

- Analyze current and historical background conditions
- Identify and analyze trends in fish abundance
- Analyze historic and future impacts of Quad Cities Nuclear Station
- Identify and evaluate the freshwater mussel community.

A substantial body of data and analyses utilizing sophisticated, state-of-the-science analytical tools has resulted from these efforts. Some of this information has been presented to and discussed with Illinois Environmental Protection Agency ("ILEPA"), USEPA Region V, Illinois Department of Natural Resources ("ILDNR"), Iowa Department of Natural Resources ("IADNR"), and the TAC. Some of the analyses underlying prior submittals have now been refined, updated, and/or revised. New data and analyses are described in this Summary and are presented in detail in the accompanying Appendices. For a description of the studies that have been performed by the Station see Appendix E.

Data has been collected since 1984 by HDR Engineering, Inc. ("HDR"), the Iowa Institute of Hydraulic Research (IIHR), and Ecological Specialists, Inc. (ESI). Analyses of available data collected by HDR, ESI, and other individuals and organizations, as well as comprehensive literature reviews have been performed by HDR, Forrest Holly[4] and Heidi Dunn (ESI)[5]. These efforts include extensive hydrothermal modeling of Pool 14 which provides important input to the biothermal assessment model developed and applied by HDR to determine the effects of the Station's thermal discharge on fish in the Mississippi River.

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[3] The team includes: HDR Inc., Southern Illinois University, Forrest Holly and Associates, and Ecological Specialists Inc.

[4] Forrest Holly formerly of IIHR and now of Forrest Holly & Associates

[5] Ms. Dunn is President of Environmental Specialists, Inc.

The Station's 316(a) variance application and supporting demonstrations are predicated on this substantial body of data and analyses. The primary data sources are described below.

1.4.1 Water Quality

Sullivan et al. (2002) compiled Upper Mississippi River (UMR) water quality data from federal, state and local agencies that conducted monitoring on the river over the period 1980-2008. Three sites from Pool 14 are included in these data. The major objectives of this effort were to increase coordination and cooperation among monitoring agencies, develop a unified database of relevant water quality information, and to use these data to produce an assessment of the UMR water quality.

1.4.2 Thermal Surveys

Several thermal studies have been conducted in Pool 14 throughout the history of Quad Cities Nuclear Station including a combination of vertical thermal profiling and infrared aerial photography which were used to calibrate the hydrothermal model described in the next section.

1.4.3 Hydrothermal Modeling

IIHR Hydroscience & Engineering simulated the Station's thermal plume using a three-dimensional (3-D) Computational Fluid Dynamics (CFD) model. The IIHR modeling effort included the following major components (as detailed in the IIHR Report, 2004):

1. Inclusion of relevant river-training structures, namely wing dams and the cross-channel closure dam in the Steamboat Slough, in the model bathymetry to better reflect real-world conditions. The resultant model grid contained nearly two million points.

2. Simulation of conditions corresponding to the HDR September 2003 thermal survey field effort, which validated the model's ability to predict the observed thermal conditions.

3. Simulation of station operations at maximum power for a series of relatively low Mississippi River flows.

4. Provision of temperature, depth, and velocity results from the multiple simulations to HDR to serve as input for the biothermal model.

5. Supplemental thermal analysis was conducted to relate measured sediment temperatures to the hydrothermal modeling (July 2007).

1.4.4 Phytoplankton

Phytoplankton studies were conducted in conjunction with and at the same locations as zooplankton studies from August 1972 through August 1973. During this period, both reactor units were in the open cycle operation mode with the two diffuser pipes employed to diffuse waste heat into the river (ComEd, 1975).

Composite phytoplankton samples were collected, preserved, and transported to a laboratory where abundance, biomass, chlorophyll *a,* and carbon fixation rates were determined. Analysis of variance was performed to identify differences in phytoplankton productivity between the intake and discharge locations and between river locations above and below the diffuser pipe discharge system.

1.4.5 Zooplankton

Zooplankton entrainment studies were conducted at Quad Cities Nuclear Station from mid-September 1972 through early August 1973, a period during which the full thermal, mechanical and chemical stresses of entrainment could be assessed, because both reactor units were in operation in the open cycle mode with the two diffuser pipes employed to diffuse waste heat into the river (ComEd, 1975).

Samples were also collected with a filter-pump system near the surface at the Station intake and from the discharge bay where condenser water entered the diffuser pipes. River locations were sampled about 1,600 feet upstream of and at approximately 375, 4,000, and 8,000 feet downstream of the diffuser pipes (ComEd, 1975).

1.4.6 Benthic Macroinvertebrates

Drifting invertebrates were sampled monthly from late March to early July 1972, primarily at the edge of the channel offshore of the station. In 2004, Exelon established a monitoring program using quantitative and qualitative techniques for freshwater unionids near the Station's thermal discharge diffuser. The program includes monitoring three beds both upstream and downstream of the diffuser pipes in July and October. These three beds were last monitored in 2008. All of these mussel sampling programs were conducted via scuba by Ecological Specialists, Inc.

Quantitative samples are collected to estimate density, relative abundance, age structure and mortality, parameters used for spatial and temporal comparisons of unionid communities for management and impact analysis. A standard quantitative sample consists of 90 0.25 m^2, 15-cm deep quadrat samples taken randomly within the bed using GIS, which are then plotted on a GPS Depthfinder. All materials are hoisted to the boat in a 6-mm bag where the contents are removed and identified accordingly.

Qualitative sampling is a visual and tactile search for unionids and by design is often biased towards large and sculptured animals. The diver takes a 5-minute interval to collect all mussels at a location along with pertinent water quality information. Usually 25 sites are selected for sampling within the bed.

1.4.7 Ichthyoplankton

Ichthyoplankton (fish eggs and larvae) were studied intensively in the vicinity of the Station from 1975 through 1985. The design of the program used after the return to open cycle cooling in 1984 included sampling three locations (near Illinois bank, main channel, and near Iowa bank) on a transect that extended from a point upstream of the intake channel on the Illinois bank to a point upstream of the confluence of the Wapsipinicon River on the Iowa shoreline. Samples were collected one meter below the surface and one meter above the bottom at each river location and were also collected one meter below the surface at one location in the discharge bay. Samples were collected in quadruplicate at each location on a weekly basis for a period of 16 weeks beginning in mid-April. A total of 448 samples were collected annually during 1984 and 1985.

1.4.8 Finfish

The Quad Cities Pool 14 fish monitoring program currently contains four different study plans:

- Adult and juvenile fish long-term monitoring.
- Freshwater drum life history and population dynamics study.
- Channel catfish, flathead catfish, walleye and sauger studies.
- Stocking assessment.

Each program is described briefly in the sections that follow.

1.4.8.1 Adult and juvenile fish long-term monitoring

Adult and juvenile fish monitoring has been conducted in Pool 14 in the area of the Station since 1971. The program was modified several times during the 1971-1977 period to address specific objectives related to Station operation. In 1978, results of the previous years' studies were reviewed and those sampling techniques (electrofishing and trawling) and sample locations that had the greatest continuity since 1971 were selected to be included in the long-term monitoring program. Locations were selected based on their continuity to evaluate trends in the species composition and dominant species of Pool 14. At the suggestion of the IADNR, an additional collection method (haul seine) was added to provide relative abundance estimates for several species deemed not to have been adequately collected in previous studies. The haul seine also provides a means of sampling for several species utilizing the side channel and slough habitats. Population estimates of catfish using hoop nets were added in 1982 as an additional component. The entire data base (1971-1994) was re-evaluated in 1995 and it was determined that bottom trawling and hoop netting were not providing new insights regarding the structure of the fish community or the plant's effect on it. Consequently, both these elements were deleted from the program beginning with the 1996 sampling year.

1.4.8.2 Freshwater Drum Life History and Population Dynamics Study

In 1978, at the recommendation of the ILDNR, freshwater drum was selected for intensive study to determine whether Station operation may be affecting population levels and growth of this species in Pool 14. Freshwater drum were the subject of this focused study because it is the only species in Pool 14 that has a truly planktonic egg stage and its larvae frequently represent the greatest percentage of ichthyoplankton drift resulting in the potential for population level effects if high percentages of its early life history stages are being lost through entrainment. Impingement also has the potential to affect population levels because freshwater drum has had the second highest impingement rate at the Station (Hazleton Environmental Sciences, 1979).

Since 1978, a variety of population parameters have been studied including standing stock, age class distribution, annual growth rates, fecundity, total annual mortality, and impingement exploitation rates. Refinements and adjustments to the freshwater drum life history program have been made during the past 31 years.

The most recent modification to the freshwater drum life history program occurred in 1993. The fecundity analysis portion of the study was deleted on the basis that ten years of data were more than adequate to determine mean fecundity for the species and that no measurable changes in fecundity had occurred as a result of Station operation.

1.4.8.3 Channel Catfish, Flathead Catfish, Walleye/Sauger Studies

Spring hoop and lead net studies conducted from 1982 to the present and directed toward freshwater drum life history and population assessments have also yielded considerable numbers of channel and flathead catfish. Consequently, ongoing life history studies were amended in 1983 to include a tagging study for channel and flathead catfish aimed at monitoring the extent of their movement and to provide an estimate of their standing crop in those same areas surveyed for freshwater drum. The tagging studies have not been conducted since 1995. However, both species continue to be monitored as part of the freshwater drum studies. Based on 25 years of monitoring, population levels and standing crop of both species have increased in Pool 14.

As a further supplement to the freshwater drum life history study and the catfish population study, a tagging program for walleye and sauger was initiated in 1984. The addition of this program to the monitoring effort was prompted by ILDNR's interest in habitat preference and utilization by walleye and sauger, and the need to develop a database on walleye in anticipation of future stocking activities in Pool 14. Too few fish of either species have been captured to date to satisfy program objectives.

1.4.8.4 Fall Stock Assessment

In 1984, under the auspices of the IADNR and the ILDNR, the inactive spray canal surrounding the Station was converted into a game fish production facility through a grant to Southern Illinois University. Species chosen for rearing were hybrid striped bass and walleye, with annual stocking objectives of 175,000 advanced fingerlings of each species for Pools 13 & 14. Production of both species has been variable from year to year, but since 1984 in excess of 4.5 million walleye and 700,000 hybrid striped bass fingerlings have been stocked in the Mississippi River.

As a result of past stocking in Pool 14 and to provide information for future stockings, the standard monitoring program was expanded to include additional analyses and sampling. Several basic elements of the long-term fisheries monitoring program (electrofishing, hoop netting and haul seining) document the relative contributions of these stocking efforts in habitats near Quad Cities Nuclear Station. However, both hybrid striped bass and walleye utilize tailwater areas both upstream and downstream from the Station rather extensively and historic monitoring programs had not included these areas. Dialogue with IADNR and ILDNR resulted in the addition of a special fall tailwater electrofishing survey to the 1984 monitoring program. That effort was expanded over a broader time frame in 1985 and continues through the present.

1.5 The comprehensive biological and hydrothermal evaluations justify granting a thermal variance

As discussed in more detail below, issuance of a 316(a) variance requires that Exelon demonstrate that future operations of Quad Cities Nuclear Station in accordance with the proposed alternative thermal standard set forth in Table 1 will assure the protection and propagation of a balanced indigenous community (BIC) of fish, wildlife, and shellfish.

To evaluate the Station's historic and prospective impacts on Pool 14, a number of comprehensive, state-of-the-science studies were conducted. The various comprehensive analyses confirm that the Station's operations have caused no prior appreciable harm to the BIC (Appendix C) and that future operations under the proposed alternative thermal standard will be protective of the BIC (Appendix B). As is shown by this Demonstration, operation of the Station under the alternative thermal standard proposed in Table 1 will adequately safeguard the populations of Pool 14. Accordingly, issuance of the requested alternative thermal standard as set forth in Section 2 of this summary is warranted.

2.0 DESCRIPTION OF QUAD CITIES NUCLEAR STATION OPERATIONS: PAST, PRESENT, FUTURE

2.1 Introduction

Construction of Quad Cities Nuclear Station began in the late 1960s on approximately 920 acres in Rock Island County, Illinois on the east bank of the Mississippi River, approximately three miles north of Cordova, Illinois, 20 miles northeast of the Quad Cities Metropolitan Area of Davenport, Iowa, Rock Island, Moline, and East Moline, Illinois and seven miles southwest of Clinton, Iowa. The Station is located on Pool 14 of the Mississippi River, at approximate River Mile 506.5 above the confluence of the Ohio River.

Quad Cities Nuclear Station is designed to operate 24 hours a day, seven days a week, with two generating units. Each unit's maximum power level is 2,957 megawatts thermal (MWt), for a combined thermal output of 5,914 MWt. This level of MWt will not be increased as a result of issuance of a revised ATS (see Appendix D, page D-2 for further discussion). Steam, which is produced at high temperature and pressure in the boiler, is exhausted from the turbine of each generating unit and condensed using non-contact cooling water from the Mississippi River. After passing through the condensers, cooling water from Units 1 and 2 mixes and then exits to the discharge canal. The Station also withdraws a small amount of service water. The condensers for Units 1 and 2 are treated daily with sodium hypochlorite to control the growth of micro-fouling organisms. The Station's NPDES permit allows for biocide treatment of each unit's circulating water system (condenser cooling) a with sodium bromide and/or sodium hypochlorite with a maximum instantaneous total residual chlorine/total residual oxidant (TRC/TRO) concentration of 0.05 ppm discharged to the river. Sodium hypochlorite is normally used as the sole biocide for treatment of the circulating water system. Circulating water is also continuously treated with a scale inhibitor 365 days per year.

The history of operations at Quad Cities Nuclear Station since commercial startup in 1972 is summarized below.

2.1.1 1972-1974 (May): Open Cycle Cooling with Shoreline-Jet Side Canal/Diffusers

The Station began operation in January 1972, when low power testing was initiated. Following low power testing, in early April 1972, startup testing began and was continued until August 1972. From January until August 1972, cooling water was withdrawn from the Mississippi River, circulated through the condenser cooling system, and discharged through a shoreline-jet discharge canal (the current discharge bay was open to the river, west of the lift Station).

A diffuser system was installed in the Mississippi River in 1972 as an interim mode of discharge until the spray canal (closed-cycle cooling) was completed. This diffuser system consists of two 16-foot diameter multi-riser manifolds that are buried in the riverbed. Open cycle, two-pipe diffuser operation began in August 1972, at which time the use of the side-jet discharge was permanently discontinued. The diffuser mode of operation continued until May 1, 1974.

2.1.2 1974/75-1979: Closed Cycle Cooling

In accordance with an agreement signed in 1972, operation of the spray canal commenced on May 1, 1974, with the Station operating with the equivalent of one unit discharging cooling water to the canal and one unit discharging directly to the river. This mode of operation continued until May 1, 1975, when cooling water from both units was routed to the canal (closed-cycle). Electrical energy to operate the spray canal (328 spray pumps and 5 lift pumps) required approximately 29 MW. Similarly, the warm water returning from the spray canal reduced turbine efficiency and resulted in significant loss of production of electricity during summer months. Due to these combined losses of electricity available to the grid during operation of the spray canal during the summer months, Commonwealth Edison sought relief from operating in the closed-cycle mode. Closed-cycle operation continued until August 2, 1979.

2.1.3 1979-1983: Partial Open Cycle Cooling

On August 2, 1979, the Station received a new NPDES permit that allowed partial open-cycle operation of the condenser cooling system at times when the temperature of the water returning from the spray canal to the intake exceeded 93^{o}F. Operation of the Station in the partial open-cycle mode was also subject to an interim modification, effective August 27, 1979, to the closed-cycle agreement which allowed the Station to operate in partial open-cycle mode to avoid substantial capacity losses. Operation in the partial open-cycle mode continued until December 23, 1983.

2.1.4 1983-Present: Open Cycle Cooling

The Station commenced the current full open cycle mode of operation via the diffuser pipes on December 23, 1983. The open-cycle agreement was signed on October 11, 1983 and approval from the ILEPA for open-cycle mode of operation was received on December 23, 1983. The Station has been operating in this mode since December 23, 1983.

2.2 Proposed Thermal Standard Conditions

Quad Cities Nuclear Station employs once-through-cooling, which entails a discharge of heated effluent to the Mississippi River.[6] This thermal discharge is authorized under the Station's

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[6] Located on Navigation Pool 14 of the Mississippi River near Cordova, IL.

NPDES Permit, issued by the ILEPA. Thermal limits in the NPDES Permit are based on Illinois environmental regulations, and studies and Demonstrations related to the thermal plume, performed under Section 316(a) of the Federal Clean Water Act.

The NPDES Permit defines the mixing zone boundary as a straight line across the Mississippi River, 500 feet downstream of the diffuser pipes, and compliance with the temperature standards in the NPDES Permit is measured at the end of this mixing zone boundary. The NPDES Permit (and Illinois regulations) requires that the discharge meets the following standards:

1. Fixed standard limiting the <u>change</u> in water temperature - Natural river water temperatures shall not be increased by more than 5°F at the downstream end of the mixing zone.

2. Variable standard defining the maximum monthly temperature <u>limit</u> – the monthly limits are set forth in Table 1.

3. Variable standard limiting the <u>duration</u> of elevated water temperatures – An exceedance of the monthly temperature thresholds (3°F less than the maximum limit) triggers the tracking of the time period elevated water temperatures occur (commonly referred to "excursion hours"). The plant is allowed to exceed the monthly temperature thresholds for up to 1% of the hours in a twelve month period ending with any month (e.g., in August, excursion hours occur when the water temperatures exceed 86°F [from Table 1]. The temperatures must still remain below the noted maximum limit (e.g., 89°F during August).

Exelon is proposing the following modification to these thermal standards:

1. Changing the method for tracking and regaining excursion hours from a rolling 12-month basis to a calendar year basis (January through December);

2. Increasing the number of excursion hours available per year from 1% (87.6 hours) to 2.5% (219 hours). .

3. Increasing the maximum excursion hour temperature limit to 5°F above the Table 1 Excursion Threshold Temperature (ETT) for up to 60% of the allotted excursion hours in July, August and September. During the balance of the allotted excursion hours, the maximum excursion hour temperature limit would remain at 3ºF above the ETT.

4. Allowing a Zone of Passage of at least 66% of the cross-sectional area or volume of the river.

3.0 VARIANCE FOR THERMAL DISCHARGES UNDER CLEAN WATER ACT SECTION 316(a)

3.1 Legal standards governing issuance and effect of a variance under Section 316(a)

Congress determined that heat should be treated differently than other pollutants. Therefore, with respect to thermal discharges, Section 316(a) of the Clean Water Act establishes a flexible, case-by-case alternative to the uniform application of standards based on either a prescribed technology or water quality criteria.[7] Section 316(a) expressly provides that:

> "With respect to any point source otherwise subject to the provisions of section 301 of this title or section 306 of this title, whenever the owner or operator of any such source, after opportunity for public hearing, can demonstrate to the satisfaction of the Administrator (or, if appropriate, the State) that <u>any</u> effluent limitation proposed for the control of the thermal component of any discharge from such source will require effluent limitations more stringent than necessary to assure the protection and propagation of a balanced, indigenous population of shellfish, fish, and wildlife in and on the body of water into which the discharge is to be made, the Administrator (or, if appropriate, the State) may impose an effluent limitation under such sections for such plant, with respect to the thermal component of such discharge (taking into account the interaction of such thermal component with other pollutants), that will assure the protection and propagation of a balanced, indigenous population of shellfish, fish, and wildlife in and on that body of water." (Emphasis supplied.)

During the 37 years since its enactment, EPA has consistently interpreted Section 316(a) to mean that a permittee will be granted a variance from otherwise applicable federal or state limits on its thermal discharge if the permittee provides "reasonable assurance" that would satisfy a "reasonable person" that a proposed alternative thermal limit will be consistent with the

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[7] *See* A Legislative History of the Water Pollution Control Act Amendments of 1972, *reprinted by* Congressional Research Service ("Legislative History") at 263 (1973) (Statement of Rep. Clausen); *id*. at p. 227 (Statement of Rep. Harsha) (Section 316 is "[i]ntended to provide modifications of effluent limitations or standards of performance under these other Sections [301, 302 and 306] because heat should be treated in a different manner than other pollutants").

protection and propagation of a balanced indigenous community ("BIC")[8] of biota in or on the receiving waterbody. This Demonstration makes the requisite showing, thereby entitling Exelon to a Section 316(a) variance for Quad Cities Nuclear Station.

3.1.1 Prospective and retrospective aspects of the 316(a) Demonstration.

In addition to showing that proposed alternate standards are protective of the BIC, the regulations implementing Section 316(a), allow an existing discharger to support a 316(a) variance based on the absence of prior appreciable harm. Specifically, such a demonstration must show:

> (i) That no appreciable harm has resulted from the … discharge (taking into account the interaction of such thermal component with other pollutants) … to the [BIC]; or
>
> (ii) That despite the occurrence of such previous harm, the desired alternative effluent limitations (or appropriate modifications therefore) will nevertheless assure the protection and propagation of a [BIC]….

40 C.F.R. § 125.73(c)(1).

Because the proposed alternate standards are only incrementally different from those that have been in place since December 23, 1983, and because past station operations (conducted pursuant to grants of temporary emergency relief) are similar to those that will be allowed under the proposed alternate standards, the retrospective Demonstration examines whether historical operations have caused any appreciable harm to the BIC.

Since early 1972, there have been numerous, comprehensive studies concerning the effects of Quad Cities Nuclear Station operations on the BIC. (See Appendices A, B, C and E.) These studies clearly show that the Station's historical impacts on the fish and freshwater mussel populations are negligible, particularly in relation to other stresses to these populations, including fishing pressure and zebra mussel infestations.

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[8] The statute uses the term "population"; the EPA regulations use the term "community." *See* 40 C.F.R. § 125.71. Recognizing that the biological term "community" consists of populations, EPA uses the terms "population" and "community" interchangeably. This Demonstration will use the EPA term "community."

In addition to the retrospective analysis, this Demonstration also includes a prospective analysis of the future effects of the Quad Cities Nuclear Station's thermal discharge under the proposed alternate thermal standards. The prospective analysis establishes that, going forward, Station operations under of the proposed alternate thermal standards will adequately protect the BIC.

As shown in this Demonstration, Illinois' standards are more stringent than necessary to protect the BIC and should be superseded by a variance authorizing Quad Cities Nuclear Station to discharge pursuant to the proposed alternate thermal standards. As will be demonstrated below and in the attached Appendices, operation of Quad Cities Nuclear Station pursuant to the proposed thermal standards will be protective of the BIC.

3.2 Results of the Prospective Assessment - Protection of balanced indigenous community

Section 316(a) of the CWA requires an applicant for a variance to demonstrate that the proposed permit limit on its thermal plume will "assure the protection and propagation of a balanced, indigenous population [community] of shellfish, fish, and wildlife in and on the body of water." For the prospective assessment, HDR conducted comprehensive literature surveys, analyzed field data collected by HDR and LMS,[9] used state-of-the-science hydrothermal models generated by Iowa Institute of Hydraulic Research and followed EPA and TAC protocols for assessing the impacts of heat on Representative Important Species (RIS) of fish. RIS species selected for this demonstration include largemouth bass, channel catfish, spotfin shiner, and walleye. River and plant operating conditions evaluated in this study were selected so that they would provide the basis for a stringent (i.e., conservative) assessment of potential plant-related biological effects. Because excursion hours occur during warm periods of the year, the biothermal assessment focused on the months of June, July, August, and September. The results indicate that the proposed thermal standard change will have a negligible impact on largemouth bass, channel catfish, and spotfin shiner. Spotfin shiner growth days may even be increased by the change. Walleye chronic mortality could be increased by 8.5% immediately downstream of the mixing

[9] The methodology, analysis, and results are explained in detail in Appendix B and summarized here. LMS was acquired by HDR in 2005.

zone, if one assumes no avoidance behavior (which is not realistic). Placed in the areal context of Pool 14, this would be less than a 1% effect on the walleye population in the Pool.[10]

Conservative values were selected for each of the major model input parameters to assure that the resultant thermal plume temperatures used in the analysis are representative of reasonable worst-case conditions. HDR reviewed Lock and Dam 13 temperature data provided by the Army Corps of Engineers for the October 1996 through April 2006 time period. The June through September 2006 time frame included periods of low river flow and warm summer temperatures. Actual river water temperatures recorded at Lock and Dam 13 (located about 12 miles upriver of the Station) during June through September 2006 were adjusted and used for ambient river temperature values. The Lock and Dam 13 temperatures were adjusted by increasing the temperatures exponentially with river flow to simulate conditions under the proposed alternate standards, i.e. exceeding 86°F at the end of mixing zone for 3.0% of annual hours and exceeding 89°F 1.5%[11] of the annual hours without exceeding 91°F. In this variable flow analysis, river flows recorded at Lock and Dam 13 during 2006 were used and the plant was assumed to operate at full capacity. A similar analysis was performed with fixed river flows ranging from the 7Q10 rate (13,800 cfs) to more typical summertime flows (30,000 cfs). While the variable flow scenario represents the worst case thermal condition under the proposed standard, the fixed flow scenarios provide results over a range of excursion hours that may be typical of less extreme conditions.

The scenario utilizing actual daily river flows (i.e., variable flows) provides the assessment of biological effects that would result under the most extreme conditions that would be allowed if proposed alternate thermal standards were granted, i.e., excursion hours of 3.0% and 1.5% for 86°F and 89°F, respectively. One additional analysis was also performed to quantify the thermal effects (if any) from ambient temperature alone (i.e., with no thermal discharge). This analysis provides the basis for determining what portion of the predicted thermal effects should be assigned to plant operations, versus those caused by the natural variation in ambient river temperatures.

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[10] The Prospective Assessment presented in Appendix B, and summarized here, evaluated increasing the number of excursion hours available to QCNS on an annual basis from 1% (87.6 hours) to 3% (262.8 hours). However, as explained in more detail in Section 1.2.1, Exelon is limiting its request to 2.5% excursion hours (219 hours). It follows that a 2.5% standard, being more stringent than the 3% standard evaluated in the Prospective Assessment would have would have even smaller effects on the RIS than those summarized here.

[11] Although the target percentage for exceedance of the 89°F EOMZ limit was 1.5%, the percentage is computed on a daily basis and exceedance of 5 days yields a 1.4% value ([5/365] * 100) while 6 days yields a 1.6% value ([6/365] * 100).

Results of the IIHR hydrothermal model at various levels of river flow were used in conjunction with the adjusted Lock and Dam 13 temperatures to predict temperatures in Pool 14 downstream of the discharge. These results were then compared to the individual temperature tolerances for each species analyzed. This analysis took into account both acclimation and exposure temperatures for each species in order to evaluate effects on three key biological functions: growth, avoidance, and chronic thermal mortality. See Appendix B.

To determine whether the Station's heat discharge under the proposed alternate thermal standard would cause any appreciable harm to any RIS, the analysis determined when and where in Pool 14 each species was located for each critical life function. Some species only spend a few months of the year in Pool 14; others move around in the Pool depending on whether they are spawning or growing.

Importantly, continued Station operation under the proposed alternative thermal standard will not impair the successful completion of life cycles of indigenous species, thus assuring the protection and propagation of a balanced, indigenous community as required under Section 316(a). Findings from the assessment are summarized below.

3.2.1 Temperature during critical growth seasons

Little change in growth for largemouth bass (less than 4%) and channel catfish (less than 1%) was predicted for all of the realizable scenarios evaluated. For spotfin shiner, it appears that the plume's higher temperatures expand the volume of water that falls within the normal temperature range for growth, and thus as the Station's thermal influence increased (i.e., at lower river flows and higher percent excursion hours), so did the predicted number of growth days. For walleye, a modest shift out of its normal temperature tolerance range is predicted, so an increase in the Station's allotted excursion hours from 1.0% to 3.0% of annual hours above 86°F and 1.4% above 89°F would increase the predicted number of lost growth days from 9.6 to 12.2 days; an increase of 2.6 days or 2.1% of total growth days for the 122 day period of study.

3.2.2 Thermal avoidance and habitat loss

The predicted overall average percentage of habitat avoided from June 1 to September 30 for all scenarios was relatively small (<2.0%) for channel catfish, largemouth bass and spotfin shiner. On the basis of this information, it was concluded that the proposed increase in percent excursion hours would not result in a material change in available habitat for these three species. Although sufficient acclimation/avoidance temperature data sets were not available to perform the same analysis for walleye, this “data gap” is addressed in Attachment 3 to Appendix B, which provides a supplemental analysis using data from the HDR Summertime Electro-fishing Program. Based on these observations, it is predicted that any displacement of walleye for either low flow or thermal reasons will be transitory and will not cause appreciable harm to the walleye population which inhabits Pool 14 or adjacent pools.

3.2.3 Predicted Chronic Mortality

The predicted chronic mortality for largemouth bass, channel catfish, and spotfin shiner is negligible. Increasing the percent of excursion hours over 86°F from 1.0% to 3.0% increased the predicted chronic mortality of walleye from 1.1% to 3.4% under the constant flow scenarios. This incremental increase of 2.3% under reasonable worst-case conditions is not expected to cause appreciable harm.

For the variable flow scenario, which simulates the most extreme excursion hour case under the proposed alternative standard, the predicted increase in chronic mortality over the current 1% standard is 8.5% (9.6-1.1%) and the predicted increase over the ambient condition is 9.5%. This assumes laboratory controlled conditions, i.e. no avoidance occurs. In the real world (e.g., Pool 14) walleye will, if possible, avoid stressful temperatures before they reach lethal levels. Given the fact that the Quad Cities Nuclear Station plume encompasses only a small portion of Pool 14 downstream of the diffuser, there should be ample opportunity for walleye to avoid lethal temperatures by moving into cooler waters. While some chronic mortality may occur with temperature working in concert with other stresses, e.g. disease or low dissolved oxygen levels, the increase over the current standard is expected to be substantially less than 8.5%. Daily inspections conducted both upstream and downstream of the diffusers during the excursion hour periods in 2006 and 2007 revealed very few dead or moribund walleye

3.2.4 Conclusions of Prospective Analysis

The proposed alternate thermal standard will not cause appreciable harm to the RIS evaluated. Furthermore, the low level of impacts predicted in this assessment for the RIS suggests that a 3% increase in excursion would be adequately protective of the overall fish community and that the requested 2.5% increase would be even more protective.. It is important to remember that the affected area represents only a small fraction of the total area of Pool 14 (approximately 8.5%). Thus the small predicted biothermal effects on the study area’s fish populations are even more negligible when viewed within the context of the entirety of Pool 14 and the river wide populations of these species.

3.3 Results of Retrospective Demonstration – No Prior Appreciable Harm

3.3.1 Identification of the Relevant Communities

Over the years that 316(a) studies have been conducted, it has become evident that certain biological communities require more detailed study and evaluation than do others. For example, as a rule the fish community always requires detailed evaluation due to recreational and/or commercial fisheries. Depending on the nature of the receiving waters, certain of the lower trophic level communities, e.g. phytoplankton and zooplankton, may not require detailed investigation due to heterogeneity of distribution, short regeneration times, and seasonality. In addition, these communities function as a source of food for various life stages of fish populations. Thus, any permanent adverse effects on these lower trophic level communities would be reflected in an adverse shift (imbalance) in the fish community.

It is generally agreed by the resource agencies that within the Station's discharge area, freshwater unionid mussel communities require a high priority of protection and warrant detailed evaluation under 316(a). For these reasons, the primary emphasis for this demonstration has been on the freshwater unionid mussel and fish communities.

3.3.1.1 Lower Trophic Levels

Although no studies were conducted to monitor the lower trophic levels (phytoplankton, zooplankton, and non-mussel benthic macroinvertebrates) between the early 1970s and the present, it is possible to reach conclusions about their status in Pool 14, both retrospectively and prospectively. Two communities that rely on these lower trophic levels as a basis for their food supply, either directly or indirectly are freshwater mussels and finfish. Both of these communities are discussed in depth retrospectively in this demonstration and the same conclusion is reached for both, i.e., operation of the Station since late 1983 has not caused appreciable harm to these balanced, indigenous communities. This demonstrates that an adequate food supply (plankton and invertebrates) has been available.

In addition, during the operating history of the Quad Cities Nuclear Station, there have been periods during which thermal conditions in the receiving waters have been similar to conditions that could result from operations under the proposed alternate thermal standards, particularly during the Summer of 2006. If the thermal conditions of 2006 had had adverse effects on the lower trophic levels, the fish and mussel communities should have manifested the effect of reduced food supply. However, no such effects were observed. The constant supply of planktonic organisms drifting downriver and their ability to quickly reproduce ensures that an adequate food supply is continually available and that any losses are quickly replaced. Taken together, these observations suggest no appreciable harm has occurred to the lower trophic levels under the current thermal standard and none will result from the small increment in added heat that could result if the proposed standard is implemented.

3.3.1.2 Freshwater Mussels

In 2007, a study was undertaken by Environmental Specialists, Inc. to define the balanced indigenous community within Pool 14 of the Mississippi River, MRM 515 to 495 (ESI, 2009). Preliminary sampling was conducted in June 2007 to identify unionid beds upstream and downstream of the thermal diffuser located at approximately MRM 506.4. A total of 15 beds was sampled with certain beds selected for more intense sampling and evaluation. Habitat and water quality information was collected for all intensively sampled beds, and substrate temperature and fish communities were sampled in the Upstream (UP), Steamboat Slough (SS), and Cordova Beds. The SS unionid bed, located on the Iowa bank at MRM 505.6, is the most proximate downstream bed to the Station's thermal diffuser. The Cordova Bed, which is listed as an Essential Habitat Area for *Lampsilis higginsii* by USFWS, is further downstream, about one mile from the diffuser. The federally endangered *Lampsilis higginsii* was most abundant in the Albany (upstream) and Cordova beds, but was found in seven of the 15 beds sampled.

In summary, unionid beds were found throughout the study area in a variety of habitats and both upstream and downstream of the QCNS. One unionid bed, the SS Bed, occurs in the immediate vicinity of the QCNS thermal diffuser. Density within this bed is similar to beds both upstream and further downstream of the diffuser with similar habitat characteristics. Unionid and fish communities within the SS Bed reflect habitat conditions, as similar communities were found in similar habitats both upstream and downstream of the diffuser. Based on the results of this study, if QCNS had not operated, the unionid community within the SS Bed would likely be similar to the community that presently exists in the bed. Likewise, the community characteristics of the other unionid beds located downstream of the plant are very similar to those observed in upstream beds that have comparable habitats. Mussel monitoring in 2004 thru 2008 indicated that some mortality occurred in 2006; however, mortality was higher in the bed upstream of the diffusers (UP bed) than in the bed located downstream of and nearest the diffusers (SS bed)

(Heidi Dunn, personal communication, 2011). In sum, based on the results of ESI's investigation and studies, QCNS operations have not harmed the unionid community in Pool 14. In addition, the unionid community in the area of the QCNS discharge, and in Pool 14, can generally be described as healthy, balanced, and composed of the indigenous species of unionids one would expect to find at this location. This finding, combined with the fact that thermal exposures experienced by the unionid community during the 2006 high ambient temperature/low river flow episode are comparable to thermal exposures that would be permitted under the proposed alternate thermal standards, supports the conclusion that the proposed thermal standards will adequately protect the balanced indigenous unionid community in the QCNS receiving waters.

3.3.1.3 Fish

3.3.1.3.1 Ichthyoplankton

Ichthyoplankton include the eggs and larvae of fish. Based on data collected during river fish larval monitoring (LMS 1985 and LMS 1986), peak larval drift tends to occur at ambient river temperatures in the range of 21 to 23ºC (69.8 to 73.4º F) and when river flows are relatively high, which suggests that they are not exposed to temperatures high enough or for sufficient duration to cause thermally-induced mortality at the end of the mixing zone where temperatures would range from 74.8 to 78.4ºF.

During the period of ichthyoplankton sampling (1978 through 1985), the majority of the eggs and larvae drifting by the Station were those of freshwater drum. The highest concentrations of these were found near the Illinois shoreline, an area in which the diffuser pipe ports are closed to approximately 840 feet offshore. Also, 95% of the freshwater drum egg drift occurs before July 2, with the peak occurring before June 5 (LMS, 1985). The peak freshwater drum larval drift occurs before June 15 (LMS, 1985). An increase in excursion hours or thermal limits (which are not being requested for June) will have a negligible effect on eggs and larvae of this species. Another species that contributes substantially to the larval drift is gizzard shad, which tend to drift closer to the Iowa shoreline where they are exposed to the thermal plume. However, based on the numbers of gizzard shad captured in the monitoring program for the past 28 years and observations of those that die natural deaths during the winters, the gizzard shad population in Pool 14 and adjacent pools has not been harmed by the thermal addition and it is not expected to be harmed by the small increment in added heat that could result if the proposed thermal standard is implemented.

3.3.1.3.2 Adults

Trends evident in the long-term electrofishing fish monitoring database covering the past 41 years include increases in numbers of freshwater drum, channel catfish, largemouth bass, and bluegill and decreases in the numbers of white crappie, black crappie, and sauger, while flathead catfish abundance has been relatively without trend[12]. These long-term sampling trends are apparent at locations both upstream and downstream of the diffuser pipes and most likely are the product of fixed locations that have undergone substantial habitat changes such as backwater siltation and the appearance of beds of rooted aquatic plants that was coincident with a noticeable increase in water clarity. Abundances of two species targeted by commercial fishermen, common carp and river carpsucker, have declined somewhat over the period of record. Changes in fishing regulations (e.g. increases in channel catfish length limits) by one or more of the resource agencies may have also influenced these trends.

Over the past 41 years, a total of 94 taxa have been collected. During most years the number collected has ranged from 50 to 60 taxa and has been reasonably stable over the 28 years of open cycle cooling.

Age analysis indicates that freshwater drum is long-lived in Pool 14, often exceeding age 20 and occasionally age 30. Annual adult survival has averaged between 70 and 75% for the past 29 years. Maximum theoretical growth has steadily increased since 1983. Standing stock estimates of freshwater drum equal to or greater than 150 mm (TL) vary among years because this metric is driven by population estimates and year class strength (HDR, 2011).

Haul seine catches are dominated by large gizzard shad and freshwater drum. Meaningful trends cannot be identified because haul seining is primarily a qualitative sampling operation that is influenced by a large number of variables which cannot be controlled.

2006 Mooneye Mortality Event

During July and early August of 2006 Illinois experienced a period of very hot weather. Upon being advised by the U.S. Army Corps of Engineers on July 31, 2006 that they were going to drop the flow in Pool 14 by 46% from 23,300 cfs to 12,700 cfs. QCNS initiated the derating process. The Station derated up to 50% and did not restore full plant power production until after the Corps restored river flows to pre-event levels (about 23,000 cfs) on August 3, 2006. On August 1, 2006 distressed and dead fish were observed both above and below the plant and Illinois DNR was notified of the event. Exelon personnel documented that during the August 1-3, 2006 period, 215 (73.7%) of the 292 dead fish counted at all upstream and downstream stations

[12] Trends in walleye are not monitored in this program because this species is stocked annually in Pool 14.

were mooneye. Three species of dead fish (sauger, smallmouth buffalo, bigmouth buffalo) were found only upstream of the plant. Seven of the 15 species of the dead fish collected during August 1-3 were represented by only one specimen. The sampling station (station 13) downstream from the plant where the highest number of dead mooneye was counted is an area of high deposition due to prevailing westerly winds and the morphology of the river. Little or no dead fish were collected at the two other sampling stations (9 and 11) directly below the diffuser. USACE data from rivergages.com indicated that during the August 1-3, 2006 period southwesterly, westerly, and northwesterly winds were gusting at 21-26 mph. Therefore, fish counted in the station 13 area likely originated not only below the Station, but from upriver as well. Steamboat Slough (stations 9 and 11) had higher water temperatures, but far fewer dead fish than did station 13, as the Slough is much less influenced by wind.

The temporal pattern of abundance of mooneye in QCNS impingement samples can aid in determining the spatial distribution of the mooneye mortality. As expected, during the August 1-3, 2006 event, the numbers of mooneye in impingement collections (August 2-3, 2006) showed a marked increase above the background levels observed in the preceding weeks and prior summers. One week after the event (August 9-10, 2006), when river flows had been restored and water temperatures had returned to normal levels, the number of mooneye collected in impingement samples was only 25% less than during the event, i.e., still well above pre-event levels. The numbers of mooneye collected in impingement samples did not return to levels close to those normally observed during the summer until August 16-17, 2006. These observations strongly suggest that dead mooneye continued to float into the QCNS intake area from upstream for over a week after the August 1-3, 2006 die-off and nearly a week after flows and temperatures had returned to normal. This means the die-off occurred not only in the vicinity of the plant but also well-upstream of the discharge. Apparently, as a result of the low river flows during the first few days of August, ambient water temperatures outside the influence of the plant's discharge, i.e., well upstream, reached levels that caused increased mortality of mooneye. As a result, it is difficult to determine to what extent the plant's discharge contributed to the mooneye die-off.

Average annual mortality is a term used to account for the many causes from which fish die naturally each year (e.g. parasites, bacterial, fungal and viral diseases, predation, old age, low flow, high ambient temperatures). Estimates of the annual mortality rate of mooneye are not readily available, however, a very conservative (i.e., biased low) estimate is the 30% average mortality rate for freshwater drum derived from the longterm monitoring of fish abundance in Pool 14 (HDR, 2011). The mooneye mortality rate is likely much lower because they are much shorter lived than drum which live 3-4 times as long.

The standing stock of mooneye in terms of biomass in Pool 14 can be estimated from the haul seine program conducted in the Pool each year. The seine program catches indicate average mooneye abundance of 1.15 lb/acre in the side channel habitat. Slough habitat sampling suggests higher abundance per acre so a conservative estimate of mooneye abundance can be derived by applying the side channel number over the entire 10,412 acres in the pool. Applying the 30% annual mortality rate to this number gives an estimate of mooneye mortality, in the absence of extreme events like that in 2006, of 0.34 lb/acre or 3,540 lbs.

An estimate of mooneye mortality possibly influenced by station operations during the August 1-3, 2006 event can be derived from the biomass of dead mooneye collected at all stations below the plant and the area sampled (93.64 acres). Dividing the 41.1 pounds of dead mooneye collected, by the 93.64 acres sampled, gives 0.44 lb/acre. The study area over which the thermal effects of the plume might be detected has been defined as covering 885 acres downstream of the plant. Making the very conservative assumption that mooneye might be affected over this entire area results in an estimate of mooneye mortality of 389 lbs. (0.44lb/acre*885 acres) within the study area. These 389 lbs represent only 10.9% of the 3,540 lbs of average annual mooneye mortality in Pool 14, calculated as described above. Furthermore, this 10.9% figure is likely a considerable overestimate because the 30% average annual mortality rate used in its calculation is probably a considerable underestimate of actual mooneye natural mortality rate.

It should be noted that the mooneye standing stock estimate for the fall of 2006, i.e., immediately after the August event, was 1.1 lb/acre, very close to the 1.15 average for the period 1986-2009. In the fall of 2007 the estimate of mooneye standing stock was 3.3 lb/acre. These data further support the conclusion that the August 2006 mooneye mortality event was of no biological consequence to the mooneye population in Pool 14.

The above information suggests that the thermal additions that have occurred since the return to open cycle cooling (1983) have caused no appreciable harm to the finfish in Pool 14 and that the requested modifications to the thermal standards will assure the protection and propagation of a balanced indigenous community of finfish in the Pool.

Monitoring During 2012 Excursion Hours

During July 2012 Illinois experienced a period of very hot weather that resulted in the use of 219 excursion hours. On any date that provisional variance hours are used, Exelon crews make three visual inspections of the Station's intake and discharge areas and document the number and general category of dead or stressed fish/aquatic life. If, during any observation, it appears a “fish kill” is occurring (numbers of individuals exhibiting difficulty in swimming or breathing), Exelon dispatches a team to determine the magnitude of the event and species affected.

As required, surveys were conducted during the July 2012 excursion hour episodes. With the exception of July 7, 8, and 9 no dead fish or presence of stress was observed. During July 7-9, when temperatures peaked, very small numbers of dead fish were observed both upstream and downstream of the plant. A total of two dead northern pike and one dead catfish were observed downstream of the diffuser. One catfish that appeared to have been dead a few days was observed at the diffuser. A total of 17 dead northern pike was found upstream of the diffuser. Two carp, two freshwater drum and two walleye were also found dead upstream of the diffuser.

These observations indicate that the thermal plume from QCNS did not cause an apparent increase in thermal stress or mortality during the excursion hour periods in July 2012.

3.3.2 Interaction with Other Pollutants

3.3.2.1 Organic Carbon

There are limited organic carbon data available on the Mississippi River system; however composite bed sediment samples were collected from the lower one-third of the Upper Mississippi River navigation pools prior to and after the summer flood of 1993. Bed sediment contaminant concentrations exhibited a general decrease following the flood. Decreases in pollutant levels were attributed to an increase in the portion of coarser sediment and low inputs or remobilization of contaminated sediments during or immediately following the flood. Bed sediment elevations in the sampling areas were found to increase significantly in the middle (Pools 5-13) and lower (Pools 14-26) reaches, likely a result of an increase in deposition of coarser sediment. System-wide, concentrations of dissolved organic carbon ranged from 3-12 mg/l. For the most part, dissolved carbon is unavailable to aquatic organisms other than bacteria. The reintroduction of organic carbon into the food web through bacteria results in additional energy to higher trophic levels (e.g., fish). The energy contributed by the QCNS thermal plume may increase bacterial growth rates but there is no indication of any harm caused by this potential interaction and there is no reason to expect that the small amount of additional heat that would be permitted to be discharged under the proposed alternative standard would cause a harmful interaction.

3.3.2.2 Total Phosphorous

In general, wastewater treatment plant discharges and urban and agricultural nonpoint source inputs are major sources of phosphorus. Agricultural watersheds contributing high concentrations of sediment are especially important because phosphorus is commonly bound to sediment particles. Nitrogen and phosphorus are abundant in the Mississippi River drainage basin because of the widespread use of commercial and animal-manure fertilizers. There are no nutrients added to the once-through cooling water during passage through the plant.

The most likely result of an interaction between the thermal plume and phosphorous would be an increase in the rate of algal growth during warm periods. However, this would be a localized effect in the less than 10% of the pool occupied by the thermal plume and no difference in algal abundance or growth has been observed in the plume. Given that there has been no evidence of a synergistic effect between total phosphorous and the thermal discharge in the past, there is no reason to expect that the small amount of additional heat that would be permitted to be discharged under the proposed alternative standard would cause any such effect

3.3.2.3 Total Nitrogen

Nitrogen is used in agricultural fertilizers to stimulate the production of crops, especially corn. Runoff from areas with intensive cultivation or large livestock densities are important sources of nitrogen. In addition, certain industrial discharges and municipal wastewater effluents may contain high concentrations of inorganic nitrogen, especially ammonia or nitrate nitrogen. Nitrogen concentrations throughout the river increased to higher levels in the 1990s, compared to concentrations observed during 1985-89. For the upper river, this response may have been partly associated with changes in municipal wastewater treatment technology (nitrification). However, changes in precipitation and river flow are additional factors associated with river-wide increases in nitrogen concentrations. The drought conditions of the late 1980s reduced non-point source runoff and increased utilization of inorganic nitrogen within the riverine pools. Increased non-point source runoff in the 1990s likely favored mobilization of nitrogen from agricultural watersheds that resulted in high nitrogen concentrations in the river during this period. The large amount of agricultural sources of nitrogen in the area suggests that the small amount discharged from the QCNS treatment plant is negligible by comparison. While nitrogen concentrations have increased during the recent decades for the reasons stated above, the Station's thermal discharge and treatment plant effluent have not contributed to this increase.

The most likely result of an interaction between the thermal plume and nitrogen would be an increase in the rate of algal growth during warm periods. However, this would be a localized effect in the less than 10% of the pool occupied by the thermal plume and no difference in algal abundance or growth has been observed in the plume. Given that there has been no evidence of a synergistic effect between total nitrogen and the thermal discharge in the past, there is no reason to expect that the small amount of additional heat that would be permitted to be discharged under the proposed alternative standard would cause any such effect.

3.3.2.4 Biocides

To control biofouling organisms in cooling water systems, power plants generally need to apply some type of biocide. Historically, Quad Cities Nuclear Station has treated its cooling water system with sodium hypochlorite. Sodium hypochlorite is normally used as the sole biocide for treatment of the circulating water system. Sodium bisulfite is used as a neutralizing agent prior to discharge to the river to ensure compliance with the TRC/TRO limit of 0.05 ppm. The detection limit is 0.05 ppm, an order of magnitude lower than the levels that cause fish mortality. Therefore, the Station's discharge of chlorine is well below levels that would cause harm to fish and the Station's use of biocides cannot reasonably be expected to alter or cause harm to fish communities in Pool 14 and adjacent pools, nor does it pose any risk of harm to the BIC. Any potential interaction of the thermal discharge with the biocides is similarly harmless.

3.3.2.5 Heavy Metals

Heavy metals are released to the Mississippi River from numerous sources including municipal wastewater-treatment plants, manufacturing industries, mining, and rural agricultural cultivation and fertilization. Heavy metals are transported as either dissolved species in water or as an integral part of suspended sediments, and may be volatilized to the atmosphere or stored in riverbed sediments.

Whether the loads and concentrations of heavy metals in the Mississippi River have increased or decreased in recent years is difficult to determine. Although most of the heavy metals in the river are associated with sediment, the majority of the previous studies have focused on the dissolved metals. Even for the dissolved metals, comparisons are difficult to draw between earlier and more recent data because analytical laboratory techniques have become markedly more sensitive in the last decade and field sampling techniques have not been adequately standardized. Those heavy metals that are found in the sediments are typically chemically bound to colloidal materials such as clay particles. This chemical bond is controlled by the electrical charge on the surface of the colloid which is controlled by the numbers of hydrogen ions present or the pH. As pH decreases (becomes more acidic), the surficial charge will eventually reverse, allowing the cation exchange phenomenon to occur. This frees the heavy metal to go into solution in the water. However, the pH of the river water ranges from about 7.0 to about 9.0 which is basic rather than acidic, thus inhibiting the process. Because movement of metals from the sediments into the water column is catalyzed principally by pH rather than temperature, the thermal discharge has not caused the release of heavy metals from the sediments and the proposed change in the thermal standard will also not affect this process. Thus, the heavy metals bound in the sediments can be expected to remain there and not interact with the biota. Therefore, there have not been and will not be any interactive impacts between the thermal plume, heavy metals and the biotic community.

3.3.2.6 Potability, Odors and Aesthetics

There is no evidence of an unnatural odor or an unaesthetic appearance in the Mississippi River in the vicinity of the Quad Cities Nuclear Station in general, and none associated with Station operations in particular. Hence, it is anticipated that the proposed alternative thermal standard will not have any effect on potability, odors or aesthetics of Pool 14.

3.3.2.7 Other Thermal Discharges

Several cooling water discharges are located on the Mississippi River from RM 517.5 to RM 513, which is approximately 10.5 km (6.5 miles) upriver from the Quad Cities Nuclear Station intake. Beaver channel is a side channel of the Mississippi River, which houses industrial discharges for Archer Daniels Midland's (ADM) Corn Processing Plant and Interstate Power Companies' M.L. Kapp Plant. The thermal component of the discharges from these plants is diluted and dissipated to ambient conditions by the time it reaches the Station. Thus, they do not interact with the Station's discharge.

3.3.2.8 Conclusions Regarding Interactions

There is no evidence of harmful interactions between the Station's thermal discharge and other pollutants including dissolved organic carbon, total phosphorus, total nitrogen, biocides, heavy metals, and other thermal discharges located upstream and there is no reason to expect that the small amount of additional heat that would be permitted to be discharged under the proposed alternative standard would cause such an effect.

3.3.3 Conclusions of Retrospective Analysis

On the basis of the analyses performed in connection with the Retrospective Assessment, it is clear that while there may have been changes in the upper trophic levels (i.e., finfish) in Pool 14 since the Station began operating, those changes are not attributable to the thermal input from QCNS. In addition, the overall stability and health of upper trophic levels suggests that lower trophic levels (i.e., zooplankton, phytoplankton) have remained stable and abundant, providing an adequate food supply to allow and sustain growth of the finfish and mussel populations. It is also clear that neither nuisance species nor heat tolerant species of fish have come to predominate in Pool 14 due to Station operations. In sum, QCNS's operations have not caused appreciable harm to the BIC.

3.4 Protection of Threatened and Endangered Species

3.4.1 Freshwater Mussels

In addition to demonstrating that historical operations have not harmed the BIC and that the proposed alternate standards will protect the BIC, the Demonstration has addressed the question of whether operations under the alternate standards could affect endangered species. There is one federally endangered species of mussel, the Higgins' Eye pearly mussel, in Pool 14 and adjacent pools along with a candidate species, the Sheepnose mussel. The more prevalent is the Higgins' Eye mussel, which can be found in several beds in Pool 14 and adjacent pools. Directly below the diffuser area is the Cordova bed, which is one of several essential habitats outlined in the Higgins' Eye Recovery Program. The Cordova bed is an essential area for the species because it is used as a source of brood stock for mitigation activities involving Higgins' Eye mussels throughout the Mississippi River system.

Quad Cities Nuclear Station initiated a consultation with USFWL in 2008 regarding endangered species concerns. With USFWL's guidance, the Station prepared a Habitat Conservation Plan (HCP). The HCP was approved and the Incidental Take Permit (ITP) was issued by USFWS in

August 2010. The Incidental Take Permit authorizes possible impacts to individual mussels (the nature of which, is not expected to be acute, but rather, at most, would be non-lethal, temporary stress), provided the Station complies with and implements the HCP.

The objective of a Habitat Conservation Plan is to avoid, minimize and/or mitigate for the proposed action (i.e. the proposed alternate thermal standard) with regard to federally endangered or threatened species. Adaptive management guidelines within the HCP allow it to be modified to include any additional data that may become evident within the life of the incidental take permit. In addition to requiring implementation of a thorough and comprehensive mussel sampling and monitoring program, the HCP provides for innovative measures designed to propagate the endangered mussels.

Through the HCP/Incidental Take Permit process, the Station satisfies the requirements of the Endangered Species Act and will enhance the likelihood that the endangered mussel species will survive.

3.4.2 Fish

There have been no federal endangered or threatened fish species collected in Pool 14 and the adjacent pools during the past 38 years of sampling.

4.0 CONCLUSIONS

In a 316(a) Demonstration, the ultimate standard used in the assessment of the thermal component of power plant discharges is whether a balanced indigenous community of shellfish, fish, and wildlife has been and will be maintained in or on the receiving water body despite the thermal discharge. Based on guidance documents and the criteria that have evolved based on our work on other 316(a) demonstrations, we believe that standard --protection of the BIC-- is demonstrated when the following criteria are met:

- No substantial increase in abundance or distribution of any nuisance species or heat-tolerant community
- No substantial decreases of formerly abundant indigenous species or community structure to resemble a simpler successional stage than is natural for the locality and season, other than nuisance species
- No unaesthetic appearance, odor, or taste of the water

- No elimination of an established or potential economic or recreational use of the waters
- No reduction in the successful completion of life cycles of indigenous species, including those of migratory species
- No substantial reduction of community heterogeneity or trophic structure
- No adverse impact on threatened or endangered species
- No destruction of unique or rare habitat, without a detailed and convincing justification of why the destruction should not constitute a basis of denial
- No detrimental interaction with other pollutants, discharges, or water-use activities.

Because this demonstration is focused on a request for a change in the thermal standard, the demonstration must show that these conditions will be satisfied in the future if the proposed standard is adopted.

Taken together, the retrospective and prospective evaluations of the QCNS thermal discharge demonstrate that the above criteria will be satisfied if the 316(a) variance is granted for the Station.

✓ **No substantial increases in abundance or distribution of any nuisance species or heat-tolerant community**

To date no apparent substantial changes in abundance of nuisance species have been observed. Our retrospective analysis suggests that there have been changes in the non-thermal components of water quality (e.g., water clarity and subsequent non-nuisance macrophytic growth along the main channel), but the Station's thermal discharge was not a contributing factor. Based on these observations, the relatively small amount of additional heat that will be discharged if the proposed standard is implemented is not expected to cause changes in abundance or distribution of nuisance species**.**

✓ **No substantial decreases of formerly abundant indigenous species other than nuisance species**

Based on results reported by the monitoring programs and special studies described in Appendix A, most indigenous species in Pool 14 have either maintained or increased in abundance during the period of open cycle cooling, with the exception of the fish species white crappie, black crappie, and sauger. Decline of white and black crappie, however, seems to be common throughout this reach of the river and not isolated to Pool 14. Much of the decline has been attributed to filling in of the backwater areas by sedimentation. As habitat changes, the fish also move out of fixed station sampling areas, which may help explain decreases in numbers collected in the long-term monitoring program. Overall, our retrospective analysis indicates that any trends in abundance are apparent at locations both upstream and downstream of the diffuser pipes, suggesting that the thermal discharge is not a significant contributing factor. The prospective analysis concludes that the proposed alternative thermal standard will not cause any appreciable harm to the indigenous fish species.

Special mussel studies conducted between 2004 and 2008 indicate that unionid mussels are similar in species composition and abundance in beds located both upstream and downstream of the diffuser pipes that have similar habitat. This suggests that the thermal discharge has not caused any appreciable harm to the unionid mussel community in Pool 14. This finding, combined with the fact that thermal exposures experienced by the unionid community during the 2006 high ambient temperature/low river flow episode are comparable to thermal exposures that would be allowed under the proposed alternate thermal standards, supports the conclusion that the proposed thermal standards will adequately protect the balanced indigenous unionid community in the QCNS receiving waters.

The demonstration of no retrospective effects on fish and shellfish supports the conclusion that the lower trophic levels on which they are dependent for food have been similarly unaffected and that no appreciable harm will result from the small increment in added heat that may be released if the proposed standard is implemented.

✓ **No unaesthetic appearance, odor, or taste of the water**

There is no evidence of an unnatural odor or an unaesthetic appearance in general, none associated with Station operations in particular, and none expected if the proposed thermal standard is adopted.

✓ **No elimination of an established or potential economic or recreational use of the waters**

No economic or recreational uses of the Mississippi River have been eliminated or minimized as a result of the Station's thermal discharge. Recreational fisheries have not been adversely impacted and Pool 14 continues to be a popular fishing destination. During the past 25 years, the number of fishing tournaments on Pool 14 has increased substantially. In fact, four national championship fishing tournaments for walleye and black bass have occurred in Pool 14 within the last 10 years. The Quad Cities Convention & Visitors Bureau and Quad Cities Sports Commission have estimated $500,000 - $1,000,000 of economic impact for the Quad Cities area from each of these individual tournaments (Quad Cities Convention & Visitors Bureau, Personal Communication, 2011). The prospective demonstration for finfish indicates the small increment in added heat that may be released if the proposed standard is implemented will not affect these conditions.

- ✓ **No reductions in the successful completion of life cycles of indigenous species, including those of migratory species**

Retrospective analyses of the long-term monitoring program and the historical biological analyses suggest that thermal effects have not compromised the overall success of indigenous species in completing their life cycles. Freshwater drum population dynamics have been studied in detail annually to detect any adverse effects attributable to operation of Quad Cities Nuclear Station. No measurable effects have been observed over the 28-year study period. Further, as demonstrated in Appendix C (Section 2.9 – Zone of Passage), past operations of QCNS, resulting in a ZOP of less than 75%, have not caused appreciable harm to the BIC. These observations combined with the prospective demonstration for finfish indicate that the small increment in added heat that could be released if the proposed standard is implemented will not cause any change in these conditions.

- ✓ **No substantial reductions of community heterogeneity or trophic structure**

Data collected during the long-term monitoring program conducted at the Station since 1984 suggest that the number of species collected has remained reasonably constant (50-60 species) across years. Any long-term changes in the fish community can be attributed to the change in water quality, clarity, and subsequent vegetation increases, in particular to the main channel border and side channel areas. These changes are seen system wide in the Upper Mississippi River Valley and there is no evidence that the Station's thermal discharge has contributed to these changes. Similarly, the proposed, relatively small, change in the thermal standard is not expected to contribute to any such changes.

- ✓ **No adverse impacts on threatened or endangered species**

The retrospective analysis identifies only one Federal endangered species of mussel in Pool 14 and adjacent pools and one Federal candidate species for the endangered list, the Higgins Eye pearly mussel and the sheepnose mussel, respectively. The analysis indicates that these two species have not been impacted by the Station's thermal discharge and are not expected to be if the proposed thermal standard is implemented. If, during the life of the operating permit, evidence of impact is found or provided, a habitat conservation plan is in place to mitigate these impacts.

- ✓ **No destruction of unique or rare habitat, without a detailed and convincing justification of why the destruction should not constitute a basis of denial**

The unique, but not rare, habitat that could potentially be affected by the thermal discharge is the Cordova Mussel Bed which has been designated as essential habitat for Higgins Eye pearly mussel. This bed is located approximately one mile downstream from the diffuser pipes and has been exposed to the thermal plume over the past 25 years, including the extreme case year of 2006 when water temperatures were unusually high and flows abnormally low. ESI began studying this bed and others in Pool 14 in 2004 continuing through 2008. The data collected indicate that the mussels in this bed were not harmed by the 2006 thermal conditions which are comparable to those that would be permitted under the proposed standard. U.S Fish and Wildlife Service has required Exelon to prepare a habitat conservation plan for Higgins Eye pearly mussel to protect this federally endangered species.

- ✓ **No detrimental interactions with other pollutants, discharges, or water-use activities.**

Operation of QCNS has not had a detrimental effect on recreational (e.g. boating and fishing) or commercial (e.g. shipping and fishing) water-use activities in Pool 14 or on potable water use by communities downstream of QCNS. No cumulative effect with thermal additions discharged by industries upstream has occurred because that heat load is dissipated by the time it reaches the QCNS diffuser pipes. Most heavy metals are bound to the sediments and the chemical reactions that would release these metals are driven by lowering the pH of the water to acidic conditions. Typical pH values in Pool 14 are in the range of 7 to 9 pH units which is basic rather than acidic. Thus, thermal discharges play an insignificant role in these chemical reactions and have not interacted with the sediments to release heavy metals. As discussed above, no harmful interactions with other pollutants such as organic carbon, phosphorus, and nitrogen are expected if the proposed standard is adopted.

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APPENDIX A

Description of the Mississippi River in the Vicinity of Pool 14: Hydrology, Geology, Water Quality, Biology, and Anthropogenic Influences

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1.0 HYDRODYNAMICS AND HYDROLOGY

1.1 Hydrographic Data

The Upper Mississippi River drains approximately 714,000 square miles of watershed and extends from Lake Itasca near Hastings, Minnesota to the mouth of the Ohio River near Cairo, Illinois (Interagency Floodplain Management Review Committee, 1994). This portion of the Mississippi River traverses 1,366 miles and comprises an integral part of one of the largest and most productive aquatic ecosystems in the world. The Upper Mississippi River is divided longitudinally into a series of navigation pools by 29 lock-and-dam structures. Pools are numerically identified as the river flows downstream, except for the two uppermost pools (Upper St. Anthony Falls and Lower St. Anthony Falls).

Pool 14 is approximately 29 miles in length and encompasses the reach of the Mississippi River between Lock and Dam 14 at river mile 493.3 and Lock and Dam 13 at river mile 522.4 at approximately the midpoint of the impounded portion of the river. The Mississippi River at Lock and Dam 14 has a drainage area of approximately 85,600 sq. miles. Tributary streams in Pool 14 add another 2,900 square miles and 1,350 cfs to the mean daily flow. The flow characteristics in the river are distinctly seasonal. Annual high flows typically occur between April and June and the annual low flows occur between December and February. The maximum daily flow was recorded on April 28, 1965 (approximately 307,000 cfs). The minimum daily flow was recorded in 1934 (6,200 cfs), five years before Lock and Dam 14 was placed in operation (USACE, 1974). According to data recorded at USGS gauging station 05420500 located in Clinton, Iowa, the mean annual flow at Lock and Dam 14 is approximately 54,114 cfs for the most recent 40 year period (1968-2008) (USGS, 2009).

1.2 Groundwater

Quad Cities Nuclear Station (QCNS) is located in the Meredosia Channel, an ancient channel of the Mississippi River. The Meredosia Channel has been filled over many thousands of years with unconsolidated sediments ranging in depth from approximately 50 to 300 feet (Blume, 1966). Water for industrial and home use in the region comes from both wells and the Mississippi River.

Groundwater sources in the area are developed from three separate aquifer systems. These aquifer systems are: (1) unconsolidated alluvial and outwash sand and gravel deposits, (2) shallow Silurian dolomitic formations, and (3) artesian sandstone aquifers of the Cambrian-Ordovician age (Commonwealth Edison, 1966).

Some wells within a few miles of the Station pump at rates up to 2000 gallons per minute (gpm). These are in the upper alluvial aquifer at depths of 20 to 100 feet below ground surface (AEC 1972). Groundwater in the area is encountered at depths from approximately 17 to 21 feet (Exelon, 2004).

The Silurian dolomitic rocks, the Niagaran and Alexandrian formations, yield moderate to high quantities of water. The highest yielding wells from the dolomite rock formations are found in areas where unconsolidated sediments consisting of sand and gravel are present (Commonwealth Edison, 1966). Wells extending into the Cambrian-Ordovician sandstones penetrate artesian aquifers that produce large quantities of water (Commonwealth Edison, 1966).

The exploration borings and the logs of wells drilled in the area of the site indicate that the ground water level is approximately 17 to 21 feet below the existing ground surface or, at approximately elevation 573 to 577. Normal pool elevation of the Mississippi River in the vicinity of the site is approximately elevation 572. The ground water gradients in the vicinity of the site are relatively flat and slope generally toward the Mississippi River (Commonwealth Edison, 1966).

There are currently eight operating wells providing water to various systems on Quad Cities Station property. The two primary wells for station operations are Wells 1 and 5. These wells provide water for the domestic drinking water system, make-up demineralizer system and gland seal condenser. The largest single use of groundwater is to maintain the former spray canal for raising fish. Water for this purpose is drawn from Wells 6, 7, 10, and 11. The final two wells, Wells 8 and 9, provide water for fire fighter training exercises and dry cask operations. Wells 2, 3 and 4 have been sealed and abandoned.

Groundwater use from all wells has averaged approximate 500 gpm over the last 10 years.

1.3 Anthropogenic Freshwater Sources

1.3.1 Wastewater Treatment Plant Discharges

QCNS has an operable sewage treatment plant that provides primary and secondary treatment before it is discharged into the Mississippi River. The maximum amount of effluent is 15,000 gallons per day. This is chlorinated to less than 3 ppm; in addition the small amount of total effluent (0.023 cfs compound to a blowdown of about 2200 cfs) is unlikely to be a source of adverse effects. The sewage treatment plant is licensed by the State of Illinois and is under the supervision of a licensed sewage-treatment operator (U.S. Atomic Energy Commission, 1972).

1.3.2 Combined Sewer Overflows

There are no combined sewer overflows from the Quad Cities Nuclear Station. The Quad Cities Generating Station NPDES permit (IL0005037) Special Condition 15 states "The Agency has determined that the effluent limitations in this permit constitute BAT/BCT for storm water which is treated in the existing treatment facilities for purposes of this permit reissuance, and no pollution prevention plan will be required for such storm water. In addition to the chemical specific monitoring required elsewhere in this permit, the permittee shall conduct an annual inspection of the facility site to identify areas contributing to a storm water discharge associated with industrial activity, and determine whether any facility modifications have occurred which result in previously-treated storm water discharges no longer receiving treatment. If any such discharges are identified the permittee shall request a modification of this permit within 30 days after the inspection. Records of the annual inspection shall be retained by the permittee for the term of this permit and be made available to the Agency on request." (IEPA, 2008).

2.0 GEOLOGY

2.1 Bedrock Geology of Northwestern Illinois and Northeastern Iowa

The geologic structure of the region is not complex. The region is situated structurally on the extreme northwest flank of the Illinois Basin. The upper bedrock consists of Paleozoic sedimentary strata which dip gently, on the order of 15 to 20 feet per mile, to the southeast towards the center of the basin. The major structure to the North is the Plum River Fault Zone which trends in the east-west direction through Carroll County and is located approximately 30 miles north of the plant site.

There is no evidence of major faulting in the area. Major tectonic deformation has not occurred in the area since the end of the Mesozoic era, some 60 million years ago. The bedrock is generally covered by unconsolidated deposits of glacial till, outwash, and lacustrine sediments that have been deposited as a result of different glaciations occurring during the Pleistocene Epoch. The upland areas are generally covered with morainal deposits left by the retreating glaciers or with wide-deposited sands or loess. Sediment-laden waters escaping from the melting glaciers and flowing down the bedrock valleys have deposited great thicknesses of sand and gravel in these valleys.

The Paleozoic sedimentary rocks underlying the region are of Silurian age or older. The bedrock units that underlie surficial deposits or that outcrop at the surface are the Niagaran and Alexandrian formations which are dolomitic rocks of Silurian age. Some deep wells in the region have penetrated the entire thickness of the Paleozoic sedimentary rocks. The thickness of the sedimentary rocks is on the order of 3,000 feet and these rocks are underlain by Pre-Cambrian crystalline rocks (Commonwealth Edison, 1966).

2.2 Pre-Glacial History

The site is situated in the Meredosia Channel which is an ancient channel of the Mississippi River. The Meredosia Channel has been filled with unconsolidated sediments ranging in depth from approximately 50 to 300 feet. The exploration test borings drilled at the site and on-site observation of the bluffs along the Mississippi River revealed that the site is underlain by predominantly granular soil (unconsolidated sediments) consisting of fine sand to coarse gravels containing some cobbles and boulders. The unconsolidated sediments were deposited by either the receding glaciers of the last glacial period, or stream action in recent times.

The pre-glacial course of the Mississippi River was immediately north and east of the site. However, the present course of the Mississippi River, over the rapids south of the site, was formed when the Meredosia Channel was blocked, in ancient times, by ice of the last glacial age. A lake was formed in the Meredosia Channel which breached a rocky upland south of the city of Cordova and eroded the present channel (Commonwealth Edison, 1966).

2.3 Glacial History

The bedrock surface in the immediate vicinity of the site has been eroded by the passage of the Mississippi River and the Wapsipinicon River in their ancient channels. The confluence of these ancient channels is believed to be located southeast of the site. The site appears to be located on the southern extremity of a rock hill that was left as an erosional remnant between these channels.

2.4 Erosion and Sedimentation

Erosion rates are measured by estimating soil loss in upland areas and measuring stream bank and stream bed erosion along drainage ways. These measurements are generally not very accurate and thus are estimated indirectly, most often through evaluation of sediment transport rates based on in-stream sediment measurements and empirical equations. Similarly, measurement of sedimentation rates in stream channels is very difficult and expensive.

Sedimentation is the process by which eroded soil is deposited in stream channels, lakes, wetlands and floodplains. In natural systems that have achieved dynamic equilibrium, the rates of erosion and sedimentation are in balance over a long period of time. This results in a stable system, at least until disrupted by extreme events. However, in ecosystems where there are significant human activities such as farming, construction, and hydraulic modifications, the dynamic equilibrium is disturbed, resulting in increased rates of erosion in some areas and a corresponding increased rate of sedimentation in other areas.

The Upper Mississippi River Conservation Committee (UMRCC) state and federal biologists are now addressing sedimentation on several fronts. One of these is through the Environmental Management Program (EMP). The EMP is a cooperative effort between the U.S. Fish and Wildlife Service, the Army Corps of Engineers, and the five UMR states. One of its objectives is to collect sedimentation data and to investigate management alternatives for restoring backwaters impacted by sedimentation. Solving this problem will be an extraordinary task because it will involve taking actions throughout the 100+ million acres of the UMR watershed. Reducing sediment input will require remedial actions from the river's mainstem (reducing stream bank erosion) to the heads of tributaries (farm land or "sheet" erosion) hundreds of miles upstream (UMRCC, 2009).

3.0 METEOROLOGY

The climate of the Mississippi River Basin is sub-humid continental with cold dry winters and warm moist summers. Average annual precipitation varies from about 22 inches in the western part of the basin to 34 inches or more in the east. About 75 percent of the total annual precipitation falls between April and September. Basin-wide, the average monthly temperature ranges from about 11°F in January to 74°F in July. Most of the river within the Upper Mississippi River National Wildlife and Fish Refuge, which covers 261 miles of Mississippi River floodplain from Wabasha, Minnesota to Rock Island, Illinois, usually freezes solid each winter. The global warming trend documented nationally and globally in recent years has affected precipitation patterns in the Midwest, resulting in unusual flooding intensity and duration.

Unusually high floods of long duration have occurred on the Upper Mississippi River over the past decade. Professor James Knox at the University of Wisconsin-Madison has found that “model results and instrument records both support the concept that global warming magnifies hydrologic variability and enhances the hydrologic cycle of the Upper Mississippi River basin (Knox, 2002).” He continues, “analyses of sediment properties [in Wisconsin] indicate that large floods on the Upper Mississippi River have commonly accompanied the beginning of warm and dry climate episodes in the region, but long-term persistence of warming and drought eventually results in smaller floods of high short-term variability. "Short-term occurrences of large floods were common about 4700, 2500-2200, 1800-1500, 1280, 1000-750, and 550-400 calendar years B.P. [before present], all times that approximate rapid warming and drought in the upper Midwest identified by others. The recent high frequency of large floods on the Upper Mississippi River since the early 1990s may be a modern analogue because these floods have accompanied major hemispheric warming during the same period." The research by Knox and others indicates that climate is less stable and predictable than people previously thought, and this means that resilience must be a primary consideration in making management decisions. Resilience requires a largely preventive or precautionary approach that leaves an adequate margin for error. The floodplain marshes and forested islands or bluffs of the Upper Mississippi River corridor could have important future roles to play in excess nutrient processing and carbon sequestration, as a means of mitigating effects of climate change (USF&W, 2006).

3.1 Air Temperature

The QCNS site is located approximately 20 miles north-northeast of the Quad Cities Airport at Moline, Illinois. This area has a temperate continental climate, with a wide temperature range throughout the year. There are some intensely hot, usually humid, periods in summer and severely cold periods in winter. Maxima of 90 degrees or more have occurred in summer as frequently as 55 days and zero or lower readings have occurred every winter. Freezing temperatures have occurred as late in spring as late May and as early in autumn as late September (National Climate Data Center, 2008).

The (5-1/2 foot) surface temperature data for Moline reflects the continental mid-latitude type climate that prevails at the Quad Cities site. In winter temperature has dropped to a low of –28°F. In summer it has climbed to 106°F. There is an average of 23.6 days per year with temperatures reaching 90°F, or higher. There are 15.2 days a year on the average when temperatures reach 0°F or lower. The average annual temperature is 50.2°F; with an average daily maximum of 59.9°F and an average daily minimum of 39.9°F (National Climate Data Center, 2008).

3.2 Precipitation

The average precipitation is about 39 inches per year. Of this total, about 29 inches falls during the growing season (March through September). There is an average of approximately 51 thunderstorms per year in the area, with about 50% of the thunderstorms occurring in July and August (Exelon, 2004).

Snowfall data from Moline is generally representative of the Quad Cities site. Moline receives an average of 35.0 inches of snowfall per year. In 2008, the Moline area received a total of 57.1 inches of snow (National Climate Data Center, 2008).

3.3 Relative Humidity

Relative humidity measured at 1200 hours averages approximately 60% over the course of the year, while at 1800 hours it averages about 63%. During the summer, humidity varies more as a diurnal range than on a monthly average (National Climatic Data Center, 2008).

3.4 Wind

Data gathered from on-site meteorological towers and from the Summary of Hourly Surface Observation at Moline, Illinois, by the U.S. Weather Bureau show a rather uniform distribution of wind direction which is typical of mid-continent locations. The most frequent wind directions are from the southwest and northwest sectors. (A sector is defined as 22-1/2 degrees.) The highest velocity of wind officially reported at various locations around the site is 87 mph at Chicago and 75 mph at Peoria. Higher gusts are reported unofficially, up to 109 mph, during heavy thunderstorms and scattered tornadic activity. Severe winds in the form of tornadoes have also been reported in the Quad Cities region with at least one damaging the plant site (Commonwealth Edison, 1971).

4.0 WATER QUALITY

Quad Cities Station operates with approximately 970,000 gpm discharged to the river with two units running at full power. The combined cooling and service water, heated 28°F above the intake temperature, is discharged through two 16-foot diameter diffuser pipes with nozzles that jet the water into the deepest part of the river channel. Biocides, chlorine, and bromine, are used at the condenser inlets to minimize aquatic growth and bacteria in the condenser tubes. Quad Cities injects a chemical to neutralize the biocide in the discharge bay so that river organisms are not affected by the biocide. A silt dispersant and scale inhibitor are also injected at the river intake. Additionally, biocide, silt dispersant, and a corrosion inhibitor are injected into the service water system. Sanitary waste from the Quad Cities site is sent to the wastewater treatment system and discharged to the Mississippi River.

In addition to serving the cooling needs of Units 1 and 2 at QCNS, the Upper Mississippi River provides water of sufficiently high quality to serve a variety of other uses, including propagation of fish and wildlife and contact recreation. However, river reach IL-M02 (Basin 9), which includes a portion of Pool 14, is identified in the Illinois State 2008 Section 303(d) list of impaired water due to the presence of mercury, polychlorinated biphenyls (PCBs) and manganese. Iowa identifies the portion of Pool 14 from Lock and Dam 13 to the mouth of the Wapsipinicon River as impaired due to aluminum and nutrient loads (2008 Iowa Impaired Waters 303(b) list). The mouth of the Wapsipinicon River is directly across from the station intake.

Pursuant to the Federal Water Pollution Control Act of 1972, also known as the Clean Water Act (CWA), the water quality of the plant effluents is regulated through the National Pollutant Discharge Elimination System (NPDES). The Illinois Environmental Protection Agency (IEPA) is authorized to issue NPDES permits. The current permit (IL0005037) was issued August 26, 2010 and in accordance with the 5-year renewal cycle is due to expire August 31, 2015 (IEPA, 2000b). This permit specifies effluent limits for pH, total residual chlorine, oil, grease, biological oxygen demand, fecal coliform, total suspended solids, boron, temperature and flow. Any new regulations promulgated by the U.S. Environmental Protection Agency (USEPA) or the State of Illinois would be reflected in future permits. The Iowa Department of Natural Resources (IA DNR) is also a signatory on the original Illinois NPDES permit, as the effluents discharge to the waters of both states (U.S. Nuclear Regulatory Commission, 2004).

Nonpoint source inputs from tributary streams, major point source discharges, and river flows are the dominant factors influencing the observed longitudinal water quality patterns. This was especially apparent in Pool 2, where the river flow is relatively low and nonpoint source pollution from the Minnesota River and wastewater discharges from the Twin Cities Metropolitan Area have a strong influence on the river's quality. Large changes in the river's quality are also observed in the lower portion of the UMR, where nonpoint source pollution from large agricultural watersheds, including the Missouri River, contributes to high nutrient and suspended solids concentrations. Point source pollutant abatement activities implemented in the 1980s have resulted in noticeable reductions in total and un-ionized ammonia nitrogen concentrations and increases in dissolved oxygen (DO) concentrations below the Twin Cities Metropolitan Area. Widespread infestations of zebra mussels in the river reach extending from Pool 9 (RM 648) to Pool 14 (RM 494) in the late 1990s are believed to have had some influence on water quality during some summers, and may partly explain the lower DO concentrations reported during late 1990s.

4.1 Water Temperature

The NPDES permit for the Quad Cities Nuclear Station defines a mixing zone as an area of the river where plant releases mix with river water. The plant is required not to exceed the temperature criteria specified in the NPDES permit outside the mixing zone. To ensure compliance with State of Illinois water quality standards, the NPDES permit for Quad Cities contains monthly maximum temperature limits for "representative locations in the main river" at the edge of the designated mixing zone, a maximum temperature increase of 5 $^{\circ}$F above ambient at the edge of the mixing zone, and restrictions on the size of the thermal mixing zone (IEPA 2000b).

An investigation was undertaken to develop strategies and associated diffuser pipe modifications to enable Quad Cities Nuclear Station to operate at full load during periods of low flow. The investigation was conducted in three major phases: development of an optimum configuration of the diffuser pipe systems by analyzing the QCNS thermal-plume data; evaluation of the cooling potential of the cooling canal; and trend analysis of the river-water discharge and temperature data. The summary and conclusions of this investigation are as follows:

- A one-dimensional analytical model and field data from eight surveys during the summer of 1988 and 1989, when the river discharges were unusually low, were used to evaluate the performance of, and to optimize, the existing QCNS diffuser pipe system. The results of the analytical model were in agreement with the field data. The overall mixing of the condenser water discharge with the ambient flow in surveys with discharge ratios less than the critical discharge ratio, was almost uniform, except for local "hot spots" and "cold spots" which occurred, respectively, due to relative deficiency and excess dilution water. A modified temperature monitoring curve, TMC-1, based on the field data and a simple procedure for monitoring the thermal plume were developed.

- Reducing the condenser water discharge near the Iowa shore and increasing it in the deeper portion of the river section could improve the performance of the diffuser system. Another modified temperature monitoring curve, TMC-2, based on the modified distribution of the condenser water discharge was developed. For TMC-2, the minimum river discharge to comply with the thermal standards at full load is about 11,000 cfs.

- The cooling potential of the cooling canal was evaluated by using a one-dimensional plug-flow model. The cooling canal could be used to cool only about 0.9 to 2.2 percent of the maximum condenser water discharge. The cooling canal would be a beneficial adjunct to the optimum diffuser configuration and could be used for river flows less than 11,000 cfs; such flows only occur about .016% of the time. The additional electric power generated by the use of the cooling canal is about 8 to 19 MW-day per year.

- A nonparametric trend test was used to analyze trends in the discharge and temperature data for the Mississippi River at Clinton, Iowa. Neither long-term nor short-term trends were detected in the data.

The NPDES permit for Quad Cities Nuclear Station also contains specific requirements for daily monitoring of plant circulating water flows, daily continuous monitoring of discharge temperatures, weekly determination of river flow rate, daily monitoring of the ambient temperature of the river, daily determination of plant load (percent power), and, as warranted, daily determination of the temperature at a river cross-section 500 feet downstream from the plant's diffuser system. This monitoring allows the operators of QCNS to respond to changing conditions in the river and to adjust power levels to ensure compliance with NPDES temperature limits (IEPA 2000b).

Based on a study of the diffuser system, Exelon concluded that Quad Cities Nuclear Station Units 1 and 2 could operate at full load without violating discharge permit limits under most river flow conditions (ComEd, 1981). To demonstrate compliance at low river flows, Exelon developed a temperature monitoring curve that allowed calculation of permissible plant load as a function of river flow. With these data and the lack of biological effects in the river, as demonstrated by ongoing monitoring, the parties agreed in 1983 to allow open-cycle operation (Open-Cycle Agreement 1983). The temperature monitoring curve was last modified in 2001 to more accurately represent current conditions. The curve may continue to be modified over the license renewal period, under agreement with affected parties (U.S. Nuclear Regulatory Commission, 2004).

4.2 Dissolved Oxygen

Dissolved oxygen (DO) is a critical water quality parameter, and its presence or absence has a dramatic impact on the distribution and abundance of fish and aquatic life in the UMR. All of the states bordering the Upper Mississippi River have established a water quality criterion of 5 mg/L to protect and support aquatic life use, including fisheries. This criterion provides a useful reference for spatial and temporal comparisons. Summer DO concentrations during four time periods generally ranged from about 5 to 12 mg/L in the Upper Mississippi River. DO levels below 5 mg/L have been reported and were most apparent below the Twin Cities Metropolitan Area in the 1980s. In the 1990s, DO concentrations in this reach improved noticeably, primarily as a result of advanced wastewater treatment technology (Johnson and Aasen, 1989; USEPA, 2000).

During the 1995 to 1999 period, DO levels below 5 mg/L were observed in a 150-mile segment of the river extending from Pool 9 to Pool 14 (RM 648 to RM 500). It is suspected that the marked growth and expansion of zebra mussel populations in this reach in 1997 may have contributed to low DO levels, due to zebra mussel respiratory demands and excretory products (Sullivan and Endris, 1998). Additional factors contributing to reduced DO levels in this reach during the 1995 to 1999 period may include increased biochemical oxygen demand and reduced algal and aquatic plant photosynthesis caused by polluted runoff and turbid inflows following major rainfall events. DO concentrations exceeding 15 mg/L were apparent in Pool 8 during the 1990 to1994 period and likely reflect periods of high photosynthetic activity. DO concentrations in the open river reach were generally lower and less variable. This may indicate higher water temperatures (lower DO saturation), increased biochemical oxygen demand and decreased photosynthetic activity (UMRCC, 2002).

4.3 Nutrients

4.3.1 Organic Carbon

There is limited organic carbon data available on the Mississippi River system. However, composite bed sediment samples were collected from the lower one-third of the Upper Mississippi River navigation pools prior to and after the summer flood of 1993. These samples were analyzed for particle size, total organic carbon, nitrogen, trace metals and organic compounds. Bed sediment contaminant concentrations exhibited a general decrease following the flood of 1993. Decreases in pollutant levels were attributed to an increase in the portion of coarser sediment and low inputs or remobilization of contaminated sediments during or immediately following the flood. Bed sediment elevations in the sampling areas were found to increase significantly in the middle (Pools 5-13) and lower (Pools 14-26) reaches and were likely a result of an increase deposition of coarser sediment (Moody et al., 1999).

4.3.2 Total Phosphorus

Phosphorus is an essential plant nutrient and is normally the major element affecting eutrophication in freshwater systems. Like nitrogen, phosphorus can be measured in several forms, but total phosphorus, representing the sum of all those forms, is most commonly measured and reported in water quality surveys. The U.S. EPA has previously suggested a total phosphorus concentration of 0.1 mg/L as a general guidance for protection of flowing waters from eutrophication (Mackenthun, 1973). National and state efforts are currently underway to develop more formal nutrient criteria for lakes and streams (USEPA, 1998). Total phosphorus concentrations were very high throughout the entire UMR, with values greater that 0.5 mg/L at many sites. In general, wastewater treatment plant discharges and urban and agricultural nonpoint source inputs are major sources of phosphorus. In particular, agricultural watersheds contributing high concentrations of sediment are especially important because phosphorus is commonly bound to sediment particles. Maximum phosphorus concentrations exceeded 1 mg/L at many sites during the most recent time period (1995 to 1999) as compared to the previous monitoring periods. Some of these high phosphorus concentrations are likely associated with high total suspended solids concentrations (> 200 mg/L), especially in the lower half of the Upper Mississippi River (UMR). This relationship does not appear to explain the high phosphorus values observed in the upper portion of the UMR, where lower suspended solids concentrations were observed. However, the Minnesota River is a major contributor of suspended solids and phosphorus to the upper portion of the UMR (UMRCC, 2002).

4.3.3 Total Nitrogen

Like phosphorus, nitrogen is also an essential plant nutrient. Nitrogen in surface water may be present in various organic and inorganic forms. As a result, the estimation of total nitrogen content may be based on direct analytical determination, or the combined sum of individual forms such as organic nitrogen, ammonia, nitrite, and nitrate. Nitrogen is an important plant nutrient and has been used in agricultural fertilizers to stimulate the production of agricultural crops, especially corn. Runoff from areas with intensive cultivation or large livestock densities is an important source of nitrogen. In addition, certain industrial discharges and municipal wastewater effluents may contain high concentrations of inorganic nitrogen, especially ammonia or nitrate nitrogen. In oxygenated surface waters, including the Mississippi River, the dominant form of nitrogen is normally nitrate. As a result, total nitrogen concentrations closely follow the patterns and trends exhibited by nitrate nitrogen. On a national scale, excessive nitrogen input from the Mississippi River to the Gulf of Mexico has been implicated in nutrient enrichment and hypoxic conditions in the Gulf (CENR, 2000). Total nitrogen concentrations in the Upper Mississippi River increase markedly in Pool 2 (RM 847.5 to RM 815) as a result of agricultural inputs from the Minnesota River Basin and point source contributions from the Twin Cities Metropolitan Area. Concentrations decrease downstream due to dilution from tributaries with lower nitrogen levels, nutrient assimilation by aquatic plants, denitrification, and sedimentation of particulate organic nitrogen. Nitrogen concentrations increase again below Le Claire, IA (Pool 15, RM 497), likely due to increased nitrogen loading from Iowa and Illinois tributaries.

Based on Pool 2 data collected over the 20-year period, total nitrogen levels were higher in the 1990s than in the 1980s. A similar temporal comparison for the lower reach of the UMR was not possible due to the unavailability of data for the early time periods (UMRCC, 2002).

Nitrite+nitrate nitrogen concentrations throughout the river increased to higher levels in the 1990s, compared to concentrations observed during 1985-89. For the upper river, this response may have been partly associated with changes in municipal wastewater treatment technology (nitrification). However, changes in precipitation and river flow are additional factors associated with river-wide increases in nitrite+nitrate nitrogen concentrations. The drought conditions of the late 1980s reduced nonpoint source runoff and increased utilization of inorganic nitrogen within the riverine pools. Increased nonpoint source runoff in the 1990s likely favored mobilization of nitrite+nitrate nitrogen from agricultural watersheds, resulting in high nitrogen concentrations in the river during this period.

4.4 pH

Measurements of pH provide an index of the acidity or alkalinity of water. Most UMR states have adopted a standard that incorporates a pH range from 6 to 9 units to protect and support aquatic life use, including fisheries. Monitoring agencies have typically used different methods to measure pH. Most summer pH values in the UMR range from 7 to 9 units, thus normally supporting full fish and aquatic life standards. At a number of locations during several time periods, summer pH values have exceeded 9. These elevated pH values were likely the result of high levels of photosynthetic activity (UMRCC, 2002).

The relatively high pH values recorded in the Upper Mississippi River can be traced to the underlying dolomitic bedrock which has high concentrations of calcium and magnesium carbonates, both of which contribute to higher pH values upon dissolution.

4.5 Water Transparency

Total suspended solids (TSS) represent the amount of filterable particulate material in water, expressed as mg/L. In general, the concentration of TSS increases with increasing river flow. Higher flows may result in increased sediment suspension or may reflect periods of runoff, both of which contribute to higher TSS concentrations. In particular, runoff from watersheds with a predominance of cultivated lands is an important source of suspended matter in the river. In addition, stream bank erosion in many tributaries contributes large loading of TSS to the river during high flow events. Once TSS has reached the river, the particulate material may contribute to sedimentation problems in backwaters, negatively influence submersed aquatic plant growth due to decreased light penetration, smother benthic invertebrates, and lead to other impairments. The states have not adopted TSS standards for the river. Highest TSS concentrations (> 500 mg/L) are found in the lower portion of the Upper Mississippi River (below RM 200) and are attributed to turbid inflows from the Illinois and Missouri Rivers. The Minnesota River is the major source of TSS in the upper portion of the river and contributes to elevated concentrations from its confluence with the UMR (RM 844) to the St. Croix River (RM 811.5) where levels decrease due to dilution. Lowest TSS concentrations in the UMR are normally found at the mouth of Lake Pepin (RM 764.5), a 25-mile long natural riverine lake, which acts as an effective sediment trap (Engstrom and Almendinger, 1998).

5.0 HUMAN USE

5.1 Surrounding Land Use

The Quad Cities Nuclear Station site is located in the Upper Mississippi River Basin, on the east bank of Pool 14 of the Mississippi River, about 16 miles below Dam 13 and 13 miles from Dam 14. The station is approximately 506.5 miles upstream from its confluence with the Ohio River (i.e., river mile [RM] 506.5). The site is on moderately high ground that rises abruptly from the surface of the river to form bluffs between 20 feet and 40 feet high. It is situated in the Meredosia Channel, an ancient channel of the Mississippi River. The topography of the site is flat, with an elevation of 23 feet above normal pool level and a grade level approximately 9 feet above the maximum recorded flood stage over a 102-year period. The river flow of the adjacent Pool 14 (an approximately 25 mile section), between Lock and Dam 13 and Lock and Dam 14 is controlled below flood stage (U.S. Nuclear Regulatory Commission, 2004).

The QCNS site consists of 920 acres. In addition to the two nuclear reactors and their turbine buildings, intake and discharge canals, and ancillary buildings, the site includes switchyards and a retired spray canal now utilized to raise fish. The retired spray canal is approximately 3 miles long and 250 feet wide and it surrounds the plant and occupies approximately 90 acres. A publicly available, paved bicycle trail passes along the eastern edge of the site property, adjacent to Route 84. The Rock Island County Land Use Plan designates the site as industrial use (U.S. Nuclear Regulatory Commission, 2004).

The Quad Cities metropolitan area, consisting of the Cities of Davenport and Bettendorf, Iowa and Rock Island, Moline, and East Moline, Illinois is located 20 miles southwest of QCNS. QCNS is about four miles north of Cordova, Illinois, and ten miles southwest of Clinton, Iowa.

The region within six miles of the site includes portions of Rock Island and Whiteside Counties in Illinois and Scott and Clinton Counties in Iowa. The area surrounding QCNS is predominantly rural, consisting of farmland and woods; however, there is an industrial park approximately one mile north of the Station and a gas-fired power plant approximately one mile southeast of QCNS. The lower segment of the Upper Mississippi River National Wildlife Refuge is across the river from QCNS, providing habitat for numerous plant and animal species. The predominant land cover in this section of the refuge is woody terrestrial with a small portion characterized by wetland emergents (Exelon, 2004).

5.2 Recreational Uses

Boating is an important recreational activity throughout the Upper Mississippi River and its tributaries. Houseboats, powerboats and fishing boats of all types are used during the warmer months of the year. Indiscriminate boat mooring along the shore is a problem influenced by the ownership of waterfront property. There are evidently limited amounts of public frontage available to boat owners. Gas and oil spills, as well as litter and human wastes discharged from these boats affect the water quality.

Sand bars, especially fresh ones, are prime river recreational areas. Boaters, swimmers, picnickers, and others seem to pick fresh sand bars over all other habitats for their recreational site. These sand bars are created at the upper ends of pools from spoil materials dredged from the river bed. The open sandy dredge bank remains a breach for a period of 5 to 6 years before sand willows become established. Sand bar formation and the associated recreational demand is probably lower at the Quad Cities site which is located some distance from both Dam 13 and Dam 14, the major areas of sand-bar formation in the Quad Cities region.

Fishing is one of the more intensely pursued recreational activities in Pool 14. Many local and non-local fishermen fish this area for many species including walleye, sauger, largemouth bass, bluegill, channel catfish, black and white crappie, and hybrid striped bass throughout the year as fishing regulations permit. Many local bass fishing tournaments are held annually on Pool 14 and several national walleye and bass tournaments have fished this Pool.

5.3 Transportation

5.3.1 Shipping

U.S. Army Corps of Engineers maintains the commercial shipping channel and operates the Lock and Dam system on the Upper Mississippi River. Clinton maintains a municipal dock directly accessible from the Mississippi Navigation Channel. Beaver Slough, a secondary channel of the river, provides an additional connection between Clinton and the navigation channel. Other towns along the shore of Pool 14 that have direct access to the Channel are Fulton, Comanche, Princeton and Le Claire (U.S. Army Corps of Engineers, 1974).

5.3.2 Airports

The Quad Cities Airport, which is located about 20 miles southwest of QCNS in Moline, IL, is the major commercial airport serving the region. Several major airlines maintain daily flight schedules to other cities in the Midwest including St. Louis and Chicago.

The Clinton Airport is located 3 miles southwest of Clinton, IA and is owned and operated by the City of Clinton. It currently serves the private sector, primarily. All municipalities along Pool 14 have access to both the Clinton Airport and the Whiteside County Airport near Rock Falls, Illinois.

5.3.3 Highways

Illinois State Route 84, a two lane paved road, follows the east bank of the river for the entire length of Pool 14, intersects Interstate 80 south of Rapids City and joins Illinois Highway 92, continuing its parallel course with the river. On the Iowa bank of the river, U.S. Highway 67 follows the entire length of the pool.

Three highway bridges cross the river within the Pool 14 area. The Fulton Bridge is a two-lane span that carries the traffic of U.S. 30A and State Road 136; the Clinton Bridge is also a two-lane span that carries U.S. 30 traffic. The Interstate 80 Bridge, south of Rapids City and Le Claire, carries two-lane traffic in each direction (U.S. Army Corps of Engineers, 1974).

5.4 Municipal, Commercial, and Industrial Use

QCNS is located on Mississippi River Pool 14, an impoundment that was established by the U.S. Army Corps of Engineers and continues to be maintained by the Corps.

Approximately one mile north of QCNS is an industrial park with several plants, the largest of which is operated by Minnesota Mining and Manufacturing Company (3M). This plant manufactures hydrofluorethers. Many of the facilities in this complex discharge to the air and to the Mississippi River. The town of Clinton, Iowa, about 10 miles upriver, also contains several large industrial facilities that influence the environmental quality of Pool 14. One such plant is the M.L.Kapp Station, a 235-megawatt coal-fired electrical generating station owned by Alliant Energy. Another is the ADM corn processing plant.

In addition to the existing, long-term industrial base near QCNS, there is a recently completed gas-fired generating plant located less than one mile southeast of QCNS. The Station is owned by MidAmerican Energy who completed the 500-megawatt Cordova Energy Center in June 2001. It withdraws makeup water for condenser cooling from groundwater, but discharges its blowdown to Pool 14 at ambient temperatures (Exelon, 2004).

5.5 Contaminants

Land use practices, floods, other natural events, spills, and other human caused incidents within the watershed affect contaminant levels in river water and sediments. These, in turn, affect quality and quantity of fish and wildlife habitat. Dissolved oxygen (DO) is crucial to fish and invertebrate survival and DO levels are good indicators of pollution (Soballe and Wiener, 1999). Water quality of the Upper Mississippi River has improved in recent decades in the area of gross sewage pollution, but the river still receives a wide array of agricultural, industrial, and urban contaminants. The risks and threats of certain herbicides, such as atrazine, on the aquatic biota are largely unknown. Excessive nutrients cause excessive plant growth, which upon decomposition, can impact benthic organisms such as fingernail clams. Polychlorinated biphenyls (PCBs) have been linked to a contaminated Upper Mississippi River food web affecting fish, mink, and burrowing mayflies (Soballe and Wiener, 1999).

The Lost Mound Unit of the Upper Mississippi River National Wildlife and Fish Refuge was formerly the Savanna Army Depot, which was placed on the National Priorities List for Superfund Cleanup in 1989. The Savanna Army Depot officially closed on March 18, 2000, as part of the Base Realignment and Closure Act. The former Depot included a total of 13,062 acres that have been transferred to four agencies: the U.S. Fish and Wildlife Service; the Local Redevelopment Authority; the U.S. Army Corps of Engineers; and the Illinois Department of Natural Resources.

On September 26, 2003, the Department of Defense agreed to transfer 9,404 acres of land to become the Lost Mound Unit of the Upper Mississippi River National Wildlife and Fish Refuge. A total of 3,022 acres was actually transferred in fee at the time of the signing of the Memorandum of Agreement. The remaining acreage will be transferred in the future as parcels are certified clean from environmental contaminants. In the meantime, the Service will manage wildlife and habitat on all 9,404 acres. The Lost Mound Unit was included in a comprehensive conservation plan (CCP) completed by the Upper Mississippi River National Wildlife and Fish Refuge in 2006. The CCP is intended to outline how the Refuge will fulfill its legal purpose and contribute to the National Wildlife Refuge System's wildlife, habitat and public use goals (USFWS, 2009).

5.6 Organic Contaminants—Types, Sources, and Risks

The Mississippi River receives a variety of organic wastes, some of which are detrimental to human health and aquatic organisms. Urban areas, farms, factories, and individual households all contribute to contamination of the Mississippi River by organic compounds. This contamination is important to consider because about 70 cities rely on the Mississippi River as a source of drinking water. Considerable gains have been made in the last two decades in controlling point-source contamination, but control of nonpoint-source contamination has been more difficult.

Organic contaminants in the Mississippi River were assessed by collecting water and sediment samples between Minneapolis-St. Paul, Minnesota, and New Orleans, Louisiana, during 10 sampling surveys conducted in 1987-92, and analyzing the samples for the organic contaminants and indicator compounds listed in Table A-1.

The most significant factors controlling the concentrations of organic contaminants in rivers are the physical processes of dispersion and dilution. Within this physical framework, the most significant chemical and biological processes controlling the fate of organic contaminants in the Mississippi River are (1) sorption to the sediment and removal by deposition, (2) desorption and diffusion of contaminants from bed sediments back into the water, (3) biological transformation to intermediate compounds, or biodegradation for complete removal, (4) volatilization to the atmosphere, (5) bioconcentration and magnification in the food chain, (6) photolysis, or the breakdown of contaminants under the influence of sunlight, and (7) hydrolysis, or the decomposition of contaminants by taking up the elements of water. Organic compounds of the type called "hydrophobic" (meaning that they prefer being adsorbed onto sediment or organic particles to being dissolved in water) can be adsorbed onto sediments in concentrations that are a thousand to a million times greater than in the associated water. Once they are adsorbed, the contaminants can be deposited and eventually become buried as sediments continue to accumulate. Buried contaminants can be remobilized, however, by resuspension of the sediments. Likewise, the sedimentary organic matter may decompose, reintroducing its adsorbed contaminants to the river by desorption and diffusion of organic colloids. If the contaminants are adsorbed onto the sediments in high concentrations, they can adversely affect bottom-dwelling organisms. The tendency of a contaminant to adsorb onto the sediment is frequently indicative of its capacity to bioconcentrate and become magnified in the food chain.

A summary of the major organic contaminants identified, their range of concentrations, their water-quality criteria, and their environmental fate is presented in Table A-2. Fecal coliform bacteria was the only contaminant that exceeded health limits. Although concentrations of most organic compounds measured in this study were below regulatory limits, their distributions indicate that the entire Mississippi River has been contaminated by point and nonpoint sources. Significant sources of organic contaminants include municipal-wastewater discharge, urban runoff, power-plant cooling-water discharges, pulp-mill effluents, feedlot runoff, commercial and recreational river traffic and refueling, discharges from industrial facilities, and agricultural runoff.

The Mississippi River carries higher concentrations of organic contaminants in the vicinity of major metropolitan areas. Concentrations are typically greatest in the upper river where the stream- dilution factors are lowest. Major tributaries such as the Minnesota, Illinois, Missouri, and Ohio Rivers have significant effects on the organic chemistry of the Mississippi River. Seasonal differences are related to hydrologic, climatic, biological, and geochemical factors. Concentrations are greatest during periods of low flow (fall) and least during periods of high flow (spring). Likewise, concentrations of biologically labile and volatile organic compounds are greatest during the winter when temperatures are lowest.

Although the data presented above provide only a brief glimpse of the water quality of the Mississippi River, comparisons with historical data show trends of improving water quality for several constituents. The improvements can be related to: (1) changes made by the chemical manufacturing industry to address the environmental fate of problematic chemicals, and (2) improved wastewater treatment by municipal and industrial dischargers. Converting primary treatment facilities to secondary treatment has resulted in improved water quality, although chemicals that are not completely removed present a challenge for treatment technology (Meade et al., 1995).

5.7 Heavy Metals Contaminants

Metals in the Mississippi River come from natural as well as artificial sources. Metals that are naturally introduced into the river come primarily from such sources as rock weathering, soil erosion, or the dissolution of water-soluble salts. Naturally occurring metals move through aquatic environments independently of human activities, usually without any detrimental effects. However, as the valleys of the Mississippi River and its tributaries were settled and industrialized, the metals added by human activities have affected the water quality of the Mississippi River and ultimately the Gulf of Mexico. Some of these metals are essential for proper metabolism in all living organisms yet toxic at high concentrations; other metals currently thought of as non-essential are toxic even at relatively low concentrations.

Heavy metals are released to the Mississippi River from numerous artificial sources. Typical sources are municipal wastewater-treatment plants, manufacturing industries, mining, and rural agricultural cultivation and fertilization. Heavy metals are transported as either dissolved species in water or as an integral part of suspended sediments, and may be volatilized to the atmosphere or stored in riverbed sediments. Toxic heavy metals are taken up by organisms with the metals dissolved in water having the greatest potential of causing the most deleterious effects.

The heavy metals are defined as those having densities five times greater than water. Well-known examples of heavy metallic elements are iron, lead, and copper. Many heavy metals can become toxic or aesthetically undesirable when their concentrations are too great. Several heavy metals, like cadmium, lead, and mercury, are highly toxic at relatively low concentrations, can accumulate in body tissues over long periods of time, and are nonessential for biological well-being.

No specific health guidelines for heavy metals associated with suspended or bed sediments have been established by the U.S. Environmental Protection Agency. This lack of national guidelines based on concise scientific criteria causes difficulty when evaluating the environmental effects of heavy metals in sediments.

Two of the largest lead-zinc mining areas in the world are located along the Mississippi River between Prairie du Chien, Wisconsin, and Galena, Illinois; thus providing the opportunity for these metals to enter the river system. Cultivated soils can become enriched with toxic metals associated with the application of fertilizers and pesticides. Although the concentrations may vary between specific formulations, many of these fertilizers contain chromium, copper, iron, manganese, nickel, and zinc. Some pesticides use heavy metals such as mercury as an integral component. During the late spring and early summer, after fertilizers and pesticides have been applied, the runoff from rain flushes these contaminants into the Mississippi River.

The atmosphere is also a source of metal contamination to aquatic environments. Metal-containing particulates that are washed from the atmosphere by rain and snow are deposited in drainage basins and find their way into lakes and rivers. As of 1973, the total nationwide airborne particulate emissions were distributed basically among three sources: 51 percent from industrial processes, 29 percent from fossil-fuel combustion, and 20 percent from miscellaneous burning practices (Magee et al., 1973). Since 1973, vehicle emissions (and perhaps other emissions as well) have decreased. Stone and rock crushing, iron and steel foundries, grain-handling operations, and cement production emit the greatest percentage of the particulates. Coal, used extensively for power generation, often contains significant concentrations of metals such as vanadium, copper, nickel, chromium, zinc, lanthanum, cobalt, molybdenum, gallium, germanium, tin, and mercury (Magee et al., 1973).

The numerous studies of the heavy-metal water quality of the Mississippi River that have been conducted over the last several decades have emphasized mostly the water quality in specific regions of the river. However, the study performed by Garbarino, Hayes, Roth, Antweiler, Brinton and Taylor assesses the heavy-metal contamination through the full length of the Mississippi River from Minneapolis, Minnesota, to the Gulf of Mexico using one set of field scientists and one set of laboratory analysts for the duration of the study. Heavy metals released into the Mississippi River, by both natural processes and human activities, can be either transported with the water and suspended sediment or stored within the riverbed bottom sediments.

The different chemical forms of heavy metals in the river influence their availability and toxicity to organisms. Heavy metals are readily available to aquatic organisms and pose a significant health hazard when they are present as dissolved inorganic or organic species in the water or loosely adsorbed to particulate surfaces. When heavy metals are present as components of particulates, such as inorganic metal-hydroxide coatings or metal-organic compounds, some chemical alterations are required before they can be released and become biologically available. Even stronger chemical reactions (cation exchange) are required to release heavy metals that are integral parts of the minerals composing river sediments. These reactions are driven by pH rather than temperature.

Information on heavy metals in the Mississippi River that are described in this section generally was based on data collected during the summer and autumn of 1991 and the spring of 1992. Data that were collected in the Lower Mississippi River during 1987-90 (Brinton et al., 1995) reinforce the findings presented here. Concentrations of toxic heavy metals dissolved in the water in the 1,800-mile reach of the Mississippi River from Minneapolis, Minnesota, to Belle Chasse, Louisiana, are well below USEPA guidelines for drinking water and water that supports aquatic life. However, heavy metals associated with suspended sediments exceeded the pollution guidelines at many of the main-stem sampling locations. Heavy-metal concentrations in the suspended sediments were generally greater in the small colloidal-sized particles than the larger silt-sized particles. Even though the colloids compose a significantly lower percentage of the total suspended sediment, their heavy-metal concentrations are greater. Sediments stored in pools upstream from every lock and dam of the Upper Mississippi River also have elevated heavy-metal concentrations. The biological accessibility to heavy metals associated with suspended and stored sediment also depends on the chemical form in which the metal exists (Meade, 1995).

Whether the loads and concentrations of heavy metals in the Mississippi River have increased or decreased in recent years is difficult to determine. Although most of the heavy metals in the river are associated with sediment, most of the previous studies have focused on the dissolved metals. Even for the dissolved metals, comparisons are difficult to draw between earlier and more recent data because analytical laboratory techniques have become markedly more sensitive in the last decade and field sampling techniques have not been adequately standardized. Specific conclusions about increases or decreases in heavy metals with time in the Mississippi River are tenuous at best (Meade et al., 1995).

5.8 Other Stressors

In the Upper Mississippi River basin, sedimentation and toxic contaminants have been identified as the major threats to biotic resources (Wiener et al. 1984).

5.8.1 Contaminant Concentrations in Surface Waters

Land use practices, floods, other natural events, spills, and other human caused incidents within the watershed affect contaminant levels in river water and sediments. Agricultural fields, animal feedlots, and urban areas are principle sources for plant nutrients that enter the river (Soballe and Wiener, 1999). Excessive inputs of nitrogen and phosphorus can cause algal blooms, contribute to excessive plant growth and subsequent decomposition that depletes DO (limiting fish and other aquatic life distribution and survival), and cause public health concerns. Plant decomposition in the sediment can also be a source of ammonia that adversely affects burrowing organisms such as fingernail clams and mayflies (USFWS, 2006)

5.8.2 Contaminant Concentrations in Sediments

The Upper Mississippi River transports moderate to high quantities of sediments that enter the river from row crop farming, mining, and urban development. Turbidity levels, a measure of suspended sediments, at the Maquoketa River (Pool 13) in Iowa are more than double all up-river inputs combined. This reflects a substantial increase in inputs from erodible agricultural lands. Sediments fill backwaters and reduce the diversity of water depths. Sediments also absorb and transport containments.

5.8.3 Contaminant Concentrations in Animal Tissue

Polychlorinated biphenyls (PCBs) have been linked to a contaminated Upper Mississippi River food web affecting fish, mink, and burrowing mayflies (Soballe and Wiener, 1999).

In 1993, investigators collected great blue heron eggs from 10 colonies on the Upper Mississippi River (8 on the Refuge) to determine the effect of organochlorines, mercury, and selenium on heron nesting (Custer et al., 1997). The authors concluded that these contaminants do not seem to be a serious threat to nesting great blue herons on the Upper Mississippi River. Organochlorine concentrations (including DDE, the metabolite of the insecticide DDT or dichlordiephenyltrichloroethane) were generally low (mean DDE = 1.3 µg/g; PCB = 3.0 µg/g; TCDD [dioxin] = 11.5 µg/g). Eggshell thickness was negatively correlated with DDE concentrations but eggshell averaged only 2.3 percent thinner than eggs collected during the years prior to the use of DDT. Mercury and selenium concentrations (mean = 0.8 and 3.1 µg/g, respectively) in eggs were within background levels.

Mercury and PCBs are present in fish of the Mississippi River. Sources of mercury are both natural and man-made; PCBs do not occur naturally. Both contaminants build up through the food chain and the highest levels occur in predatory fish (walleyes, bass, and northern pike), scavengers (catfish) and bottom feeders (carp). Fish consumption advisories are issued by the Health Departments of the four states overlapping the Upper Mississippi River National Wildlife & Fish Refuge.

Minnesota, Wisconsin, and Illinois all have advisories directed primarily toward reducing intake of mercury and PCBs by pregnant women and children under the age of 15. Minnesota and Wisconsin have detailed advisories for consumption of fish taken from various pools of the Refuge. However, the extent of consumption and the number of species included on the lists vary between states along the same pool.

6.0 AQUATIC HABITATS

Pool 14 encompasses a variety of aquatic habitats and communities in the vicinity of Quad Cities Station. Although municipal and industrial waste discharges from the Clinton, Iowa area have occasionally resulted in excessive slime growths in the slough areas in the vicinity of the station, Pool 14 is a relatively unpolluted environment. (U.S. Atomic Energy Commission, 1972)

Major Mississippi River habitats near the station are the channel habitat, channel border habitat, side-channel habitat, river lake and pond habitat, slough habitat, and island lake habitat. These habitats are chiefly defined by location, depth, bottom material and vegetation. The main channel in the vicinity of the station is characterized by a scoured sand bottom and the highest current velocity. Directly downstream from the station along the Illinois shore are several small islands with adjacent, relatively quiet, shallow water areas. Further downstream, across the main channel, are extensive areas of side channel and slough habitats. The 16-mile portion of the pool upstream of the station has a large amount of side-channel and slough habitat, five or six times as much as that downstream from the station (U.S. Atomic Energy Commission, 1972).

7.0 AQUATIC LIFE

Biological studies in Pool 14 and other pools in the river have established the existence of relatively diverse and productive planktonic, periphytic and benthic communities which support commercial and sport fisheries.

7.1 Producers

7.1.1 Submerged Aquatic Vegetation

Submerged aquatic vegetation includes plants that grow below the surface of the water and are usually anchored to the bottom by their roots. This group of plants generates dissolved oxygen, filter suspended material, stabilize bottom sediments, and cycle nutrients (Rogers and Theiling, 1999). Submerged aquatics provide crucial fish habitat, provide substrate for invertebrate growth, and are important foods for mammals and migratory birds. They are most often found in backwater areas of low water velocity, adequate light penetration and relatively stable water levels. Beginning in the 1960s and 1970s, river scientists and users noted declines in submerged (and emergent) vegetation cover throughout the Refuge. Factors included wind and wave action, poor light penetration due to highly turbid water conditions, sedimentation and filling of backwaters, major flooding events, and long term inundation with few drying periods. Due to these factors, there is an uneven distribution of submerged plants through the length of the Refuge. Recovery of lost submerged plant beds has occurred naturally or through habitat rehabilitation projects in Pools 4, 5A, 7, 8, 9, and 13. Within the last decade, beds of submerged plants have been naturally re-established throughout Pool 14 (HDR, 2009a; USF&WS, 2006).

7.1.2 Emergent Aquatic Vegetation

Emergent aquatic vegetation (emergents) are plants whose roots are anchored under water with much of the plant extending above the water surface. They include cattail, river bulrush, giant reed grass, burreed, arrowheads and wild rice. They are backwater plants adapted to low water velocities and shallow- to deep-water marsh conditions. The emergent plant community in Pool 14 and throughout this reach of the river is sparse and a concern of resource managers. It is characterized by the abundant river bulrush and reduced numbers of cattail, burreed, and arrowhead. Much of the declines of the last three taxa has occurred since the 1970's (USF&WS, 2006)

7.1.3 Phytoplankton

Biological studies conducted for Commonwealth Edison by Biotest Laboratories Inc. (1970 a, b) documented that the most prevalent phytoplankton were diatoms of genera Cyclotella, Melosira, and Stephanodiscus. Even in summer samples, diatoms were the common organisms and blue-green alga seldom comprised 10% of the population. Species lists of typical phytoplankton species found near Quad Cities Station during the periods March through July 1972 and August 1972 through January 1973 are given in Tables 2 and 3 of the report titled "An Evaluation of the Quad Cities Station of Commonwealth Edison Company for a 316(a) Demonstration" dated January, 1975. This original January, 1975 316(a) Report concludes that organisms present between river mile 501 and 509 in the Mississippi River are characteristic of a somewhat enriched habitat and, although seasonal variations exist, the phytoplankton communities have been relatively stable. Comparisons of total phytoplankton, major algal divisions, and dominant species at locations upstream and downstream from the originally designed side-jet discharge or of the diffuser pipe dissipation system indicated that neither mode of heat discharge had any detectable effect upon phytoplankton numbers or community composition. This evidence led to the eventual discontinuation of phytoplankton studies in the Mississippi River in the area of Quad Cities Station (Commonwealth Edison, 1975).

Phytoplankton studies were conducted in conjunction with and at the same locations as zooplankton studies from August 1972 through August 1973. During full open-cycle cooling, an overall stimulatory effect on phytoplankton was measured in the river downstream of the diffuser pipe, which was not interpreted as a negative influence. Mean values for carbon fixation rates, chlorophyll *a* concentrations and phytoplankton abundances during chlorination and non-chlorination periods were compared at several upstream and downstream locations. No trends of significant differences ($P<0.05$) in phytoplankton productivity and chlorophyll *a* concentrations for the sample period between the sampling locations immediately upstream and downstream of the diffuser pipes were observed. Many of the individually significant differences that were identified during this period between upstream and downstream locations were attributed to non-homogeneity of phytoplankton populations between locations.

7.1.4 Periphyton

Growth of periphyton occurs upon many submerged substrates in the Mississippi River. Biological studies conducted for Commonwealth Edison by Industrial Bio-Test Laboratories, Inc. (1970 a, b) in Pool 14 indicate that periphytic growths are common on logs and rocks in slack-water locations. Cladophora was the principal genus in the periphyton of Pool 14, although a variety of other forms (Oscillatoria, Melosira, Stigeoclonium and Lyngbya) were common. During July, abundant growths of blue-green algae (Aphanizomenon) were collected on substrata at two locations. Also, Microcystis was found to be abundant at one location and Plectonema at one location from this monitoring. A species list of typical periphytic alga found in the vicinity of Quad Cities Station during May-June 1972 monitoring by Industrial Biotest Laboratories Inc. is given in Table 4 of the report titled "An Evaluation of the Quad Cities Station of Commonwealth Edison Company for a 316(a) Demonstration" dated January, 1975. No consistent differences between upstream and downstream periphyton colonizing the artificial substrates were attributable to diffuser pipe operation (Clark, 1974). All changes in periphytic algal communities or chlorophyll a production were related to seasonal fluctuations or other hydrological conditions and were not affected by operation of the Quad Cities Station during the diffuser pipe mode of discharge. This evidence led to the discontinuation of periphyton studies in the Mississippi River in the area of Quad Cities Station (Commonwealth Edison, 1975).

7.2 Consumers

7.2.1 Zooplankton

The nature and distribution of zooplankton populations in the Mississippi River, particularly in Pool 14, has not been well documented with the exception of the work that has been conducted for Commonwealth Edison Company by Industrial Bio-Test Laboratories, Inc. Studies in other river systems in North America, however, have described the nature of these organisms and examined the problem of survival in relationship to a variety of factors. The relationship between species richness and abundance in streams appears to be largely due to changes in flow rate and specific habitats within a specific river system. Studies in Pool 14 substantiate this finding. One of the major factors affecting variations in zooplankton density and community composition at locations with similar habitats are the hydrological conditions in the river. Densities were found to be inversely related to flow conditions while the species richness observed on a particular sampling date was directly related to flow. The dynamic nature of the Mississippi River with its variable flow and water levels, as well as the contribution from its many tributaries, enhances the randomness of zooplankton distribution (Commonwealth Edison, 1975).

The zooplankton community in Pool 14 is dominated by several true planktonic species such as Cyclops vernalis, Cyclops bicuspidatus thomasi, Diaptomus siciloides, and Bosmina longiorstris. Additional dominant taxa are total Rotiferia and tycohoplanter Chydorus spaericus. Other species such as Diaphanosoma spp. and Moina spp. demonstrate seasonal pulses. Remaining species are considered incidental forms which are present as results of hydrologic conditions (Commonwealth Edison, 1975).

Figures 4 and 5 of the original 316(a) report (Commonwealth Edison, 1975) show the seasonal variations of the zooplankton community in the Mississippi River from February 1973 through January 1974. Table 5 of this report is a species list of the typical representative planktonic crustaceans collected during the period August 1973 through January 1974. Comparisons of total zooplankton and the three major groups of zooplankters prior to and during all phases of the station operation at locations upstream and downstream from the Quad Cities Station did not reveal any differences attributable to plant operations. This evidence led to the eventual discontinuation of zooplankton studies in the Mississippi River in the area of Quad Cities Station (Commonwealth Edison, 1975).

7.2.2 Benthic Invertebrates

In the July 1969 – June 1970 study by Industrial Bio-Test Laboratories, Inc. the benthic organisms were found to be composed mainly of "facultative" forms (adaptable to a wide range of conditions). The dominant organisms were insects of the orders Ephemeroptera (mayflies), Trichoptera (caddisflies), and Diptera (family Chironomidae or midge flies). Oligochaete worms were present in some of the organically rich sediments. Samples from the main channel contained few organisms probably because of a combination of two factors: (1) scouring action of the current and (2) the presence of sandy substrates which are regarded as unsuitable habitat for aquatic animals (Hynes, 1970). In areas such as wing dams, sloughs, and shorelines, which are protected from the current and where more suitable substrates occur, a greater abundance and diversity of invertebrates were observed. In July, 1970, two genera, midges (*Chironomus*) and sludge worms (*Limnodrilus*), were the two most abundant groups present, comprising 34.7 and 41.1 percent of the 297 organisms collected. Other groups, such as crustaceans, caddisflies, and leeches comprised 3% or less of the total organisms found during this period. Mollusks were found in very small numbers and generally exhibited no consistent pattern of distribution. A species list of typical benthic invertebrates collected in the Mississippi River near the Quad Cities Station during the periods of February – July 1973 and August 1973 – January 24, 1974 is shown in Tables 6 and 7 of the 316(a) demonstration (1975). Analyses of the data indicated no discernable effects on the benthos relative to the thermal discharge from Quad Cities Station. The benthos data that was compiled over a four year time period indicated that the variation of the major organisms between locations upstream and downstream of Quad Cities Station was due to seasonal fluctuations, substrate differences and changes in river flows. This evidence led to the discontinuation of benthic studies in the Mississippi River in the area of Quad Cities Nuclear Station.

Studies of aquatic macroinvertebrates were conducted during 1972 in Pool 14 (U.S. Army Corps of Engineers, 1974). During this study, 33 families representing 40-53 genera were found to be present. The Chironomidae (midges) consistently contributed the major portion of genera (13 to 28) and represented 28 to 50 percent of the total genera identified in the samples. The mussels (Unionidae) most often contributed the second highest number of genera, with four to six, or nine to 13 percent of the genera present. The highly productive mayflies (Ephemeridae) contributed three or four genera (seven to nine percent) to most samples. Other invertebrate families were usually represented by only one genus although one family of the caddisflies (Hydropsychidae) was often represented by three genera.

The caddisflies (Trichoptera) generally contributed the greatest numbers of individuals at two stations sampled along the navigation channel between miles 504.5 and 506; however, midges (primarily Chrironomidae) nearly equaled the caddisflies in numbers of individuals collected. Mayflies, sideswimmers (amphipoda), and aquatic worms (Oligochaeta) occupied the next three positions in number of individuals collected in most samples.

Caddisfly larvae, snails (Gastropoda), stonefly nymphs (Plecoptera), and mussels (Unionidae) live on course substrates. Caddisflies and sideswimmers live on a variety of substrates, including the silty bottoms of Pool 14. Midges, mayflies, and aquatic earthworms are confined mostly to silty bottoms.

7.2.3 Drifting Invertebrates

Sampling for drifting macroinvertebrates was conducted in 1971 in Pool 14. The dominant forms comprising typical drift organisms during the period April through December 1971 are shown in Table 8 of the 316(a) demonstration (Commonwealth Edison, 1975). Subsequent to that time sampling for drifting macroinvertebrates was conducted near the area of the diffuser pipe discharge from May-November 1972. The amphipod Hyalella azteca was the most abundant drifting invertebrate collected. Mayfly nymphs, Hexagenia spp., were the second most abundant taxa in the collections, and the two-winged fly Chaoborus punctipennis was the third most abundant taxon collected.. Other important organisms reaching high seasonal peaks were: caddisfies (Cheumatopsyche sp., Potamyia flava, and Hydropsyche orris); mayflies (Caenis spp., Brachycerus spp., Tricorytnodes spp., Baetis spp., Baetisca spp., and Isonychia spp.); water mites (Acari sp), and a diverse population of midges. No consistent effects on the drifting macroinvertebrate populations were attributable to operation of the diffuser-pipe mode of heat dissipation. This evidence led to the discontinuation of drifting benthic macroinvertebrate studies in the Mississippi River in the area of Quad Cities Station.

7.2.4 Mussels

The Upper Mississippi River contains a rich assemblage of freshwater mussels. Historically, as many as 50 species of mussels were documented from the Upper Mississippi River, but only 30 species have been reported in recent surveys. Two of these are listed as federally endangered; and many of the others are rare (i.e., listed as endangered, threatened, rare, or of special concern by one or more states (USGS, 1999). The freshwater mussels have been adversely impacted by activities such as the pearl button and cultered pearl industries, siltation (associated with agriculture, poor land management, and impoundments), pollution from agricultural and industrial chemicals, establishment and maintenance of the navigation channel, and competition from exotic species, particularly the zebra mussel (*Dreissena polymorpha*) (Exelon 2003; USGS, 1999). A high mussel die-off occurred in Pools 14 and 15 in the 1980s, but the cause was not identified (USGS, 1999).

Mussels are often found in dense aggregations called mussel beds. While these beds may be miles apart, an individual bed can be up to several miles long (USGS, 1999). Thirty-one species of unionid have been collected from Pool 14. The most abundant species include threeridge (*Amblema p. plicata*; 37.9 percent), pimpleback (*Quadrula p. pustulosa*; 16.4 percent), plain pocketbook (*Lampsilis cardium*; 10.1 percent), Wabash pigtoe (*Fusconaia flava*; 6.2 percent), threehorn wartyback (*Obliquaria reflexa*; 5.8 percent), mapleleaf (*Quadrula quadrula*; 4.8 percent), and giant floater (*Pyganodon grandis*; 4.5 percent) (Exelon 2003a). These species are widespread and relatively common throughout the Mississippi River and its tributaries (Cummings and Mayer, 1992). Populations of fingernail clams (Sphaeriidae) have declined in certain reaches of the Upper Mississippi River during recent decades. The declines have occurred chiefly during low-flow periods associated with droughts (Fremling and Drazkowski, 2000).

The zebra mussel became established in the upper Mississippi River by 1992 and has continued to spread throughout the river system. Their increase causes a decline among many native mussels, as it can out-compete native species for oxygen and food and is so prolific that it can smother native mussels (USFWS 2001c). The zebra mussel has also increasingly displaced other macroinvertebrates, such as hydropsychid caddisflies that live on submerged hard surfaces (Fremling and Drazkowski, 2000).

The Higgins' eye pearlymussel (*Lampsilis higginsi*) was listed as a federally endangered species on June 14, 1976 (41 FR 24064) (USFWS 1976). It is only found in the Mississippi River, St. Croix River in Wisconsin, the Wisconsin River, and the Rock River in Illinois. It was never abundant, historically comprising only about 0.5 percent of the mussel population. At the time the original recovery plan was written in 1983, the Higgins' eye pearlymussel had undergone a 53 percent decrease in its known range (USFWS undated). It is generally found in mussel beds with at least 15 other species present (USFWS 2003b).

No critical habitat has been designated for the Higgins' eye pearlymussel. However, fourteen Essential Habitat Areas for this species occur within the Upper Mississippi River watershed. Essential Habitat Areas are locations known to contain reproducing populations in association with a healthy and diverse unionid community (e.g., mussel beds) (USFWS, 1998). An Essential Habitat Area begins approximately 1.0 mile downstream of Quad Cities, Units 1 and 2 at River Mile (RM) 505.5 and continues to RM 503.0 at Cordova, Illinois (USFWS, 2003b). A second essential habitat (designated in 2008) begins at RM 509.1 and continues to RM 510.1. This area is known as Hanson's Slough.

The only other Essential Habitat Area located downstream of the Quad Cities site occurs in Pool 15 in the Sylvan Slough at RMs 485.5 through 486.0, and pool 16 near Buffalo, Iowa at RM 470-471 The other Essential Habitat Areas are upstream of Pool 14 in Pools 9, 10, and 11 of the Mississippi River, St. Croix River, and the Wisconsin River (USFWS, 2003b; USFWS, 2008). Nearly all the remaining habitat for the Higgins' eye pearlymussel within the Mississippi River occurs within the navigation channel. In a 2000 Biological Opinion, the USFWS concluded that the continued operation and maintenance of the navigation channel would jeopardize the continued existence of the Higgins' eye pearlymussel (USFWS, 2000a).

Several mussel species have been designated as threatened or endangered by the State of Illinois and the State of Iowa. The spectaclecase (*Cumberlandia monodonta*), which is listed as endangered in both Illinois and Iowa, inhabits large rivers with swiftly flowing waters among boulders in patches of sand, cobble, or gravel in areas where current is reduced (Cummings and Mayer, 1992). Within Illinois, it is currently restricted to the Mississippi River (Herkert, 1992).

The butterfly (*Ellipsaria lineolata*), which is listed as threatened in both Illinois and Iowa, usually inhabits medium to large rivers. It inhabits areas of strong current on coarse sand or gravel bottoms and at water depths from a few inches to four feet (Parmalee, 1967). The black sandshell (*Ligumia recta*), which is listed as threatened in Illinois, is a medium to large river species that occurs in riffles or raceways on firm sand or gravel bottoms at depths of four-to-six feet or more. It is less tolerant of siltation and pollution than many other mussel species (Cummins and Mayer, 1992; Herkert, 1998; Parmalee, 1967). The sheepnose (*Plethobasus cyphyus*), which is listed as endangered in both Iowa and Illinois, inhabits currents of medium to large rivers in gravel or mixed sand and gravel substrates at depths of up to 6.6 feet (Cummings and Mayer, 1992; Parmalee, 1967). Reasons for the decline of these mussel species are similar to those discussed above for the Higgins' eye pearlymussel; dredging, sand and gravel mining, siltation, pollution, and/or zebra mussels (Herkert, 1992, 1998).

In 2004, Exelon established a monitoring program for freshwater unionids near the QCNS thermal discharge diffuser. The purpose of the monitoring program is to provide data and information regarding the unionid community, to evaluate the effects QCNS discharge has had on the community, and to establish the baseline unionid community characteristics for comparison with community characteristics observed following the issuance of alternate thermal standards.

Three unionid beds occur within 3500 m (approximately two river miles) of the QCNS thermal diffuser: The Steamboat Slough (SS) Bed, located approximately 675 to 1125 meters (m) downstream of the QCNS mixing zone; the Upstream (UP) Bed, located approximately 730 to 1130 m upstream of the QCNS diffuser; and the Cordova Bed, located about 3300 to 3700 m downstream of QCNS (Figure 1-1). Ecological Specialists, Inc. (ESI) monitored each of these unionid beds in 2004, 2005, 2006, 2007, and 2008. In 2007, the monitoring program added 400 m sections of three additional beds to further evaluate unionid community characteristics among and within unionid beds. The three additions were: The Albany Bed, located approximately 14,000 to 14,400 m upstream of the diffuser, Hansons Slough (HS) Bed, located approximately 5000 to 5400 m upstream of the diffuser, and Woodwards Grove (WG) Bed located approximately 10,500 to 10,900 m downstream of the diffuser.

Upstream Bed

The Upstream Bed habitat has remained consistent among monitoring events (July 2004, July and October 2005, August and September 2006, October 2007, August 2008). The UP Bed is located near the mouth of the Wapsipinicon River and upstream of the QCNS diffuser discharge. Substrate in the Upstream bed is a mixture of sand, silt, and clay, with sand being the major constituent. However, substrate constituents varied considerably among sample points. Substrate in the shallower areas at the upstream end of the bed contained more clay, and sand was more abundant along the edges of the bed (ESI, 2009).

Steamboat Slough Bed

The Steamboat Slough Bed is located approximately 750 m downstream of the QCNS mixing zone. In previous years, the northern portion of the sampling area was downstream and riverward of a small island. This island was absent in 2007 and 2008. Substrate in the SS Bed was primarily sand in 2004 and 2005, but in 2006 silt increased from <10% to >20%, forming a layer over the sand. Substrate in 2007 was nearly equal parts sand and silt, with silt forming a layer over the sand. Substrate again changed in 2008; with an average of 55% sand and 39% silt. However, substrate in the upstream part of the bed contained more silt, and substrate in the downstream portion of the bed consisted of sand mounds with silt valleys. Unionids were more abundant in the silt valleys. This change in substrate with flow conditions (low flow years more silt, higher flow in Spring/Summer 2008 resulting in sand and silt waves) was not as apparent in other unionid beds (ESI, 2009).

Cordova Bed

The Cordova Bed is one of the Essential Habitat Areas designated in the *L. higginsii* recovery plan (USFWS, 2004). The portion of the Cordova Bed sampled in this study is approximately 3300 m downstream of QCNS mixing zone, on the Illinois bank of the river. The Cordova Bed differs from the Upstream and Steamboat Slough beds in that it occurs along a slight outside bend in the river and its substrate is coarser (higher percentages of gravel, cobble, and shell). Zebra mussel shells contributed 44% to substrate constituents in 2007, but only 13% in 2008 perhaps due to high spring flows. In some areas, a 1 to 1.5 ft layer of dead zebra mussel shells covered the substrate in 2007, whereas dead zebra shells were mixed in the substrate in 2008, although live zebra mussels covered the substrate in some parts of the bed (ESI, 2009).

Albany Bed

Albany Bed was the upstream-most bed sampled. The bed extends upstream from Albany, IL (near RM 513) to Cattail Slough (near RM 516). Although very long, the bed is narrow, extending an average of only about 40 m from the bank into the river. The widest portion of the bed (about 70 m wide) was within the town of Albany, IL, near RM 513 and was selected for sampling. Land use along the riverbank is residential, and the bank is lined with rip-rap. The Albany Bed was most similar to the Cordova Bed in habitat characteristics. Substrate was primarily zebra mussel shells mixed with cobble, gravel, and sand. Substrate was silty near the bank, a heterogeneous mixture within 40 m of the bank, and well sorted sand or zebra mussel shells riverward of 40 m in 2008 (ESI, 2009).

Hansons Slough Bed

The Hansons Slough Bed (HS Bed) is upstream of the QCNS diffuser, approximately 4600 to 6400 m. The bed appears to extend from approximately RM 509.1 to 510.1. This bed was recently (USFWS, 2008) designated as an Essential Habitat Area (EHA) based on the criteria for designation listed in the Higgins' Eye recovery plan (USFWS, 2004). These criteria include *L. higginsii* comprise at least 0.25% of the community (0.4% in 2008 HS Bed), density >10/m^2 (HS Bed density 11.1/m^2 in 2007), and contain at least 15 other unionid species with density >0.01/m^2 (19 other species in HS Bed >0.01/m^2). The bed is within the upstream portion of Hansons Slough and within a dike field, similar to the SS Bed. However, the HS Bed was shallower (0.3 to 2.7 m) and substrate was sandier and less silty (primarily fine sand similar to UP Bed) than within the SS Bed (ESI, 2009).

Woodwards Grove Bed

The Woodwards Grove mussel bed is downstream of the QCNS diffuser, approximately 8300 to 10,900 m. The bed appears to extend from approximately RM 499.5 to 500.8 along the Iowa bank within a slight outside bend. The bed extends from the bank at least 150 m riverward. Other than zebra mussels, substrate was primarily silt and clay closer to the bank, turning to finer sand riverward. A deeper, sandy channel occurred in the center of the bed in 2008, perhaps a result of high spring flow in 2008 (ESI, 2009).

The high ambient water temperature and low river flows over almost a month in July/August 2006 resulted in the use of 222.75 excursion hours in 2006. Although July and August water temperatures in 2007 were high, they never reached 2006 levels and only 74.00 excursion hours were used in 2007. Unusually high discharges occurred in mid-August 2007 that reduced water temperatures. Substrate temperature was similar to water temperature in 2007, and the buffering effect noted in 2006 was not observed in 2007. High flows (>200,000 cfs) occurred within Pool 14 in early 2008. Water temperature and substrate temperature within the monitored mussel beds remained fairly low throughout the summer. The high spring flow did affect substrate characteristics at least in the SS Bed, where sand peaks and silt valleys were observed in the downstream portions of the sampled area, and perhaps in the WG Bed, where a sandy, deep channel bisected the bed in 2008. Flow was fairly low during the August sampling (27,000 to 33,500 cfs), but did not fall to the levels observed in August of 2006 and 2007 (<20,000cfs). No excursion hours were used in 2008, and some current velocity was present at sample points in all beds except the Cordova Bed. The area within 10 to 20m of the Cordova Bed was covered with a heavy algae mat, which was not observed in other monitoring years (ESI, 2009).

Changes to unionid community characteristics were observed in all three beds in 2006 compared to prior years. However, these changes seemed to be temporary or simply due to stochastic factors. Community characteristics in October 2007 and August 2008 in the UP, SS, and Cordova beds were similar to previous monitoring events. In 2007 and 2008, recruitment (% young individuals) was high and mortality was low. Total density of live unionids fluctuated among monitoring events, but no increasing or decreasing trends were apparent (see Figure 4-1 of ESI, 2009). Increased mortality was observed in the UP and Cordova beds in 2006, but declined to pre-2006 levels in 2007 and 2008 (see Figure 4-1 of ESI, 2009). Density of both live Ambleminae and Lampsilinae has similarly fluctuated over time (Figure 4-2 of ESI, 2009). Most of the increase in 2006 mortality, particularly in the UP Bed, was due to mortality of Lampsilinae (Figure 4-3 of ESI, 2009), which was most apparent upstream of the QCNS (ESI, 2009).

The monitoring program added three beds in October 2007: Albany Bed, HS Bed, and WG Bed. The Albany Bed shared many of the same habitat and unionid community characteristics with the Cordova Bed in both 2007 and 2008. Both of these beds appear to have been heavily affected by zebra mussel infestation, species composition was similar, and species richness higher than in other beds. *Ligumia recta* and *L. higginsii* were fairly common in both beds. The HS Bed shares some habitat and community characteristics with both the SS and UP beds. The bed is within a slough and dike field similar to the SS Bed, but substrate consisted more of fine sand similar to the UP Bed. Zebra mussel infestation was also apparent within this bed in 2007, but shells were not a major substrate constituent. However, zebra mussel infestation in the HS and SS beds was much lower than within other beds in 2008. Similar to the SS Bed, Ambleminae dominated the community, and the percentage of young Ambleminae was high and Lampsilinae low in the HS Bed, but *Q. p. pustulosa* rather than *A. plicata* was the dominant species. Similar to the UP Bed, density was high in the HS Bed and *L. higginsii* were present. The WG Bed, downstream of QCNS, differed in substrate (mostly silt and clay) but shared some community characteristics with the other beds. Adding these beds to the 2007 and 2008 study expanded the knowledge base for comparisons of mussel bed and community characteristics upstream and downstream of the QCNS diffuser, and strengthened the conclusions that can be drawn from such comparisons in evaluating the impacts, if any, on the mussel beds and communities associated with the plant's discharges.

The 2007 and 2008 studies show that community characteristics within unionid beds sampled in this study do not seem to be significantly affected by the QCNS thermal effluent, including the increased river temperatures experienced during the Summer of 2006, at least in the short-term. Unionid beds downstream of the QCNS exhibited similarities and differences in habitat and unionid community characteristics with unionid beds upstream of the QCNS. Increased mortality noted in some beds in 2006 was not observed in 2007 or 2008 and did not appear to affect unionid density either upstream or downstream of the QCNS (ESI, 2009).

7.2.5 Fish

Adult and Juvenile Fish

Despite the modifications and multiple competing uses of the Upper Mississippi River, the overall fish biodiversity has been persistent and resilient (USGS, 1999). The river's main channel, navigation and wing dams, side channels, sloughs, chutes, backwater lakes and ponds, marsh areas, flooded bottomland forests, and tributaries create diverse habitats for at least 118 species of fish (USFWS 1991a). However, over-wintering habitats for fish have declined due to water depth reductions caused by sedimentation. Also, recent die-offs of aquatic vegetation have reduced the suitability of many areas as nursery habitats for fishes (Fremling and Drazkowski, 2000). Within the last decade, this trend has been reversed in Pool 14 (HDR, 2009a).

Ninety-four (94) fish species representing 22 families have been collected in Pool 14 during the 41-year monitoring program at QCNS (Table A-3). Hybrid striped bass, hybrid sunfish and one carp X goldfish hybrid have also been collected. Steuck et al. (2010) list 163 species that have been collected in the Upper Mississippi River, 100 of them in Pool 14. Seven species on Steuck's list for Pool 14 have not been collected by the QCNS program, but one species that was not listed by Steuck et al., crystal darter (*Crystallaria asprella*), has been identified. The crystal darter that was collected in 2009 (HDR, 2010) was thought to have been extirpated from this reach of the Mississippi River since the early 1900's. This species has not been reported as collected from any of the pools (Pools 1-26) listed by Steuck et al. (2010), but a few individuals have been collected in Iowa waters in recent years near the confluence of the Turkey River and the Mississippi River (RM 608) in Clayton County, Iowa (Pool 11), and two specimans were collected from the Mississippi River near Cotton Island (RM 77) downstream of Grand Tower (Jackson County, Illinois) in 1998 and at Picayune Chute (RM 55, Alexander County, Illinois) in 2004(Stewart, et al., 2005). Prior to that, the crystal darter had not been collected in Illinois since 1901.

Three cyprinid species (bigmouth shiner, southern redbelly dace, and pearl dace) were captured exclusively by minnow seining that was conducted during the early years (prior to 1976) of the QCNS long-term monitoring program (Bowzer and Lippincott, 1995). Six of the species collected are presently listed as endangered (weed shiner, pearl dace, lake sturgeon) or threatened (grass pickerel, western sand darter, chestnut lamprey) by the Iowa DNR (2009).

Five of the species collected are listed as endangered (lake sturgeon, pallid shiner, weed shiner, western sand darter) or threatened (longnose sucker) by the Illinois Endangered Species Board (2011). The crystal darter is not currently protected in either Iowa or Illinois as it was assumed to have been extirpated from the waters of both states.

Review of historical data failed to document the collection of the starhead topminnow as was first reported in 1983. Several species have been represented by only one or two specimens during the 41-year monitoring program. Most were collected by minnow seine or impingement during the early years of the monitoring program. These species include the lake trout, grass carp, central stoneroller, weed shiner, common shiner, mimic shiner, southern redbelly dace, pearl dace, blacknose dace, longnose sucker, and pallid shiner.

Fish species considered abundant within the Upper Mississippi River include gizzard shad (*Dorosoma cepedianum*), common carp (*Cyprinus carpio*), emerald shiner (*Notropis atherinoides*), river shiner (*N. blennius*), bullhead minnow (*Pimephales vigilax*), and bluegill (*Lepomis macrichirus*). Common species include longnose and shortnose gar (*Lepisosteus osseus* and *L. platostomus*), bowfin (*Amia calva*), mooneye (*Hiodon tergisus*), spottail shiner (*N. hudsonius*), river carpsucker (*Carpiodes carpio*), quillback (*C. cyprinus*), bigmouth buffalo (*Ictiobus cyprinellus*), shorthead redhorse (*Moxostoma macrolepidotum*), channel catfish (*Ictalurus punctatus*), white and hybrid striped bass (*Morone chrysops* and *M. chrysops x M. saxatilis*), rock bass (*Ambloplites rupestris*), green sunfish (*Lepomis cyanellus*), and river darter (*Percina shumardi*) (Bowzer and Lippincott, 2000; USFWS 1991a). Favorite sport fish species include walleye, sauger (*Stizostedion canadense*), largemouth bass (*Micropterus salmoides*), smallmouth bass (*M.dolomieu*), white bass, bluegill, black and white crappie (*Pomoxis nigromaculatus* and *P. annularis*), pumpkinseed (*L. gibbosus*), and channel catfish (USFWS 1991a). Commercial fisheries also exist for some species, such as the bigmouth buffalo, common carp, catfish and bullheads, and freshwater drum (*Aplodinotus grunniens*) (USFWS 1991a). The carp is the most important non-native fish species in the Mississippi River, comprising most of the commercial harvest; it is the dominant species in the Upper Mississippi River (USGS, 1999).

The abundance of walleye and hybrid striped bass has increased in the vicinity of the Quad Cities site since 1985 due to stocking of these fish (Bowzer and Lippincott, 2000; LaJeone and Monzingo, 2000). The walleyes are reared in the Quad Cities Units 1 and 2 inactive spray canal, while hybrid striped bass are maintained in the fish laboratory at the Quad Cities site (Exelon, 2003a). Conservatively, the adult walleye population in Pool 14 is comprised of approximately 30 percent stocked fish, with lesser, yet measurable contributions to downstream pools (LaJeone and Monzingo, 2000). Results indicate that the contribution of stocked walleye to the population of

Age 0 walleye in the Pool is within the range of 15-40% most years (HDR, 2009b). Riverine species, such as the freshwater drum, channel catfish, flathead catfish (*Pylodictis olivaris*), and white bass have generally increased in Pool 14; while backwater species, such as white and black crappies have generally decreased due to degradation of the backwater areas and sloughs from sedimentation associated with operation of the 9-foot navigation channel (Bowzer and Lippincott, 2000).

Population estimates for freshwater drum are considered to be relative among years rather than absolute estimates because very few marked fish are recaptured in any year. Age analysis indicates that freshwater drum are long lived in Pool 14, often exceeding age 20 and occasionally age 30. Survival has averaged between 70 and 75% for the past 29 years. Maximum theoretical growth has steadily increased since 1983. Standing crops vary amongst years because this metric is driven by population estimates and year class strength (HDR, 2009a).

Trends in the long term data base include increases in numbers of freshwater drum, channel catfish, largemouth bass, bluegill and decreases in the numbers of white crappie, black crappie, and sauger. These trends are apparent at locations both upstream and downstream of the diffuser pipes and most likely are the product of long term sampling at fixed locations that have undergone substantial habitat changes such as backwater siltation and the appearance of beds of rooted aquatic plants (HDR, 2009b).

The trend in haul seine catches is that they are dominated by large gizzard shad and freshwater drum. Gizzard shad, freshwater drum, bluegill, white bass and channel catfish have consistently dominated impingement. Gizzard shad and freshwater drum together typically account for more than 80% of fish impinged by number and weight each year. Impinged fish are predominately small, juvenile specimens, regardless of species (HDR, 2009b).

Impingement increases in the fall and remains high throughout the spring under any operational mode. Peak impingement occurs during the winter months with very few fish being impinged during the May-August period. Since the return to open-cycle operation in 1984, annual projections of fish impinged have been highly variable. In any year, the level of fish impingement is influenced by several environmental variables such as river flow, winter conditions, and standing crop of individual species. Station operation influences impingement depending on the number of units operating; however, Station operation is relatively constant compared to the high variability of environmental factors affecting the River's fishery (HDR, 2009b). Despite the ineffectiveness of barrier nets in reducing impingement under open-cycle operation, the ecological impact of such losses appears to be minimal. Evaluation of the condition of fish trapped on the intake barrier net indicates that greater than 90% of the fish impinged during the winter months are drifting passively with the river flow and are either dead or moribund when they arrive at the intake (LMS, 1989). Gizzard shad and freshwater drum are particularly sensitive to near freezing water temperatures, which result in greatly reduced swimming stamina and high mortality (Lewis and Bodensteiner, 1986; Lippincott, 2006). The high rate of fish impingement occurring during the winter is not a result of Station operation, but a reflection of natural high winter mortality for species such as gizzard shad and freshwater drum.

An estimated total of 9,194,604 fish (uncorrected for dead and moribund fish) representing 75 taxa, 72 species, and 20 families were collected in 538 impingement collections that were conducted from January 1996 through December 2005 (HDR/LMS, 2007). The 538 impingement samples represent 12,728 hours of sampling effort. The total number of taxa collected during each year of the 10-year period ranged from 52 (1998) to 61 (2002). Total estimated annual impingement for the 10-year period ranged from 173,046 fish in 1998 (due to an extended two unit outage) to 1,600,676 fish (2001), with a 10-year estimated mean of 919,460 fish/year.

The 10-year data set and the data from each individual year shows that fluctuations in the fish community in Pool 14 do not result from impingement effects but that they are driven by changes in natural conditions. It has become evident over the Long Term Aquatic Monitoring Program that fluctuations in impingement are reflecting the natural dynamic equilibrium of populations that occur in the pool and are not driving those changes.

Ichthyoplankton

During sampling in 1978 and 1979, freshwater drum eggs and larvae were abundant at all locations, demonstrating that all of Pool 14 above the Station serves as a spawning and nursing area (LMS, 1986). Results also showed sizable contribution of freshwater drum eggs and larvae to Pool 14 and Pool 13. The intensive 1978 study concluded that there was little difference between average day and night abundance; however, more ichthyoplankton was caught during the day than at night. The difference, less than 10%, was statistically significant due to the large of number of samples included in the hypothesis testing. There were also no substantial differences in vertical distribution of all larval stages combined. A few statistically significant differences in vertical distribution were found, (yolk-sac larvae, which exhibited much higher abundances in the bottom samples at night) which was to be expected given the large number of tests conducted. There were, however, horizontal differences in abundances, with the Illinois side of the river exhibiting greater larval abundances than the Iowa side. These conclusions were based on all larval stages combined (LMS, 1986). Sampling at these locations was discontinued after 1979 because the objectives of the 1978 and 1979 programs were met.

From 1980 through 1983 only one location was sampled upstream of the intake (LMS, 1986). In previous years a minimum of three upstream locations were sampled. This adequately documented the diel, vertical, and horizontal differences in ichthyoplankton abundance. The return to an open-cycle operation in 1984 necessitated a more intensive ichthyoplankton sampling that included entrainment monitoring. Ichthyoplankton samples were collected near the surface and bottom on the Illinois side, in midchannel, and on the Iowa side in Pool 14 of the Mississippi River in the vicinity of the Quad Cities Station and only at the surface in the discharge canal in 1984 and 1985. These samples and results are the most indicative of current operations (LMS, 1986).

Ichthyoplankton (fish egg and larvae) typically begins to drift by QCNS in late April or early May and continues to be present into August with the peak numbers (driven by freshwater drum) passing the Station during the first half of June. Based on information derived from river ichthyoplankton monitoring studies (LMS, 1985 and LMS, 1986), 65 to 96% of the total larvae and 94 to 99% of freshwater drum larvae cumulative passage occurs by the end of June. Peak larval drift tends to occur at ambient river temperatures in the range of 21 to 23ºC.

The results of this program showed that eggs were present in the river from April 30 to July 30. Freshwater drum eggs made up 84.0% of the catch and emerald shiner eggs constituted another 11.7%. Cyprinid, carp, and unidentifiable eggs constituted the remaining 4.3%. Approximately 84% of the freshwater drum eggs drift occurred between 7 and 28 May; 95% of the drift occurred during a nine-week period ending July 2. This drift period was similar to that of previous years with the exception of 1983, which was unusually short. A two-way ANOVA was preformed on freshwater drum and emerald shiner eggs. Freshwater drum egg concentrations were significantly higher on the Illinois side than on the Iowa side of the river. No other differences were found.

Larvae of 23 taxa were collected during these studies. Freshwater drum, emerald shiner, and cyprinids were the most abundant taxa collected. Collectively, these three taxa constituted 90.4% of the total catch. The remaining 20 taxa constituted 9.6% of the catch. ANOVAs were preformed on densities of the seven most abundant species using location and depth. During most years of sampling, freshwater drum larval concentrations were greatest near the Illinois shoreline with concentrations being significantly lower in the mid-river and near the Iowa shoreline (LMS, 1986). Mid-river is defined as being approximately 1100 ft from the Illinois

Bank. The nearest open port to the Illinois bank is about 840 ft from the shoreline or approximately 80% of the distance to mid-river. Consequently, most of the freshwater drum larvae drifting through this portion of the river will not pass over the open ports. Therefore, it is expected that the majority of these larvae will not be exposed to the maximum discharge temperatures which would result in thermal mortality.

The analysis also showed that gizzard shad densities were significantly different by location, with higher densities occurring on the Iowa side of the river. No other species exhibited significant location difference. Emerald shiner, cyprinid, and gizzard shad densities were significantly greater near the surface. Freshwater drum densities were significantly greater near the bottom. All other results indicated no significant differences in densities in 1985.

The effect of potentially being exposed to an instantaneous increase of 15.2°C as larvae pass the diffusers was evaluated (LMS, 2000b). Several conditions of this potential exposure are described below.

- The nearest open port to the Illinois shoreline is approximately 840 ft from the shore.
- The nearest open port to the Iowa shoreline is approximately 200 ft from the Iowa bank.
- The river width at the diffuser placement is approximately 2200 ft.
- Ports are spaced 19-20 ft apart in the deeper portions of the river and 39-40 ft apart in the shallow zones.
- Ports are angled 20° from the bottom.
- This analysis was a worst-case approximation because it assumed that all organisms were exposed to the maximum temperature. This most likely is not true either vertically or horizontally.
- Duration of exposure to maximum temperature is not known; but several assumptions regarding incipient lethal temperatures (ILT), which are threshold temperatures for mortality, and incorporation of flow information permitted modeling that predicts mortality.
- Data were developed for total larvae, freshwater drum, and gizzard shad. These species are the two most abundant species taken in impingement collections at the Station (LMS, 2000b) and freshwater drum was selected as the indicator species for the Station's fish monitoring program beginning in 1980.
- Estimates of mortality were calculated for a variety of ambient river temperatures to determine the thresholds at which mortality begins to occur.

Based on data collected during river fish larvae monitoring (LMS, 1985 and LMS, 1986), peak larval drift tends to occur at ambient river temperatures in the range of 21 to 23ºC. Estimates of mortality at these temperatures indicate that there will be no mortality. By contrast, species that spawn during the June through August period may lose some percentage of their larvae at the maximum temperature increase of 15.2ºC, depending upon river flow and ambient river temperatures.

Data indicate that mortality for freshwater drum larvae will begin to occur at an ambient river temperature of about 22ºC and river flows of approximately 30,000 cfs. Mortality is expected to remain below 1% until ambient river temperatures reach approximately 23.5ºC at this flow. These data suggest that this thermal addition has little effect on freshwater drum through their period of peak drift. The small percentage of freshwater drum larvae that are spawned later in the summer may experience high mortality as they drift over the diffusers. A similar comparison of data calculated for gizzard shad indicates that mortality will first occur at ambient river temperatures of approximately 25ºC for ILT's of 28 and 29ºC when flows are about 30,000 cfs. As the flows increase, these threshold ambient river temperatures for mortality increase. It is expected that, at flows in the range of 60,000 cfs, threshold ambient river temperatures for mortality would exceed 25ºC. Only those gizzard shad spawned later in the season when flows are lower may suffer some mortality.

8.0 BIRDS

The Upper Mississippi River National Wildlife & Fish Refuge is a 261-mile refuge, which is the longest river refuge in the continental U.S. The refuge begins at the confluence of the Chippewa River near Wabasha, Minnesota, and ends near Rock Island, Illinois. The refuge lies within four states: Minnesota, Wisconsin, Iowa, and Illinois. The refuge provides migratory habitat for a large percentage of the migratory birds in the Mississippi Flyway, through which an estimated 40 percent of the continent's waterfowl migrate. It is a critical migration corridor (Reid et al., 1989) for 10 species including tundra swans, ring-necked duck and hooded merganser. The other seven species are also on the U.S. Fish & Wildlife Service's Region 3 Resource Conservation Priority List and include: lesser snow geese, Canada geese, wood duck, mallard, blue-winged teal, canvasback, and lesser scaup.

Songbirds include a wide array of land birds such as hummingbirds and woodpeckers, as well as the large order of birds called passerines or "perching" birds. Passerines comprise more than half the world's species of birds. The refuge still provides a vital migration corridor for songbirds, many of which fly thousands of miles each year between Central and South America and the

United States and Canada. It is estimated that millions of birds migrate through the area each year.

Colonial nesting birds on the refuge include species that nest on floating mats of aquatic vegetation, such as the black tern, and tree-nesting species, including great blue herons, double-crested cormorants, great egrets, and green herons. Colonies are often on islands and/or located in the upper third of the pools where forests are more extensive. Secretive marsh birds include bitterns and rails that utilize wet meadow and emergent wetland habitats, both of which are declining on the refuge.

Raptors are birds of prey that include vultures, hawks, and eagles. Several species nest on the Refuge and more migrate along the Mississippi River Corridor. The refuge supports approximately 160 nesting pairs of bald eagles. The bald eagle, northern goshawk, red-shouldered hawk, and peregrine falcon occur on the refuge and are on the Regional Resource Conservation Priority list. In recent years, large numbers of bald eagles spend the winters along the shoreline of Pool 14 (USFWS, 2006).

9.0 THREATENED AND ENDANGERED SPECIES

This section addresses one federally listed threatened and endangered species and three candidate threatened and endangered species that occur on or very near the refuge. State listed threatened and endangered species are not described in this section but will be addressed in the Comprehensive Conservation Plan and appropriate step-down plans. The state listed species that occur on refuge include: six mammals, 40 birds, 18 fish, seven reptiles, three amphibians, and 20 mussels (USFWS, 2006).

9.1 Higgins Eye Pearlymussel

The Higgins eye pearlymussel *(Lampsilis higginsii)* was listed as endangered in 1976 due to declines in abundance and distribution. Higgins eye pearlymussel recovery teams have identified Essential Habitat Areas that are believed to contain viable reproducing *L. higginsii* populations. These teams indicate that recovery of the species could not be accomplished without maintaining the Essential Habitat Area populations. One of the 14 identified Essential Habitat Areas, Cordova, Illinois, Pool 14 (River Mile 503.0 - 505.5) is located immediately downstream of the diffuser pipes (USFWS, 2008).

9. 2 Candidate Threatened and Endangered Species

The eastern massasauga rattlesnake *(Sistrurus catenatus catenatus)* has declined throughout its range, an area that extends from New York and southern Ontario westward to Iowa and Missouri. Small populations of massasaugas are scattered along the length of the lower Wapsipincon River in Scott and Clinton Counties, Iowa, which are adjacent to Pool 14 (VanDeWalle and Christiansen, 2002). The most recent records of live specimens found in that area were near Long Grove and Calamus, 13 and 30 miles west of the Upper Mississippi River floodplain, respectively. Searches in 2001 and 2002 found no live specimens in these counties (USFWS, 2006).

The unionid mussel sheepnose *(Plethobasus cyphyus)* has been eliminated from two-thirds of the total number of streams from which it was historically known (26 streams versus 77, historically). It was uncommon in what are now Mississippi River Pools 13-23. In the upper Mississippi River, the sheepnose is an example of a rare species becoming more so (Upper Mississippi River Refuge Final Environmental Impact Statement/Comprehensive Conservation Plan, July, 2006).

The spectaclecase *(Cumberlandia monodonta)* mussel was declared a candidate species May 4, 2004 (USFWS, 2002b). As reported in the Federal Register, the spectaclecase is apparently more of a habitat specialist than are most mussel species. Primarily a large-river species, it can occur on outside river bends below bluff lines. The only live specimens found recently on the Upper Mississippi River were in Pool 15 and further down river; none on the Refuge portion of the Upper Mississippi River, Pools 4-14 (USFWS, 2006).

10.0 COMMUNITY ECOLOGY

10.1 Upper Mississippi River Fish Communities

The Upper Mississippi River National Wildlife & Fish Refuge supports at least 119 species of fish, including sport fish, commercial fish, forage fish, ancient fish (paddlefish and sturgeon), and many other unique species that make the river's fishery so diverse (Gutreuter and Theiling, 1999). Populations of at least 41 fish species are so low that they are listed as threatened or of concern by state or federal agencies along the Upper Mississippi River. Loss of habitat, the navigation system, over-exploitation, and impacts of exotic species (see discussion below) are the main causes (USFWS, 2006).

Favorite sport fish in Pool 14, as well as the rest of the refuge, include walleye, sauger, white bass, largemouth bass, smallmouth bass, channel catfish, northern pike, bluegill, and crappies. Bluegills are the number one harvested fish species of the Upper Mississippi River backwaters. Presently, smallmouth bass populations in Pools 1-14 are increasing and are a significant component of the fishery. Fishing tournaments are ever-increasing and may put extra pressure on local fish populations (USFWS, 2006).

10.1.1 Other Fish

The paddlefish is one of the ancient fish of the Upper Mississippi River and is distinguished from all other fish by its broad, flat bill-like snout. People consume paddlefish meat and roe (caviar). The worldwide protection of sturgeon species in 1998 is expected to have a dramatic impact on commercial paddlefish harvest by creating a greater demand for paddlefish caviar as a surrogate to sturgeon roe. It has declined throughout its range due to habitat loss and over-harvest. Competition from invasive species such as silver and big head carp, plankton eaters, is a potential serious threat to paddlefish if these species move up the Upper Mississippi River (UMRCC, 2004a).

10.1.2 Sturgeon

Included in the list of "ancient species" three kinds of sturgeon inhabit the Upper Mississippi River: The lake, pallid and shovelnose. The pallid sturgeon is endangered and occurs in waters well south of the Refuge. Lake and shovelnose are rare or uncommon in most Refuge waters, but the shovelnose is found in modest numbers in Pool 14. A decline in shovelnose numbers is attributed to overharvest, habitat degradation and fragmentation by dams, water pollution, and flow alteration (USFWS, 2006).

10.1.3 Invasive Fish Species

Invasive and exotic species are the "greatest threat to ecosystem integrity within the refuge system" (USFWS 2004a). The refuge and Upper Mississippi River System are inundated with invasive fish, plants, and invertebrates. Asian carp threaten native paddlefish via competition for plankton. These carp also can potentially eliminate vegetation beds, snail and mussel populations, and deplete the commercial fishing industry on the Upper Mississippi River System (USFWS, 2006).

The common carp, a native of Europe and Asia, was first found in the Upper Mississippi River in 1883 and presently comprises most of the commercial harvest of fish in the Upper Mississippi

River. It has increased in abundance in Pools 4, 8, 13, and 26 of the Upper Mississippi River from 1990-94 (Gutrueter and Theiling, 1999). As the common carp increased, the native buffalo fish, the ecological equivalent, has declined in the harvest by about 50 percent.

Findings of a recent feasibility study funded by Minnesota Department of Natural Resources noted "that an acoustic deterrent such as a Sound Projector Array based acoustic bubble curtain downstream of a lock location perhaps in conjunction with attractants (i.e. pheromones, plankton, lights, etc.), and an integrated management/harvest plan may provide the most feasible opportunity to limit or slow the upstream invasion of Asian Carp" (FishPro, 2004).

10.2 Navigation Pool 14 Fish Communities

Exelon Generation and its contractors have monitored the fish populations of Pool 14 (the reach of the Mississippi River between Lock and Dam 13 and Lock and Dam 14) since 1971. A number of common species (gizzard shad, freshwater drum, emerald shiner, river shiner, bullhead minnow, carp and bluegill) have consistently dominated fish collections. A number of other species, including mooneye, river carpsucker, smallmouth buffalo, shorthead and golden redhorse, channel and flathead catfish, white bass, largemouth bass, black crappie, sauger, and walleye have also been regularly collected.

The long-term monitoring program has not identified any measurable impacts on the fishery of Pool 14 attributable to station operation (LMS, 1995; LMS, 2000b; HDR, 2009b). Monitoring has demonstrated that the physical characteristics of the river (i.e., flow, temperature and silt loads) are highly variable and subject to relatively rapid changes that do affect the Pool 14 fish community. As a consequence, individual fish species in Pool 14 have shown both short term and long term fluctuations in abundance, but community composition has remained relatively stable (LMS, 1995).

Two significant changes in the Pool 14 fishery (neither of which is associated with QCNS operations) have been observed since the early 1970's. First, the abundances of two popular game fish, walleye and hybrid striped bass, have increased in the vicinity of the Station since 1985 as a result of a stocking program carried out by Southern Illinois University and QCNS. The adult walleye population of Pool 14 is presently comprised of approximately 30 percent stocked fish (LaJeone and Monzingo, 2000); increasing numbers of these canal-reared walleye are also appearing in downstream pools.

Second, the abundance of riverine fish species (e.g., freshwater drum, channel catfish, flathead catfish, and white bass) has generally increased in Pool 14, while the abundance of backwater fish species (e.g., white and black crappie) has generally decreased as sedimentation associated with operation of the navigation channel has degraded backwater areas and sloughs (LMS, 2000b). Increases in channel catfish numbers are also believed to be related to changes in commercial fishing regulations that allow more fish to survive to adulthood and spawn (LaJeone and Monzingo, 2000).

11.0 ENERGY FLOW AND TROPHODYNAMICS

11.1 Energy Flow and the Riverine Food Web (Odum, 1971)

The transfer of food energy from the source in plants through a series of organisms with repeated eating and being eaten is referred to as the food chain. At each transfer a large portion, 80 to 90 percent, of the potential energy is lost as heat. Therefore, the number of steps or "links" is a sequence is limited, usually to four or five. The shorter the food chain is (or the nearer the organism to the beginning of the chain), the greater the available energy.

Food chains are of two basic types: the grazing food chain, which, starting from a green plant base, goes to grazing herbivores (i.e., organisms eating living plants) on to carnivores (i.e., animal eaters); and the detritus food chain, which goes from dead organic matter into micro-organisms and then to detritus-feeding organisms (detritivores) and their predators. Food chains are not isolated sequences but are interconnected with one another. The interlocking pattern is often spoken of as the food web. In complex natural communities, organisms whose food is obtained from plants by the same number of steps are said to belong to the same trophic level. Thus, green plants (the producer level) occupy the first trophic level, plant-eaters the second level (the primary consumer level), carnivores, which eat the herbivores, the third level (the secondary consumer level), and the secondary carnivores the fourth level (the tertiary consumer level).

Figure A-1 shows very simplified food web for a river system. With the exception of certain species that are mentioned, such as trout and grass carp, this food web is indicative of the food web in the Mississippi River.

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13.0 TABLES AND FIGURES

Table A-1. Organic compounds measured to evaluate wastewater contamination of the Mississippi River, 1987-1992

Contaminant	Abbreviation	Compounds and sources
Dissolved organic carbon	DOC	All natural and synthetic organic compounds; regional-scale natural sources.
Fecal coliform bacteria	None	Bacteria derived predominantly from human and livestock fecal wastes; from unchlorinated sewage effluents and feedlot and agricultural runoff.
Methylene-blue-active substances	MBAS	Composite measure of synthetic and natural anionic surfactants; predominantly from municipal sewage-wastewater discharges.
Linear alkylbenzenesulfonate	LAS	Complex mixture of specific anionic surfactant compounds used in soap and detergent products; primary source is domestic sewage effluent.
Nonionic surfactants	NP, PEG	Complex mixture of compounds derived from nonionic surfactants that includes nonylphenol (NP) and polyethylene glycol (PEG) residues; from sewage and industrial sources.
Adsorbable organic halogen	AOX	Adsorbable halogen-containing organic compounds, including by-products from chlorination of DOC and synthetic organic compounds, solvents and pesticides; from multiple natural and anthropogenic sources.
Fecal sterols	None	Natural biochemical compounds found predominantly in human and livestock wastes; primary source is domestic sewage and feedlot runoff.
Polynuclear aromatic hydrocarbons	PNA	Complex mixture of compounds, many of which are priority pollutants; from multiple sources associated with combustion of fuels.
Caffeine	None	Specific component of beverages, food products, and medications specifically for human consumption; most significant source is domestic sewage effluent.
Ethylenediaminetetraacetic acid	EDTA	Widely used synthetic chemical for complexing metals; from a variety of domestic, industrial, and agricultural sources.
Volatile organic compounds	VOC	A variety of chlorinated solvents and aromatic hydrocarbons; predominantly from industrial and fuel sources.
Semivolatile organic compounds	TTT, THAP	Wide variety of synthetic organic chemicals including priority pollutants and compounds such as trimethyltriazinetrione (TTT) and trihaloalkylphosphates (THAP); predominantly from industrial sources.

Table A-2. Summary assessment of organic contaminants in the Mississippi River and its major tributaries. Compound abbreviations are listed in Table A-1.

[mg/L, milligram per liter; CFU/100 mL, colony-forming units per 100 milliliters; µg/L, microgram per liter; mg/kg, milligram per kilogram; nd, not determined; Sorp, sorption; Bio, biodegradation; Vol, volatilization; >, greater than]

Compound	Concentration		Drinking water standard	Aquatic[1] toxicity	Environmental fate affected by		
	River water	Bed sediment			Sorp	Bio	Vol
DOC	3–12 mg/L	nd	4 mg/L[2]	Unknown	Yes	Yes	No
Fecal coliform	2–700,000 CFU/100 mL	nd	[3]0	200 CFU/100 mL[6]	Yes	Yes	No
MBAS	20–100 µg/L	nd	500 µg/L[3]	250 µg/L[7]	Yes	Yes	No
LAS	0.1–10 µg/L	0.1–1 mg/kg[14]	None	25 µg/L[8]	Yes	Yes	No
NP	0.1–10 µg/L	nd	None	130 µg/L[9]	Yes	No	Yes
PEG	5–150 µg/L	nd	None	1,000 mg/L[10]	Yes	Yes	No
AOX	10–120 µg/L	nd	60 µg/L[4]	Unknown	Yes	Yes	Yes
Coprostanol	nd	0.1–1 mg/kg[14]	None	Unknown	Yes	Yes	No
Total PNAs	nd	0.1–16 mg/kg	0.1–0.4 µg/L[5]	4 mg/kg[11]	Yes	Yes	Yes
Caffeine	0.01–0.1 µg/L	nd	None	Unknown	Yes	Yes	No
EDTA	1–30 µg/L	nd	None	>1,000 µg/L[12]	No	No	No
Total VOC	0.2–3.1 µg/L	nd	5–1,000 µg/L[5]	>1,000 µg/L[13]	Yes	Yes	Yes
TTT	0.01–0.5 µg/L	nd	None	Unknown	No	No	No
THAP	0.01–1.4 µg/L	nd	None	Unknown	No	No	No

[1] Aquatic toxicity of organic compounds is a complex issue that involves many factors including the characteristics of the particular chemical, concentration of the chemical, overall water composition, and the aquatic species under consideration. The scientific literature is rich in specific studies of aquatic toxicity for a wide range of compounds, species, and conditions. The data presented in this table, although limited, are representative of the range of concentrations shown to exhibit toxic effects for sensitive aquatic species.

[2] Pontius, 1993. Drinking water sources with more than 4 mg/L DOC may require pretreatment to minimize formation of disinfection by-product (see the following chapter by R.E. Rathbun).

[3] U.S. Environmental Protection Agency, 1994.

[4] Pontius, 1993. Although no MCLs have been established for AOX, anticipated MCLs for the total of five trihaloacetic acids that are measured as a component of the AOX have been proposed.

[5] Range of MCL values for individual compounds detected in this study. U.S. Environmental Protection Agency, 1994.

[6] Fecal coliform bacteria are not toxic to aquatic species, but rather are indicators of bacterial water quality. This standard is for human primary contact recreation (Dufour, 1984).

[7] MBAS is a nonspecific measure of LAS and related compounds. This value was established based on the assumption that 10 percent of the MBAS response comes from LAS (Kimerle, 1989).

[8] Kimerle, 1989.

[9] McLeese and others, 1981.

[10] Patoczka and Pulliam, 1990. Based on toxicity of linear alcohol ethoxylates that are parent compounds for PEG. PEG will have significantly lower toxicity than the parent compound.

[11] Persaud and others, 1993. Value listed is for sediment toxicity: PNAs are primarily sorbed to bed sediments.

[12] Curtis and Ward, 1981. At concentrations less than 500 µg/L, however, EDTA can reduce the toxicity of heavy metals by forming complexes that lower the concentrations of free metal ions.

[13] Verhaar and others, 1992.

[14] Range of values reported in the table and in figure 55 refers only to bed-sediment samples collected in the main-stem navigation pools. Values of 20 mg/kg of LAS and 7.5 mg/kg of coprostanol were measured in bed sediment in Pigs Eye Slough, which receives effluent from a wastewater-treatment facility in St. Paul, Minn.

TABLE A-3. Master taxa list for selecting the Representative Important Species in Pool 14 of the Upper Mississippi River near Quad Cities Station.

TAXON	SPECIES STATUS[a]	OCCURRENCE[b]
Chestnut lamprey (*Ichthyomyzon castaneus*)[c]	U	X
Silver lamprey (*Ichthyomyzon unicuspis*)	O	X
Lake sturgeon (*Acipenser fulvescens*)[c]	R	X
Shovelnose sturgeon (*Scaphirhynchus platorynchus*)	O	X
Paddlefish (*Polyodon spathula*)	O	X
Longnose gar (*Lepisosteus osseus*)	C	X
Shortnose gar (*Lepisosteus platostomus*)	C	X
Bowfin (*Amia calva*)	C	X
American eel (*Anguilla rostrata*)	U	X
Skipjack herring (*Alosa chrysochloris*)	R	X
Gizzard shad (*Dorosoma cepedianum*)	A	X
Goldeye (*Hiodon alosoides*)	R	X
Mooneye (*Hiodon tergisus*)	C	X
Rainbow trout (*Onchorhynchus mykiss*)	X	X
Brown trout (*Salmo trutta*)	X	X
Lake trout (*Salvelinus namaycush*)	X	X
Central mudminnow (*Umbra limi*)	R	X
Grass pickerel (*Esox americanus*)[c]	R	X
Northern pike (*Esox lucius*)	O	X
Central stoneroller (*Campostoma anomalum*)	-	X
Common carp (*Cyprinus carpio*)	A	X
Grass carp (*Ctenopharyngodon idella*)	U	X
Silvery minnow (*Hybognathus nuchalis*)	U	X
Speckled chub (*Macrhybopsis aestivalis*)	C	X
Silver chub (*Macrhybopsis storeriana*)	C	X
Golden shiner (*Notemigonus crysoleucas*)	O	X
Pallid shiner (*Notropis amnis*)[c]	R	X
Emerald shiner (*Notropis atherinoides*)	A	X
River shiner (*Notropis blennius*)	A	X
Ghost shiner (*Notropis buchanani*)	H	X
Common shiner (*Luxilus cornutus*)	R	X
Bigmouth shiner (*Notropis dorsalis*)[d]	R	X
Pugnose minnow (*Opsopoeodus emiliae*)	R	X
Spottail shiner (*Notropis hudsonius*)	C	X
Red shiner (*Cyprinella lutrensis*)	R	X
Spotfin shiner (*Cyprinella spiloptera*)	C	X
Sand shiner (*Notropis stramineus*)	C	X
Weed shiner (*Notropis texanus*)[c]	-	X
Mimic shiner (*Notropis volucellus*)	R	X
Suckermouth minnow (*Phenacobius mirabilis*)	R	X
Southern redbelly dace (*Phoxinus erythrogaster*)[d]	X	X
Bluntnose minnow (*Pimephales notatus*)	O	X
Fathead minnow (*Pimephales promelas*)	U	X
Bullhead minnow (*Pimephales vigilax*)	C	X
Creek chub (*Semotilus atromaculatus*)	X	X
Pearl dace (*Margariscus margarita*)[c,d]	X	X
Blacknose dace (*Rhinichthys atratulus*)[d]	X	X
River carpsucker (*Carpiodes carpio*)	C	X
Quillback (*Carpiodes cyprinus*)	C	X
Highfin carpsucker (*Carpiodes velifer*)	O	X
White sucker (*Catostomus commersoni*)	X	X
Longnose sucker (*Catostomus catostomus*)[c]	X	X
Blue sucker (*Cycleptus elongatus*)	U	X
Smallmouth buffalo (*Ictiobus bubalus*)	C	X
Bigmouth buffalo (*Ictiobus cyprinellus*)	C	X
Black buffalo (*Ictiobus niger*)	U	X
Spotted sucker (*Minytrema melanops*)	O	X
Silver redhorse (*Moxostoma anisurum*)	U	X
Golden redhorse (*Moxostoma erythrurum*)	O	X
Shorthead redhorse (*Moxostoma macrolepidotum*)	C	X

TABLE A-3. (Continued)

TAXON	SPECIES STATUS[a]	OCCURRENCE[b]
Black bullhead (*Ameiurus melas*)	O	X
Yellow bullhead (*Ameiurus natalis*)	O	X
Channel catfish (*Ictalurus punctatus*)	C	X
Stonecat (*Noturus flavus*)	U	X
Tadpole madtom (*Noturus gyrinus*)	U	X
Flathead catfish (*Pylodictis olivaris*)	C	X
Blackstripe topminnow (*Fundulus notatus*)	-	X
Trout-perch (*Percopsis omiscomaycus*)	-	X
Mosquitofish (*Gambusia affinis*)	R	X
Brook silverside (*Labidesthes sicculus*)	O	X
White bass (*Morone chrysops*)	C	X
Yellow bass (*Morone mississippiensis*)	U	X
Rock bass (*Ambloplites rupestris*)	U	X
Green sunfish (*Lepomis cyanellus*)	O	X
Pumpkinseed (*Lepomis gibbosus*)	C	X
Warmouth (*Lepomis gulosus*)	U	X
Orangespotted sunfish (*Lepomis humilis*)	C	X
Bluegill (*Lepomis macrochirus*)	A	X
Smallmouth bass (*Micropterus dolomieu*)	O	X
Largemouth bass (*Micropterus salmoides*)	C	X
White crappie (*Pomoxis annularis*)	C	X
Black crappie (*Pomoxis nigromaculatus*)	C	X
Western sand darter (*Ammocrypta clarum*)[c]	U	X
Mud darter (*Etheostoma asprigene*)	U	X
Rainbow darter (*Etheostoma caeruleum*)	X	X
Johnny darter (*Etheostoma nigrum*)	U	X
Yellow perch (*Perca flavescens*)	U	X
Logperch (*Percina caprodes*)	O	X
Slenderhead darter (*Percina phoxocephala*)	R	X
River darter (*Percina shumardi*)	U	X
Sauger (*Sander canadense*)	C	X
Walleye (*Sander vitreum*)	C	X
Freshwater drum (*Aplodinotus grunniens*)	A	X

[a]Species listed as collected in Pool 14 by Pitlo et al., (1995) and their status.
[b]"X" indicates the species was collected during the 38-year monitoring period.
[c]Listed as protected by Iowa Department of Natural Resources (2009) or Illinois Endangered Species Protection Board (2011).
[d]Collected by minnow seine only.

X - Probably occurs only as a stray from a tributary or inland stocking.
H - Records of occurrence are available, but no collections have been documented in the last 10 years.
R - Considered rare. Some species in this category may be on the verge of extinction.
U - Uncommon; does not usually appear in sample collections.
O - Occasionally collected; not generally distributed, but local concentrations may occur.
C - Commonly taken in most sample collections; can make up a large portion of some samples.
A - Abundant; taken in all river surveys.

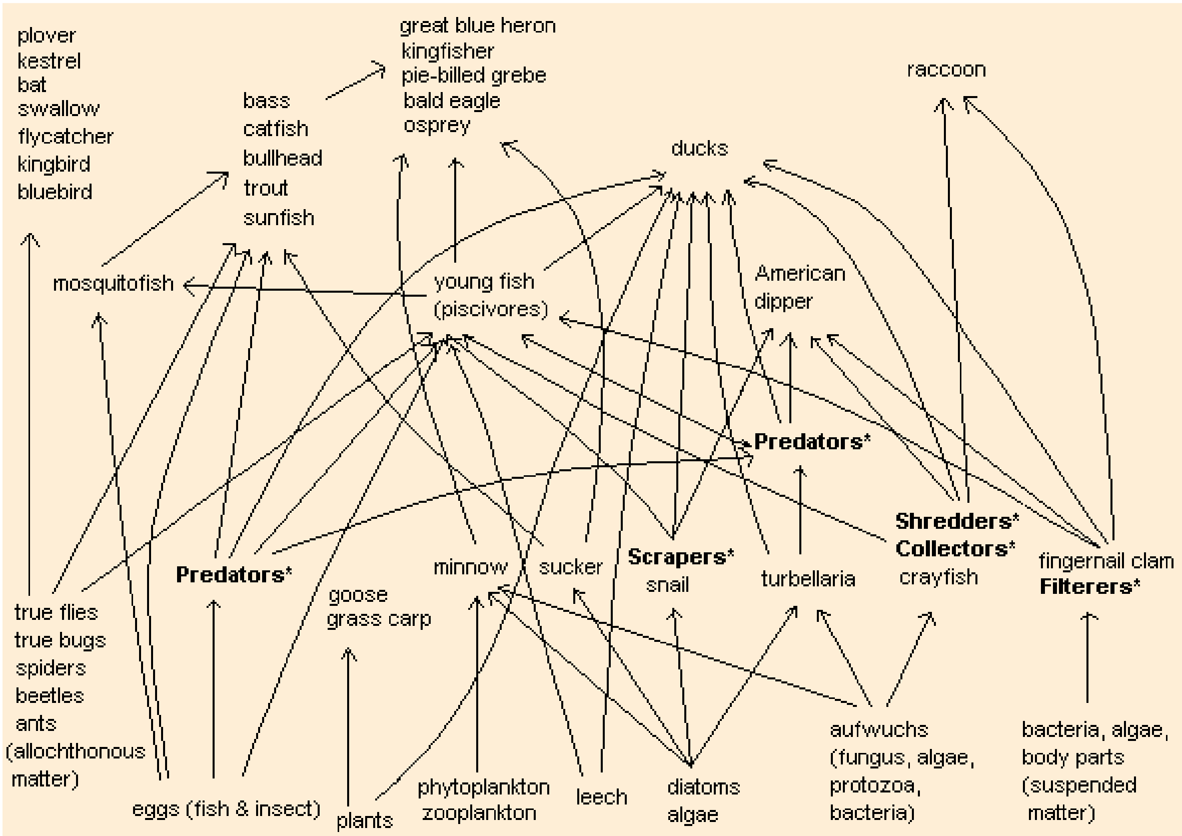

Figure A-1. Simplified food web for a typical river system

APPENDIX B

Biothermal Assessment:
Prospective Demonstration

TABLE OF CONTENTS

1. INTRODUCTION

1.1 Regulatory Background and Project Objective

The Quad Cities Nuclear Generating Station (QCNS) employs once-through-cooling, which involves a discharge of heated effluent to the Mississippi River.[1] This thermal discharge is authorized under QCNS' NPDES Permit, issued by the Illinois Environmental Protection Agency. Thermal limits in the NPDES Permit are based on the Illinois environmental regulations, and studies and demonstrations related to the thermal plume performed under Section 316(a) of the Federal Clean Water Act.

The NPDES Permit defines the mixing zone boundary as a straight line across the Mississippi River, 500 feet downstream of the diffuser pipes (See Figure 1), and compliance with the temperature standards in the NPDES Permit is measured at the end of this mixing zone boundary. The NPDES Permit (and Illinois regulations) requires that the QCNS discharge meets the following standards:

Fixed standard limiting the <u>change</u> in water temperature - Natural river water temperatures shall not be increased by more than 5°F (the temperature increase above natural or ambient water temperatures is termed ΔT).

Variable standard defining the maximum temperature <u>limit</u> – As shown in Table 1, the Illinois regulations detail monthly temperatures limits.

Variable standard limiting the <u>duration</u> of elevated water temperatures – An exceedance of the monthly temperature thresholds (3°F less than the maximum limit) triggers the tracking of the time period elevated water temperatures occur (commonly referred to "excursion hours"). The plant is allowed to exceed the monthly temperature thresholds for up to 1% of the hours in a twelve month period ending with any month (e.g., in August, excursion hours occur when the water temperatures exceed 86°F [from Table 1]. Importantly, the temperatures must still remain below the noted maximum limit (e.g., 89°F during August) and within the 5ºF ΔT limit.

The objective of this prospective demonstration is to determine the biological implications for the indigenous community of fish in Pool 14 of Exelon's request for a site-specific Alternate Thermal Standard (ATS) that includes: *(1) changing the method for tracking and regaining*

[1] Located on Navigation Pool 14 of the Mississippi River near Cordova, IL.

excursion hours (during which the plant is authorized to exceed thermal limits) from a rolling 12-month basis to a calendar year basis (January through December); (2) increasing the number of excursion hours available per year from 1% (87.6 hours), which is currently allowed by the plant's NPDES Permit to 3% (262.8 hours[2], of which only 1.5% (131.4 hours) of those hours may be between 89°F and 91°F; (3) increasing the excursion hour downstream temperature limit to no more than 5°F delta-T (i.e., 91°F downstream instead of current NPDES Permit limit of 89°F in July and August and 90°F downstream rather than current NPDES Permit limit of 88°F in September); and (4) reducing the size of the ZOP to 66% . Adoption of these new standards will be subject to the Illinois Environmental Protection Agency's (IEPA) issuance of Quad Cities Station's N.P.D.E.S Permit.

Exelon's request that it be allowed to track excursion hours on a calendar year basis instead of over a 12-month rolling period should have no biological consequence or impact. Excursion hours have been tracked at QCNS for the past 28 years(1983-2011). During that time, excursion hours have occurred exclusively during the March-August period. There is virtually no possibility that Exelon would use excursion hours in December or January, that is, at the end of one calendar year and the beginning of another. Thus, there is no concern that tracking excursion hours at QCNS would result in allowing the plant to use two years of allotted hours over a two or three month contiguous period.

Exelon also is requesting relief from the generally applicable requirement that a zone of passage (ZOP) of at least 75% of the volume or flow of the river be maintained, to accommodate periods of extreme low river flows and high ambient temperatures. However, Exelon is not seeking relief from the generally applicable limitation that the QCNS discharge not cause temperatures to increase by more than 5°F above ambient at the end of the mixing zone. As a result of maintaining compliance with the 5ºF above ambient standard, QCNS will be required to derate, i.e., shed load, at river flows of 13,000 cfs. In order assure that the ZOP does not fall below 66% on a volume or discharge basis QCNS will derate at river flows at the slightly higher value of 13,200 cfs. (See Appendix C.) Reducing the allowable ZOP to 66% is expected to have a negligible effect on the species studied as part of this prospective analysis and hence will not change its conclusions. Of the four species considered in the prospective analysis only one,

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[2] Since the preparation of this document, Exelon has reduced the proposed increase of the number of excursion hours 3% (262.8 hrs) to 2.5% (219 hrs). The modeling analysis, data interpretations and conclusions presented here for the 3% case fully support the more restrictive 2.5% modified proposal. The results from the 3% case presented here represent a very conservative measure of the effects of a 2.5 % increase in excursion hours.

walleye, shows seasonal movements that, at least in theory, could be affected by reducing the ZOP. However, walleye move within the pool two times of the year: (1) during late March to early April they stage and then move to spawning grounds; and (2). during October walleye migrate to the head end of the pool over a period of weeks. Records of river flows show that since 1986, they have been below 16,400 cfs, the level below which model calculations indicate ZOP will be less than 75%, on only four days during March -May. Over the same 26 year flow record, river flow has been below 16,400 cfs on only 21 days during October. It is apparent from this historical record that river flows low enough to result in a ZOP of 66 to 75% occur very rarely in the spring and fall when walleye seasonal movements take place. Consequently, reducing the ZOP from 75% to 66% should have no impact on walleye migration/movement in Pool 14 in the future.

The remaining sections of this report describe the methods used and results of a prospective analysis of the anticipated environmental consequences of the proposed ATS on the balanced indigenous community in Pool 14.

1.2 Project Background

This report represents the culmination of an extensive data acquisition, research, and analysis effort. Figure 2 shows the series of project steps or tasks that have been taken in preparation for performing the biothermal assessment detailed in this Report. The biothermal assessment links and melds the acquired biological information for pertinent resident species, with the final hydrothermal modeling results detailing characteristics of the QCNS thermal plume to predict the impacts that the proposed alternate standard may have on the indigenous fish community in Pool 14.

A summary of the basic information generated in preparation for the biothermal model is as follows (refer to Figure 2):

Phase I (biology) – Under this task, HDR[3] developed the methods of species selection (including a brief narrative describing the selection process for each relevant species), detailed the literature search methods, and tabulated the resultant temperature tolerance database.

[3] The tasks to collect basic information in preparation for the biothermal model were conducted by LMS in 2003. LMS was acquired by HDR Engineering, Inc. (HDR) in May 2005.

Phase I (preliminary hydrothermal modeling) – Under this task, HDR performed a preliminary examination of the thermal plume characteristics using the CORMIX hydrothermal model.

Phase IIA (field survey) – In September of 2003, HDR conducted a thermal field study comprising river-wide surface and vertical-profile temperature measurements from above the plant diffuser pipes down to the southern end of Steamboat Island. (See Figure 3.) Concurrent with the waterside boat measurements, an aerial infrared survey was also conducted, which provided a qualitative overview of the fate and transport of the thermal plume. The thermal survey effort provided a refined spatial characterization of the QCNS discharge for the specific field conditions measured (e.g., river flow ranging from approximately 28,500 to 30,000 cfs). Based on the detailed thermal survey results, it became apparent that a more refined hydrothermal model was required to accurately simulate the QCNS thermal plume.

Phase IIB (Final hydrothermal modeling) – IIHR Hydroscience & Engineering simulated the thermal plume using a three-dimensional (3-D) Computational Fluid Dynamics (CFD) model. The IIHR modeling effort included the following major components (as detailed in the IIHR Report):

Inclusion of relevant river-training structures, namely wing dams and the cross-channel closure dam in the Steamboat Slough, in the model bathymetry to better reflect real-world conditions. The resultant model grid contained nearly 2 million points.

Simulation of conditions corresponding to the HDR September 2003 thermal survey field effort, which validated the model's ability to predict the observed thermal conditions.

Simulation of station operations at maximum power for a series of relatively low Mississippi River flows.

The IIHR modeling effort provided water temperature, depth, and velocity values that were used by HDR as inputs for the biothermal model.

1.3 General Approach to the Biothermal Modeling

1.3.1 Selection of Species to be Evaluated

The initial step in the evaluation of potential effects of additional excursion hours and increased maximum temperatures on the biological community that inhabits Pool 14 entailed the selection of "representative important species (RIS)." The RIS would be the subject of a detailed evaluation that would provide the basis for conclusions regarding effects on the broader fish community. The starting point for the species selection was a master fish taxa list containing 93 species that had been developed for Pool 14 during the course of 32 years of monitoring studies at QCNS. To reduce this list to a manageable, representative number, a set of screening criteria was developed. The objective of this screening was to produce a set of species that were indigenous, riverine species and included forage fish, threatened or endangered species, recreationally important species, and, if possible, commercially important species. Also, the intent was to have at least one predator and one forage species included on the final list. The screening process included the following exclusion criteria to reduce the number of fish species to an acceptable level:

Hybrid taxa
Exotic taxa
Taxa not collected within the last 10 years (but not threatened or endangered)
Incidental taxa, e.g. trout, small stream species
Taxa known to have upper avoidance temperatures considerably higher than 89^{o}F
Taxa that are captured only occasionally
Taxa that are collected regularly but for which less than 200 specimens had been collected over the decades long total monitoring period
Congeneric species, i.e. one or more of closely related species were eliminated

This general screening process filtered the master list down to the 15 species shown in Table 2. Comprehensive literature searches were then conducted for each of these species to determine if the thermal tolerance data needed to conduct the analyses were available in the scientific literature. A number of species on the list did not have sufficient documented thermal histories to develop thermal tolerance criteria; hence, a biothermal assessment of these species was not possible. As shown in Table 2, sufficient thermal tolerance information was available for the following four species:

Channel catfish - This is an important recreational and commercial species in Pool 14 and representative of a large number of temperature-tolerant temperate species (warm-water guild) that are indigenous to the Pool including: flathead catfish, black bullhead, yellow bullhead, common carp, river carpsucker, quillback, bigmouth buffalo, smallmouth buffalo, black buffalo, longnose gar, shortnose gar, gizzard shad, and freshwater drum. It is a predator species.

Largemouth bass - This is arguably one of the most popular game fish living in Pool 14, as well as throughout the United States. It is a member of the warm-water guild living in Pool 14 and is representative of several popular recreational species including bluegill, pumpkinseed, and green sunfish. It also is a predator species.

Spotfin shiner - This is a commonly collected forage species in Pool 14 and is representative of a number of common forage species in the Pool including bullhead minnow, sand shiner, river shiner, emerald shiner, spottail shiner, and silver chub.

Walleye - In Pool 14, walleye may be one of the more sought after game fish throughout the year. Walleye are native to Pool 14 and are a member of the cool water guild that inhabits the Pool. Other members of this guild that are found in Pool 14 include sauger, northern pike, and shorthead redhorse. Walleye was selected as representative of this group because it falls in the middle of a field information-based ranking system for estimating fish temperature tolerances for these species (Eaton *et al*. 1995). Walleye is also a predator in the system.

Because these species are representative of many species residing in Pool 14, and have sufficient data available for analysis of thermal effects, they were selected as the Representative Important Species (RIS) for this study. Application of the thermal tolerance information for these species in the biothermal assessment is described in Section 2.1.

1.3.2 Selection of Plant and River Conditions Evaluated

River and plant operating conditions to be evaluated in this study were selected so that they would provide the basis for a stringent (i.e., conservative) assessment of potential plant-related biological effects. Because excursion hours occur predominantly during warm periods of the year, the biothermal assessment focused on the months of June, July, August, and September. The major plant and river parameters, and the values used, were:

Plant Operation (the amount of waste heat discharged) - the change in the temperature of the water discharged to the river relative to the intake ($\Delta T_{discharge}$) times the discharge water flow rate (Q_{plant}) defines the amount of heat added to the river. These parameters are a function of the level at which the plant is operating (i.e., the percent of plant operating capacity).

River Flow (Q_{river}) - Defines the amount of source water available to mix with the QCNS discharge. As the river flow decreases, less river water is available to mix with the thermal discharge. Therefore, the plant's effects on river temperatures are potentially highest at low river flows.

Natural or Ambient River Temperature (T_{amb}) – Defines the temperature of the source water (i.e. the water temperature upriver of the discharge) that mixes with the thermal discharge from the plant. It follows that the potential effect from the plant's addition of heat to the river is highest when the natural river water temperatures (T_{amb}) are elevated (i.e., the water temperature downriver of the discharge equals T_{amb} plus the heat added from the plant [as defined by the IIHR model simulations]).

Conservative values were selected for each of the major design parameters to assure that the resultant thermal plume temperatures used in the analysis are representative of reasonable worst-case conditions. HDR reviewed Lock and Dam 13 temperature data provided by the Corps of Engineers for the October 1996 through April 2006 time period. The June through September 2006 period was the period during which periods of low river flow and warm summer temperatures were experienced. Actual river water temperatures recorded at Lock and Dam 13 (located about 12 miles upriver of the Plant) during June through September 2006 were adjusted and used for ambient river temperature values. The Lock and Dam 13 temperatures were adjusted by increasing the temperatures exponentially with river flow with the goal of exceeding the 86°F criterion at the end of mixing zone (EOMZ) temperature 3.0% of annual hours and exceeding the 89°F EOMZ temperature 1.5% of the annual hours without exceeding the 91°F EOMZ temperature limit. In this variable flow analysis, river flows recorded at Lock and Dam 13 during 2006 were used and the plant was assumed to operate at full capacity (see Attachment 1). A similar analysis was performed with fixed river flows ranging from the 7Q10 rate (13,800 cfs) to more typical summertime flows (30,000 cfs).

Biothermal effects were evaluated for nine scenarios - eight assumed (or simulated) river flow rates between 13,800 and 30,000 cfs; the ninth scenario utilized the actual daily river flow rates. For each scenario, the number of excursion hours that would be experienced during the entire June through September period was calculated. (The number of excursion hours calculated for each flow rate is converted to percent of hours per year and presented on Table 4.) Table 4 shows that for the six lowest flow simulations – 13,800 cfs, 15,000 cfs, 17,500 cfs, 20,000 cfs, 22,500 cfs and 25,000 cfs – the number of excursion hours would exceed the proposed new 3.0% limit on exceeding 86°F at EOMZ and for the two lowest flow simulations – 13,800 cfs, and 15,000 cfs – the number of excursion hours would exceed the proposed new 1.5% limit on exceeding 89°F at EOMZ. In actuality, for these scenarios the Plant would be required to reduce operations to maintain compliance with the new limits. HDR performed a biothermal assessment under these sustained low flow scenarios for comparative purposes only. The scenario utilizing actual daily river flows (i.e., variable flows) provides the assessment of biological effects that would result if the most extreme conditions requested by Exelon in the site specific thermal standard were realized, i.e., excursion hours of 3.0% and 1.5% for 86°F and 89°F, respectively. One additional analysis was also performed to quantify the thermal effects (if any) from ambient temperature alone (i.e., with no thermal discharge). This additional analysis provides the basis for determining what portion of the predicted thermal effects is assigned to plant operations, versus those caused by the natural variation in ambient temperatures.

2. BIOTHERMAL ASSESSMENT METHODS

The biothermal modeling assessment is designed to assess the extent to which heat introduced to the river system from QCNS' thermal discharge may cause adverse biological effects on fish. For each of the RIS species studied, sophisticated, state-of-the-art modeling techniques were employed to determine the effect of the Station's thermal discharge on three biological parameters:

Growth: A thermal discharge could shift water temperature into or out of the range conducive to growth in fish.

Avoidance: A thermal avoidance response occurs when fish evade high temperatures because they find them stressful.

Chronic thermal mortality (prolonged exposure): Fish species that choose not to or cannot avoid elevated temperatures by leaving the area (a very rare circumstance), could potentially succumb to elevated temperatures during a prolonged exposure.

This section of the report summarizes the biothermal modeling process used to quantify the potential for thermal impacts related to the above biological parameters.

2.1 Basic Steps to the Biothermal Modeling Process

The modeling tool developed by HDR combines biological and thermal (hence, "biothermal") inputs through the following six-step process:

Obtain spatial and temporal characterization of the QCNS thermal plume: As noted above, the spatial characterization of the plume was obtained from by IIHR Hydroscience & Engineering's simulations of the thermal plume using its three-dimensional (3-D) Computational Fluid Dynamics (CFD) model for several river flow conditions. The temporal characterization of the thermal plume (i.e., extending the steady-state results into 4 months of daily temperature predictions) was done using the baseline 2006 USACE temperatures (as measured at Lock & Dam 13), adjusted as per the methods outlined in Attachment 1.

Determine acclimation temperatures in each "results grid" cell:[4] Monthly ambient temperatures in Pool 14 vary substantially. From the beginning of June to late-July, for example, average ambient (i.e., no-plant effect) water temperature typically increases from about 67°F to 83°F (see Figure A1-2 in Attachment 1). In response to such temperature changes, fish undergo physiological changes that alter their thermal preferences and tolerances. This adjustment process (acclimation) was incorporated into the biothermal assessment. The basic reason acclimation occurs is that fish lack the physiological mechanisms to control tissue temperature, and thus their peripheral body temperature is essentially the same as the surrounding water. Therefore, as water temperature and, thus, fish body temperature change, corresponding changes occur in thermal preference (which determines the growth tolerances, avoidance, and mortality thresholds). These changes reflect physiological adjustment that "influences interaction of enzymes with substrates, inhibitor, and allosteric effectors, as well as promotes conformational changes in proteins" (Hazel and Prosser 1974). Thus, acclimation, or changes in thermal preference and tolerance made in response to changing water temperature, results from effects observable at the cellular level. Acclimation temperature is the temperature to which a fish has been exposed for a period of time sufficient to allow adjustment of physiological processes, e.g., metabolic rates (Brett 1956; Coutant 1972). The time required for acclimation to a given temperature varies from several days to more than a week (Fry 1971). For this biothermal assessment, an acclimation

[4] As noted in Section 1.3.1, the IIHR hydrothermal model grid contained nearly 2 million points. This raw IIHR model output was then distilled by HDR into a 50ft by 50ft "results grid" using the Surfer gridding program. This resulted in a grid-cell size that; (1) accurately reflected the raw model output, (2) retained sufficient spatial resolution to pinpoint any potential biothermal effects, and (3) reduced the number of data points to a level that made biothermal data post-processing manageable.

temperature was developed for each species habitat for each day, under each of the river flow scenarios studied. The acclimation temperature for a given day and habitat was assumed to be equivalent to the average temperature in the habitat area for the seven day period that proceeded the day being evaluated.

Determine the growth, avoidance, and chronic mortality temperature tolerances for the four RIS evaluated (data permitting): Figures 4 through 7 are temperature tolerance polygons for the four RIS evaluated. The polygon is a diagrammatic presentation of data which demonstrates how temperature tolerances change in response to changing combinations of acclimation and exposure temperatures (Beitinger and Bennett 2000). For the biothermal assessment, acclimation/exposure temperature relationships were defined for growth, avoidance (wherever possible), and thermal mortality. As can be seen in Figures 4 through 7, in general, the higher the acclimation temperature, the higher the tolerance temperature—until a maximum limit is reached, which is the point at which no further increase in thermal tolerance is possible via acclimation. This limit is shown in the figures as the point where the avoidance and chronic mortality lines plateau. Temperature tolerances plotted in the polygons were derived from the scientific literature (see Attachment 2 for more details).

The temperature tolerance polygon permits a stochastic component in biothermal assessments — namely, the simulation of a population response around the mean thermal threshold (which defines the level of impact or intensity of the temperature effect). This is important because response of individuals, within a fish species to a change in temperature is not uniform. Figure 8 shows an example of how the range of responses was modeled around the mean chronic mortality line for largemouth bass. (Attachment 2 provides additional information explaining this approach.)

A stochastic component is employed because a biothermal response of a fish population is properly understood to occur over a range or continuum of temperatures, not at a single, isolated value. In fact, reliance on a single thermal threshold can grossly oversimplify assessment findings. For example, it can lead to the conclusion that an exposure temperature 0.1°F above a single threshold would cause the whole population to be adversely affected or, conversely, that an exposure temperature 0.1°F below the threshold would cause no discernable effect. Such an all-or-nothing “binary” response is not representative of biological reality. The use of temperature tolerance polygons in the river-wide assessment of the plume’s biothermal effects accommodates a stochastic analysis that shows the continuous change in predicted biothermal effect over a range of temperatures. Only by incorporating the effect of variable response can a biothermal assessment realistically quantify the level of impact on aquatic organisms.

> **Determine when the life stages of the RIS inhabit Pool 14**: The times of year that the species' life stages reside in the study area (i.e., their "periods of occurrence") are detailed in Table 5. This information reflects the findings of decades-long sampling programs (LMS 2004) combined with period-of-occurrence data found in the scientific literature.

> **Determine horizontal and vertical habitats for the RIS in Pool 14**: Figures 9 through 12 delineate each species' life-stage habitats (in plan view) used in assessing biothermal effects. This information was derived from the scientific literature and the above noted HDR sampling programs and is summarized in Table 5. For the benthic species in Table 5, the acclimation and exposure temperatures were determined using the predicted bottom layer temperatures. For pelagic species, the average of the full water column temperatures was used.

> **Apply the preceding inputs to predict the plume's effects on the RIS' biological functions:** For each species' habitat, the acclimation temperature (the average of the habitat's temperatures during the preceding seven days) was determined from modeling output (see step 1). Then, for each day for each biothermal metric evaluated, the acclimation temperature and grid-cell exposure temperature were evaluated in light of the thresholds presented in the temperature tolerance polygon to predict expected biothermal effects.

The preceding process was carried out for each river flow scenario (and associated % excursion hours). Table 5 summarizes the life stages, habitats, and periods of occurrence that were evaluated. Collectively, these parameters comprised the inputs to the analytical process. The various species' life stages were selected based on an exhaustive literature search. Life stages not included in Table 5 were not analyzed either due to the lack of pertinent data in the scientific literature or because the life stage occurs outside the period evaluated.[5]

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[5] For example, walleye spawn from early to mid-April at temperatures of 47 to 53°F and the eggs hatch approximately seven to 10 days later." D. Bergerhouse, 2009.

3. RESULTS OF THE BIOTHERMAL ASSESSMENT

The following sections present the results of the biothermal assessment for the four RIS evaluated. For each biothermal metric evaluated, a brief discussion of methodology developed specifically for the model precedes the findings. It is important to remember that the biothermal assessment modeled effects under the reasonable worst-case design conditions detailed in Section 1.3.2. Thus the results approximate the near-highest levels of Station effects expected to occur. In most years, the effects would be less (e.g., if more typical higher river flows were simulated, and/or water temperatures for a cooler year were employed, reduced effects would be predicted).

3.1 Growth

Each species evaluated has a temperature range over which growth occurs. (The tolerance zones for each species are shown in Figures 4 through 7). Depending on the species and environmental circumstances, a thermal discharge could shift temperature in the river toward or away from the normal temperature range for growth. During the summer, the temperatures may occasionally be sufficiently high to cause the normal growth temperature for some of the species studied to be exceeded. A prolonged period of growth reduction could potentially decrease reproductive success and survival for the affected species, because fish that grow more slowly as a result of exposure to temperatures that exceed normal growth temperatures typically produce fewer eggs. Furthermore, slower growing individuals may be more vulnerable to predation, which often decreases with increasing size. Alternatively, warmer temperatures during some periods of the year can result in more favorable conditions for growth and, thus, potentially increase reproduction and survival.

3.1.1 Process of Determining Potential Growth Effects

The effect of plume temperatures on growth was evaluated for each day from June 1st to September 30th. For the analysis, it was assumed that the rate of species growth is uniform throughout the growth zone (i.e., the preference/tolerance zone shown in Figures 4 through 7). It was also assumed that sufficient food is available to allow for growth when exposure temperatures are within the growth zone range.

To determine the potential growth effects under the various river flow (and associated % excursion hours) scenarios, the following steps were performed:

Using the temperature tolerance polygons, each 50 ft by 50 ft grid cell within the species habitat was evaluated by comparing the exposure temperature (the temperature on the day being evaluated) to the acclimation temperature (average of the species habitat temperatures during the preceding seven days).[6] Then, referring back to the temperature tolerance polygons (Figures 4 through 7), if the point at which the acclimation temperature and exposure temperature intersect on the polygon fell within the tolerance-zone temperature limits, that portion of the habitat (i.e., grid-cell) was designated as available for growth. If the point of intersection was outside the tolerance-zone, then no growth was predicted for that grid-cell on that day.

The total habitat area available for growth was determined by summing together the areas of the individual grid cells available for growth, for each day evaluated.

For each day from June 1st through September 30th (122 days), the daily total habitat area available for growth was divided by the total species habitat area (e.g., where a value of 1.0 indicated that growth was predicted in every grid-cell in the species habitat on that day). The sum of these values yields the cumulative number of days for which growth is expected. This was determined for each species evaluated (the implicit assumption is that the population is equally distributed over the delineated habitat). The difference between potential total number of growth days (i.e., 122 days) and the cumulative number of days for which growth is predicted, yields the number growth days lost (i.e., the cumulative number of days in which the water temperatures were not favorable for growth).

3.1.2 Findings of the Growth Assessment

The results of the growth assessment are presented in Table 6. Little to no change in growth for largemouth bass and channel catfish is predicted. For spotfin shiner, it appears that the thermal discharge tends to shift temperatures into the temperature range favorable for growth. Apparently, during the cooler months of June and September, the plume's higher temperatures expand the volume of water that falls within the normal temperature range for growth needed by the spotfin shiner (i.e., above 72°F [24°C], as shown in Figure 7). Consequently, the number of growth days lost with the plant operating is less than under ambient conditions with no plant effects.

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[6] For example, the acclimation temperature applied for June 1 was the average temperature within the species' habitat from May 25 through May 31.

For walleye, a modest shift out of the normal temperature tolerance range is predicted when water temperatures are warmest.[7] Figure 13 shows the results of fitting a 2nd order polynomial through the biothermal model output (i.e., the number of growth days lost versus percent excursion hours). The 2nd order polynomial provides a good fit of the data (R^2 = 0.886; where R^2=1 represents a "perfect fit"). This polynomial equation was developed in order to estimate the number of growth days lost for the targeted 1.0% and 3.0% excursion hours (as noted in Section 1.1). As shown in Figure 13, the increase from 1.0% to 3.0% in excursion hours increases the number of walleye growth days lost from 9.6 to 15.0 days under the constant river flow scenarios. Therefore, approximately 5.7 additional walleye growth days are predicted to be lost if excursion hours are increased from 1.0% to 3.0% (under reasonable worst-case conditions).

Under the variable flow scenario the number of walleye growth days lost if the excursion hours (above 86°F) are set at 3.0% and 1.4%[8] above 89°F is 12.2 days an increase of 2.6 days over the 1.0% case or 2.13% of the 122 days available.

3.2 Thermal Avoidance and Habitat Loss

Thermal avoidance occurs when mobile species evade stressful high temperatures. This action often precedes and thus averts exposure to potentially lethal temperatures. This avoidance response is identified by Neill (1979) as "reactive thermoregulation." Although thermal avoidance can prevent exposure to harmfully high temperatures, it can also deter species from occupying otherwise useful habitat in the vicinity of a thermal plume.

3.2.1 Process of Determining Potential for Thermal Avoidance

Using the mean avoidance line in the polygons, with the lower and upper bounds around the mean set at ±5°C (see Attachment 2 for more details), the percent avoidance in each results grid

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[7] As previously indicated, the predicted (shaded) results for walleye in Table 6 for river flows of 13,800 cfs, 15,000 cfs, 17,500 cfs, and 20,000 cfs (excursion hours of 5.2%, 4.1%, 3.6%, and 3.8%, respectively) in actuality would not be experienced because the Plant would be required to curtail operations to comply with the proposed 3.0% limit.

[8] Although the target percentage for exceedance of the 89°F EOMZ limit was 1.5%, the percentage is computed on a daily basis and exceedance of 5 days yields a 1.4% value ([5/365]*100) and exceedance by 6 days yields a 1.6% value ([6/365]*100).

cell within the species habitat was determined for each day. The average percentage of total habitat avoided was then determined by:

Summing together the products of predicted avoidance and area for all grid cells in the habitat

Dividing the summed result by the total species habitat area and then multiplying by 100.

The preceding was done for largemouth bass, channel catfish, and spotfin shiner. As indicated in Table 5, insufficient paired data sets were found in the scientific literature to define an acclimation/exposure temperature relationship for walleye. Thus, an avoidance evaluation using the biothermal model was not possible for this species. This "data gap" is addressed in Attachment 3, which provides a supplemental analysis using a different data source, namely—the HDR Summertime Electro-fishing Program.

3.2.2 Findings of the Thermal Avoidance Assessment

The average and daily maximum avoidance results are presented in Table 7. The overall average percent habitat avoided for all of the scenarios over the June 1st to September 30th period was relatively small (≤ 1.00%).

Table 7 also lists the predicted maximum percentage of habitat avoided. For all species, the maximum result occurred on July 18. The maximum avoidance result occurred on the 18th because the simulated ambient river temperatures was relatively high (85.2°F), and the average water temperatures over the prior seven days was relatively cool (i.e., the fish were acclimated to water temperatures approximately 5.5°F cooler). Thus, the simulated sudden increase in temperature caused a spike in thermal avoidance. As is shown below, this condition was transitory and avoidance declined as acclimation to the higher temperatures proceeded.

For the variable flow scenario the average percentage of habitat avoided was 0.32% for channel catfish, 0.99% for spotfin shiner and 1.10% for largemouth bass. The daily maximum avoidance result of 15.8% for largemouth bass occurred on August 2nd because the simulated ambient river temperatures was relatively high (85.5°F) compared to the cooler average water temperatures over the prior seven days (i.e., the fish were acclimated to water temperatures approximately 3°F cooler), and the river flow on the 2nd and the preceding two days varied from only 12,600 to 12,700 cfs, and were the lowest flows to occur over the June 1st to September 30th period.

Figures 14 and 15 show the predicted daily percentage of habitat avoided for largemouth bass and spotfin shiner (the predicted avoidance for catfish was well below these two species). The predicted results for 1.0% and 3.0% excursion hours were determined by interpolation of the biothermal model output. This was done in order to estimate the predicted change in avoidance for the current and proposed level of allowable excursion hours (1.0% and 3.0%, respectively). Figures 14 and 15 illustrate the following:

In all cases, the instances of percent habitat avoided above the nominal level of 5% are both infrequent and brief.
The proposed alternative thermal standards increase from 1.0% to 3.0% would yield only a very slight increase in the average percentage of habitat avoided.

The use of the aforementioned 50 ft by 50 ft results grid in the biothermal assessment also allows for the contouring of the spatial distribution of predicted avoidance. Figures 16 and 17 show the percent predicted avoidance in the species' habitat area on the day of maximum avoidance for largemouth bass and spotfin shiner, respectively. In general, while the results show isolated pockets of elevated avoidance along the Iowa shoreline, the difference in the overall depth-weighted avoidance percentage is small. On the basis of this information, it was concluded that proposed alternate standard requested by Exelon would not result in a material change of available habitat for the species evaluated.

As noted above, insufficient information exists in the scientific literature to calculate avoidance for walleye using this methodology. However, this "data gap" is addressed in Attachment 3, which provides a supplemental analysis using data from the HDR Summertime Electro-fishing Program. The HDR field observations of temperature and abundance indicate that any displacement of walleye due to the plant's thermal plume will be transitory and will not cause appreciable harm to the walleye population in Pool 14.

3.3 Potential for Chronic Mortality from Prolonged Exposure

Including the potential for thermal mortality due to a prolonged exposure in this study assumes that a fish chooses not to or cannot avoid elevated temperatures. As indicated earlier, as a general rule, fish will avoid stressful elevated temperatures and thus will avoid a prolonged exposure that would result in mortality.

In addition, obviously, a fish cannot be subject to prolonged exposure to elevated temperatures if it has instead avoided the area. Thus, any lethal effects would be instead of, and not in addition to, any avoidance effects.

3.3.1 Process of Determining Potential Chronic Mortality

The assessment of thermal mortality due to a prolonged exposure followed the same analytical approach used for avoidance. That is, the population response around the mean (i.e., TL50) was determined as shown in Figure 8.

Several conservative assumptions were made in assessing mortality due to prolonged exposure to elevated temperatures:

The maximum daily exposure temperature was applied. Had weekly average temperatures been used, as suggested by the 1972 USEPA Water Quality Criteria (NAS/NAE, 1973), fewer chronic mortality effects would be predicted.

No thermal avoidance was assumed. As noted earlier, an avoidance response precludes exposures to lethal temperatures.

3.3.2 Findings of the Chronic Mortality Assessment

Table 8 summarizes the percent mortality for exposure to elevated temperatures for the four species evaluated. Little or no mortality is predicted for largemouth bass, catfish or spotfin shiner. Mortality predicted for walleye is relatively small under the constant river flow scenarios.[8] Based on the results presented in Figure 18, the proposed increase from 1.0% to 3.0% in excursion hours increases the potential of chronic mortality for walleye from 1.1% to 3.4%. This incremental increase of 2.3 percentage points (i.e., 3.4% - 1.1%) under reasonable worst-case conditions is not expected to cause appreciable harm to the local walleye population.

The variable flow scenario shows a 9.63% chronic mortality for walleye when the ambient temperature is adjusted to cause a 3.0% exceedance of the 86°F limit and 1.4% exceedance of 89°F. However, this estimate of mortality was made under the very conservative assumption that walleye would not avoid the warmer temperatures that could cause mortality. Based on real

[8] As previously explained, during the low flow conditions of 13,800 cfs, 15,000 cfs, 17,500 cfs, and 20,000 cfs, plant operations would be curtailed. Thus, the shaded mortality rates shown on Table 8 would not be experienced under the proposed 3.0% limit.

world data (as opposed to laboratory-derived data) collected over the past 11 years from Pool 14 and described in Attachment 3, low flows cause walleye to move away from warmer shoreline habitats as they become too shallow for use. It is reasonable to surmise that during these periods walleye move to deeper water and that this movement is transitory rather than permanent as they appear to return to the habitats when more favorable flow and temperature conditions develop in the fall.

4. CONCLUSIONS OF THE BIOTHERMAL ASSESSMENT

Several key analytical objectives were established by HDR for the biothermal assessment to ensure that sound results were developed:

Prediction of population-wide effects: Stochastic elements, such as responses around a mean, were incorporated into the model's logic so that laboratory results for individual fish at various temperatures can be translated into a population's predicted range of responses.

Retain the maximum amount of spatial resolution of the IIHR hydrothermal model results: The raw IIHR model output was distilled by HDR into a fine mesh 50 ft by 50 ft "results grid." Each 50 ft by 50 ft grid cell in a species' habitat was individually examined in the biothermal assessment. For the benthic species (as detailed Table 5), the acclimation and exposure temperatures were determined using the predicted bottom layer temperatures. For pelagic species, the average of the full water column temperatures was used. This single grid-cell approach (from a plan view), coupled with the designation of the appropriate vertical strata, ensures that the precise location in the study area of any predicted biothermal effect can be pinpointed.

Evaluate only the pertinent portions of the study area: Species and life-stage habitats were delineated so that only the areas where the species reside were evaluated.

Assess potential long-term temperature effects: Chronic thermal mortality due to a prolonged exposure to elevated temperatures was assessed under the very conservative assumption that no avoidance occurred.

Implement a conservative analytical approach: Wherever possible (e.g., by using a "reasonable worst-case" 2006 adjusted warm year ambient temperatures and the Station's maximum level of heated water discharge), parameter values that result in effects that are the same as or more severe than what are likely to actually occur were used.

Based on these approaches and methodologies, HDR was able to make the following findings and reach the following conclusions:

Growth - Little to no change in growth for largemouth bass and channel catfish was predicted for all of the scenarios evaluated. For spotfin shiner, it appears that the plume's higher temperatures expand the volume of water that falls within the normal temperature range for growth, and thus as the station's thermal influence increased (i.e., at the lower river flows and higher % excursion hours), so did the predicted number of growth days. For walleye, a modest shift out of its normal temperature tolerance range is predicted, so an increase in the Station's allotted excursion hours from 1.0% to 3.0% of annual hours above 86°F and 1.4% above 89°F would increase the predicted number of lost growth days from 9.6 to 12.2 days an increase of 2.6 days or 2.1% of total growth days for the 122 day period of study. The ambient condition (i.e., no plant effect) would result in 1 day (0.8% of total growth days) of lost growth for walleye.

Avoidance (Habitat Loss Due to Elevated Temperatures) - The predicted overall average percentage of habitat avoided from June 1 to September 30th for all scenarios was relatively small (<2.0%). For catfish, the average percentage of habitat avoided was less than 1%. The maximum (i.e., the highest daily value under the proposed alternative thermal standard) was approximately 6.0% habitat avoidance. For largemouth bass and spotfin shiner, the instances of percent habitat avoided above the 5% are both infrequent and brief. For both of these species, the proposed increase in the Station's excursion hours from 1.0% to 3.0% under the constant flow cases yielded only a very slight increase in the average percentage of available habitat avoided (0.6% to 1.1%) of overall average habitat avoided for largemouth bass and 0.6% to 1.0% for spotfin shiner. Under the variable flow scenario, which simulated the most extreme condition under the alternative standard requested by Exelon, the predicted overall average habitat avoided was 1.10% for largemouth bass and 1.0% for spotfin shiner. On the basis of this information, it was concluded that the proposed increase in percent excursion hours would not result in a material change in available habitat for the three species evaluated.

Although sufficient acclimation/avoidance temperature data sets were not available to perform the same analysis for walleye, this "data gap" is addressed in Attachment 3, which provides a supplemental analysis using data from the HDR Summertime Electro-fishing Program. Based on these observations, there is reason to expect that any displacement of walleye for either low flow or thermal reasons will be transitory and will not cause appreciable harm to the walleye population which inhabits Pool 14 or adjacent pools.

Potential for Chronic Thermal Mortality (Due to a prolonged exposure, under the assumption that fish do not or cannot avoid stressful temperatures) – Under all flow scenarios (which included excursion hours as high as 5.2%), the predicted chronic mortality for largemouth bass, channel catfish, and spotfin shiner is negligible. Based on the regression curve for walleye in Figure 18, increasing the percent of excursion hours over 86°F from 1.0% to 3.0% increased the predicted chronic mortality from 1.1% to 3.4% under the constant flow scenarios. This incremental increase of 2.3 percentage points (i.e., 3.40% - 1.1%) under reasonable worst-case conditions is not expected to cause appreciable harm.

For the variable flow scenario, the walleye chronic mortality corrected for the no plant flow condition is 9.5%. This assumes laboratory controlled conditions, i.e. no avoidance occurs. *In situ*, avoidance becomes the controlling behavioral survival mechanism. While some chronic mortality may occur with temperature working in concert with other stresses, e.g. disease or low dissolved oxygen levels, that percentage is expected to be substantially less than 9.5%.

The conclusion is that the proposed adjusted standard will not cause any appreciable harm to the RIS evaluated herein. Furthermore, the low level of impacts predicted in this assessment for the RIS suggests that the proposed alternate thermal standard will be adequately protective of the overall fish community. In support of this position, it is important to remember that the study area (see the habitat Figures 9 through 12) represents only a small fraction of the total area of Navigation Pool 14 (approximately 8.5%). Thus the small predicted biothermal effects on the study area's fish populations are even more negligible when viewed within the context of the entirety of Navigation Pool 14[9] and the river wide populations of these species.[10]

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[9] Stated numerically, a 2% predicted biothermal effect on study area translates to a 0.17% effect on Navigation Pool 14 (i.e., a 2% effect [population fraction of 0.02] in an area that comprises 8.5% of Navigation Pool 14 [area fraction of 0.085], is equivalent to 0.02 times 0.085, which equals 0.0017 [or 0.17%].)

[10] For example, largemouth bass are widely distributed throughout North America, which includes the Mississippi River.

5. TABLES

Table 1. Temperature Criteria Applied at the end of the QCNS Mixing Zone

Month	Monthly Maximum Temperature limit		Temperature Threshold for the tracking of Excursion Hours (3°F or 1.7°C less than the maximum limit)	
	° F	° C	° F	° C
January	48	8.9	45	7.2
February	48	8.9	45	7.2
March	60	15.6	57	13.9
April	71	21.7	68	20.0
May	81	27.2	78	25.5
June	88	31.1	85	29.4
July	89	31.7	86	30.0
August	89	31.7	86	30.0
September	88	31.1	85	29.4
October	78	25.5	75	23.8
November	68	20.0	65	18.3
December	55	12.8	52	11.1

Table 2. Results of the Scientific Literature Search (for the targeted 15 species)

Species	Literature Search Results	
	Insufficient or no thermal information found	Sufficient thermal information was found
Higgins-eye pearly mussel[1]	√	
Western sand darter	√	
Grass pickerel	√	
Paddlefish	√	
Bullhead minnow	√	
Emerald shiner	√	
Mooneye	√	
Shovelnose sturgeon	√	
Golden redhorse	√	
Freshwater drum	√	
White bass	√	
Channel Catfish		√
Largemouth bass		√
Spotfin shiner		√
Walleye		√

Notes:

[1] It is relevant to note that the Higgins-eye pearly mussel, a Federally endangered species, does occupy portions of the river bed downriver of the discharge, near the Illinois shoreline. An exhaustive literature search for this species yielded no thermal tolerance data. Thus, while a quantitative bio-thermal analysis is not possible, a narrative assessment, to the extent possible, is included in the Summary (pages 27, 34, and 35), Appendix A (pages A-31 thru A-36), and on pages C-14 and 15 in Appendix C.

Table 3. Summary and Brief Explanation of the Values Selected for the Plant and River Design Conditions
(See Attachment 1 for more details)

Design Condition	Selected Values	Remarks
Plant Operation	The level of the heated water discharged to the river (ΔT_{plant}) times the cooling water flow (Q_{plant}) defines the amount of heat added to the river. The values used were: Q_{plant} = 2192 cfs ΔT_{plant} = 28°F (15.6°C)	These values represent the maximum level of QCNS heat discharge.
River Flow in cfs	13,800, 15,000, 17,500, 20,000, 22,500, 25,000, 27,500, 30,000 and actual daily river flows	This series of fixed river flow conditions begin at the reasonable worst-case low flow event (i.e., 7Q10)[1] of 13,800 cfs, and progress up to 30,000 cfs (i.e., typical summertime flow).
Natural or Ambient River Temperature	Adjusted daily USACE temperatures from June 1 through September 30, 2006 (maximum unadjusted temperature equal to 84.54°F; maximum adjusted temperature equal to 85.5°F).[2]	After an extensive literature search, it was determined that the USACE water temperature readings at Lock and Dam 13 represent the best available data source to define ambient temperature (located approximately 12miles upriver of the QCNS). The USACE provided daily temperature readings from mid-October 1996 through mid-April 2004 (i.e., their entire record, at the date of the request).Additional daily data through 2006 was available on the USACE website.

Notes:

[1] The 7-day, 10-year low flow (7Q10) is the flow rate below which the annual minimum 7-day-mean flow dips at intervals whose average length is 10 years (that is, once in 10 years, on average).

[2] See Attachment 1.

Table 4. Synthesis of the Design Scenarios for the Bio-thermal Assessment

Simulated River Flow (cfs)	Associated Percent Excursion Hours (EOMZ >= 86°F)	Associated Percent Excursion Hours (EOMZ >= 89°F)
13,800 (7Q10 value)	5.2	2.2
15,000	4.1	1.6
17,500	3.6	0.5
20,000	3.8	0.5
22,500	3.0	0.0
25,000	2.7	0.0
27,500	2.2	0.0
30,000	2.2	0.0
Actual daily river flow	3.0	1.4[1]

Notes:

[1] Although the target percentage for exceedance of the 89°F EOMZ limit was 1.5%, the percentage is computed on a daily basis and exceedance of 5 days yields a 1.4% value ([5/365]*100) and exceedance by 6 days yields a 1.6% value ([6/365]*100).

Table 5. Biothermal Metrics Evaluated (Page 1 of 2)

Species	Life stage	Biothermal Metrics to be evaluated	Thermal tolerance equation available from the liter.	Period of Residence	Habitat with the Study Area	
					Horizontal delineation	Vertical Strata
Largemouth bass	YOY	Chronic Mortality	Yes	June 1 to Sept 30: critical summer period (They remain for the remainder of the year)	Figure 9A. Littoral Zone:[1] Young spend the first summer of life in sheltered littoral, weedy areas near spawning grounds and some move offshore in fall (substrate: vegetation, sand, mud, detritus; occasionally stone or rubble). Typically reside in wood (i.e., tree roots) and fallen log structures along the river banks.	Bottom: Usually to 6 ft; also found at depths of 14-20 ft around structures.
	Juveniles & Adults	Growth	Yes	June 1 to Sept 30: Emphasis on the critical summer season (as bass are relatively sedentary during this period).	Figure 9B. Prefer the littoral zone.	Both bottom and pelagic (i.e., full water column)
		Avoidance	Yes			
		Chronic mortality	Yes	June 1 to Sept 30 (see above)		

Walleye	YOY	Insufficient paired data sets were found in the scientific literature for this life stage		Includes the critical summer period: June 1 to Sept 30	Littoral Zone: During June 1 through July, YOY select areas along the river bank and base of wing dams. By mid- to-late summer (August through September) the YOY move out of the shallows into deeper water due.	Bottom
	Juveniles & Adults	Growth	Yes	Includes the critical summer period: June 1 to Sept 30	Figure 10. Inhabit wing dams throughout the summer and fall. Use the near channel flats at depths of 6 to 12 ft. Prefer clean, hard bottoms rather than bottoms of silt, muck or other soft materials. Favor bottoms with a combination of sand, gravel and rock.	Pelagic
		Avoidance: Insufficient paired data sets were found in the scientific literature to define an acclimation/exposure temperature relationship				
		Chronic mortality	Yes			

Notes:

[1] The area in and adjacent to shallow, fresh water, where light penetration extends to the bottom sediments, giving a zone colonized by rooted plants (helophytes).

Table 5. Biothermal Metrics Evaluated – continued (Page 2 of 2)

<table>
<tr><th rowspan="2">Species</th><th rowspan="2">Life stage</th><th rowspan="2">Biothermal Metrics to be evaluated</th><th rowspan="2">Thermal tolerance equation available from the liter.</th><th rowspan="2">Period of Residence</th><th colspan="2">Habitat with the Study Area</th></tr>
<tr><th>Horizontal delineation</th><th>Vertical Strata</th></tr>
<tr><td rowspan="4">Channel Catfish</td><td>YOY</td><td>Growth</td><td>Yes</td><td>Mid-August/ September to end of year – The critical summer period of June 1 to Sept 30 evaluated herein</td><td>Figure 11A. Larvae remain in nest up to 8 days &; young-of-the-year apparently move into the deeper waters of the main channel. Also use some near-shore shallow areas.</td><td>Bottom</td></tr>
<tr><td rowspan="3">Juveniles & Adults</td><td>Growth</td><td>Yes</td><td rowspan="3">Includes the critical summer period: June 1 to Sept 30</td><td rowspan="3">Figure 11B. Inhabit Because they are sensitive to light, they seek out shaded, deep pools around submerged logs, rocks, and other debris.</td><td rowspan="3">Prefer bottom</td></tr>
<tr><td>Avoidance</td><td>Yes</td></tr>
<tr><td>Chronic mortality</td><td>Yes</td></tr>
</table>

Spotfin Shiner	YOY, Juveniles & Adults	Growth	Yes	Includes the critical summer period: June 1 to Sept 30	Figure 12. Very close to shore: Prefers near-shore shallow waters, and most frequently inhabit shallow flats and island points.	Prefers full water column (pelagic), sometimes at surface (Note: this distinction is not that important, given the very shallow preferred habitat)
		Avoidance	Yes			
		Chronic mortality	Yes			

References used to develop this table:

(1) LMS, 2004
(2) Allaby, 1994
(3) EPA, 2002
(4) Coker et al, 2001
(5) Schneider, 2002
(6) Iowa DNR Website: http://www.iowadnr.com/fish/programs/research/mississ/mrlmb.html

Table 6. Summary of Biothermal Growth Effects: Number of Potential Growth Days Lost
(From June 1st to September 30th; Total number of days evaluated = 122)

Simulated River Flow (cfs)	Associated Percent Excursion Hours	Number (and percent) of Growth Days Lost			
		Largemouth Bass Juveniles & Adults	Channel Catfish YOY, Juveniles, & Adults	Spotfin Shiner YOY, Juveniles, & Adults	Walleye Juveniles & Adults
13,800 (7Q10 value)	5.2	7.0 (5.8%)	6.1 (5.0%)	12.9 (10.6%)	23.2 (19.0%)
15,000	4.1	6.8 (5.6%)	5.1 (4.2%)	12.9 (10.61%)	21.9 (18.0%)
17,500	3.6	3.5 (2.9%)	3.1 (2.6%)	13.5 (11.1%)	17.7 (14.5%)
20,000	3.8	2.5 (2.0%)	0.0 (0.0%)	13.9 (11.4%)	15.8 (12.9%)
22,500	3.0	2.0 (1.7%)	0. 0 (0.0%)	14.5 (11.9%)	15.3 (12.5%)
25,000	2.7	1.6 (1.3%)	0. 0 (0.0%)	14.9 (12.2%)	13.7 (11.2%)
27,500	2.2	1.5 (1.2%)	0. 0 (0.0%)	15.0 (12.3%)	13.2 (10.8%)
30,000	2.2	1.1 (0.9%)	0. 0 (0.0%)	15.2 (12.5%)	12.8 (10.5%)
Actual Daily River Flow	3.0	3.4 (2.8%)	0.20 (0.2%)	15.2 (12.5%)	12.2 (10.0%)
Ambient temperature effects (i.e., without the influence of the Station's thermal plume)	0.0	0.0 (0.0%)	0.0 (0.0%)	18.0 (14.8%)	1.0 (0.8%)

<u>Note:</u> The objective of this study is to determine the feasibility of requesting a site-specific, permanent adjusted standard that would increase the Station's allotted excursion hours above an EOMZ temperature of 86°F from 1% to 3% of annual hours and to allow an allotment of excursion hours above an EOMZ temperature of 89°F of 1.5% of annual hours. Thus, the shaded results for river flows of 13,800, 15,000, 17,500 and 20,000 cfs (excursion hours of 5.2%, 4.1%, 3.6% and 3.8%) should be overlooked as they are above the targeted standard of 3.0%.

Table 7. Summary of Predicted Avoidance Results (from June 1 to September 30)

Simulated River Flow (cfs)	Associated Percent Excursion Hours	Percent of Habitat Avoided					
		Largemouth Bass Juveniles & Adults		Channel Catfish YOY, Juveniles, & Adults		Spotfin Shiner YOY, Juveniles, & Adults	
		Average	Daily maximum	Average	Daily maximum	Average	Daily maximum
13,800 (7Q10 value)	5.2	1.53	16.1	0.46	5.3	1.26	13.5
15,000	4.1	1.51	16.1	0.45	5.0	1.27	13.6
17,500	3.6	1.37	15.1	0.38	4.1	1.21	13.2
20,000	3.8	1.17	13.5	0.32	3.3	1.06	12.2
22,500	3.0	1.09	12.9	0.29	3.0	1.01	11.7
25,000	2.7	1.00	12.1	0.26	2.6	0.95	11.2
27,500	2.2	0.95	11.6	0.24	2.3	0.91	10.9
30,000	2.2	0.88	10.9	0.22	2.2	0.85	10.4
Actual Daily River Flow	3.0	1.10	15.8	0.32	6.2	0.99	11.9

Ambient Temperature effects (i.e., without the influence of the Station's thermal plume)	0.0	0.4	5.5	0.11	1.4	0.46	6.1

Note: The objective of this study is to determine the feasibility of requesting a site-specific, permanent adjusted standard that would increase the Station's allotted excursion hours from 1% to 3% of annual hours. Thus, the shaded results for river flows of 13,800, 15,000, 17,500 and 20,000 cfs (excursion hours of 5.2%, 4.1%, 3.6% and 3.8%) should be overlooked as they are above the targeted standard of 3.0%. Based on the results presented in Figures 14 and 15 for largemouth bass and spotfin shiner, the proposed increase from 1% to 3% in excursion hours yields only a slight increase in the % habitat avoided.

Table 8. Summary of Predicted Area-weighted Chronic Mortality

Simulated River Flow (cfs)	Associated Percent Excursion Hours	Predicted Chronic Mortality within the Species Habitat			
		Largemouth Bass YOY, Juveniles & Adults	Channel Catfish YOY, Juveniles, & Adults	Spotfin Shiner YOY, Juveniles, & Adults	Walleye Juveniles & Adults
13,800 (7Q10 value)	5.2	0.02%	0.00 %	0.14%	10.79%
15,000	4.1	0.03%	0.00 %	0.18%	9.96%
17,500	3.6	0.03%	0.00 %	0.25%	7.45%
20,000	3.8	0.02%	0.00 %	0.14%	4.84%
22,500	3.0	0.02%	0.00 %	0.16%	3.95%
25,000	2.7	0.01%	0.00 %	0.12%	3.01%
27,500	2.2	0.01%	0.00 %	0.10%	2.56%
30,000	2.2	0.01%	0.00 %	0.07%	1.88%
Actual Daily River Flow	3.0	0.02%	0.00 %	0.16%	9.63%
Ambient temperature Effects (i.e., without the influence of the Station's thermal plume)	0.0	0.0%	0.0%	0.01%	0.11%

<u>Note:</u> The objective of this study is to determine the feasibility of requesting a site-specific, permanent adjusted standard that would increase the Station's allotted excursion hours from 1% to 3% of annual hours. Thus, the shaded results for river flows of 13,800, 15,000, 17,500 and 20,000 cfs (excursion hours of 5.2%, 4.1%, 3.6% and 3.8%) should be overlooked as they are above the targeted standard of 3.0%. Based on the results presented in Figure 18, the proposed increase to 3% in excursion hours increases the potential of chronic mortality for Walleye to at most 3.4%.

6. FIGURES

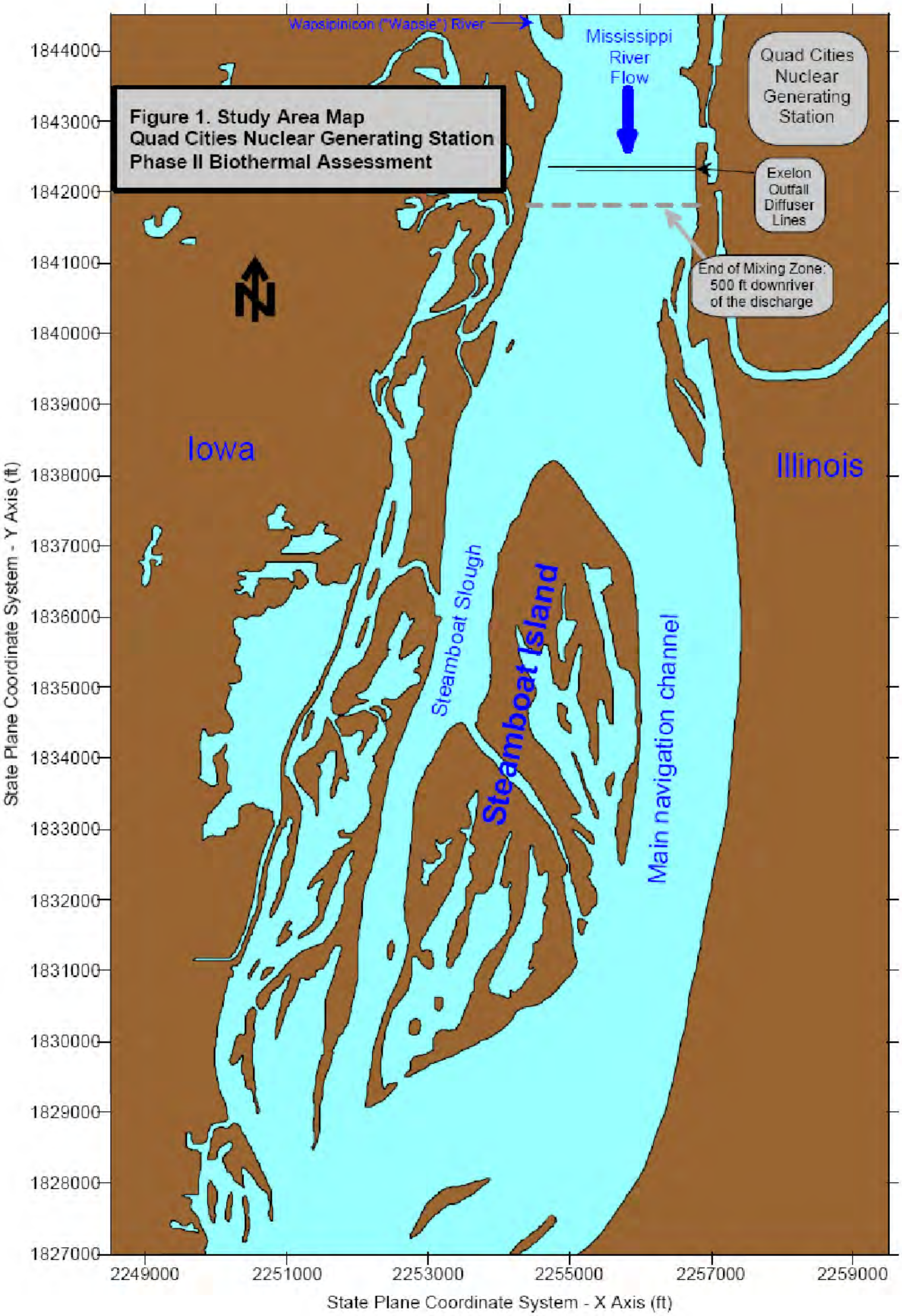
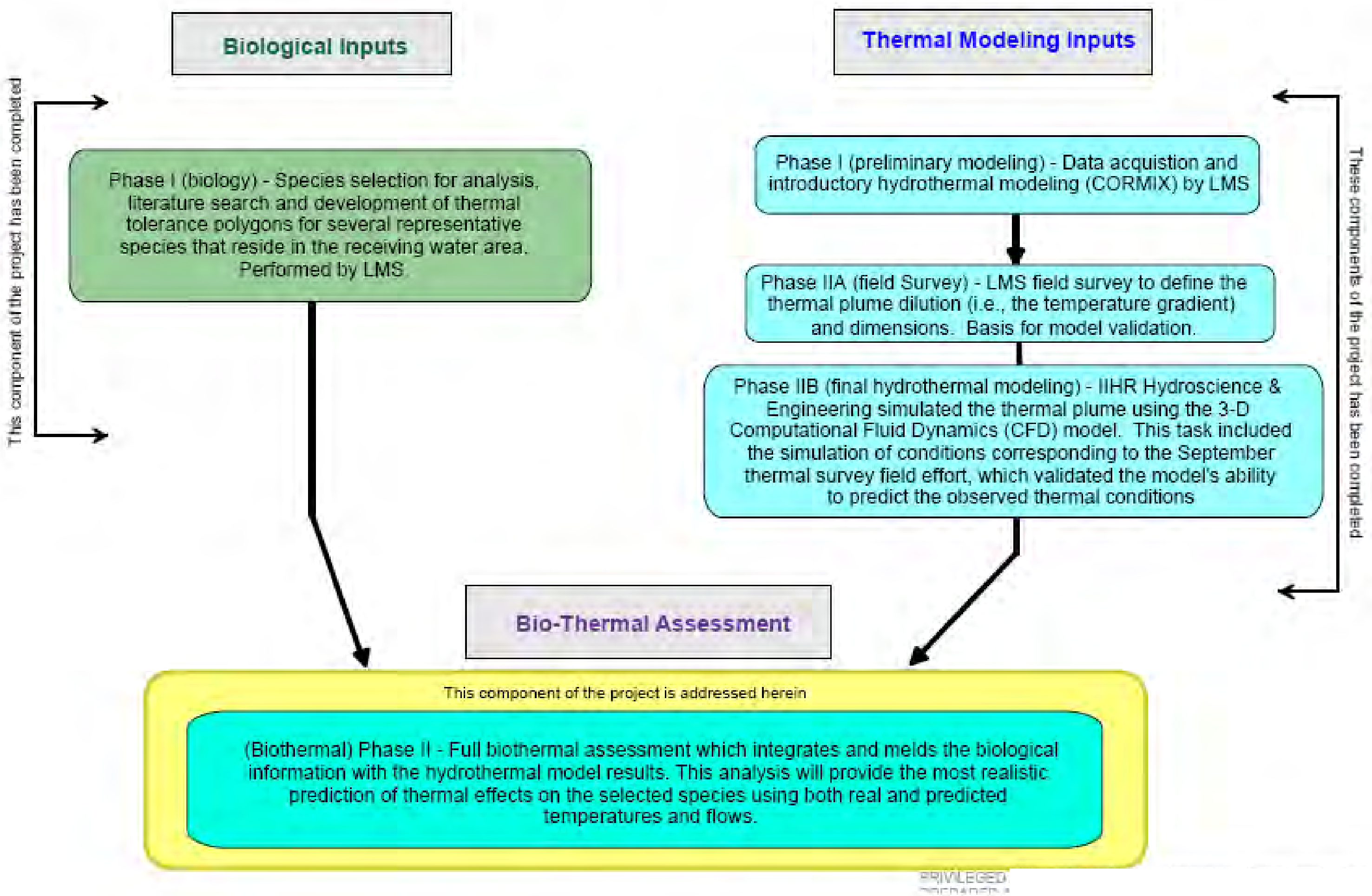
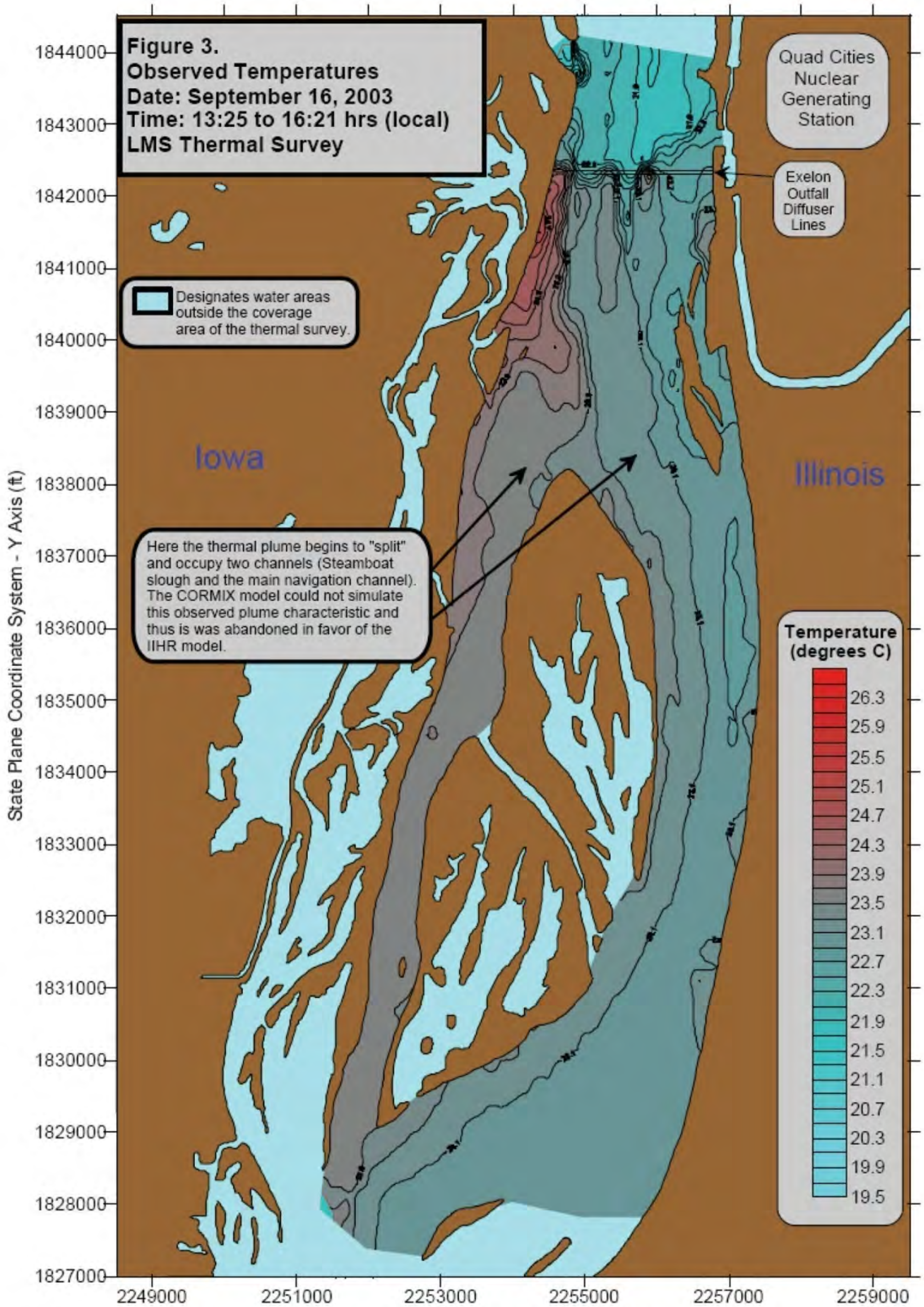


Figure 1. Study Area Map
Quad Cities Nuclear Generating Station
Phase II Biothermal Assessment
Wapsipinicon ("Wapsie") River
Mississippi River Flow
Quad Cities Nuclear Generating Station
Exelon Outfall Diffuser Lines
End of Mixing Zone: 500 ft downriver of the discharge
Iowa
Illinois
Steamboat Slough
Steamboat Island
Main navigation channel
N
State Plane Coordinate System - Y Axis (ft)
State Plane Coordinate System - X Axis (ft)
1844000
1843000
1842000
1841000
1840000
1839000
1838000
1837000
1836000
1835000
1834000
1833000
1832000
1831000
1830000
1829000
1828000
1827000
2249000
2251000
2253000
2255000
2257000
2259000

Figure 2. Quad Cities Generating Station - Overview of Project Tasks
Biothermal Assessment of the Thermal Plume's Effect in the receiving waters of the Mississippi River





Source: LMS Thermal Survey Report

Figure 4. Temperature Tolerance Polygon for Largemouth Bass

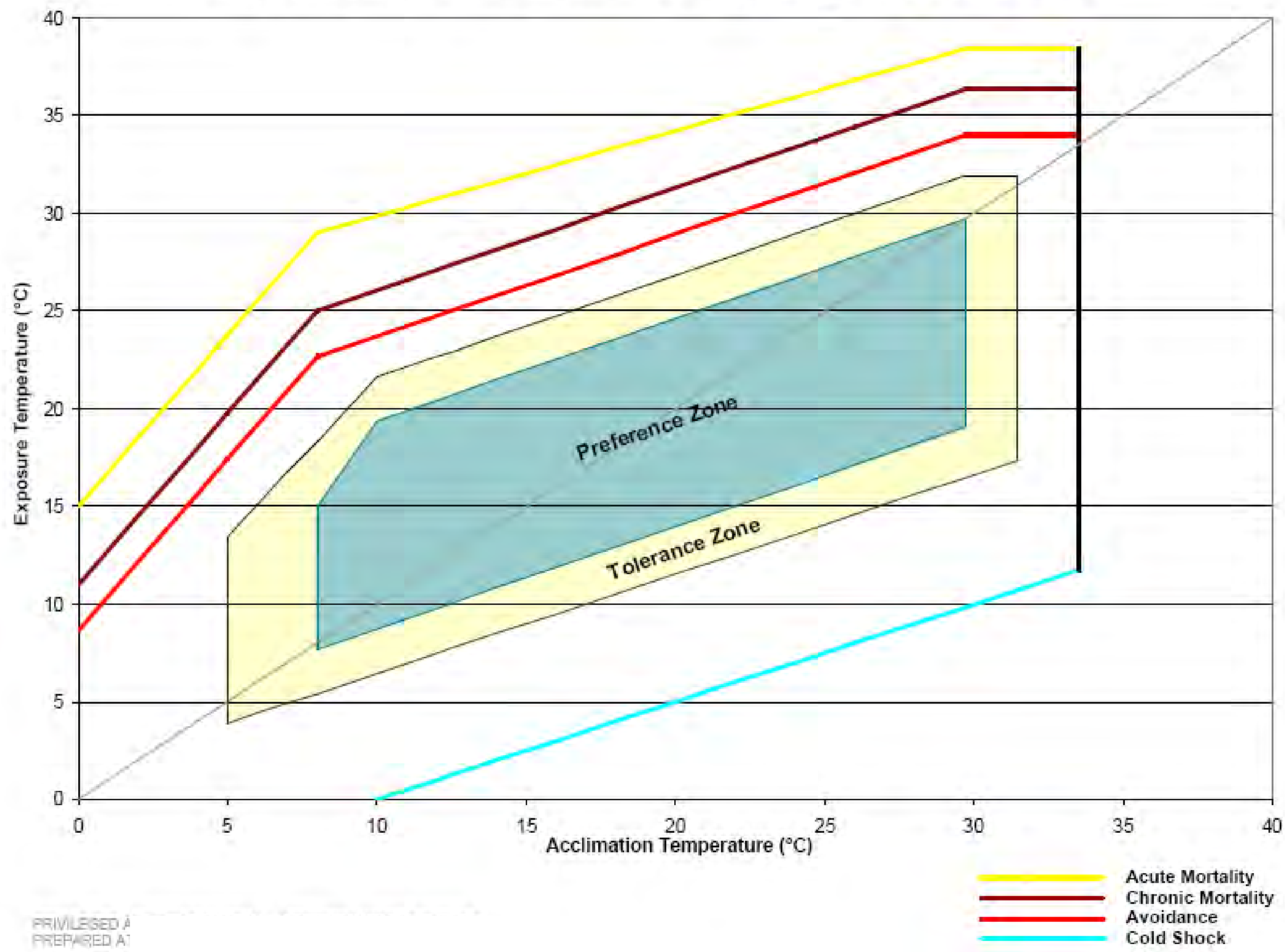


Figure 5. Temperature Tolerance Polygon for Walleye

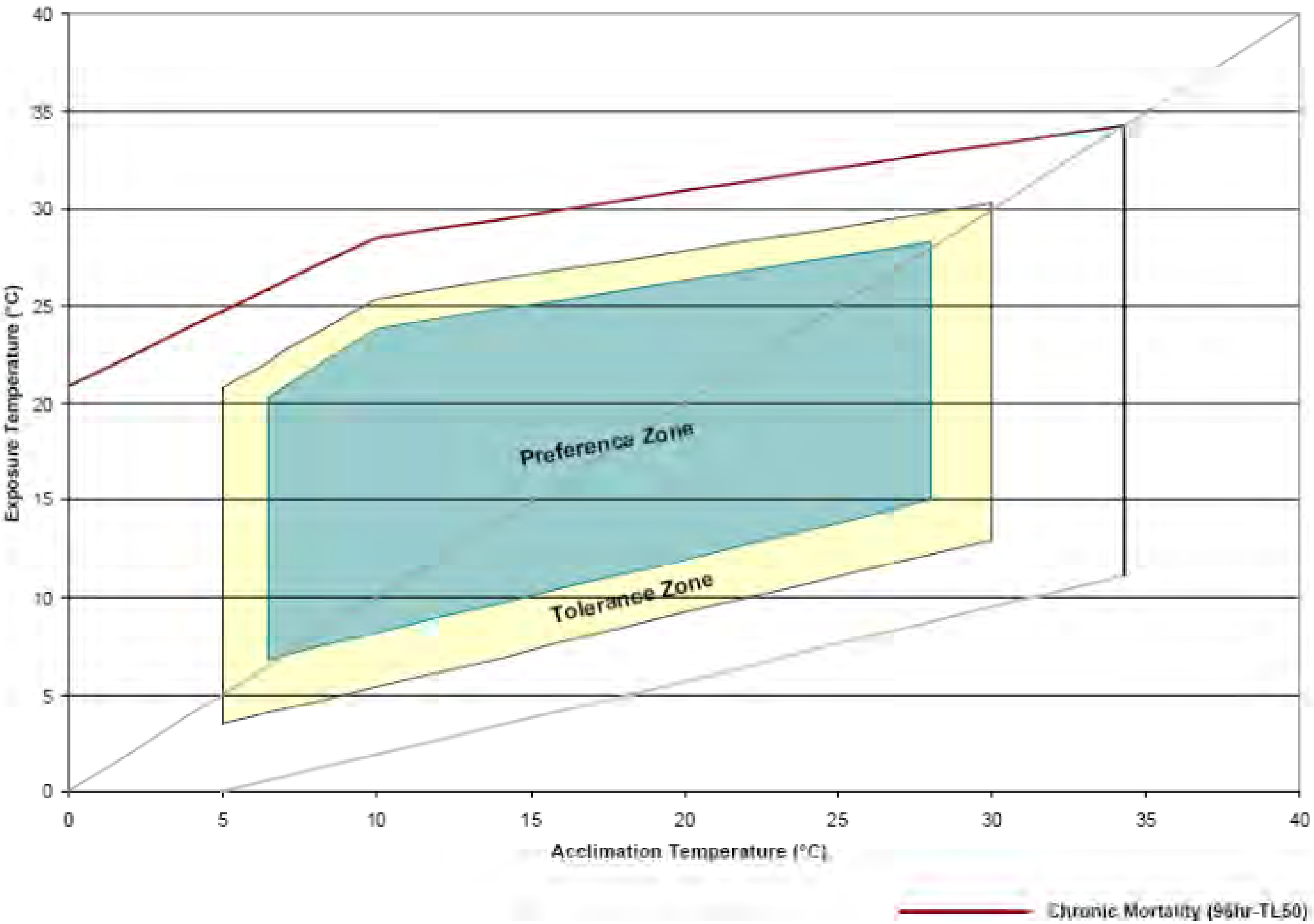


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Figure 6. Temperature Tolerance Polygon for Channel Catfish

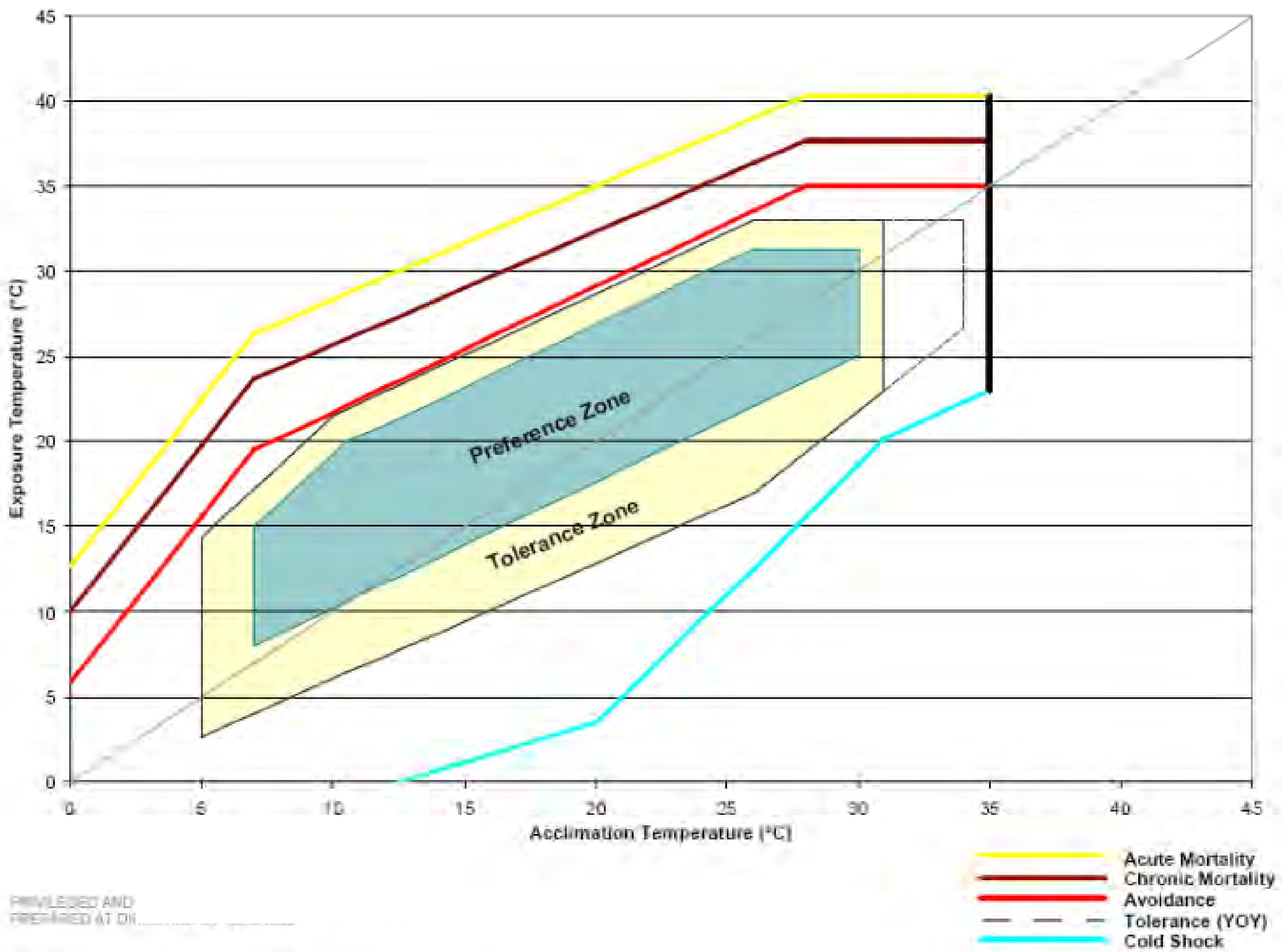


Figure 7. Temperature Tolerance Polygon for Spotfin Shiner

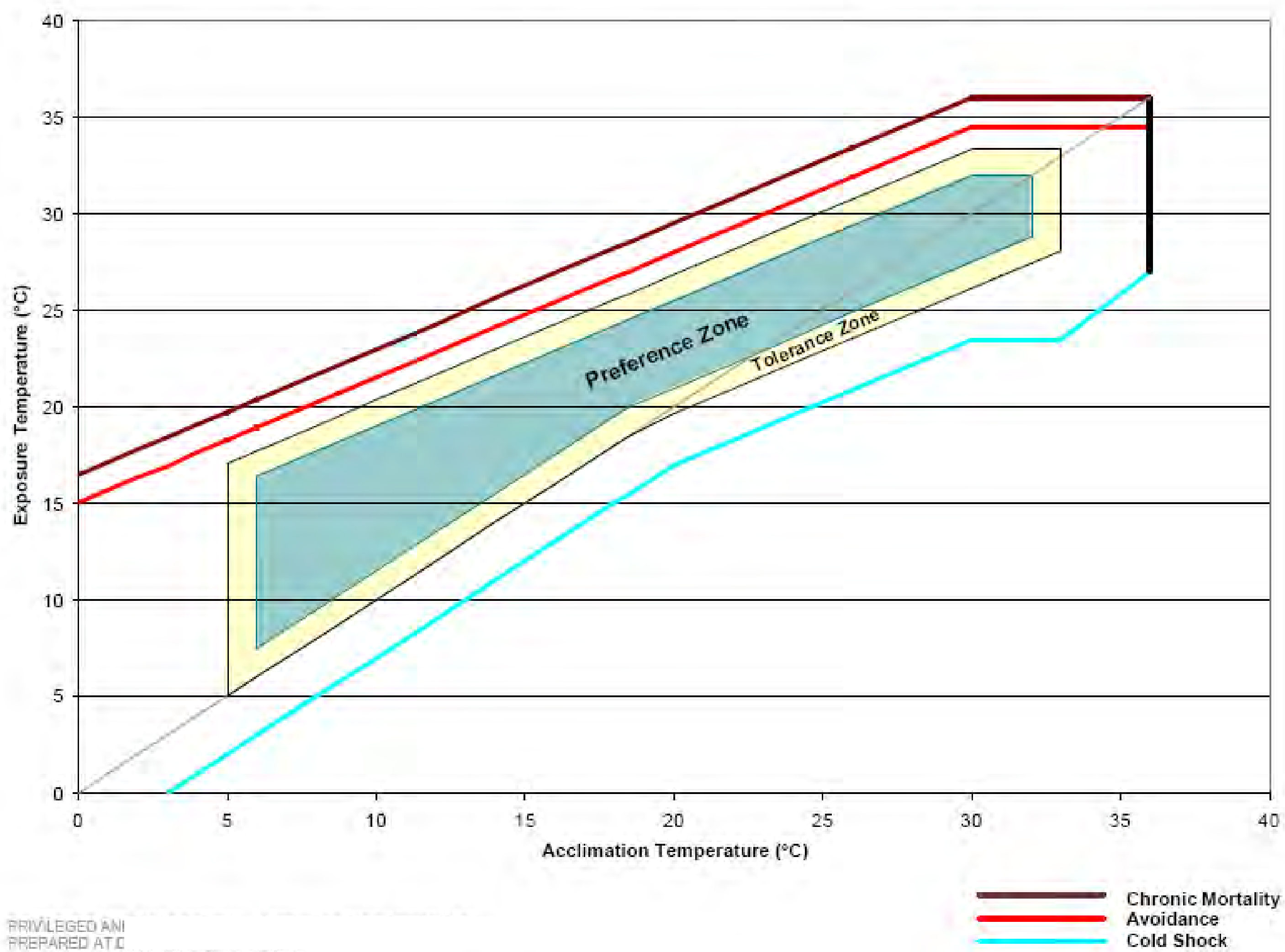
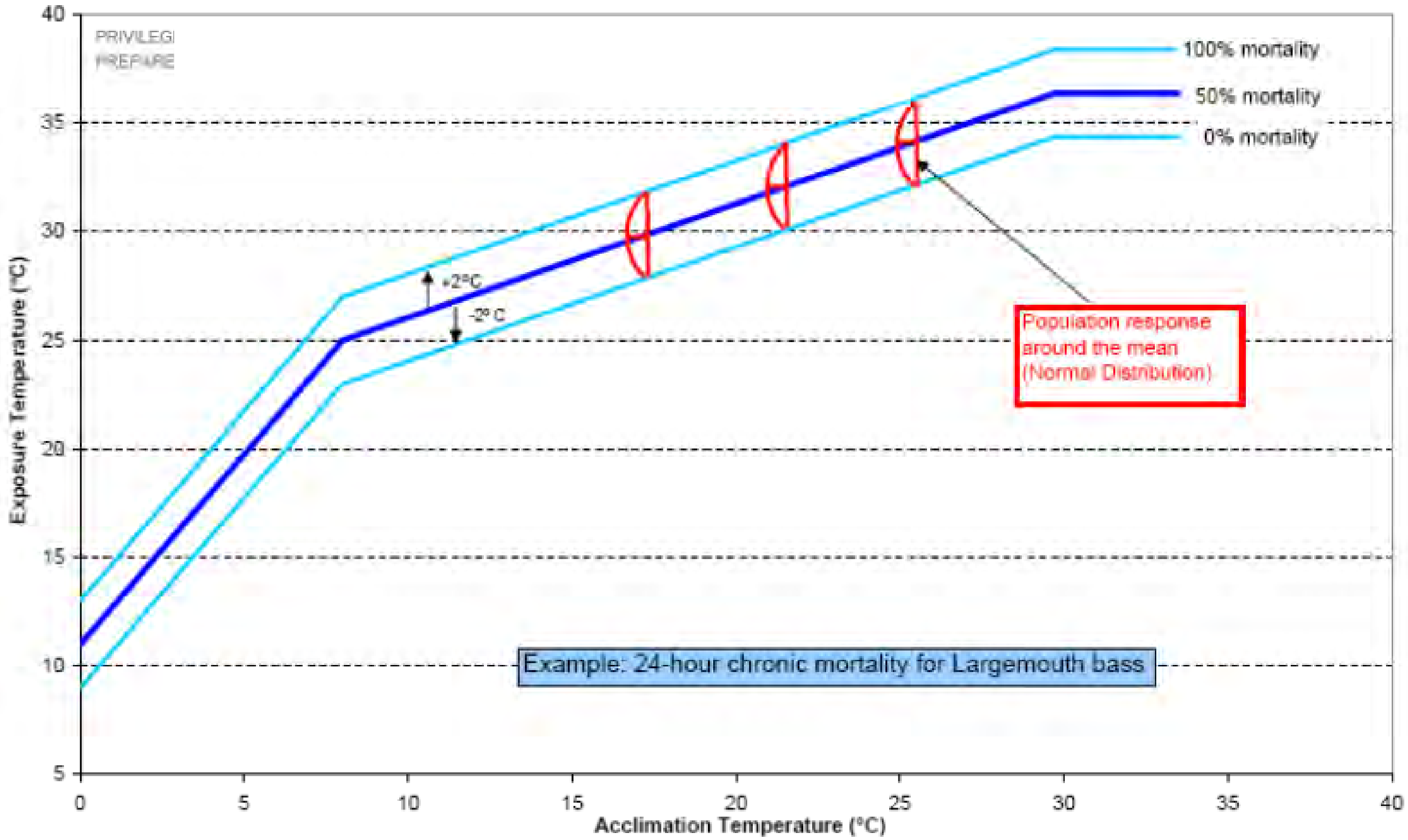


Figure 8. Range of Responses Modeled
(2°C above and below the mean)



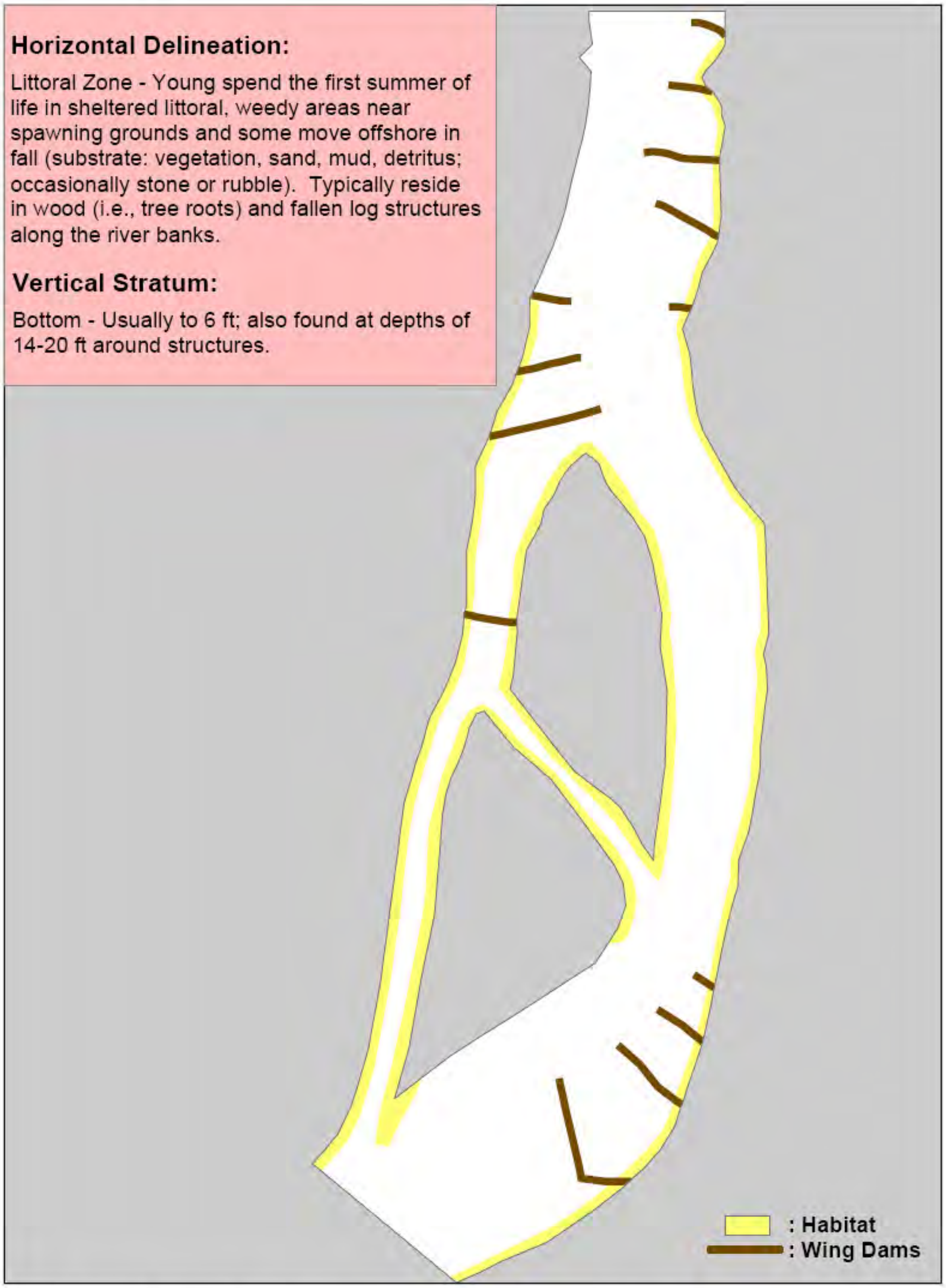


Figure 9A. Young-of-the-Year (YOY) Largemouth Bass habitat in the project study area (downriver of the Quad Cities Nuclear Generating Station's Thermal Discharge)

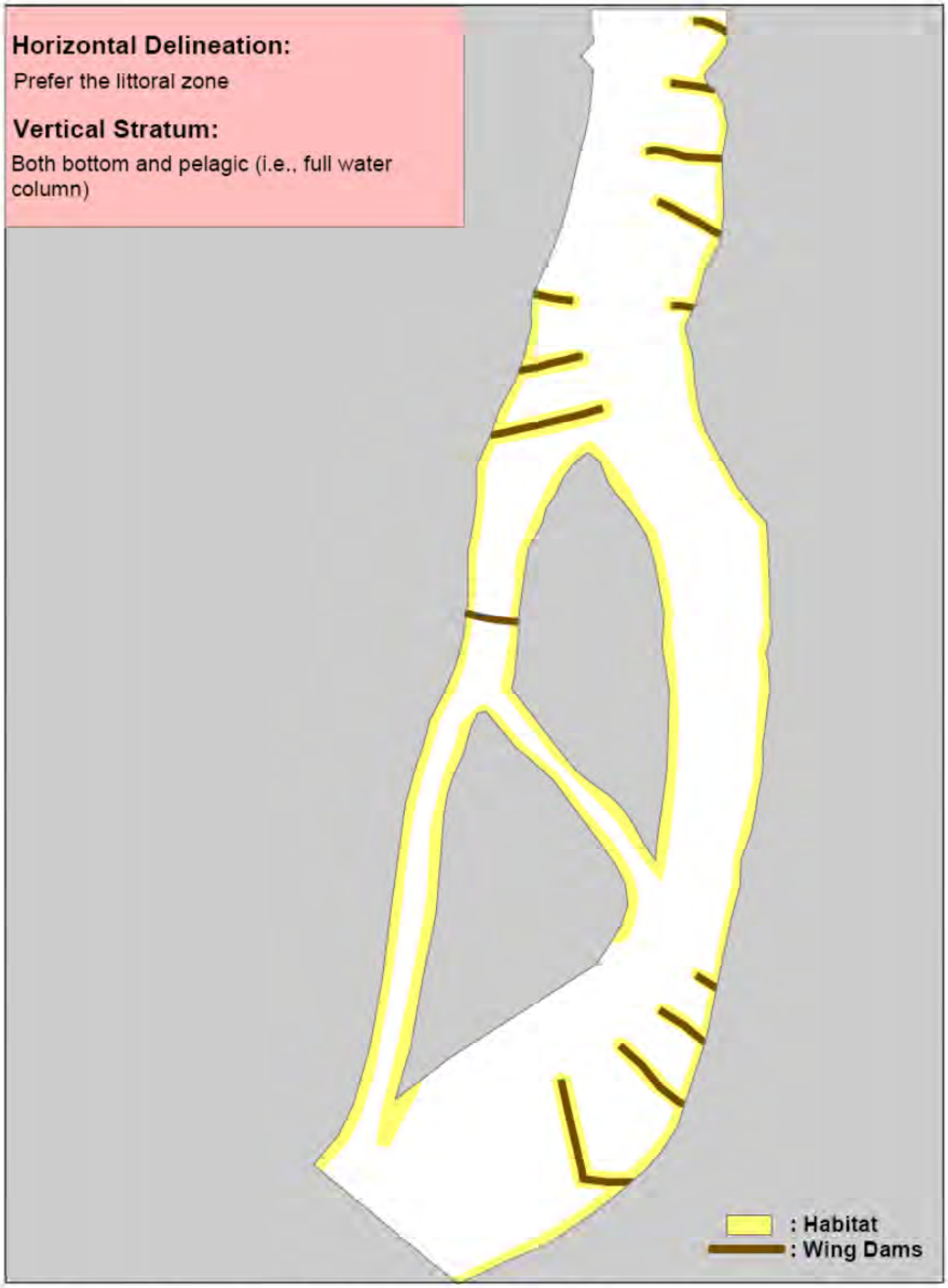


Figure 9B. Juveniles and adults Largemouth Bass habitat in the project study area (downriver of the Quad Cities Nuclear Generating Station's Thermal Discharge)

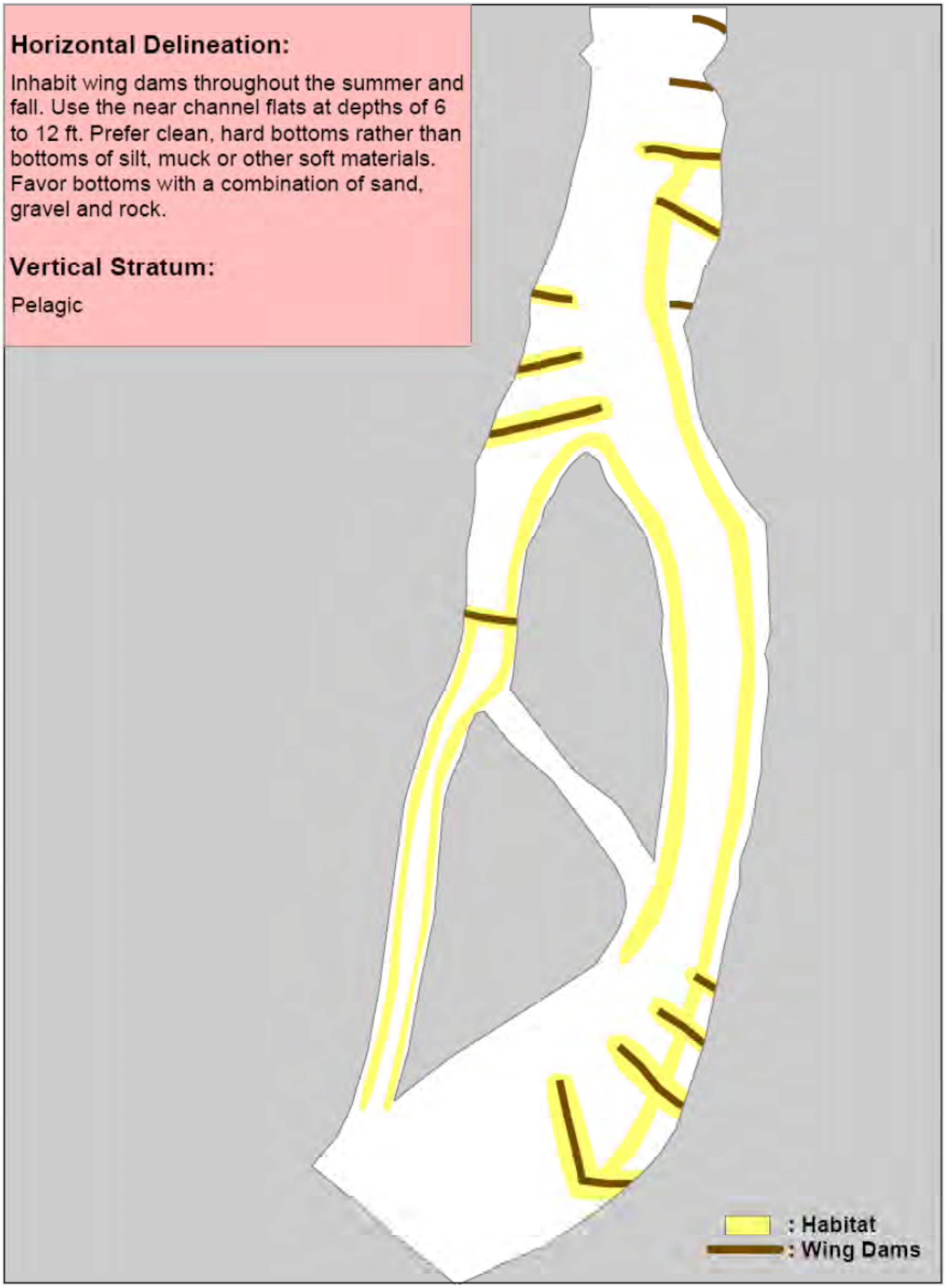


Figure 10. Juveniles and adults Walleye habitat in the project study area (downriver of the Quad Cities Nuclear Generating Station's Thermal Discharge)

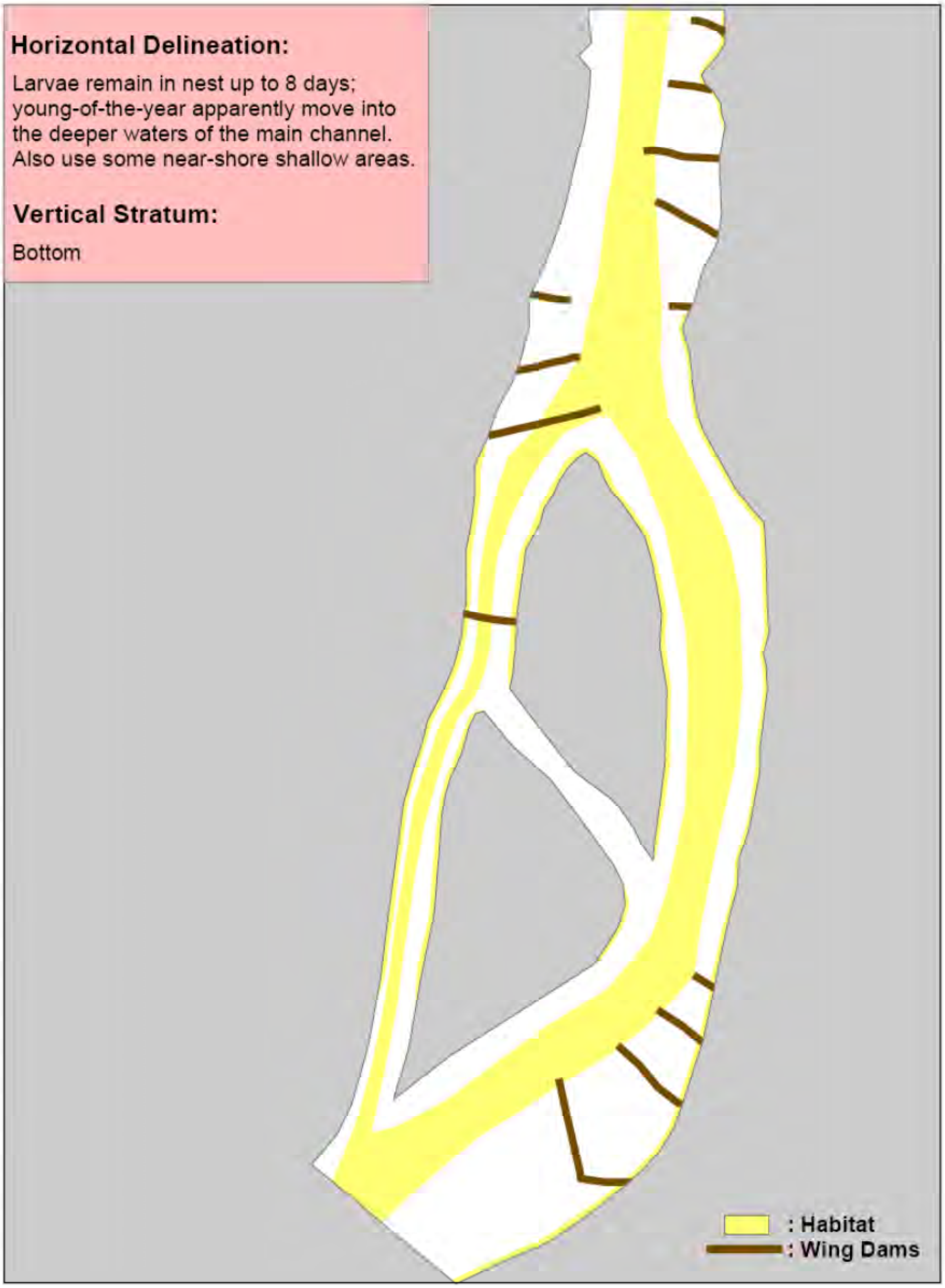


Figure 11A. Young-of-the-Year (YOY) Channel Catfish habitat in the project study area (downriver of the Quad Cities Nuclear Generating Station's Thermal Discharge)

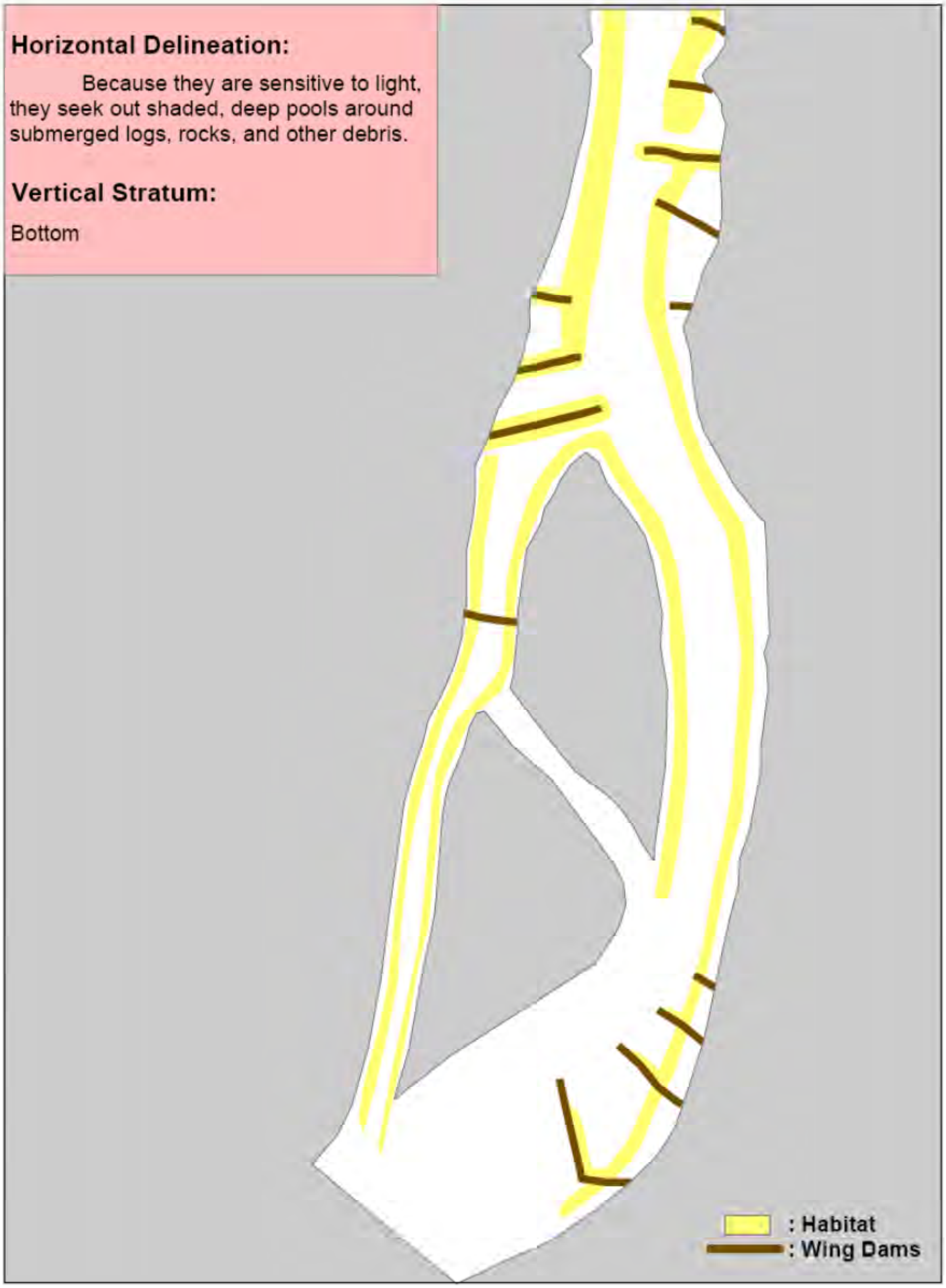


Figure 11B. Juveniles and adults Channel Catfish habitat in the project study area (downriver of the Quad Cities Nuclear Generating Station's Thermal Discharge)

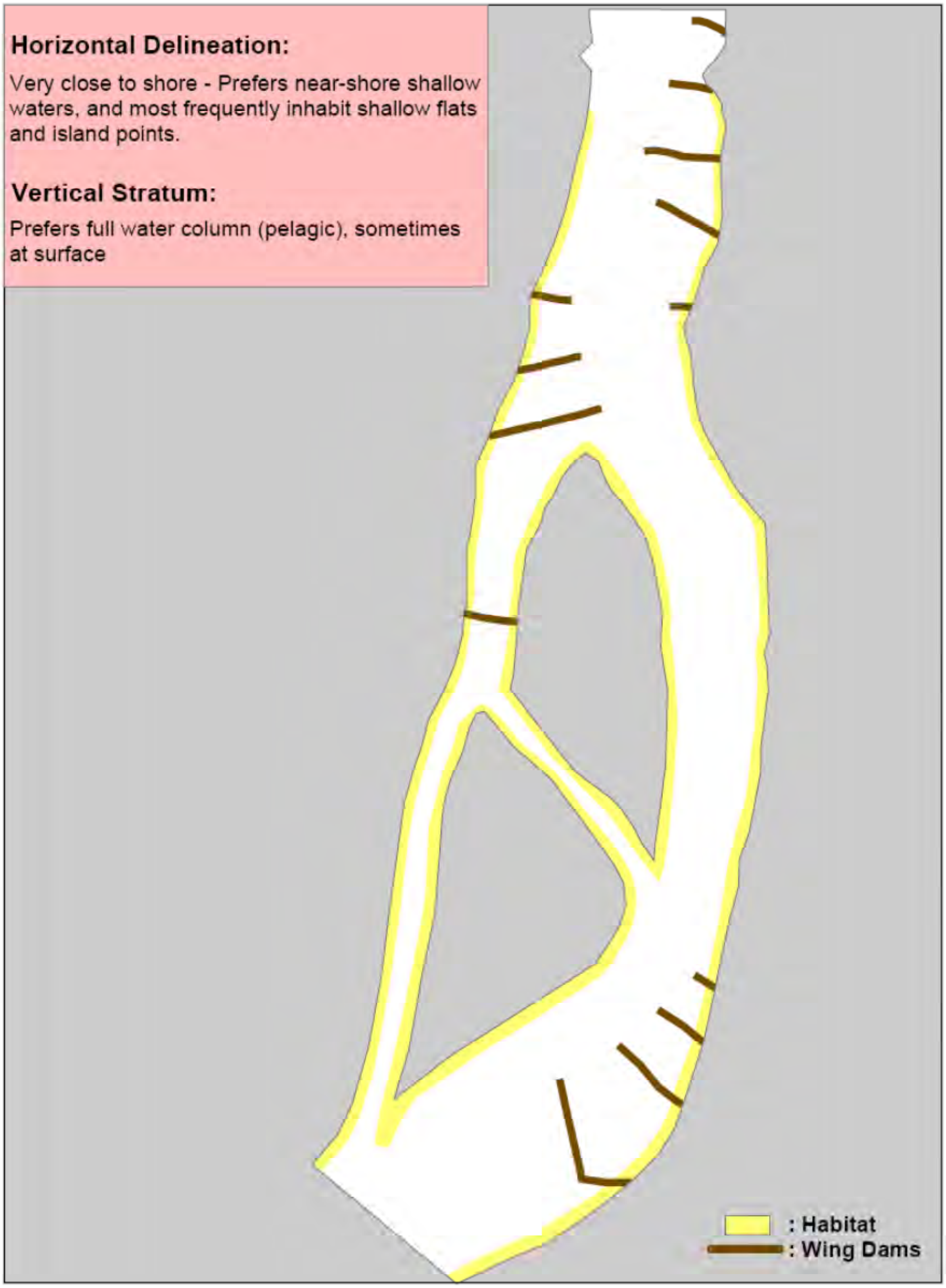


Figure 12. Juveniles and adults Spotfin Shiner habitat in the project study area (downriver of the Quad Cities Nuclear Generating Station's Thermal Discharge)

Figure 13. Biothermal Model's Growth results for Walleye
Number of Growth Days Lost vs. % Station Excursion Hours

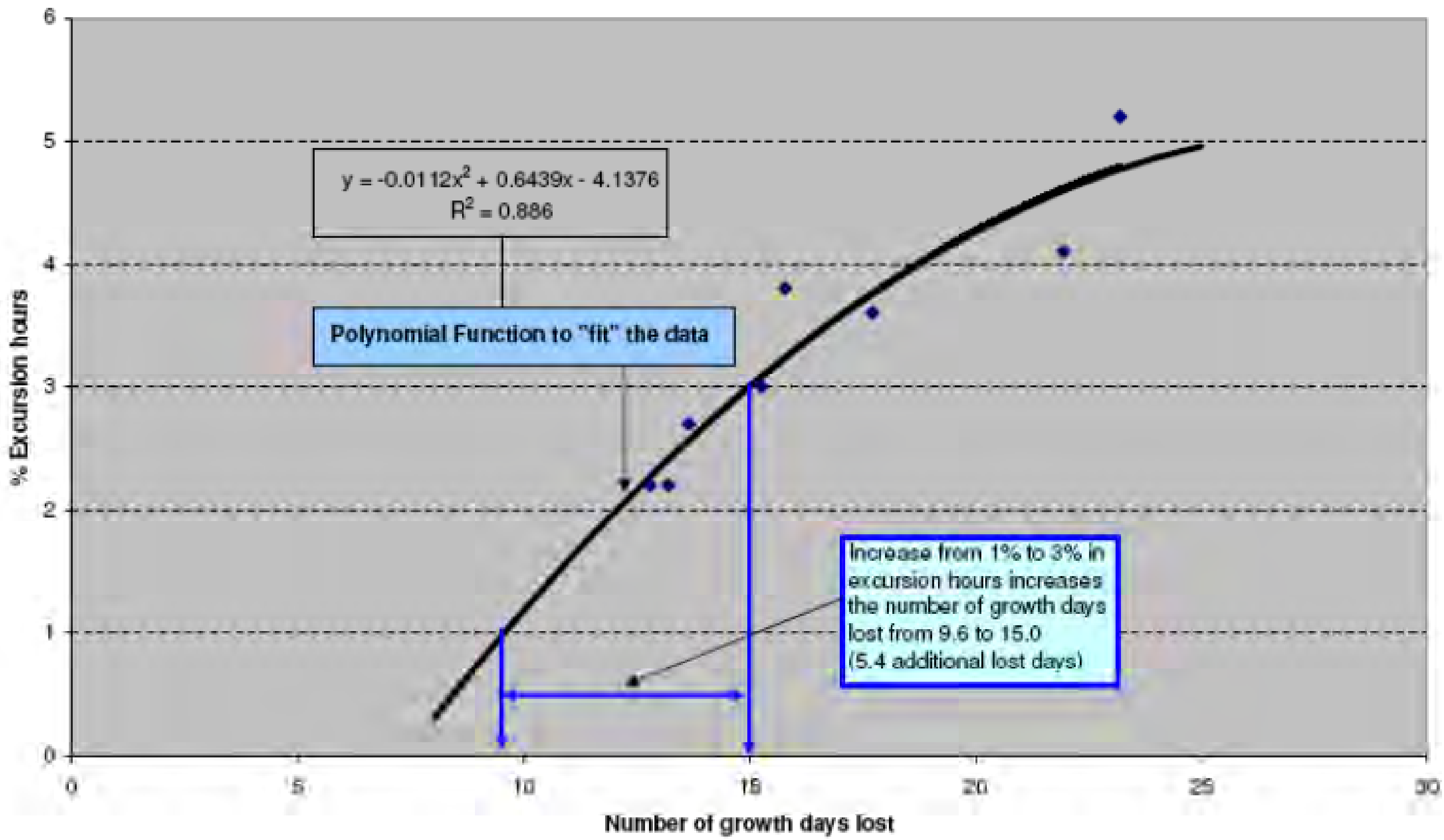


Figure 14. Daily Time-Series of Percent Habitat Avioded
Largemouth Bass - Adults and Juveniles

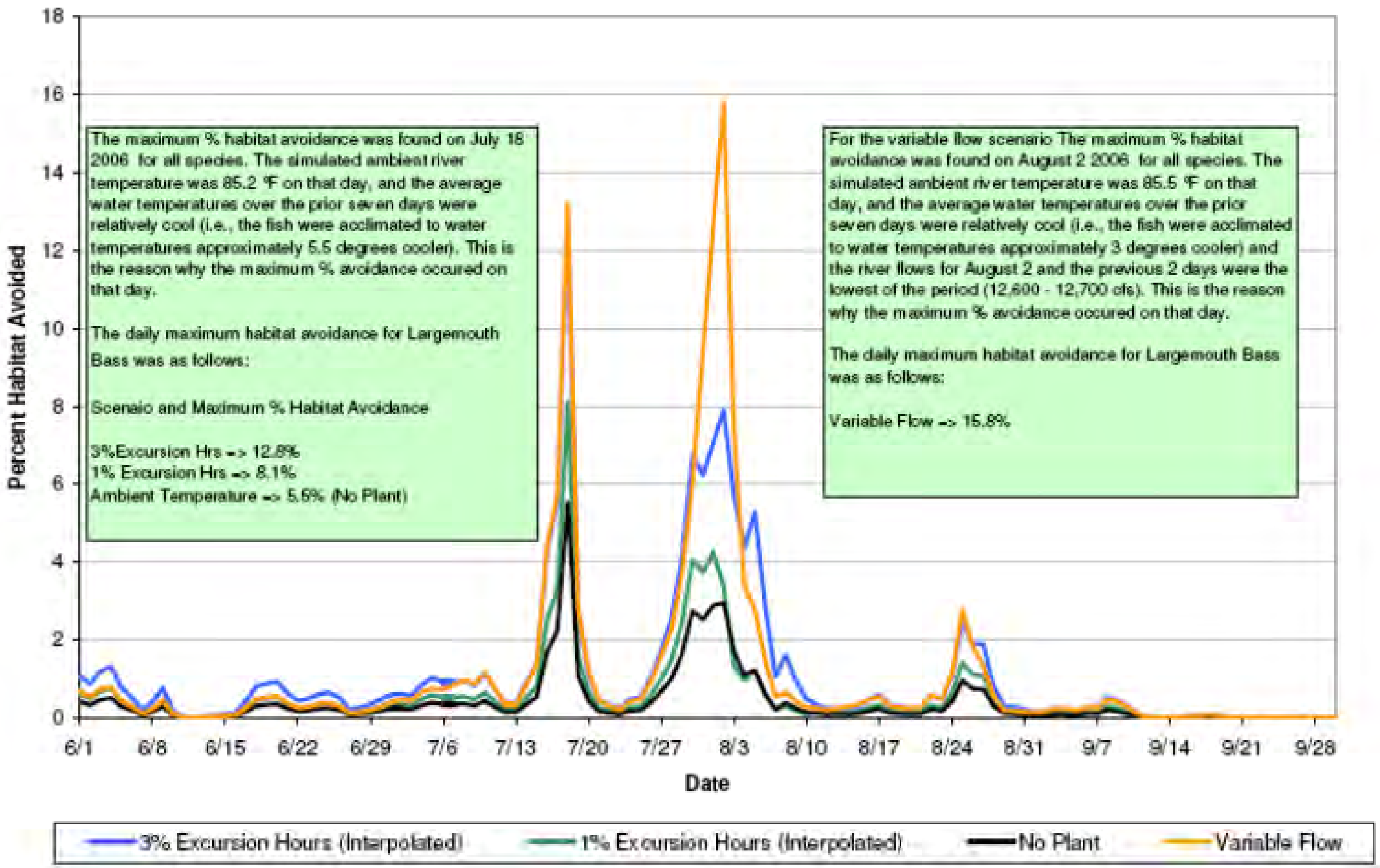


Figure 15. Daily Time-Series of Percent Habitat Avioded
Spotfin Shiner - Adults and Juveniles

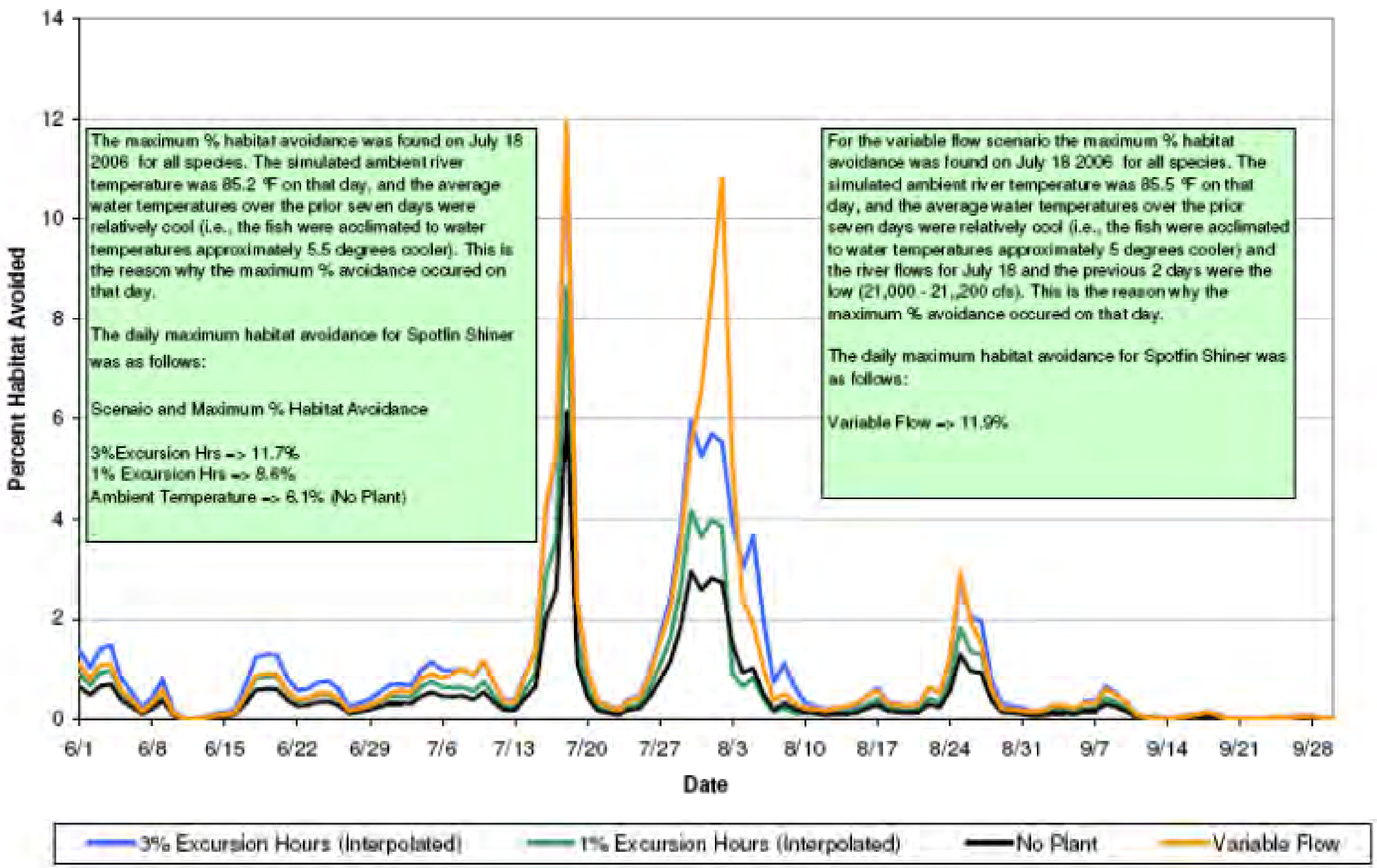
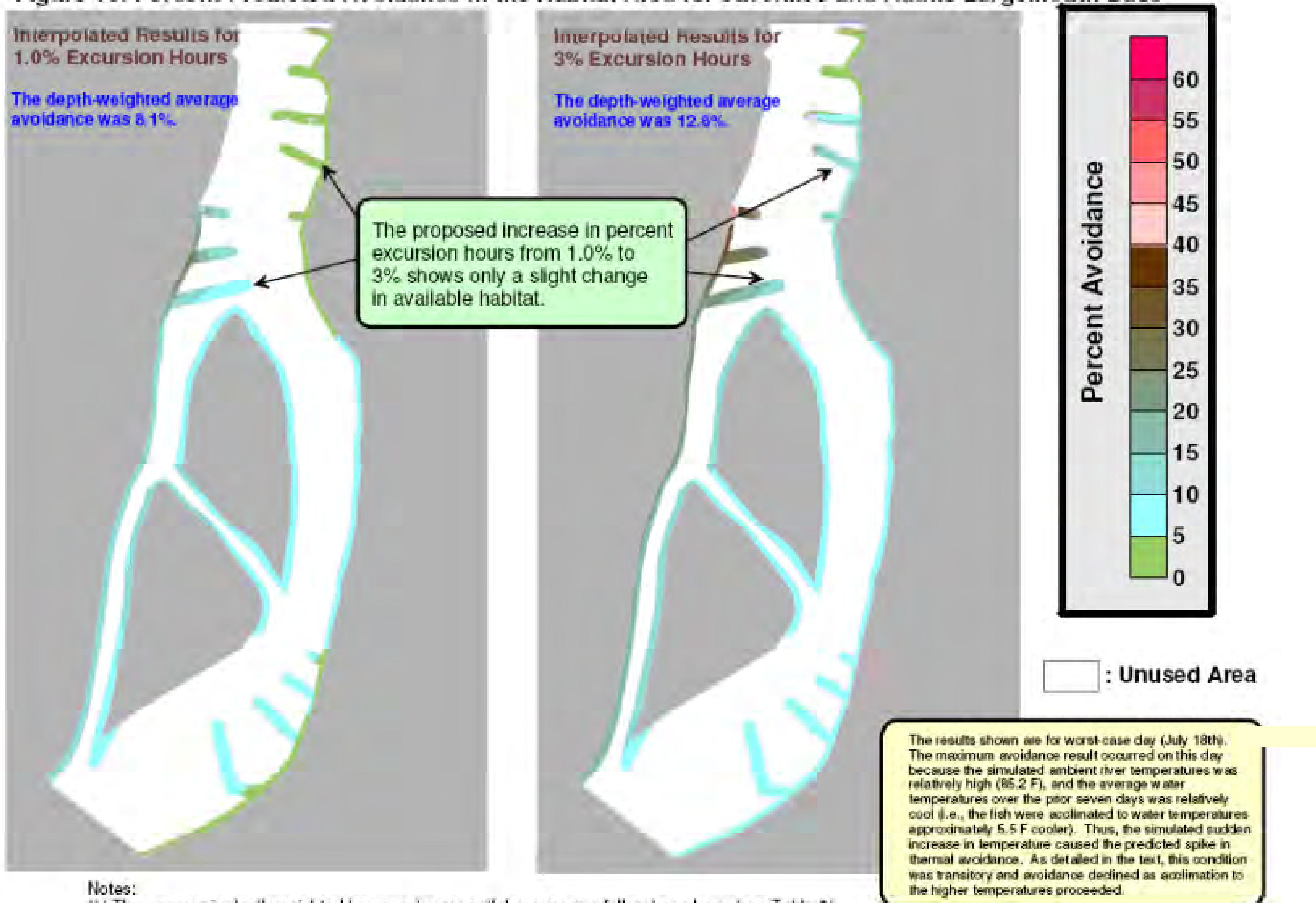
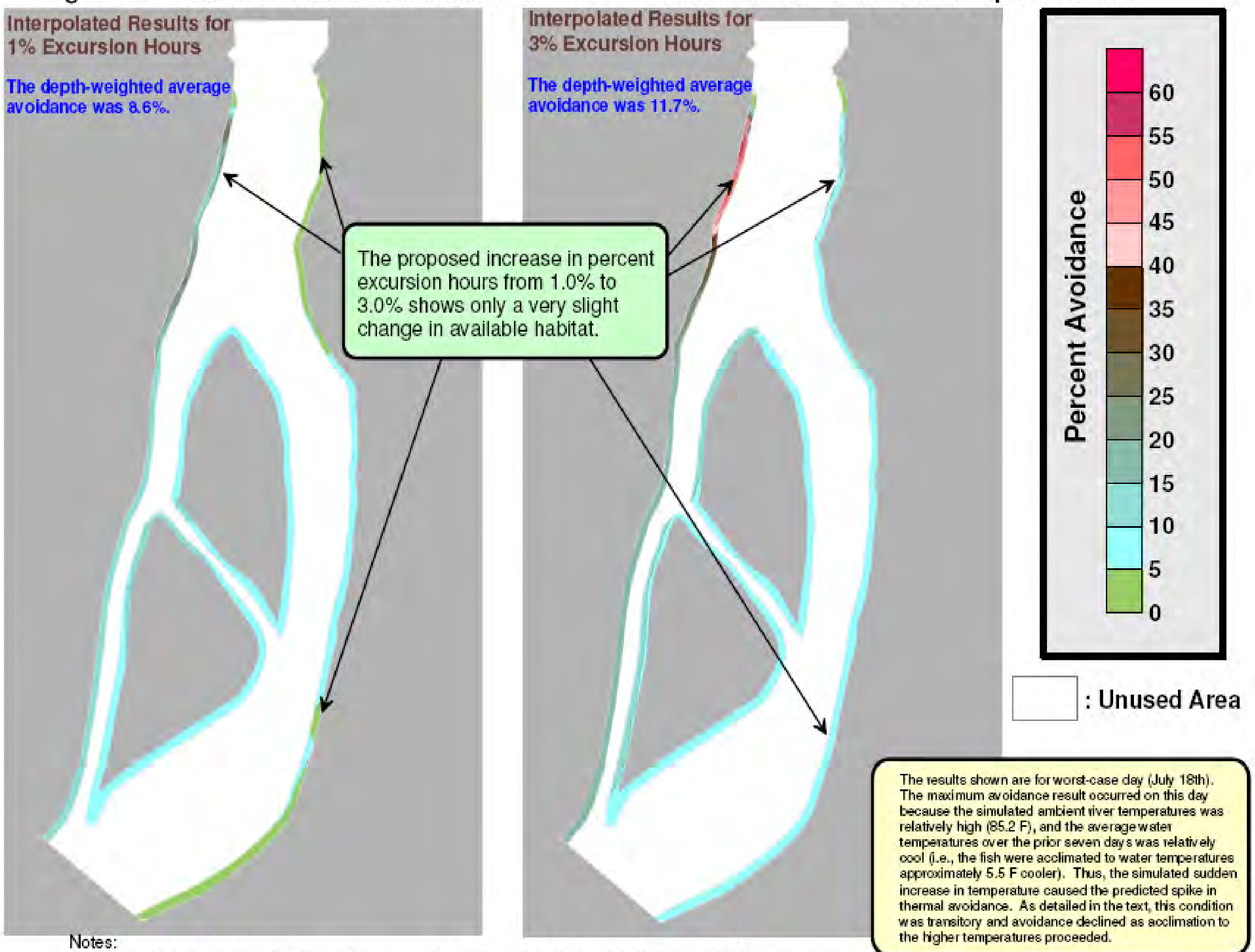


Figure 16: Percent Predicted Avoidance in the Habitat Area for Juveniles and Adults Largemouth Bass



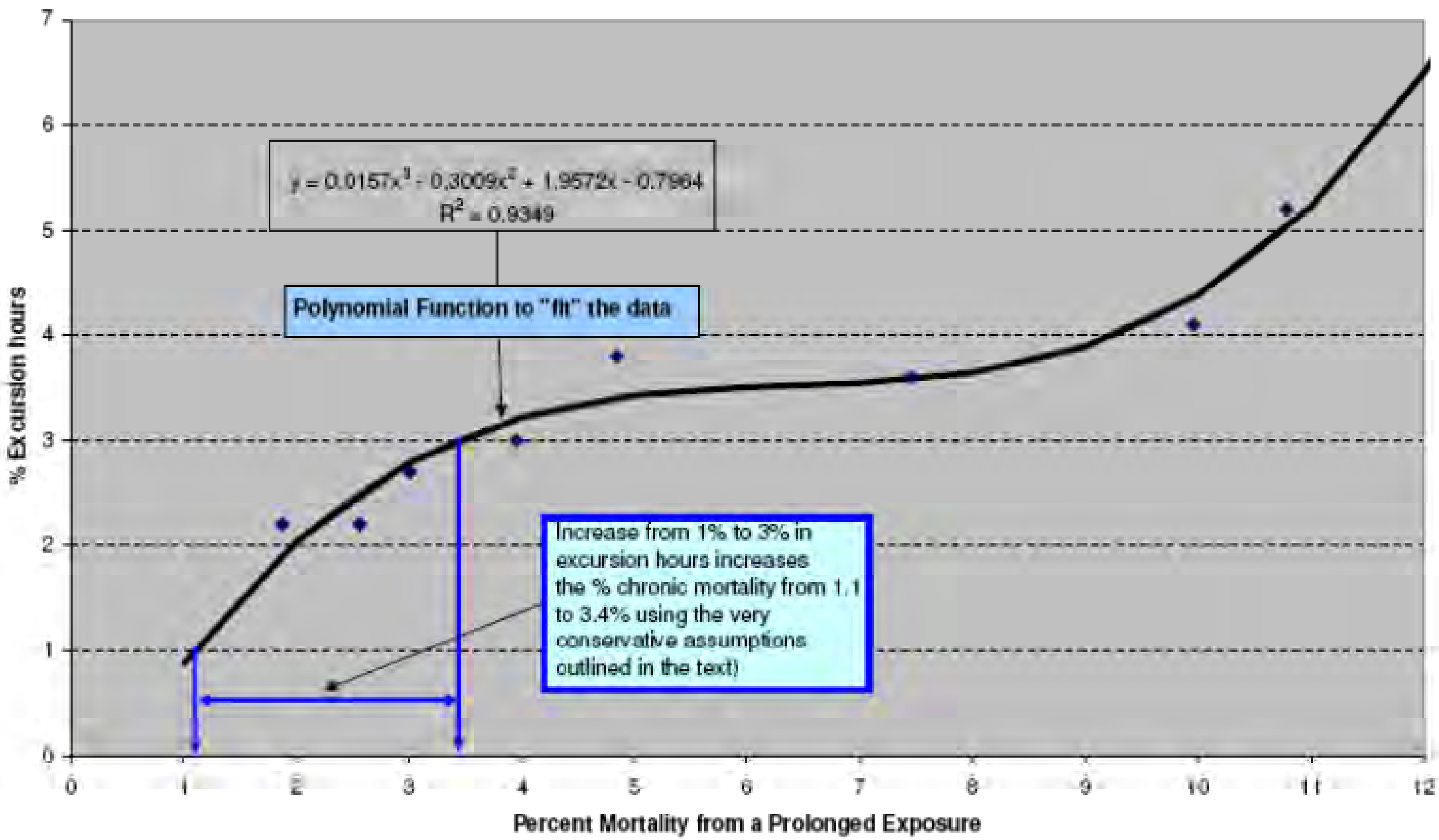
Notes:
(1) The average is depth-weighted because largemouth bass occupy full water column (see Table 5).
(2) The depth-weighted avoidance for largemouth bass under ambient conditions (i.e., no thermal disharge) was 5.5%

Figure 17: Percent Predicted Avoidance in the Habitat Area for Juveniles and Adults Spotfin Shiner



Notes:
(1) The average is depth-weighted because spotfin shiner occupy full water column (see Table 5).
(2) The depth-weighted avoidance for spotfin shiner under ambient conditions (i.e., no thermal disharge) was 6.1%

Figure 18. Biothermal Model's Chronic Mortality results for Walleye
% Mortality vs. % Station Excursion Hours



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ATTACHMENT 1

Background on the Selection of the Model Input Parameters

Attachment 1
Biothermal Assessment Report

Background on the Selection of the Model Input Parameters

The objective of this attachment is to provide the technical and conceptual details associated with the definition of the reasonable worst-case plant and river conditions (i.e., the design conditions) used for the biothermal modeling. The front-end of the analysis is the generation of thermal plume temperatures from June 1 through September 30 (the period of interest), which relies heavily on the University of Iowa College of Engineering, IIHR – Hydroscience & Engineering plume modeling results.

As discussed in Section 1.3.2 of the main text (Appendix B), the major design condition parameters are as follows:

- Plant Operation (waste heat discharged)
- River Flow (Qriver)
- Natural or Ambient River Temperature (Tamb)

The IIHR model simulates steady-state conditions (i.e., all of the model input parameters are held constant). As detailed in the IIHR report, plant operation was set at maximum capacity, river flow ranged from the 7Q10 value of 13,800 cfs up to 30,000 cfs, and the ambient upriver water temperature was constant at 72.0°F (22.23°C). However, for the analysis of potential biological effects, a times-series of the temperature conditions in the study area is required for the following two reasons:

- **Period of interest**: The June through September months are the seasonally warm critical period of interest for the biothermal assessment. Furthermore, excursion hour events (i.e., elevated river water temperatures at the end of the Station's mixing zone) historically occur during the months of July and August (from 1987 to 2006, some excursion hours were recorded in 1987 to 1989, 1995, 1999, and 2001, 2002, 2005 and 2006)

- **Prior thermal history is biologically important**: As detailed in Section 2.1 concerning species acclimation, thermal tolerances are a function of the prior thermal history of the aquatic organism.

To meet this objective the following steps were taken to project daily river-wide water temperatures over the period of interest:

Step 1 - Isolate the increase in river water temperature caused by the plant (i.e., excess temperature) from the background ambient temperature: The excess temperature (□Texcess) caused by the plant's heated discharge was determined by subtracting ambient temperature of 72.0°F (22.2°C) from the model output (based on a simplified 50 ft x 50 ft plan view results grid).[9]

Step 2 - Project the plant effect (ΔTexcess) upon a representative time -series of daily ambient temperatures: As shown in Table 3 (page B-24 of the main text), water temperature readings at Lock and Dam 13 for 2006 had a period of simultaneous warm daily average temperatures (maximum of 84.54 °F and low river flows (minimum of 12,600 cfs) for the USACE database. The Lock and Dam 13 temperatures for 2006 were adjusted by increasing the temperatures exponentially with river flow to arrive at a target of exceeding the 86°F EOMZ temperature 3.0% of the time annually and exceeding the 89°F EOMZ temperature 1.5% of the time annually without exceeding the 91°F EOMZ temperature limit when the actual river flows are used on a daily basis. The maximum temperature of the adjusted daily ambient temperatures was 85.50°F. Thus, the excess temperature (∆Texcess) field for each river flow simulation was added to these adjusted daily ambient temperatures from June 1 through September 30, 2006 (where; adjusted daily ambient temperatures + IIHR's predicted plant thermal effect (∆Texcess) = daily thermal plume temperatures over the period of interest). This type of computation is valid because, as detailed in the IIHR Report, "…buoyancy effects do not depend on the absolute background temperature. In this range, changes in background temperature have a negligible effect on dilution, and therefore on predicted downstream temperatures."

With regard to the selection ambient temperature (Tamb) parameter, a vast range of daily values from June 1 to September 30th could be hypothetically tested (e.g., data from different years). But the selection of ambient temperature data was limited by several factors and concerns, as well as being shaped by certain project objectives. These are detailed below:

[9] As noted in Section 1.2 (page B-4) of the main text, the IIHR hydrothermal model grid contained nearly 2 million points. This raw IIHR model output was then distilled by HDR into a 50ft by 50 ft "results grid" using the Surfer gridding program. This resulted in a grid-cell size that; (1) accurately reflected the raw model output, (2) retained sufficient spatial resolution to pinpoint any potential biothermal effects, and (3) reduced the number of data points to a level that made biothermal data post -processing reasonable.

The objective is to quantify the worst-case effects from the QCNS thermal plume: The general objective of the biothermal assessment is to quantify the worst-case effects derived from plant operation. One measure of "plant effects" is to compare the predicted biothermal impacts with the plant operating to those predicted with no-plant operation (i.e., ambient conditions only). Plant operation at full capacity would maximize the plant effect and thus provide a conservative assessment. Any potential scenario with the plant de-rated (i.e., at higher ambient conditions) would assign less of a biothermal effect to the plant and more to the natural background temperature regime. Therefore, while there are an infinite number of ambient temperature and plant capacity (with de-rating) combinations, the maximum waste heat discharge and a maximum ambient temperature of 85.50°F represents the worst-case condition with regard to effects that are caused directly by the plant.

The overarching objective of the biothermal assessment is to evaluate whether an increase in annual allotment of excursion hours (EOMZ T ≥ 86°F) from 1% to 3% and an annual allotment of 1.5% of these excursion hours to have EOMZ T ≥ 89°F and ≤ 91°F would cause biologically significant effects. Therefore, for the set of design conditions shown in Figure A1-2, the USACE 2006 river water temperatures provide a range of annual exceedance percentages from 0.5% to 3.6% for exceeding the 86°F EOMZ temperature and a range of annual exceedance percentages from 0.0% to 0.5% for exceeding the 89°F EOMZ temperature (see Table A1-2). The main reason why the range of excursion hours reaches such high levels (e.g., 3.6%) is due to the extremely conservative assumption that the low river flows would be <u>sustained</u> throughout June through September. Thus, the hypothetical worst-case 3.6% excursion hour scenario is predicted using 7Q10 river flow (<u>that remains constant from June to September</u>), and plant operation at full capacity.[10] It is extremely unlikely that, in reality, such a hypothetical worst case set of conditions could ever occur. A 7Q10 river flow of 13,800 cfs or below occurred less than 3% of the time during June – September 2006 (see Figure A1-1).

To estimate the biothermal effects as a result of the EOMZ temperatures exceeding the 86°F limit 3% of the time and exceeding a 89°F limit 1.5% of the time (without exceeding the 91°F limit, a synthetic ambient temperature distribution was developed by increasing the actual 2006 ambient temperatures as an exponential function of river flow. The parameters of this function were selected to yield a maximum EOMZ temperature of 91°F at the lowest June – September

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[10] The IIHR model predicted ΔT at the EOMZ of 5.4F° under 7Q10 river flow conditions is in violation of the fixed 5.0F° permit limit. As detailed in the Phase IIB IIHR Report, the model predictions for the validation process were generally warmer than those observed (i.e., the hydrothermal model was conservative). Thus, the possibly exists, that if the simulated worst-case conditions were to actually occur, Station de-rating would not automatically be required (e.g., EOMZ temperatures would be measured by Exelon in real-time, under such conditions, to check whether or not a reduction in power production is required).

2006 river flow of 12,600 cfs and to exceed EOMZ temperatures of 86°F and 89°F 3.0% and 1.5% of the annual excursion hours, respectively.

The original and adjusted (synthesized) 2006 June – September ambient temperatures are shown in Figure A1-2 along with the EOMZ temperatures resulting from the adjusted ambient temperatures. The EOMZ temperature was computed by adding the EOMZ ΔT estimated from IIHR model results to the ambient temperatures. The IIHR model calculated the EOMZ ΔT for a series of constant flows from 13,800 cfs to 30,000 cfs. These EOMZ ΔT's were fitted to an exponential function (see Figure A1-3) and the function used to estimate the EOMZ ΔT based on the Lock and Dam 13 river flow for each day from June 1 – September 30, 2006. The daily estimated EOMZ ΔT was added onto the daily adjusted ambient temperature to arrive at the daily EOMZ temperature.

The exceedance hours resulting from the use of the adjusted ambient temperature is shown in Table A1-3. As can be seen in the last row of the table, using the actual flows results in a 3% exceedance of the 86°F EOMZ limit and a 1.4% exceedance of the 89°F EOMZ limit.[11]

Therefore, the application of the daily ambient temperature time-series shown in Figure A1-2 fulfills the exceedance hours analysis objectives, and provides for a conservative biothermal assessment that allows for a series of river flow scenarios with the plant operating at maximum capacity. Using this approach, biothermal effects were evaluated under each fixed river flow scenario (8 different flows) as well as the actual 2006 river flow scenario for each species (4), for a total of 36 results. As a final point, the use of the fixed river flow scenarios yields biothermal assessment results which are overestimates for the 86°F EOMZ limit for fixed flows less than 22,500 cfs which is exceeded 75% of the time and overestimates for the 89°F EOMZ limit for fixed flows of 15,000 cfs or less which are exceeded 95% of the times.

[11] Although the target percentage for exceedance of the 89°F EOMZ limit was 1.5%, the percentage is computed on a daily basis and exceedance of 5 days yields a 1.4% value ([5/365]*100) and exceedance by 6 days yields a 1.6% value ([6/365]*100).

Table A1-1 – Summary of Permit Compliance for an Ambient River Water Temperature of 86° F

Simulated River Flows (cfs)	Average ΔT at the end of the Mixing Zone (°F)[1]	Average Temperature at the end of the Mixing Zone (°F) [ΔT + 86°F][2]	Plant De-rate Required to meet permit conditions (i.e., temperature exceeds 89°F)
13,800 (7Q10 value)	5.3 (exceeds the permit limit by 0.3 °F)	91.3	Yes (analysis of this condition represents an extreme hypothetical condition that in reality will not occur, as the plant would have to de-rate)
15,000	4.7	90.7	
17,500	3.8	89.8	
20,000	3.9	89.9	
22,500	3.5	89.5	
25,000	3.0	89.0	
27,500	2.6	88.6	No
30,000	2.3	88.3	

Note: The highlighted cells indicate a hypothetical permit violation.

[1] permit limit = 5°F

[2] Analysis assumes the application of the July and August mixing zone temperature limit of 86°F.

Table A1-2. Summary of Annual Excursion Days
Scenarios using the USACE 2006 Daily Temperature Data

Simulated River Flow (cfs)	Number of Excursion Days (EOMZ T ≥ 86°F)	Number of Excursion Days as an annual percentage (i.e., # days/365)	Number of Excursion Days (EOMZ T ≥ 89°F)	Number of Excursion Days as an annual percentage (i.e., # days/365)
13,800 (7Q10 value)	13	3.6	2	0.5
15,000	11	3.0	1	0.3
17,500	8	2.2	0	0.0
20,000	8	2.2	0	0.0
22,500	7	1.9	0	0.0
25,000	5	1.4	0	0.0
27,500	3	0.8	0	0.0
30,000	2	0.5	0	0.0

Table A1-3. Summary of Annual Excursion Days
Scenarios using the adjusted USACE 2006 Daily Temperature Data

Simulated River Flow (cfs)	Number of Excursion Days (EOMZ T ≥ 86°F)	Number of Excursion Days as an annual percentage (i.e., # days/365)	Number of Excursion Days (EOMZ T ≥ 89°F)	Number of Excursion Days as an annual percentage (i.e., # days/365)
13,800 (7Q10 value)	19	5.2	8	2.2
15,000	15	4.1	6	1.6
17,500	13	3.6	2	0.5
20,000	14	3.8	2	0.5
22,500	11	3.0	0	0.0
25,000	10	2.7	0	0.0
27,500	8	2.2	0	0.0
30,000	8	2.2	0	0.0
Actual Daily Flow	11	3.0	5	1.4[1]

Notes:

[1] Although the target percentage for exceedance of the 89°F EOMZ limit was 1.5%, the percentage is computed on a daily basis and exceedance of 5 days yields a 1.4% value ([5/365]*100) and exceedance by 6 days yields a 1.6% value ([6/365]*100).

Figure A1-1. Cumulative Frequency <= Flow

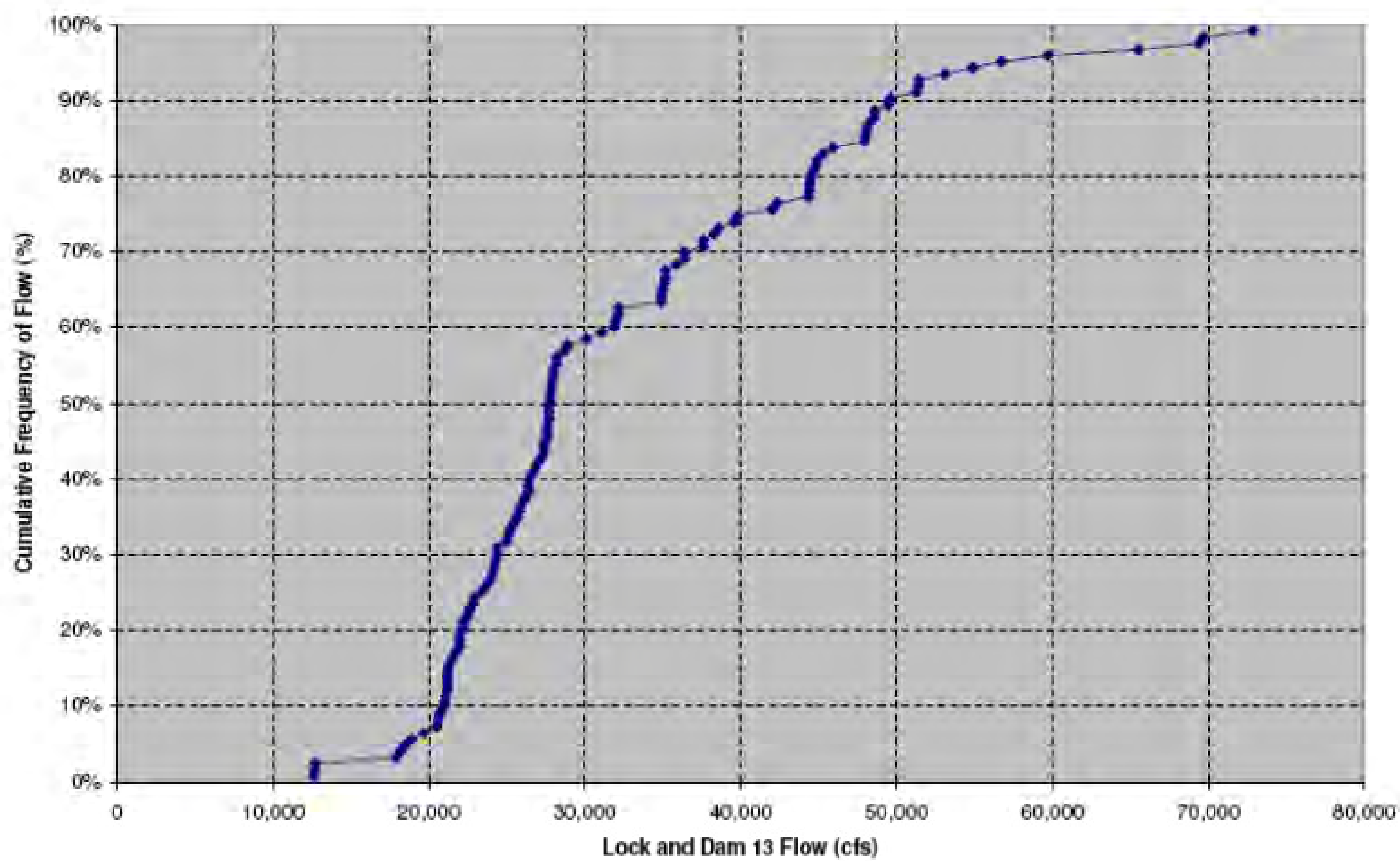


Figure A1-2. Ambient River Water Temperatures for the Bio-thermal Assessment 2006 Observed Data at Lock and Dam 13 (provided by the USACE)

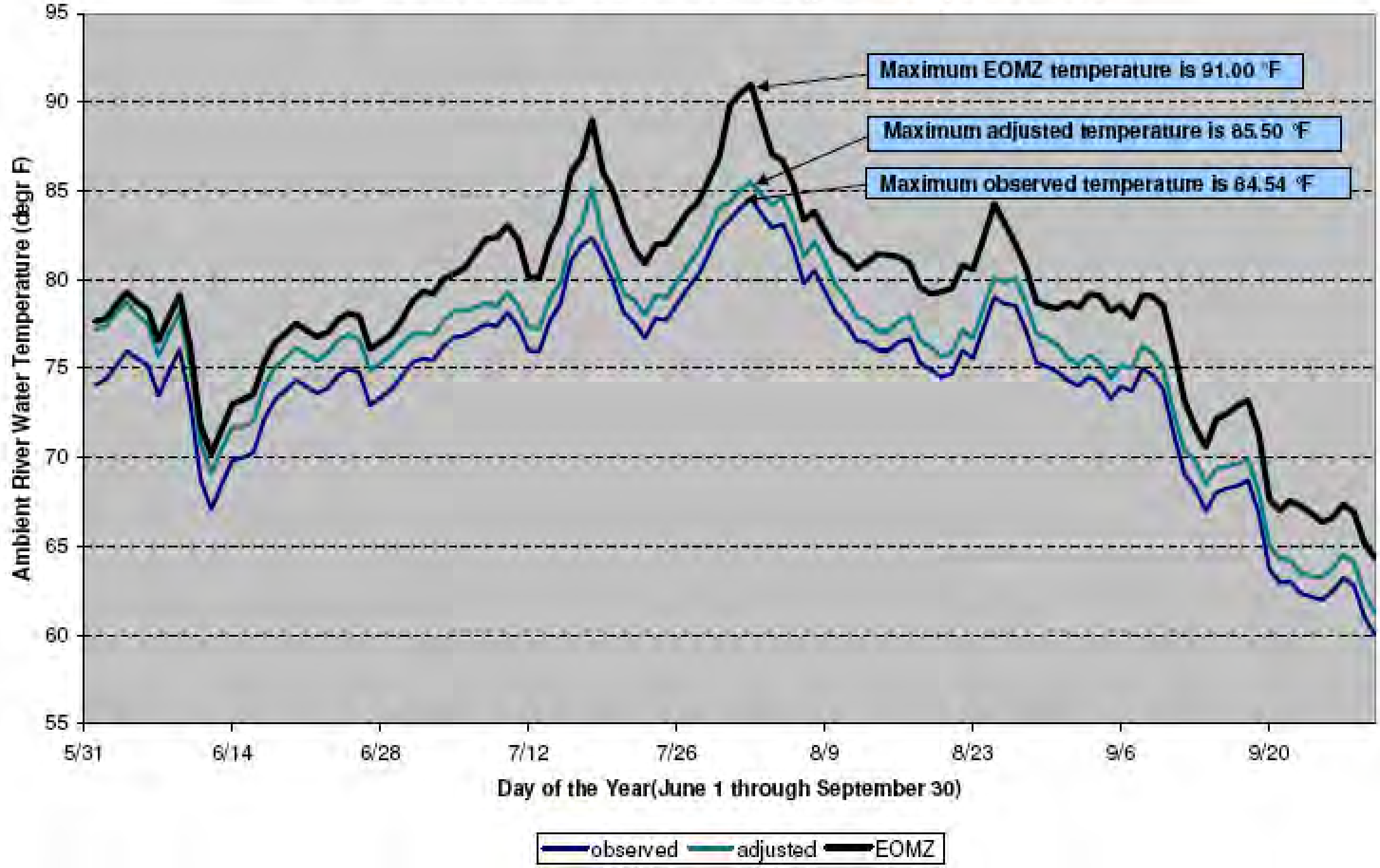
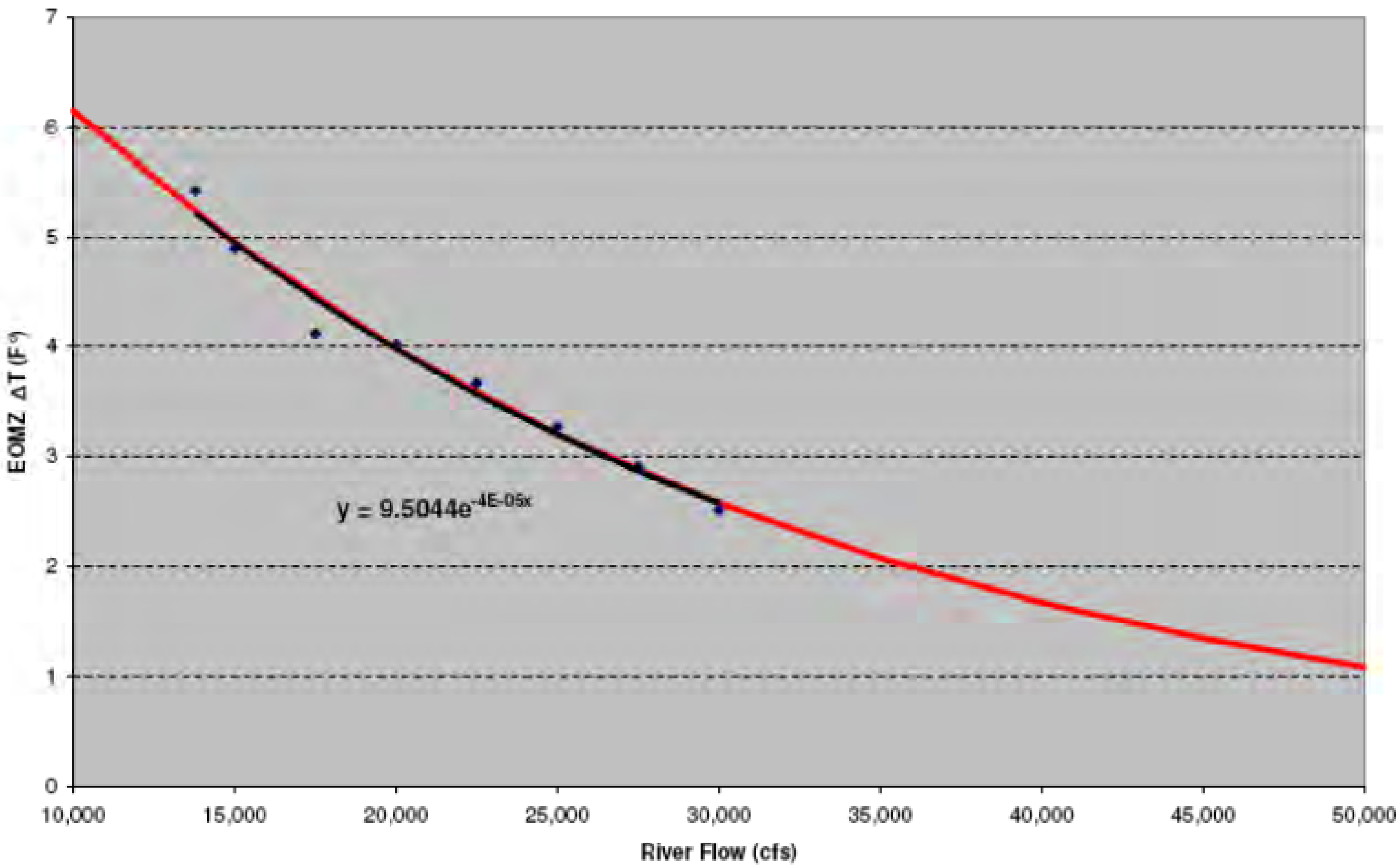


Figure A1-3. EOMZ ΔT vs River Flow



ATTACHMENT 2

Development of Thermal Tolerance Polygons

Attachment 2

Biothermal Assessment Report
Development of Thermal Tolerance Polygons

The temperature tolerance polygon is useful in summarizing information related to a species' physiology (Beitinger and Bennett 2000) and in depicting relationships that exist among multiple biothermal metrics (e.g., the relative position of a species' avoidance response threshold compared to lethal temperatures). Such relationships can provide insight into a species' overall thermal responsiveness at different temperatures.

The polygons presented in Section 2 of the main text (Figures 4 to 7) are a synthesis of results from multiple studies that include a variety of species life history and laboratory test data. The lines shown summarize the mean thermal tolerances applied in the biothermal assessment. The use of mean threshold values in the polygon made it possible to present acclimation/exposure temperature relationships for a range of biothermal effects in a single graphic display.

An explanation of the data presented in Figures 4 to 7 follows.

Chronic thermal mortality under a prolonged exposure (brown line): This line depicts the species mean tolerance limit—that is, the acclimation/exposure-temperature combinations at which 50% mortality would occur due to elevated temperatures —for a prolonged exposure of more than 24 hours (laboratory results ranged from 24 to 96 hrs [$TL50_{24\text{ to }96\text{ hrs}}$]).

Based on Coutant (1972) and USEPA (1976), and as depicted in Figure 8 (in the main text), the temperature at which the species' chronic thermal mortality approaches zero was set at 2°C lower than the mean tolerance line ($TL50_{24\text{ to }96\text{ hrs}}$) shown in the polygon. By extension, assuming a normal distribution, chronic thermal mortality would effectively be 100% at 2°C higher than the TL50.

This ±2°C range around the mean was used to incorporate the variable response of individuals within a population to a prolonged exposure to elevated temperatures. (The phenomenon of variable response is observed in numerous dose-response studies and is, in fact, the underlying basis of dose-response curves.) Within the ±2°C range around the mean, a normal distribution was assumed, e.g., at 0.5°C above the mean temperature, approximately 75% of the population would have a response.

As is detailed in the main text, the assessment of chronic mortality is very conservative because it assumes that fish choose not to or cannot avoid elevated temperatures by vacating the area, and thus could potentially succumb to elevated temperatures during a prolonged exposure.

Avoidance (red line): A thermal avoidance response occurs when mobile species evade stressful high temperatures by moving to water with lower, more acceptable temperatures (Meldrim et al. 1974). The avoidance response can deter a species from occupying otherwise useful habitat in the vicinity of a thermal plume.

The avoidance line in Figures 4 to 7 of the main text represent the mean tolerance limit—that is, the acclimation/exposure-temperature combinations at which half of the population is expected to have an avoidance response. Lower and upper bounds around the mean were set at ±5°C based on the extensive laboratory avoidance test results reported in Mathur et al. (1983).

Preference Zone (green-blue area): This area delineates the acclimation and exposure temperature combinations for which optimal growth (i.e., preferred temperatures) is predicted (McCullough 1999). This zone is not evaluated herein because to do so would not account for the fact that growth occurs over a range of temperatures, and that a thriving population can be maintained even when temperatures are at non-optimal values.

Temperature Tolerance Zone (yellow area): This area is outside the preference zone. It delineates the temperature regime over which each species can survive and continue to grow. The upper limit of the growth-zone was defined as roughly half-way between the optimal growth temperature and the temperature producing net-zero growth. The 1972 EPA Recommended Water Quality Criteria specify that, in the absence of zero-growth data, growth-zone limits can also be approximated via the equation below (NAS/NAE 1973):

Critical growth limit = optimal temperature + (UILT – optimal temperature)/3

Where optimal temperature is the "temperature preference" of fish in a thermal gradient—an adaptive mechanism that allows the organisms to be positioned in an environment where they can achieve optimal physiological performance (Coutant 1977; Hutchison and Maness 1979).

Maximum growth temperatures are not consistently maintained in nature, and delineation of a tolerance "zone" makes clear the fact that non-optimal temperatures are not necessarily adverse. Areas of the polygon outside the tolerance zone and below the onset of predicted chronic mortality, delineates the temperature regime over which each species can survive, but in which they are stressed and experience near-zero or negative growth, i.e., weight loss (Beitinger and Bennett 2000).

Supporting information for the polygons is presented in Figures A2-1 to A2-4 and shows the polygon thermal thresholds or limits, as well as the raw data from which they were developed. The raw data shown are the basis for the thermal thresholds established for growth, avoidance, and chronic thermal mortality (when adequate data was available to assess this biothermal metric).

The main advantage of using temperature tolerance polygons is that it provides the opportunity to incorporate thermal variability and physiological function information into one compact graphical representation. The use of polygons also ensures a level of quality control of the various thermal limits, as the graphical presentation serves to depict temperature tolerance thresholds in a manner that identifies conflicting data from multiple scientific literature sources (i.e., facilitates data conflict resolution). As noted above, the polygons also introduce a stochastic element into the subsequent biothermal assessment, by detailing thermal responses around a mean. This provides the mechanism to translate laboratory results for individual fish at various temperatures into a population's predicted range of responses.

For this biothermal assessment, the time period targeted is the June to September season, which eliminates from consideration both thermal effects on reproduction of spring-spawning species and effects of minimum temperatures on survival. Thus, the main focus of the polygons developed herein is the effect of water temperatures typically greater than 63°F (17.2°C) on the selected species at various ambient temperatures, with an emphasis on the temperature range specific to the summertime regulatory standards (86 to 89°F [30.0 to 31.7°C]).

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Figure A2-1. Temperature Tolerance Data & Polygon for Adult & Juvenile Largemouth Bass

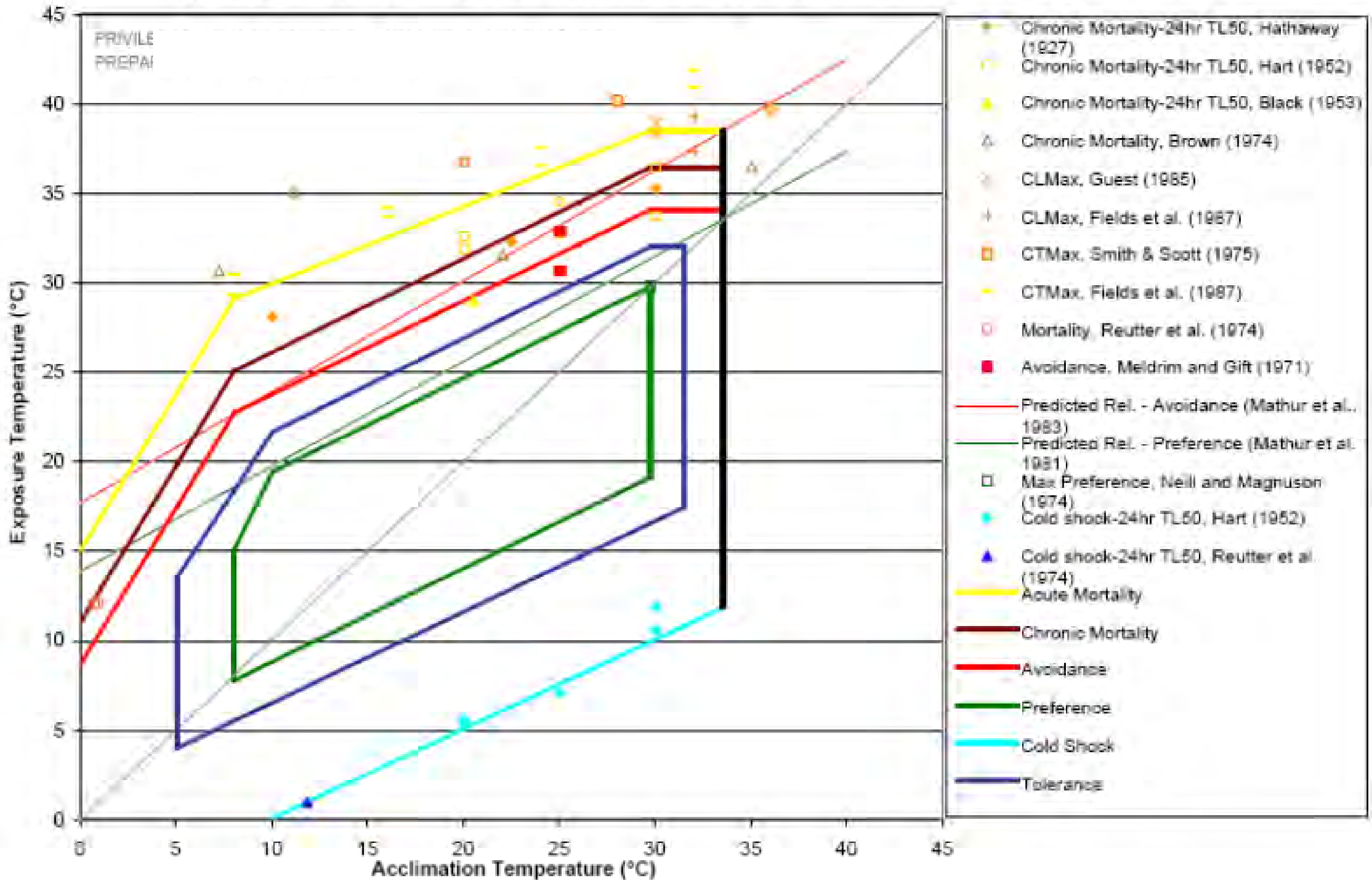


Figure A2-2. Temperature Tolerance Data & Polygon for Adult & Juvenile Channel Catfish

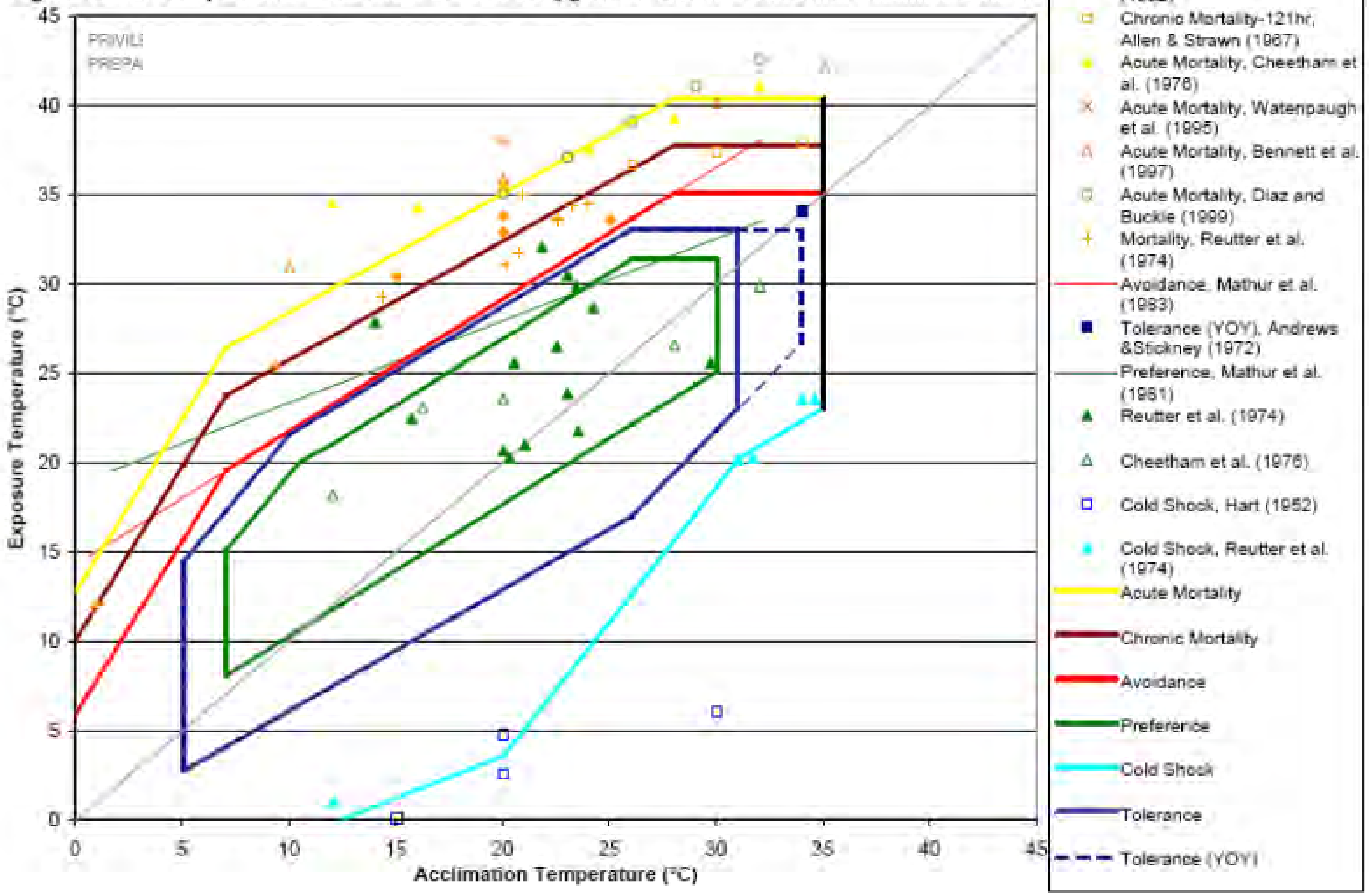


Figure A2-3. Temperature Tolerance Data & Polygon for Adult & Juvenile Walleye

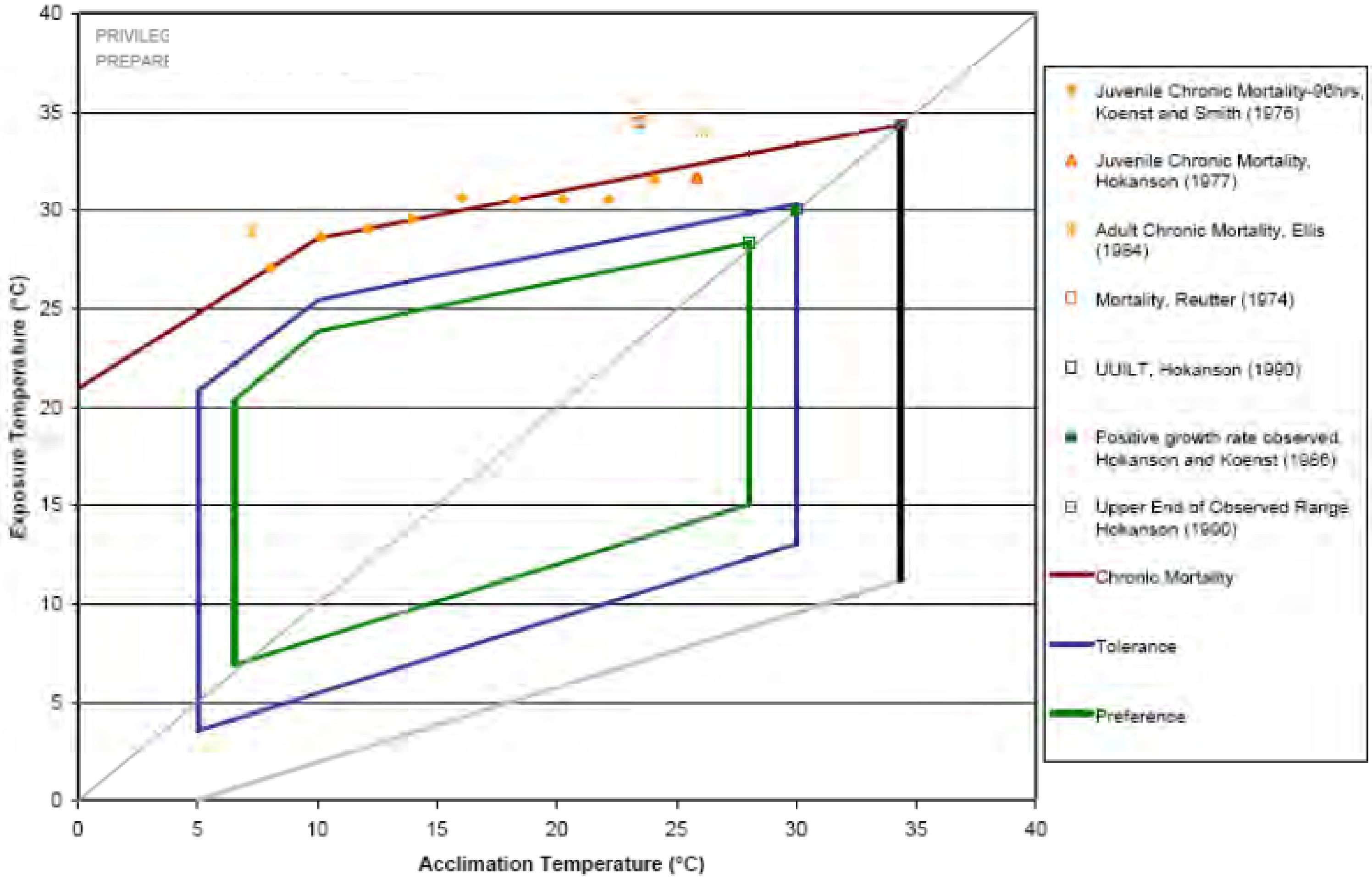
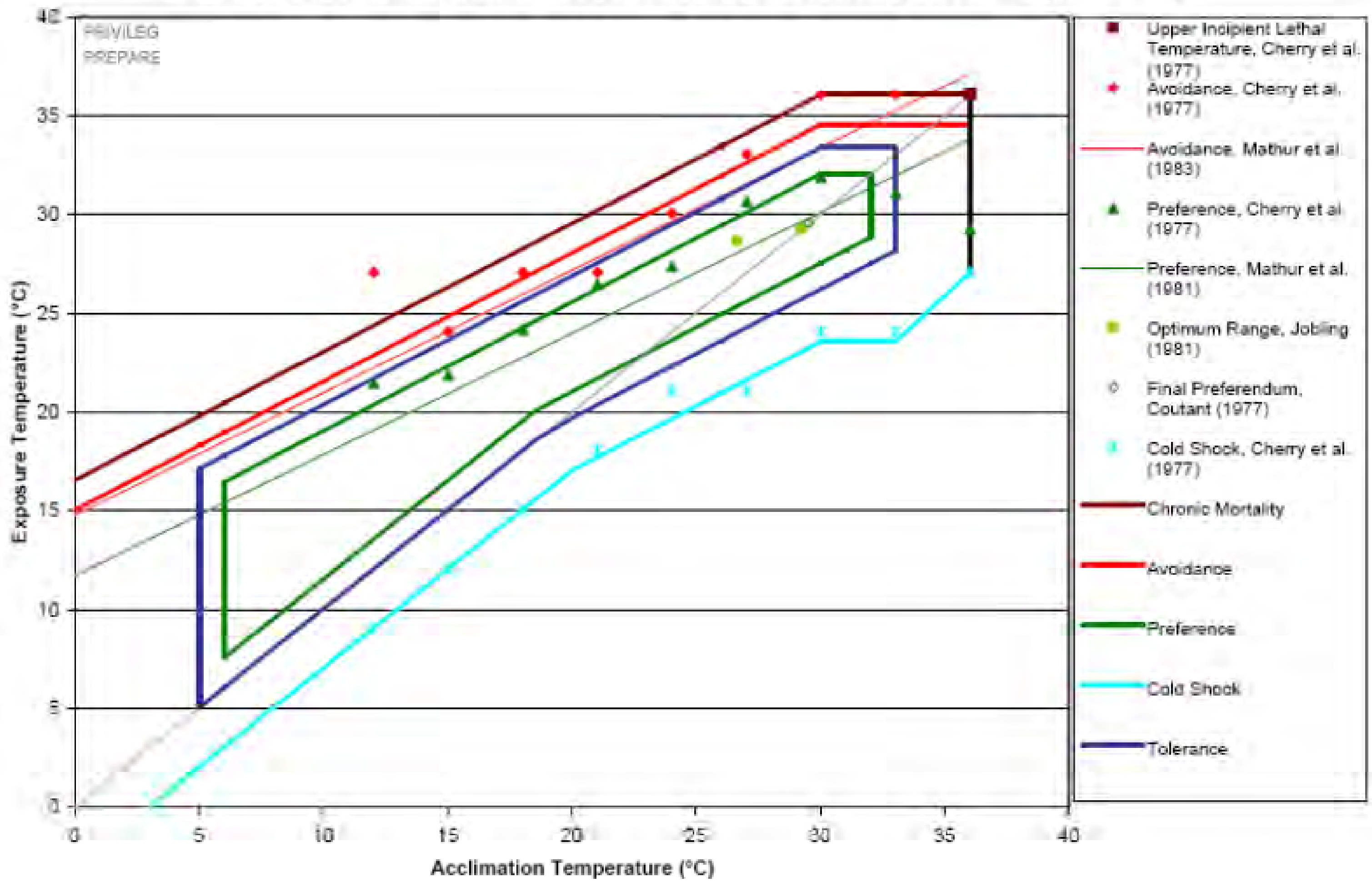


Figure A2-4. Temperature Tolerance Data & Polygon for Adult & Juvenile Spotfin Shiner



ATTACHMENT 3

Comparison of Walleye Abundance to River Water Temperature

Attachment 3

Biothermal Assessment Report

Comparison of Walleye Abundance to River Water Temperature

Introduction

As detailed in Table 5 of Appendix B, insufficient paired data sets were found in the scientific literature to define an acclimation/exposure temperature relationship for walleye. Thus, an avoidance evaluation using the biothermal model was not possible for this species. The objective of this attachment is to address this "data gap" by providing a supplemental analysis using a different data source, namely—the Quad Cities Station Long-Term Monitoring Program's Summertime Electro-fishing data.

Given the lack of laboratory avoidance data for walleye, it is appropriate to consider an evaluation of the available field data (i.e., the monitoring program's summertime electro-fishing data). Still, care must be taken in the interpretation of the results. Importantly, if walleye abundance is shown to remain unchanged at elevated temperatures then it would be reasonable to conclude that little to no avoidance was observed (i.e., walleye chose to occupy areas with elevated water temperatures). The converse of this condition, however, is not as meaningful. If walleye abundance is shown to diminish at elevated temperatures, this field observation does not, in fact, demonstrate a causal link between temperature and avoidance because it potentially includes the influence of non-thermal environmental factors such as the relationship between river stage and availability of structural habitat.

Electro-fishing Methods

Eight locations were sampled by electro-fishing (Figure A3-1). These included sites both upstream and downstream of the Station and represented three habitat types: main channel border, slough, and side channel (Sternberg 1971). Shoreline electro-fishing was conducted using a 16-ft Jon boat equipped with a 4000 watt, 230 volt AC, 10 amp 3-phase Model GDP-4000 Multiquip generator. The electrode array consisted of three paired stainless steel cables (1.5 m long, 9.5 mm in diameter) arranged in line 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.

Each location was sampled for 20 min while the electro-fishing boat was driven in an upstream direction. Sampling was scheduled once each week during the first two weeks of June, July, August, and September (eight fixed locations sampled eight times per season). Sampling was randomized among downstream and upstream locations during each collection effort. The order of sampling upstream versus downstream locations was also randomized. All electro-fishing efforts were conducted between 0800 and 1700 hours. Water temperature and conductivity were also measured during each sampling period, at the location of each sampling station.[12]

Data Analysis

This fish sampling and water temperature data provides an opportunity to assess whether the elevated river water temperatures alter the relative abundance of walleye. The basic hypothesis is to test whether the fish monitoring data shows a relationship to temperature, specifically—do the walleye remain in the study area on days when elevated water temperatures occur?

Figure A3-2 shows a histogram (i.e., a frequency distribution) comparing river water temperature to the number of walleye caught downriver of the discharge during the electro-fishing program during the period from 1997 to 2008. The x-axis shows the temperature 'bins" used to develop the histogram, where "58 to 60" means sampling events that occurred for river water temperatures >58°F and ≤60°F. The y-axis details the number of "walleye caught," which was normalized to the number of sampling events.[13] This was done to account for the fact that the sampling events were not evenly distributed over the range of observed temperatures.

Figure A3-2 suggests a decline in abundance between the 72 to 74°F bin and the 74 to 76° F and 76 to 78° F temperature bins. Both of these bins fall within the walleye preference and tolerance ranges (Figure 5 of the main report). Furthermore, abundance within the 86 to 88° F bin, which exceeds the current EOMZ standard, is very similar to both the 74 to 76° F and 76 to 78° F temperature bins. This suggests that 1) some other

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[12] The temperatures are taken just below the surface (1 to 2 ft down), using a YSI S-C-T meter.

[13] For example, for the "bin" for temperatures >62°F and ≤64°F a total of 12 walleye were caught. The total number of sampling events that occurring within this temperature range was 2. So the normalized catch value is 6 (i.e., 12/2).

environmental factor is influencing these abundances and 2) walleye avoidance is probably in excess of 88° F for individuals acclimated to higher water temperatures in this reach of the river.

Observations made by the HDR field crews during the period of record indicate that walleye abundance at any of the fixed sampling locations seems to be driven by river stage. That is, low flows eliminate suitable habitat structure availability; and consequently, numbers of walleye collected decrease accordingly. We suspect that this is the explanation for the decreases in abundance within preference and tolerance zones (and by extension temperature standard exceedance bin) noted above.

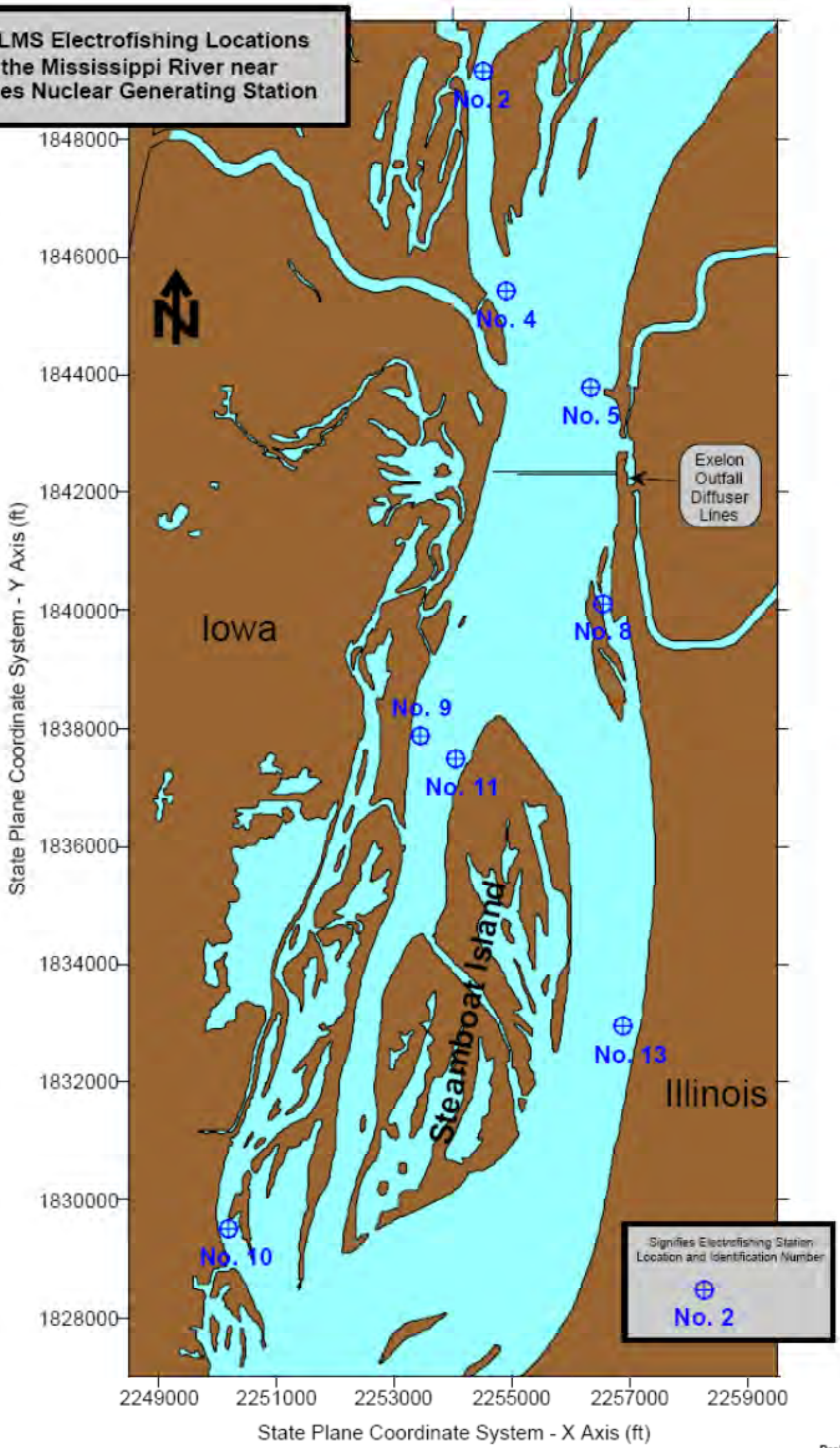
Conclusions

Figure A3-2 shows that the numbers of walleye collected at river temperatures from 86 to 88°F are comparable to those collected at 74-76, 76-78 and more than at 78-80°F. This suggests that the avoidance temperature at high acclimation temperatures is in excess of 88°F, which is two degrees above the EOMZ standard for the months of July and August and consistent with the upper end of the tolerance zone shown in Figure 5 of the main report.

The underlying data used to develop Figure A3-2 support observations that low flow reduces numbers of walleye collected at fixed shoreline locations and that movement from these locations for any reason is transitory. For example, total numbers of walleye collected in 2006, 2007, and 2008 were 4, 10, and 43, respectively. Consistent with the increased catch, the mean monthly flows in 2008 were substantially higher during June and July than either of the two previous years and August flows were greater than 2006 but less than 2007 (HDR, 2009). The larger numbers collected during 2008 indicate a return to the sampled habitats when those habitats are available.

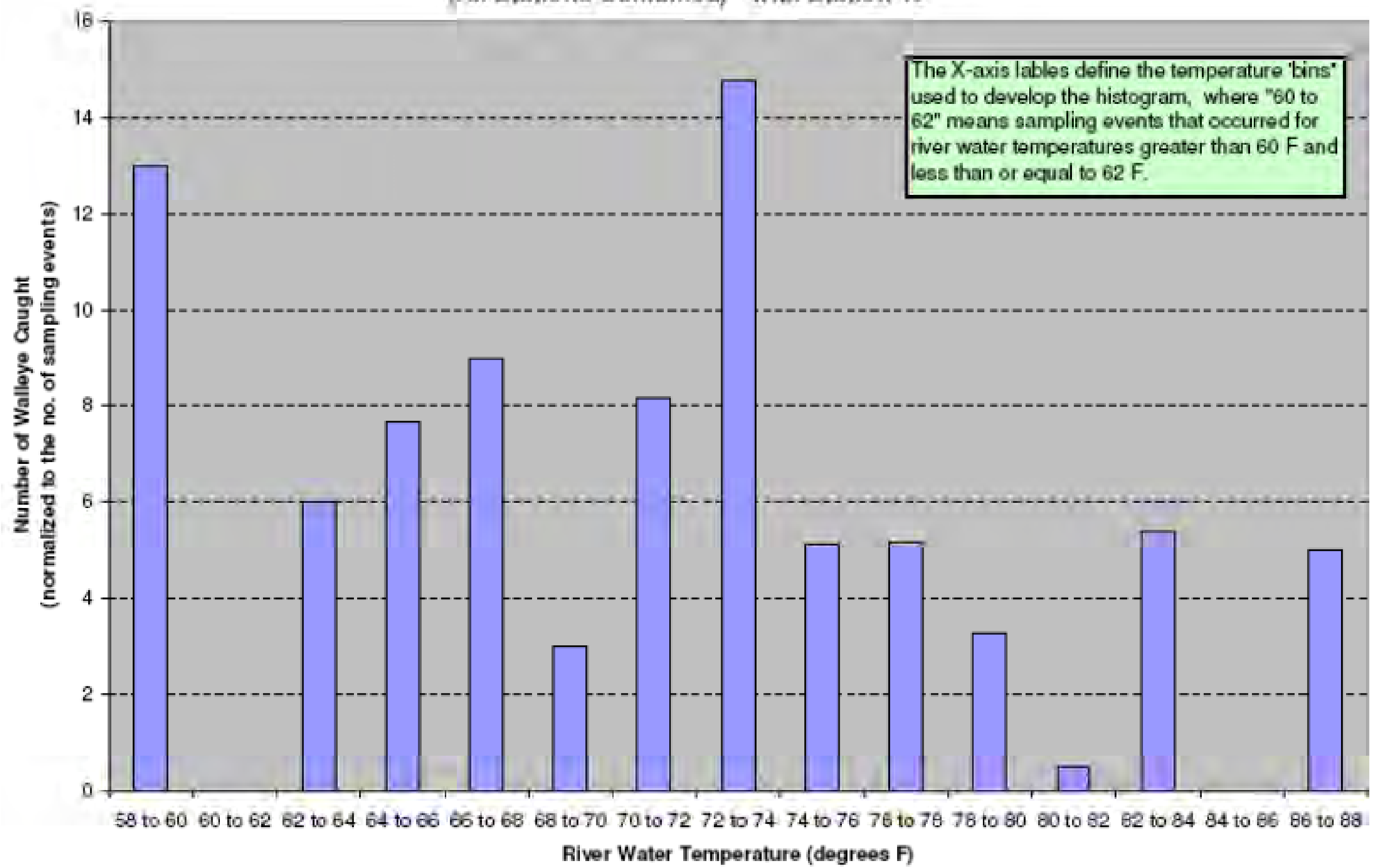
Based on these observations, there is reason to expect that any displacement of walleye for either low flow or thermal reasons will be transitory and will not cause appreciable harm to the balanced indigenous fish community which inhabits Pool 14 or adjacent pools.

Figure A3-1. LMS Electrofishing Locations in Pool 14 of the Mississippi River near the Quad Cities Nuclear Generating Station



Preliminary Draft

Figure A3-2. Histogram of Walleye Catch Data in the Vicinity of the QCNGS
(All Stations Combined) - with Station 10



APPENDIX C

Retrospective Demonstration and Conclusions Regarding Protection and Propagation of a Balanced Indigenous Community under Clean Water Act Section 316(a)

TABLE OF CONTENTS

1. INTRODUCTION

This appendix provides a retrospective evaluation that supports approval of the proposed Alternate Thermal Standard (ATS) by demonstrating that prior QCNS operations have not caused appreciable harm to the balanced indigenous community in Pool 14. The prospective evaluation of the effects of future QCNS operations with the ATS in place is provided in Appendix B. Both evaluations demonstrate that the proposed ATS will "assure the protection and propagation of a balanced, indigenous population[1] of shellfish, fish, and wildlife in and on the body of water [Pool 14]", the standard for granting of a thermal variance under section 316(a) of the Clean Water Act.

2. RETROSPECTIVE EVALUATION

2.1 Approach

In performing the retrospective evaluation, the biotic categories analyzed are: (1) phytoplankton, (2) habitat formers, (3) zooplankton and meroplankton, (4) shellfish and macroinvertebrates, (5) fish, and (6) other vertebrate wildlife.

The analysis focuses on Pool 14 and adjacent Pools, the receiving waters for the Quad Cities Nuclear Station (QCNS) thermal discharge and the Wapsipinicon River, the tributary with discharges immediately above the thermal mixing zone. Pool 14 is near the middle of the Upper Mississippi River Lock and Dam complex, which extends from near Minneapolis, Minnesota to St. Louis, Missouri.

The retrospective evaluation is conducted in two parts. First, we analyze the condition of each biotic category as a whole by comparing available information on its current abundance and species composition to what would be expected without the operation of Quad Cities Nuclear Station. Second, we analyze the long-term trends in abundance for each of the biotic categories within the river community to determine whether a change in population abundance has occurred that can be attributed to the Station's operations. Taken together, the biotic category and long-term trend analyses provide a thorough and technically sound assessment of the status of the biological community in Pool 14 consistent with Section 316(a) guidance and practice.

Over the years that 316(a) studies have been conducted, it has become evident that certain biological communities require more detailed study and evaluation than do others. For example, as a rule the fish community always requires detailed evaluation due to recreational and/or

[1] Later amended to be balanced, indigenous community (BIC)

commercial fisheries. Depending on the nature of the receiving waters, certain of the lower trophic level communities, e.g. phytoplankton and zooplankton, may not require detailed investigation due to heterogeneity of distribution, short regeneration times, and seasonality. In addition, these communities function as the source of food for various life stages of species populations that comprise the fish community. Thus, any permanent adverse effects on these lower trophic level communities would be reflected in an adverse shift (imbalance) in the fish community.

It is generally agreed by the resource agencies that within the Station's discharge area, freshwater unionid mussel communities require a high priority of protection and warrant detailed evaluation under 316(a). For these reasons, the primary emphasis for this demonstration has been on the freshwater unionid mussel and fish communities.

2.2 Water Quality Changes

While excess heat is the primary concern of Section 316(a), a number of other factors influence water quality and thereby influence the biological function of aquatic systems. These factors may interact with other pollutants in the water body, interact with the heat and chemical discharges, or interact with other uses of the water body. Accordingly, this demonstration identifies some of the numerous factors that may influence water quality, and considers those factors in connection with Quad Cities Nuclear Station's discharge of heat.

2.2.1 Nutrients

Power plants, including Quad Cities Nuclear Station, are not significant sources of nutrients. Organic carbon, phosphorus, and nitrogen are the elements most often associated with nutrient richness. The current status of each of these in the upper Mississippi is discussed in the subsections that follow.

2.2.1.1 Organic Carbon

There are limited organic carbon data available on the Mississippi River system; however composite bed sediment samples were collected from the lower one-third of the Upper Mississippi River navigation pools prior to and after the summer flood of 1993. Bed sediment contaminant concentrations exhibited a general decrease following the flood of 1993. Decreases in pollutant levels were attributed to an increase in the portion of coarser sediment and low inputs or remobilization of contaminated sediments during or immediately following the flood. Bed sediment elevations in the sampling areas were found to increase significantly in the middle

(Pools 5-13) and lower (Pools 14-26) reaches, likely a result of an increase in deposition of coarser sediment (see Appendix A). System-wide, concentrations of dissolved organic carbon ranged from 3-12 mg/l. For the most part, dissolved carbon is unavailable to aquatic organisms other than bacteria. The reintroduction of organic carbon into the food web through bacteria results in additional energy to higher trophic levels (e.g., fish). The energy contributed by the QCNS thermal plume may increase bacterial growth rates but there is no indication of any harm caused by this potential interaction and there is no reason to expect that the small amount of additional heat that would be permitted to be discharged under the proposed alternative standard would cause a harmful interaction.

2.2.1.2 Total Phosphorus

In general, wastewater treatment plant discharges and urban and agricultural nonpoint source inputs are major sources of phosphorus. Agricultural watersheds contributing high concentrations of sediment are especially important because phosphorus is commonly bound to sediment particles. Nitrogen and phosphorus are abundant in the Mississippi River drainage basin because of the widespread use of commercial and animal-manure fertilizers. There are no nutrients added to the once-through cooling water during passage through the plant.

The most likely result of an interaction between the thermal plume and phosphorous would be an increase in the rate of algal growth during warm periods. However, this would be a localized effect in the less than 10% of the pool occupied by the thermal plume and no difference in algal abundance or growth has been observed in the plume. Given that there has been no evidence of a synergistic effect between total phosphorous and the thermal discharge in the past, there is no reason to expect that the small amount of additional heat that would be permitted to be discharged under the proposed alternative standard would cause any such effect.

2.2.1.3 Total Nitrogen

Nitrogen is used in agricultural fertilizers to stimulate the production of crops, especially corn. Runoff from areas with intensive cultivation or large livestock densities are important sources of nitrogen. In addition, certain industrial discharges and municipal wastewater effluents may contain high concentrations of inorganic nitrogen, especially ammonia or nitrate nitrogen. Nitrogen concentrations throughout the river increased to higher levels in the 1990s, compared to concentrations observed during 1985-89. For the upper river, this response may have been partly associated with changes in municipal wastewater treatment technology (nitrification). However, changes in precipitation and river flow are additional factors associated with river-wide increases in nitrogen concentrations. The drought conditions of the late 1980s reduced non-point source runoff and increased utilization of inorganic nitrogen within the riverine pools. Increased non-point source runoff in the 1990s likely favored mobilization of nitrogen from agricultural watersheds, resulting in high nitrogen concentrations in the river during this period. The large amount of agricultural sources of nitrogen in the area suggests that the small amount discharged from the QCNS treatment plant is negligible by comparison. While nitrogen concentrations have increased during the recent decades for the reasons stated above, the Station's thermal discharge and treatment plant effluent have not contributed to this increase.

The most likely result of an interaction between the thermal plume and nitrogen would be an increase in the rate of algal growth during warm periods. However, this would be a localized effect in the less than 10% of the pool occupied by the thermal plume and no difference in algal abundance or growth has been observed in the plume. Given that there has been no evidence of a synergistic effect between total nitrogen and the thermal discharge in the past, there is no reason to expect that the small amount of additional heat that would be permitted to be discharged under the proposed alternative standard would cause any such effect.

2.2.2 Biocides

To control biofouling organisms in cooling water systems, power plants generally need to apply some type of biocide. Biocides are typically halogenated (i.e., chlorine and bromine) substances used specifically to control the growth of micro-fouling organisms within the cooling system of the power plant. The most common method of micro-fouling control is periodic bulk treatment with sodium hypochlorite.

Historically, Quad Cities Nuclear Station has treated its cooling water system with sodium hypochlorite. Sodium hypochlorite is normally used as the sole biocide for treatment of the circulating water system. (See Section 4.2 in Appendix D of this Demonstration for additional details about biocide application at Quad Cities Nuclear Station.) Sodium bisulfite is used as a neutralizing agent prior to discharge to the river to ensure compliance with the TRC/TRO limit of 0.05 ppm. The detection limit is 0.05 ppm, an order of magnitude lower than the levels that cause fish mortality. Therefore, the Station's discharge of chlorine is well below levels that would cause harm to fish and the Station's use of biocides cannot reasonably be expected to alter or cause harm to fish communities in Pool 14 and adjacent Pools, nor does it pose any risk of harm to the BIC. Any potential interaction of the thermal discharge with the biocides is similarly harmless.

2.2.3 Heavy Metals

Metals in the Mississippi River come from natural as well as artificial sources. Some of these metals are essential in low concentrations for proper metabolism in all living organisms yet toxic at high concentrations; other metals currently thought of as non-essential are toxic even at relatively low concentrations. Heavy metals can be harmful to fish at low concentrations, by altering prey availability via shifts in community structure.

Heavy metals are released to the Mississippi River from numerous sources. Typical sources are municipal wastewater-treatment plants, manufacturing industries, mining, and rural agricultural cultivation and fertilization. Heavy metals are transported as either dissolved species in water or as an integral part of suspended sediments. Heavy metals may be volatilized to the atmosphere or stored in riverbed sediments (see Appendix A for more information).

Whether the loads and concentrations of heavy metals in the Mississippi River have increased or decreased in recent years is difficult to determine. Although most of the heavy metals in the river are associated with sediment, the majority of the previous studies have focused on the dissolved metals. Even for the dissolved metals, comparisons are difficult to draw between earlier and more recent data because analytical laboratory techniques have become markedly more sensitive in the last decade and field sampling techniques have not been adequately standardized. Those heavy metals that are found in the sediments are typically chemically bound to colloidal materials such as clay particles. This chemical bond is controlled by the electrical charge on the surface of the colloid which is controlled by the numbers of hydrogen ions present or the pH. As pH decreases (becomes more acidic), the surficial charge will eventually reverse allowing the cation exchange phenomenon to occur. This frees the heavy metal to go into solution in the water. However, the pH of the river water ranges from about 7.0 to about 9.0 which is basic rather than acidic, thus inhibiting the process. Because movement of metals from the sediments into the water column is catalyzed principally by pH rather than temperature, the thermal discharge has not caused the release of heavy metals from the sediments and the proposed change in the thermal standard will also not affect this process. Thus, the heavy metals bound in the sediments can be expected to remain there and not interact with the biota.

Therefore, there have not been and will not be any interactive impacts between the thermal plume, heavy metals and the biotic community.

2.2.4 Potability, Odors and Aesthetics

There is no evidence of an unnatural odor or an unaesthetic appearance in the Mississippi River in the vicinity of the QCNS in general, and none associated with Station operations in particular. Given the small incremental change in the thermal standard that is proposed, there is no reason to expect it will have any effect on potability, odors or aesthetics of Pool 14.

2.2.5 Other Thermal Discharges

Several cooling water discharges are located on the Mississippi River from RM 517.5 to RM 513, which is approximately 10.5 km (6.5 mi) upriver from the QCNS intake. Beaver channel is a side channel of the Mississippi River, which houses industrial discharges for Archer Daniels Midland's (ADM) Corn Processing Plant and Interstate Power Companies' M.L. Kapp Plant. The thermal component of the discharges from these is diluted and dissipated to ambient conditions by the time it reaches QCNS. Hence, they do not interact with the Station's thermal discharge.

2.2.6 Summary

There is no evidence of harmful interactions between the Station's thermal discharge and other pollutants including dissolved organic carbon, total phosphorus, total nitrogen, biocides, heavy metals, and other thermal discharges located upstream and there is no reason to expect that the small amount of additional heat that would be permitted to be discharged under the proposed alternative standard would cause one.

2.3 Phytoplankton Biotic Category Analysis

2.3.1 Background

Phytoplankton are free-floating microscopic plants that are transported by the water currents. Generally, phytoplankton is broadly distributed and abundant, with high reproductive and growth rates, and short generation times. They are rapidly transported and dispersed by water currents. This rapid dispersal and prolific rate of reproduction enable phytoplankton to recover rapidly from localized stresses within the environment.

Numerous studies of power plant thermal discharges into estuaries and coastal marine waters were conducted during the 1960s and 1970s. In general, the studies showed that adverse effects on phytoplankton populations from power plant thermal discharges are rare and occurred, if at all, in a small area in the immediate vicinity of the discharge. Such effects were limited to periods of maximum discharge temperatures during the summer and during those hours when the circulating water was chlorinated to control biofouling of the condensers (*Jensen, 1974, 1978; EA, 1978; UWAG, 1978a, b*).

2.3.2 Site Specific Studies

Phytoplankton studies were performed at the Quad Cities Nuclear Station as part of the pre-operational studies conducted during the early 1970's and the first 316(a) and (b) studies conducted in 1972 and 1973. The original January, 1975 316 (a) Report, which includes post-operational studies (1972 and 1973), concludes that phytoplankton present between river mile 501 and 509 in the Mississippi River are characteristic of a somewhat enriched habitat and, although seasonal variations exist, the phytoplankton communities have been relatively stable, with diatoms dominating the communities. Comparisons of total phytoplankton, major algal divisions, and dominant species at locations upstream and downstream from the originally designed side-jet discharge or of the diffuser pipe dissipation system indicated that neither mode of heat discharge had any detectable effect upon phytoplankton numbers or community composition. These findings led to the eventual discontinuation of phytoplankton studies in the Mississippi River in the area of Quad Cities Station (Commonwealth Edison, 1975).

Phytoplankton studies were conducted in conjunction with and at the same locations as zooplankton studies from August 1972 through August 1973. During full open-cycle cooling, an overall stimulatory effect on phytoplankton was measured in the river downstream of the diffuser pipe, which was not interpreted as a negative influence. Mean values for carbon fixation rates, chlorophyll *a* concentrations and phytoplankton abundances during chlorination and non-chlorination periods were compared at several upstream and downstream locations. No trends of significant differences ($P<0.05$) in phytoplankton productivity and chlorophyll *a* concentrations for the sample period between the sampling locations immediately upstream and downstream of the diffuser pipes were observed. Many of the individually significant differences that were identified during this period between upstream and downstream locations were attributed to non-homogeneity of phytoplankton populations between locations.

Observations made by HDR field staff during fish monitoring efforts indicate that phytoplankton blooms begin in the backwater areas during the late April/May period and are often seen in the main channel areas by the latter half of June. These blooms typically occur until about the middle of October. The early blooms are primarily both filamentous and non-filamentous green algae which are replaced by brown algae as the season progresses. These blooms do not appear to be dominated by "nuisance" algae.

2.3.2 Summary

Based on the studies conducted at other facilities and data collected as part of the pre- and post-operational studies at QCNS, the Station has not caused appreciable harm to the phytoplankton community. Hence, the proposed, relatively small, incremental changes in the station's thermal limits are not expected to have any detectable effect on the phytoplankton community in Pool 14 and, thus, will not cause appreciable harm to the BIC in this regard.

2.4 Zooplankton Biotic Category Analysis

2.4.1 Background

Zooplankters are animal microorganisms that live freely in the water column, have relatively limited powers of locomotion, and drift with the currents. Zooplankton may eat phytoplankton, other zooplankton, or particles of suspended organic matter; in fact, many are omnivores and eat particles of suitable size regardless of origin. Zooplankton include two subgroups: holoplankton and meroplankton. Holoplankton spend their entire lives as plankton. Meroplankton are planktonic only during part of their life cycles. Examples include the eggs and larvae of fish and shellfish. Meroplankton are addressed as part of the shellfish and fish biotic categories below.

Zooplankton generally are not expected to be adversely impacted by thermal discharges. First, because holoplankton spend their entire life in a variable environment, they have evolved broad physiological tolerances and behavioral patterns that allow them to survive changing conditions. Second, zooplankton are rapidly transported and dispersed by currents, such that no organism is likely to spend any significant amount of time (conservatively less than 10 minutes) in the permitted mixing zone. Third, they have short generation times and high reproductive capacities, allowing populations to readily offset the loss of individuals and to recover rapidly from local perturbations. With optimum temperature (78° to 86°F) and food supply, protozoan populations can double their numbers up to three times per day. Under such conditions, small crustaceans such as rotifers and cladocerans can double their numbers up to five times per day (Edmondson et al., 1962; Hall, 1964). Accordingly, the probability is low that there could be any meaningful change (positive or negative) in growth or reproduction of zooplankters transported through the thermal plume.

Numerous studies during the 1970s and 1980s of power plant thermal discharges support the conclusion that zooplankton are a low potential impact category. Effects on zooplankton populations were limited to a small area in the immediate vicinity of the discharge, occurring with maximum discharge temperatures in the summer and during those hours when the circulating water was chlorinated to control fouling of the condensers (EA, 1978; Tetra Tech, 1978; UWAG, 1982).

2.4.2 Site Specific Studies

Zooplankton studies were conducted in concert with the phytoplankton studies at the Station during the early 1970's for pre-operational studies and the first 316(a) & (b) studies (post-operational) were conducted from 1972 to early 1974 (see Appendix E). Comparisons of total zooplankton and the three major groups of zooplankters prior to and during all phases of the station operation at locations upstream and downstream from the Quad Cities Station did not reveal any differences attributable to plant operations (Commonwealth Edison, 1975).

As documented in Appendix A, seasonal cycles of species composition and abundance in the Mississippi River are typical, i.e. the relationship between species richness and abundance in streams appears to be largely due to changes in flow rate and specific habitats with a specific river system. No commercially important species of zooplankton and no threatened or endangered species of this biotic category occur in the vicinity of QCNS. Studies following initiation of plant operations confirmed that the species diversity and abundance of zooplankton, both upstream and downstream of the diffuser pipes, were typical for the Mississippi River.

2.4.3 Summary

Based on zooplankton's broad physiological tolerances, short time spent in the mixing zone, short generation times and high reproductive capacities, and data collected as part of the pre and post-operational studies at QCNS, operation of the Station has not caused prior appreciable harm to the zooplankton community. Hence, the proposed, relatively small, incremental changes in the station's thermal limits are not expected to have any detectable effect on the zooplankton community in Pool 14 and thus will not cause any harm to the BIC in that regard.

Two communities that rely on both phytoplankton and zooplankton as a basis for their food supply, either directly or indirectly are freshwater mussels and finfish. Both of these communities are discussed in depth retrospectively in this demonstration and the same conclusion is reached for both, i.e., operation of the Station since late 1983 has not caused appreciable harm to these balanced, indigenous communities. This demonstrates that an adequate food supply (plankton) has been available.

In addition, during the operating history of the Quad Cities Nuclear Station, there have been periods during which thermal conditions in the receiving waters have been similar to conditions that could result from operations under the proposed alternate thermal standards, particularly during the summer of 2006. If the thermal conditions of 2006 had had adverse impacts on the lower trophic levels, the fish and mussel communities should have reflected the effect of reduction in food supply. However, no such effects were observed. The constant supply of planktonic organisms drifting downriver and their ability to quickly reproduce ensures that an adequate food supply is continually available and that any losses are quickly replaced. Taken together, these observations suggest no appreciable harm has occurred to the lower trophic levels under the current thermal standard and none will result from the small increment in added heat that could result if the proposed standard is implemented.

2.5 Habitat Formers Biotic Category Analysis

2.5.1 Unique or Rare Habitats

There are unique habitats in Pool 14 and the adjacent pools. Two essential habitats for the federally endangered Higgins Eye pearly mussel have been established as part of the long-term recovery plan for this mussel. One is the Cordova mussel bed, which is directly downstream of the station's thermal mixing zone (RM 505.5 to RM 503). The second is the Hanson Slough bed, which was designated in 2008, and is located at RM 510 to RM 509. No other designated habitats for Higgins Eye pearly mussel are within the influenced areas (See Appendix A). Issues regarding the essential habitats are addressed in the habitat conservation plan prepared in collaboration with the US Fish and Wildlife Service.

It should be noted that the Higgins-eye pearly mussel (a Federal, Illinois, and Iowa endangered species) occupies portions of the river bed both upriver and downriver of the discharge. An ecological risk assessment of this area and species was completed in March 2005 by Ecological Specialists (ESI 2005). ESI concluded that an increase in excursion hours from 1.0% to 3.0% should not result in any additional adverse impacts to the downriver mussel beds. The report recommended that a unionid monitoring program be implemented for confirmatory purposes, if the proposed alternate standard was granted. Subsequently, ESI conducted a monitoring program and a balanced indigenous community study between river miles 495.5 and 516.0 in Pool 14 (ESI, 2008) and concluded that unionid beds, both upstream and downstream of the diffuser, are similar in community structure.

Based on the analysis conducted by ESI, Higgins Eye mussels and other native mussels have endured maximum water temperatures as high as 91.6^0 F and temperatures in excess of 86.0^0 F for 10.5 consecutive days downstream of the diffuser pipes within the last 10 years, with no apparent harm to their populations or community structure. Thus, the QCNS thermal discharge has not caused prior appreciable harm to this community and there is no reason to believe that the proposed, relatively small, change in the thermal standard will either.

2.5.2 Nuisance Species

There is strong evidence that zebra mussels, *Dreissena polymorpha*, are distributed throughout the study area and have had a detrimental effect on the wellbeing of native freshwater mussels and other users of mussel beds for habitat (ESI, 2009a). Zebra mussels were first noted in fisheries samples at QCNS in 1994 and a monitoring program for them was initiated in 1996. These exotic mussels have a direct, negative effect on native mussel populations as they cover any surface available, including other zebra mussels, to densities not seen with any native species. The impact on native mussels is considered to be the most destructive element currently threatening native freshwater mussels. Zebra mussels are mentioned under habitats only because the dead shell layer observed in the Cordova bed as well as other Mississippi River beds can be inches to more than a foot thick, virtually eliminating the natural substrate of the river from use by indigenous species (ESI, 2009b).

Although zebra mussels became established in Pool 14 during the period of open cycle cooling, they appear to be distributed in similar concentrations both upstream and downstream of the diffuser pipes in areas with similar habitat characteristics, suggesting that the thermal discharge has had little or no influence on this species' invasion and is not expected to have any influence in the future.

2.5.3 Succession

As water receives increasingly large loads of nutrients, there is a strong tendency for phytoplankton populations to increase within the existing limitations of temperature and light availability (Wetzel, 1983). This succession pattern is usually observed at the lower trophic levels during the eutrophication process. However, the zebra mussel invasion may have changed the dynamics of this process due to their immense filtering capabilities. As noted in Appendix A, water clarity has improved in the river at approximately the same time as the proliferation of zebra mussels occurred. This change in water clarity along with a decreased Total Suspended Solids (TSS) load brought about by improved land use practices has caused an increase of, submerged macrophyte abundance in the receiving Pools, including Pool 14. This increase of macrophyte beds has occurred both upstream and downstream of the diffuser pipes during this period and does not appear to have been influenced by the thermal discharge.

It appears the thermal discharge has not had an effect on these organisms and the requested change in the thermal standard is not expected to have an influence on the succession of either macrophytes or native mussels (see zebra mussel discussion above) beds in Pool 14 and adjacent Pools.

2.6 Shellfish and Macroinvertebrates Biotic Category Analysis

2.6.1 Threatened and Endangered Species

There is one federally endangered species of mussels in Pool 14 and adjacent Pools, the Higgins' Eye pearly mussel, and a candidate species, the Sheepnose mussel. The more prevalent species is the Higgins' Eye mussel, which can be found in several beds in Pool 14 and adjacent Pools. Directly below the diffuser area is the Cordova bed, which is one of several essential habitats outlined in the Higgins' Eye Recovery Program. The Cordova bed is an essential area for the species because it is used as a source of brood stock for mitigation activities involving Higgins' Eye mussels throughout the Mississippi River system. The QCNS has completed a Habitat Conservation Plan as part of an Incidental Take Permit application. The plan provides the details of a mitigation plan that will be implemented if an incidental take of Higgins' Eye mussel were to occur in the future. The plan also includes actions to be taken to avoid and/or minimize any incidental take of these mussels. The current draft plan states that no acute take is expected with the proposed change in thermal limits, but a take in the form of harassment could occur in the future (harassment is defined in the Endangered Species Act as a non-lethal stress that can occur one or more times). The Habitat Conservation Plan was prepared at the direction of USFWS to answer any questions regarding potential harm to the endangered and threatened mussels of the local pool.

2.6.2 Mussel Communities

In 2007, a study was undertaken by Environmental Specialists, Inc. to define the balanced indigenous mussel community within Pool 14 of the Mississippi River, MRM 515 to 495 (ESI, 2008). The Station's thermal diffuser is located at approximately MRM 506.4.

Preliminary sampling was conducted in June 2007 to identify unionid beds upstream and downstream of the thermal diffuser. A total of 15 beds were sampled; certain beds were selected for more intense sampling and evaluation. Habitat and water quality information was collected for all intensively sampled beds, and substrate temperature and fish communities were sampled in the Upstream (UP), Steamboat Slough (SS), and Cordova Beds in 2007. The SS unionid bed, located on the Iowa bank at MRM 505.6, is the most proximate downstream bed. The Cordova Bed, which is listed as an Essential Habitat Area for *Lampsilis higginsii* (the Higgins' Eye pearly mussel) by USFWS, is further downstream, about one mile from the diffuser.

Federal and state listed threatened and endangered species were distributed throughout the study area. The federally endangered *Lampsilis higginsii* was most abundant in the Albany (upstream) and Cordova beds, but was found in seven of the 15 beds sampled. *Lampsilis teres* (Iowa endangered species) and *Ellipsaria lineolata* (Illinois threatened species) were each collected in eight of the 15 beds.

Unionid beds are found throughout the study area in a variety of habitats both upstream and downstream of the QCNS (ESI, 2009b). One, the Steamboat Slough bed (SS), occurs in the immediate vicinity (Primary Area, defined as being in the thermal plume at temperatures greater than 3.6^0 F above ambient) of the QCNS diffuser. Density within this bed is similar to beds both upstream and further downstream of the diffuser with similar habitat characteristics. Unionid mussel and fish communities within the SS bed are indicative of its habitat conditions, as similar communities were found in similar habitats both upstream and downstream of the diffuser. Based on the results of this study, it is expected that the unionid community that currently exists within the SS Bed would be similar to the community that would exist in the bed if the Station and its thermal discharge were not present. Likewise, the community characteristics of the other unionid beds located downstream of the plant are very similar to those observed in upstream beds that have comparable habitats.

This finding, combined with the fact that thermal exposures experienced by the unionid community during the 2006 high ambient temperature/low river flow episode are comparable to thermal exposures that would be permitted under the proposed alternate thermal standards, supports the conclusion that the proposed thermal standards will adequately protect the balanced indigenous unionid community in the QCNS receiving waters.

2.7 Fish Biotic Category Analysis

2.7.1 Threatened and Endangered Species

There have been no federal endangered or threatened fish species collected in Pool 14 and the adjacent Pools.

2.7.2 Ichthyoplankton

Ichthyoplankton include the eggs and larvae of fish. Appendix A summarizes available information regarding the species of ichthyoplankton collected in Pool 14. Based on data collected during river fish larvae monitoring (LMS 1985 and LMS 1986), peak larval drift tends to occur at ambient river temperatures in the range of 21 to 23ºC (69.8 to 73.4^{o} F) and when river flows are relatively high, both of which suggest that ichthyoplankton are not exposed to temperatures high enough or for sufficient duration to cause thermally-induced mortality at the end of the mixing zone where temperatures would range from 74.8 to 78.4ºF.

During the period of ichthyoplankton sampling (1978 through 1985), the majority of the eggs and larvae drifting by QCNS were those of freshwater drum. The highest concentrations of these were found near the Illinois shoreline, an area in which the diffuser pipe ports are closed for a span extending approximately 840 feet offshore. Nearly all (95%), of the freshwater drum egg drift occurs before July 2, with the peak occurring before June 5 (LMS, 1985). Prior to 2009 no excursion hours had been used before July 7. In 2009, five hours were used on June 26 and in 2010, 36 hours were used during May 30 to June 1. In 2011 hours were not used until July 22.

In March 2012, record breaking air temperatures caused the upstream water temperature at Lock and Dam 13 to reach and exceed the monthly excursion temperature threshold of 57 ºF. As a result, during the period March 18 through March 29, 2012 QCNS used a total of 223.5 excursion hours, 168.9 of which were accumulated under a provisional variance. On each day that provisional variance hours were used QCNS made three visual inspections, spaced throughout the day, of the intake and discharge areas up to 1000 feet downstream of the diffuser. Crews were asked to document the number and general category of dead or stressed fish/aquatic life. No mortality or evidence of stress to any aquatic life was observed and there was no evidence of any fish kills during any of these inspections. This indicates that fish were able to adapt to the unseasonable, record breaking temperatures through acclimation and/or avoidance of regions of elevated temperature. Impingement data collected before, during and after the event showed species distribution and abundance consistent with that observed in prior years at the same temperatures offering further evidence that the unusually warm temperatures in March 2012 did not cause appreciable harm to the BIC in Pool 14.

Although anomalous temperature patterns like the one observed in March 2012 may occur, it is anticipated that the temporal pattern of excursion hour use in the future will be similar to that experienced over the last 28 years, with only rare usage prior to July 1. Therefore, the proposed increases in excursion hours should have a negligible effect on eggs and larvae of freshwater drum.

Another species contributing substantially to the larval drift is gizzard shad that tend to drift closer to the Iowa shoreline where they are exposed to the thermal plume. Based on the numbers of gizzard shad captured in the monitoring program for the past 25 years and observations of those that die natural deaths during the winters, the gizzard shad population in Pool 14 and adjacent pools has not been harmed by the thermal addition and it is not expected to be harmed by the small increment in added heat that could result if the proposed thermal standard is implemented.

2.7.3 Finfish

Trends evident in the long-term electrofishing fish monitoring database covering the past 41 years include increases in numbers of freshwater drum, channel catfish, largemouth bass, and bluegill and decreases in the numbers of white crappie, black crappie, and sauger (Figure C-1), while flathead catfish abundance has been relatively without trend (Figure C-2). These trends are apparent at locations both upstream and downstream of the diffuser pipes and most likely are the product of long term sampling at fixed locations that have undergone substantial habitat changes such as backwater siltation and the appearance of beds of rooted aquatic plants that was coincident with a noticeable increase in water clarity. Figure C-1 also shows that abundances of two species targeted by commercial fishermen, common carp and river carpsucker, have declined over the period of record, with some recovery of carpsucker in recent years. Changes in fishing regulations (e.g. channel catfish length limit increase) by one or more of the resource agencies may have influenced these trends. Channel catfish, in fact, have shown an increase in abundance in recent years with catch-per-hour rates exceeding historical values.

Over the past 25 years, a total of 94 taxa have been collected in the QCNS electro fishing program. During most years the number collected has ranged from 50 to 60 taxa and has been reasonably stable over the 25 years of open cycle cooling.

Age analysis of fish collected in the program indicates that freshwater drum are long-lived in Pool 14, often exceeding age 20 and occasionally age 30. Annual adult survival has averaged between 70 and 75% for the past 29 years (HDR, 2011). Maximum theoretical growth has steadily increased since 1983 (Figure C-3) (HDR, 2012). Standing stock estimates, expressed as biomass, of freshwater drum equal to or greater than 150 mm (TL) vary among years because this metric is driven by year class strength which is influenced by complex interactions of many factors (HDR, 2011).

The observed trends suggest that the thermal additions that have occurred since 1983 have caused no appreciable harm to the finfish in Pool 14 and that the requested modifications to the thermal standards will assure the protection and propagation of a balanced indigenous population of finfish in the pool.

2.7.4 Fisheries

Fishing is an important recreational and commercial use of the Mississippi River; this is particularly true for Pool 14 and the adjacent Pools. The primary recreational species of interest are largemouth bass, walleye, sauger, catfish, and crappie. White bass, bluegill, freshwater drum, paddlefish, and northern pike are also sought after in these Pools. QCNS, in conjunction with Southern Illinois University, operates a fish hatchery on site. Currently, walleye are raised in the abandoned spray canal and are stocked into Pools 13 and 14 as advanced fingerlings during the summer. Hybrid striped bass are raised in the indoor tanks over the winter and are stocked in Pool 14 as yearlings in the early spring. The walleye stockings are intended to augment natural recruitment and are doing so within the range of 15 to 40% annually based on follow-up sampling conducted during the fall. Walleye have become a targeted species by both local and non-local fishermen in Pool 14. Within the last 10 years national championship fishing tournaments for walleye and black bass held on the Upper Mississippi River have included Pool 14 in the fishable area. Hybrid striped bass are stocked to create a trophy fishery and that objective is currently being met.

Commercial fishermen tend to target more rough fish than the recreational fishermen. Primary flesh species include buffalo, common carp, channel catfish, flathead catfish, carpsucker, and redhorses. Other species such as shovelnose sturgeon and bowfin are primarily sought after for their roe. All of these species are readily available in Pool 14 and the adjacent Pools. Trends in these fish populations tend to be negatively correlated with fishing pressure. For example, as caviar prices increase, roe fish (listed above) tend to be harvested commercially in higher numbers; thereby, adversely impacting the available spawning adult populations; and hence, abundance of the species in the future. These commercial and recreational fishing pressures on fish populations operate independently of thermal input. In addition, population levels of certain species, notably white and black crappie, have been declining in recent years in Pool 14 and adjacent pools as the backwater areas have been filling in with sediment, a process completely unrelated to thermal addition. Because the abundance of the important commercial and recreational species in the vicinity of the station is predominantly influenced by fishing pressure and habitat availability, it is not expected that the proposed change in the Station's thermal standard will have any noticeable influence on recreational or commercial fishing in Pool 14 and adjacent Pools.

2.8 Other Vertebrate Wildlife Biotic Category Analysis

The waters and shoreline of Pool 14 and adjacent Pools are used by various resident mammalian, avian, reptilian and amphibian species as nesting, nursery, and foraging grounds, and by migratory birds. Water birds commonly seen in the area include local and migratory waterfowl, wading birds, and bald eagles. Substantial increases in the cormorant population have been widely publicized in the popular press. Waterfowl known to use these waters include several species of geese and numerous species of ducks.

Several bald eagle pairs nest along the river and its tributaries within several miles of the QCNS. This use by the eagles has occurred and continues to occur during the period of open cycle operation. The thermal discharge has not inhibited the activities of these nesting pairs. Migrating bald eagles, pelicans, and cormorants routinely use the diffuser area as a resting and feeding area during the winter months, a period not affected by the requested change in the thermal standard. Therefore, the requested change in the thermal standard will not affect these activities.

2.9 Zone of Passage (ZOP)

This section addresses ZOP issues in the context of the retrospective demonstration. ZOP is addressed prospectively in Appendix B.

The USEPA Interagency 316(a) Technical Guidance Manual (USEPA, 1977) sets forth the rationale for determining whether a Zone of Passage is sufficient for the protection and propagation of the balanced indigenous [community]. The ZOP rationale provides that a zone of passage will not be deemed impaired if it provides for the normal movement of populations of representative important species of fish, dominant species of fish, and economically (commercial or recreational) species of fish, shellfish, and wildlife.

The information and data which follow demonstrate that the Zone of Passage proposed for the Quad Cities plant satisfies the USEPA 316(a) test criterion cited above. In addition, the information presented in this section shows that the generally applicable ZOP standard imposed by Illinois regulation -- 75% of the cross-sectional area or volume of flow of a stream -- is more stringent than necessary to assure the protection and propagation of a balanced indigenous population of shellfish, fish, and wildlife in and on the body of water into which the discharge is to be made.

As early as 1971 (two years prior to QCNS beginning commercial production in 1973), the Illinois Pollution Control Board (Case R 70-16) noted that "The utilities [that own the plant] believe that their diffuser pipe will enable them to meet the 5° limit at all times, and the monthly maxima except during rare occasions when extremely low flows coincide with extremely high natural temperatures … We add that our initial fears that the wide diffuser pipe might not leave a sufficient zone of passage for organisms to travel up and down river have been allayed by evidence showing that the jets of warm water from the diffuser (5°F and more above natural temperatures) will occupy far less than 25% of the cross-section of the stream." Thus, the Board recognized that even though the diffuser would extend across most of the river, the total amount of the heat discharged from the ports in the diffuser would comply with the requirement in their Order that no more than 25% of the cross-sectional area of the river be 5°F above natural temperatures.

The objective of the April 2002 Iowa Institute of Hydraulic Research Report (Jain, et al, 2002) was to present and support an updated ZOP curve reflecting the effects of the proposed QCNS power uprate (increase to 28°F temperature rise). That study once again noted that the ZOP with respect to discharge (volume) is always smaller than the ZOP with respect to area; therefore ZOP with respect to discharge is the controlling factor. The authors noted that temperature increases greater than 5°F are usually found only in regions close to the diffuser ports. Thus, each port has its own mixing zone. The study found that the ZOP criteria with respect to discharge were satisfied for river discharges higher than 16,400 cfs for the existing diffuser configuration. The ZOP curve developed by Jain also indicates that at the 7Q10 of 13,800 cfs the ZOP with respect to discharge is about 69%. With a flow of 13,800 cfs and the plant in operation at rated capacity, the surface area with a temperature rise greater than 5°F is less than two acres.

In 2011, Jain analyzed ZOP modeling results with respect to cross-sectional area (which were available but not included in the above noted 2002 Iowa Institute of Hydraulic Research Report). Jain concluded that ZOP with respect to river cross-sectional area should be 75% at river flows of 12,700 cfs and above (Jain, 2011).

The above information demonstrates that, based on modeling studies, QCNS meets the mixing zone and ZOP requirement for cross-sectional area and volume at and above river flows of 12,700 cfs and16,400 cfs, respectively. As the ZOP with respect to discharge is always smaller than the ZOP with respect to area, the question then becomes, first, how often have river flows been below 16,400 cfs and, second, has operation of QCNS during these periods had any adverse effect on the aquatic community. The first question is addressed in the following paragraph based on data obtained from U.S. Army Corps of Engineers (USACE) records for Lock and Dam 14 found at www.rivergages.com). The second is addressed in sections 2.9.1-2.9.3 which discuss the effects of the ZOP on the aquatic community in Pool 14.

USACE records of river flow show that during the past 26 years (January 1986 – December 2011) there were 209 days when river flows were less than 16,400 cfs (2.2% of the time). Thus, flows were 16,400 cfs or above 97.8% of the time. During the past 26 years, of the 209 days with flows less than 16,400 cfs, only 25 days occurred during March, April, May, or October, the biologically important months in terms of fish movement (Haas, 2011). The sections that follow address the effects of the ZOP on the biological community.

2.9.1 ZOP Effects on Finfish

Haas (2011) noted that of the 155 fish species found in the Mississippi River, only 34 are migratory. Of those species, 30 have been documented to occur in Pool 14. A review of these species' behavioral and reproductive characteristics shows that the principal reasons for their migratory behavior are to move to spawning areas, to conduct spawning, to move for feeding advantage, or to migrate to wintering areas. These important biological movements rarely occur during the mid-summer or winter seasons. They occur principally during spring and fall, when flows are typically high and temperatures are moderate. These migration events are not immediate events; they are seasonal changes that occur over a period of several weeks.

Since 1986, river flows have been below 16,400 cfs, the level below which model calculations indicate ZOP is less than 75%, on only four days during biologically important times in the spring (March, April, and May). The four days were 5/27-29/1988 and 3/2/1990. Flow values were 14,921, 14,887, 15,195, and 14,539 cfs respectively on these days and the resulting ZOP was 71-72% (Table C-1) .

If one were to include the month of June in the biologically important spring time-frame, then 1988 (the historic drought year) needs discussion. During 1988, flows were less than 16,400 cfs from June 9 through June 3. However, during the last 20 years (1991-2011) there have been only 33 days on which flows were less than 16,400 cfs, none of which were in the March thru June period. Two species, freshwater drum and flathead catfish, could be potentially affected by a low flow June event. Freshwater drum spawning has been documented in the QCNS environmental monitoring programs. Drum exhibit a "spawning run" which generally coincides with a rise in water level. Because freshwater drum has semi-demersal egg and larval stages that drift with the currents it was selected as a species of interest as regards entrainment and, as a result, QCNS initiated a life history and population dynamic study of this species in 1971. This study has continued to the present and has provided no indication that the operation of the QCNS has had any measurable effect on the freshwater drum population of Pool 14. Flathead catfish also exhibit a tendency for a cyclic move to spawning areas, normally within the first ten days of June. This move is more temperature than flow driven and usually occurs over a week's time. Prime spawning areas are known to be directly above and below the diffuser area. Long-term monitoring studies show very little fluctuation in flathead catfish populations since QCNS returned to open cycle cooling in 1983.

During the fall, movement to wintering areas for most species normally begins in October. These migrations normally span a period of several weeks. Flows less than 16,400 cfs during the month of October have occurred on a total of 21 days, distributed among four years since 1986. Thirteen of the 21 days occurred in the drought years of 1988-1989. The remaining eight days occurred in 2000 and 2003, with one day at approximately 68% ZOP and the remaining days in the 72-73% range. Because fall migration occurs over a period of weeks, a slight reduction in ZOP for a brief period is of negligible biological consequence.

The historical record of river flows indicates that based on the relationship between river flow and ZOP developed by Jain (Table C-1) there have been brief periods during the last 26 years when the ZOP was less than 75% during biologically important times. However, there is no evidence that these brief periods of relatively small reductions in the ZOP have caused appreciable harm to the fish populations in Pool 14.

Similarly, periods of nominal reductions in ZOP during non-biologically important times of the year should also have no adverse impacts on the biological life history of fishes in Pool 14. This subject is discussed at length in Appendix B, Section 3.2.2, pages 16-17 and the corresponding tables and figures on pages B-33-34 and B-53-54. The data (for the Representative Important Species of largemouth bass, spotfin shiner, walleye, and channel catfish) show that there is abundant habitat for these species both above and below the mixing zone in the event that the fish were unable to navigate the existing ZOP.

The long-term fish monitoring program conducted over the last 41 years since 1971 and a number of other comprehensive, state of the science studies (as discussed in detail later in this Demonstration document) support the conclusion that the QCNS thermal discharge (including temporary periods during which the ZOP was below 75%) has caused no appreciable harm to the fish populations in Pool 14.

2.9.2 ZOP Effects on Freshwater Mussels

Due to their life history, freshwater mussels are not be affected by the size of the ZOP. Mussel reproduction, host fish infection with glocidia, and glocidial drop all occur in the spring or early summer and the late fall. Host fish usually drop transformers weeks after spring infestation, therefore long migrations of mussels via fish are uncommon. Fall infested fish hold their glocidia throughout the winter and the transformers fall off as water temperatures rise in the spring. Prime mussel habitat can be found throughout Pool 14 as shown by the designated essential habitats for the Higgins eye pearly mussel which occur both upstream and downstream of QCNS. River flow data indicate that the 75% ZOP has been maintained from March through June for the past 20 years (1991-2011).

2.9.3 Basis for Proposed ZOP Standard

Exelon is proposing a ZOP Standard of 66% for QCNS. Table C-1 (page C-32) shows the approximate size of the ZOP at different river flows based on modeling studies with the plant operating at full capacity and assuming complete mixing within the mixing zone. Specific milestones such as the 7Q10 and the point at which the plant begins derating to maintain compliance with the standard that requires that discharges from the plant not cause river temperatures to increase by more than 5º F are also included in the table.

Model calculations based on complete mixing within the mixing zone indicate that when river flows are 13,000 cfs or less, QCNS will have to derate (i.e., shed load) in order to maintain the 5℉ delta T limit between upstream and downstream temperatures (see Table C-1). Historical operating data show that, in fact, the facility has not operated at flows below 13,600 cfs without derating. In order to assure that a ZOP of at least 66% will be maintained, Exelon has committed to derate QCNS when river flow falls below 13,200 cfs (Table C-1).

3. SUMMARY AND CONCLUSIONS REGARDING PROTECTION AND PROPAGATION OF A BALANCED INDIGENOUS COMMUNITY

In a 316(a) Demonstration, the ultimate standard used in the assessment of the thermal component of power plant discharges is whether a balanced indigenous community of shellfish, fish, and wildlife has been and will be maintained in or on the receiving water body despite the thermal discharge. Based on guidance documents and the criteria that have evolved based on our work on other 316(a) demonstrations, we believe that standard -- protection of the BIC -- is demonstrated when the following criteria are met:

- No substantial increase in abundance or distribution of any nuisance species or heat-tolerant community;
- No substantial decreases of formerly abundant indigenous species or community structure to resemble a simpler successional stage than is natural for the locality and season, other than nuisance species;
- No unaesthetic appearance, odor, or taste of the water;
- No elimination of an established or potential economic or recreational use of the waters;
- No reduction in the successful completion of life cycles of indigenous species, including those of migratory species;
- No substantial reduction of community heterogeneity or trophic structure;

- No adverse impact on threatened or endangered species;
- No destruction of unique or rare habitat, without a detailed and convincing justification of why the destruction should not constitute a basis of denial;
- No detrimental interaction with other pollutants, discharges, or water-use activities;

  Because this QCNS demonstration is focused on a request for a change in the thermal standard, the demonstration must show that these criteria will be satisfied in the future if the proposed standard is adopted.As discussed below, taken together, the retrospective and prospective evaluations of the QCNS thermal discharge demonstrate that the above criteria will be satisfied if the 316(a) variance is granted for the Station.

✓ **No substantial increases in abundance or distribution of any nuisance species or heat-tolerant community**

To date no apparent substantial changes in abundance of nuisance species have been observed. Our retrospective analysis suggests that there have been changes in the non-thermal components of water quality (e.g., water clarity and subsequent non-nuisance macrophytic growth along the main channel), but the Station's thermal discharge was not a contributing factor to these changes. Based on these observations, the relatively small amount of additional heat that could be discharged if the proposed standard is implemented is not expected to cause changes in abundance or distribution of nuisance species**.**

✓ **No substantial decreases of formerly abundant indigenous species other than nuisance species**

Based on results reported by the monitoring programs and special studies described in Appendix A, most indigenous species in Pool 14 have either maintained or increased in abundance during the period of open cycle cooling with the exception of the fish species white crappie, black crappie, and sauger. Decline of white and black crappie seems to be common throughout this reach of the river and not solely in Pool 14. Much of the decline has been attributed to filling in of the backwater areas by sedimentation. As habitat changes, the fish also move out of fixed station sampling areas, which may help explain decreases in numbers collected in the long-term monitoring program. Overall, our retrospective analysis indicates that any trends in abundance are apparent at locations both upstream and downstream of the diffuser pipes, suggesting that the thermal discharge is not a significant contributing factor. The prospective analysis concludes that the proposed alternative thermal standard will not cause any appreciable harm to the indigenous fish species.

Special mussel studies conducted between 2004 and 2008 indicate that unionid mussels are similar in species composition and abundance in beds located both upstream and downstream of the diffuser pipes that have similar habitat. This suggests that the thermal discharge has not caused any appreciable harm to the unionid mussel community in Pool 14. This finding, combined with the fact that thermal exposures experienced by the unionid community during the 2006 high ambient temperature/low river flow episode are comparable to thermal exposures that would be allowed under Exelon's proposed alternate thermal standards, supports the conclusion that the proposed thermal standards will adequately protect the balanced indigenous unionid community in the QCNS receiving waters.

The demonstration of no retrospective effects on fish and shellfish supports the conclusion that the lower trophic levels on which they are dependent for food have been similarly unaffected and that no appreciable harm will result to them from the small increment in added heat that may be released if the proposed standard is implemented.

✓ **No unaesthetic appearance, odor, or taste of the water**

There is no evidence of an unnatural odor or an unaesthetic appearance in general, and none associated with Station operations in particular, and none expected if the proposed thermal standard is adopted.

✓ **No elimination of an established or potential economic or recreational use of the waters**

No economic or recreational uses of the Mississippi River have been eliminated or minimized as a result of the Station's thermal discharge. Recreational fisheries have not been adversely impacted, and Pool 14 continues to be a popular fishing destination. During the past 25 years, the number of fishing tournaments on Pool 14 has increased substantially. The prospective demonstration for finfish indicates the small increment in added heat that may be released if the proposed standard is implemented will not affect these conditions.

✓ **No reductions in the successful completion of life cycles of indigenous species, including those of migratory species**

Retrospective analyses of the long-term monitoring program and the historical biological analysis suggest that there were no effects to compromise the overall success of indigenous species in completing their life cycles. Freshwater drum population dynamics are studied in detail annually to detect any adverse effects attributable to operation of QCNS. No measureable effects have been observed over the 27 - year study period. Further, as discussed earlier (Section 2.9, Appendix C), past operations of QCNS, resulting in a ZOP less than 75%, have resulted in no measurable adverse effects on migratory behavior within the BIC. These observations combined with the prospective demonstration for finfish indicate that the small increment in added heat that could be released if the proposed standard is implemented will not cause any change in these conditions.

✓ **No substantial reductions of community heterogeneity or trophic structure**

Data collected during the long-term monitoring program conducted at QCNS since 1984 suggests that the number of species collected has remained reasonably constant (50 to 60 species). Long-term changes in the fish community can be attributed to the change in water quality, clarity, and subsequent vegetation increases, in particular to the main channel border and side channel areas. These changes are seen system wide (Upper Mississippi River Valley) and there is no evidence that the station's thermal discharge has contributed to these changes.

✓ **No adverse impacts on threatened or endangered species**

The retrospective analysis identifies only one Federal endangered species of mussels in Pool 14 and adjacent Pools and one Federal candidate species for the endangered list, Higgins Eye pearly mussel and the sheepnose mussel, respectively. The analysis indicates that these two species have not been impacted by the Station's thermal discharge and are not expected to be in the future. If during the life of the operating permit, evidence of impact is found or provided, then a habitat conservation plan is in place to mitigate these events.

✓ **No destruction of unique or rare habitat, without a detailed and convincing justification of why the destruction should not constitute a basis of denial**

The unique habitat that could potentially be affected by the thermal discharge is the Cordova Mussel Bed which has been designated as essential habitat for Higgins Eye pearly mussel. This bed is located approximately one mile downstream from the diffuser pipes and it has been exposed to the thermal plume over the past 25 years, including the extreme case year of 2006 when flow temperatures were unusually high and flows abnormally low. ESI began studying this bed and others in Pool 14 in 2004 continuing through 2008. The data collected indicate that the mussels in this bed were not harmed by the thermal conditions that they experienced in 2006. U.S Fish and Wildlife Service has required Exelon to prepare a habitat conservation plan for Higgins Eye pearly mussel to protect this federally endangered species.

✓ **No detrimental interactions with other pollutants, discharges, or water-use activities.**

Operation of QCNS has not had a detrimental effect on recreational (e.g. boating and fishing) or commercial (e.g. shipping and fishing) water-use activities in Pool 14 or on potable water use by communities downstream of QCNS. No cumulative effect with thermal additions discharged by industries upstream has occurred because that heat load is dissipated by the time it reaches the QCNS diffuser pipes. Most heavy metals are bound to the sediments and the chemical reactions that would release these metals are driven by lowering the pH of the water to acidic conditions. Typical pH values in Pool 14 are in the range of 7 to 9 pH units which is basic rather than acidic. Thus, thermal discharges play a limited role in these chemical reactions and have not interacted with the sediments to release heavy metals. As discussed above, no harmful interactions with other pollutants such as organic carbon, phosphorus, and nitrogen are expected if the proposed standard is adopted.

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5. TABLES AND FIGURES

Table C-1. Zone of Passage Based on Flow (assumes full thermal load and perfect uniform mixing)

Flow (cfs)	Approximate ZOP[1]	
12500	57%	
12700	60%	
13000	64%	- initial derating required due to 5°F delta T
13200	66%	- proposed ZOP Standard
13500	67%	
13800	69%	- 7Q10 for Pool 14
14000	70%	
14500	71%	
15000	72%	
15500	73%	
16000	74%	
16400	75%	

[1]Jain, et al., 2002

Date	Flow	ZOP	Date	Flow	ZOP	Date	Flow	ZOP	Date	Flow	ZOP
9/5/1987 7:00	14,693	71%	8/2/1988 7:00	11,879	<57%	8/11/1989 7:00	10,221	<57%	1/17/1990 6:00	16,352	74%
5/27/1988 7:00	14,921	71%	8/3/1988 7:00	10,347	<57%	8/12/1989 7:00	7,706	<57%	1/30/1990 6:00	16,319	74%
5/28/1988 7:00	14,887	71%	8/4/1988 7:00	10,129	<57%	8/13/1989 7:00	6,138	<57%	1/31/1990 6:00	16,447	75%
5/29/1988 7:00	15,195	72%	8/5/1988 7:00	9,549	<57%	8/14/1989 7:00	6,156	<57%	2/1/1990 6:00	16,151	74%
6/9/1988 7:00	16,045	74%	8/6/1988 7:00	10,416	<57%	8/15/1989 7:00	6,170	<57%	2/2/1990 6:00	15,824	73%
6/10/1988 7:00	13,598	68%	8/7/1988 7:00	10,360	<57%	8/16/1989 7:00	7,952	<57%	2/3/1990 6:00	15,756	73%
6/11/1988 7:00	13,607	68%	8/8/1988 7:00	10,421	<57%	8/17/1989 7:00	9,540	<57%	2/4/1990 6:00	15,799	73%
6/12/1988 7:00	13,727	68%	8/9/1988 7:00	12,718	60%	8/18/1989 7:00	14,605	71%	2/5/1990 6:00	15,717	73%
6/13/1988 7:00	13,785	69%	8/10/1988 7:00	15,290	72%	9/18/1989 7:00	14,291	70%	3/2/1990 6:00	14,539	71%
6/14/1988 7:00	13,633	68%	8/19/1988 7:00	16,195	74%	9/19/1989 7:00	12,707	60%	7/27/1990 7:00	16,369	74%
6/15/1988 7:00	13,697	68%	8/20/1988 7:00	14,904	71%	9/20/1989 7:00	12,086	<57%	8/16/1998 7:00	15,296	72%
6/16/1988 7:00	12,791	61%	8/21/1988 7:00	15,272	72%	9/21/1989 7:00	14,463	70%	12/26/1998 6:00	16,019	74%
6/17/1988 7:00	12,110	<57%	8/22/1988 7:00	14,154	70%	9/22/1989 7:00	16,090	74%	12/27/1998 6:00	16,229	74%
6/18/1988 7:00	11,778	<57%	8/23/1988 7:00	14,509	71%	9/25/1989 7:00	15,913	73%	12/29/1998 6:00	15,476	72%
6/19/1988 7:00	11,158	<57%	9/2/1988 7:00	15,858	73%	9/26/1989 7:00	14,694	71%	12/22/1999 6:00	14,362	70%
6/20/1988 7:00	10,335	<57%	9/3/1988 7:00	15,849	73%	9/27/1989 7:00	14,668	71%	12/23/1999 6:00	14,581	71%
6/21/1988 7:00	10,351	<57%	9/4/1988 7:00	15,748	73%	9/28/1989 7:00	16,072	74%	12/24/1999 6:00	14,903	71%
6/22/1988 7:00	12,623	58%	9/5/1988 7:00	15,864	73%	9/29/1989 7:00	16,151	74%	12/25/1999 6:00	16,133	74%
6/23/1988 7:00	16,021	74%	9/8/1988 7:00	14,709	71%	10/5/1989 7:00	15,195	72%	12/28/1999 6:00	15,933	73%
6/24/1988 7:00	16,038	74%	9/9/1988 7:00	13,312	67%	10/6/1989 7:00	15,220	72%	10/10/2000 7:00	15,144	72%
6/25/1988 7:00	15,921	73%	9/10/1988 7:00	12,665	59%	10/12/1989 7:00	16,057	74%	10/11/2000 7:00	15,086	72%
6/26/1988 7:00	15,858	73%	9/11/1988 7:00	11,822	<57%	10/13/1989 7:00	16,188	74%	10/19/2000 7:00	13,879	69%
6/27/1988 7:00	15,823	73%	9/12/1988 7:00	10,457	<57%	10/14/1989 7:00	16,175	74%	10/20/2000 7:00	15,300	72%
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6/29/1988 7:00	14,418	70%	9/14/1988 7:00	11,255	<57%	10/16/1989 7:00	15,973	73%	8/31/2003 6:00	16,203	74%
6/30/1988 7:00	13,515	67%	9/15/1988 7:00	11,124	<57%	11/20/1989 6:00	15,330	72%	9/1/2003 6:00	16,423	75%
7/1/1988 7:00	12,587	57%	9/16/1988 7:00	11,183	<57%	11/25/1989 6:00	15,378	72%	9/7/2003 6:00	16,054	74%
7/2/1988 7:00	11,099	<57%	9/17/1988 7:00	10,183	<57%	11/28/1989 6:00	15,717	73%	9/8/2003 6:00	13,648	68%
7/3/1988 7:00	10,310	<57%	9/18/1988 7:00	10,292	<57%	12/4/1989 6:00	13,193	66%	9/9/2003 6:00	13,583	67%
7/4/1988 7:00	10,282	<57%	9/19/1988 7:00	12,665	59%	12/13/1989 6:00	13,075	65%	9/10/2003 6:00	13,591	68%
7/5/1988 7:00	10,434	<57%	9/20/1988 7:00	15,031	72%	12/14/1989 6:00	13,234	66%	9/11/2003 6:00	13,653	68%
7/6/1988 7:00	10,393	<57%	10/12/1988 7:00	15,900	73%	12/15/1989 6:00	13,393	67%	9/12/2003 6:00	15,293	72%
7/7/1988 7:00	7,932	<57%	10/13/1988 7:00	14,231	70%	12/16/1989 6:00	13,435	67%	9/30/2003 6:00	16,082	74%
7/8/1988 7:00	7,164	<57%	10/14/1988 7:00	13,495	67%	12/17/1989 6:00	13,471	67%	10/1/2003 6:00	14,518	71%
7/9/1988 7:00	7,195	<57%	10/15/1988 7:00	13,470	67%	12/18/1989 6:00	13,587	67%	10/4/2003 6:00	15,998	73%
7/10/1988 7:00	8,032	<57%	10/16/1988 7:00	15,008	72%	12/19/1989 6:00	13,652	68%	10/5/2003 6:00	15,967	73%
7/11/1988 7:00	11,275	<57%	10/28/1988 7:00	15,116	72%	12/20/1989 6:00	13,576	67%	1/6/2004 6:00	15,385	72%
7/16/1988 7:00	15,825	73%	12/12/1988 6:00	13,296	66%	12/21/1989 6:00	12,931	63%	1/7/2004 6:00	14,657	71%
7/17/1988 7:00	15,692	73%	12/13/1988 6:00	14,104	70%	12/22/1989 6:00	12,654	59%	1/8/2004 6:00	15,218	72%
7/18/1988 7:00	15,926	73%	12/14/1988 6:00	14,030	70%	12/23/1989 6:00	12,377	<57%	1/9/2004 6:00	15,839	73%
7/19/1988 7:00	15,119	72%	12/15/1988 6:00	14,218	70%	12/25/1989 6:00	12,038	<57%	1/10/2004 6:00	16,163	74%
7/20/1988 7:00	15,134	72%	12/16/1988 6:00	14,009	69%	12/26/1989 6:00	12,073	<57%	1/30/2004 6:00	16,451	75%
7/21/1988 7:00	14,196	70%	12/17/1988 6:00	13,915	69%	12/27/1989 6:00	12,170	<57%	8/1/2006 6:00	12,780	61%
7/22/1988 7:00	14,288	70%	12/18/1988 6:00	13,662	68%	12/28/1989 6:00	12,168	<57%	8/2/2006 6:00	12,650	59%
7/23/1988 7:00	13,532	67%	7/16/1989 7:00	14,953	71%	12/29/1989 6:00	12,724	60%	1/19/2007 6:00	16,388	74%
7/24/1988 7:00	13,540	67%	7/17/1989 7:00	14,104	70%	12/30/1989 6:00	13,029	64%			
7/25/1988 7:00	13,576	67%	7/18/1989 7:00	14,204	70%	12/31/1989 6:00	13,183	66%			
7/26/1988 7:00	13,696	68%	7/19/1989 7:00	14,199	70%	1/1/1990 6:00	13,485	67%			
7/27/1988 7:00	13,441	67%	7/29/1989 7:00	16,421	75%	1/2/1990 6:00	13,713	68%			
7/28/1988 7:00	13,454	67%	7/30/1989 7:00	13,187	66%	1/3/1990 6:00	13,519	67%			
7/29/1988 7:00	12,634	58%	7/31/1989 7:00	11,841	<57%	1/4/1990 6:00	14,771	71%			
7/30/1988 7:00	12,136	<57%	8/1/1989 7:00	11,898	<57%	1/5/1990 6:00	14,773	71%			
7/31/1988 7:00	12,136	<57%	8/2/1989 7:00	13,404	67%	1/8/1990 6:00	16,469	75%			
8/1/1988 7:00	12,136	<57%	8/3/1989 7:00	13,704	68%	1/9/1990 6:00	16,049	74%			
			8/10/1989 7:00	15,176	72%	1/16/1990 6:00	16,128	74%			

*4/15/1995 & 9/6/1987 Not included due to

TABLE C-2. Historical Overview of Dates, Flows, and Approximate Zone of Passage (for days where flows were near or below 16,400 cfs (1986-2011), assumes QCNS is operating at full capacity).

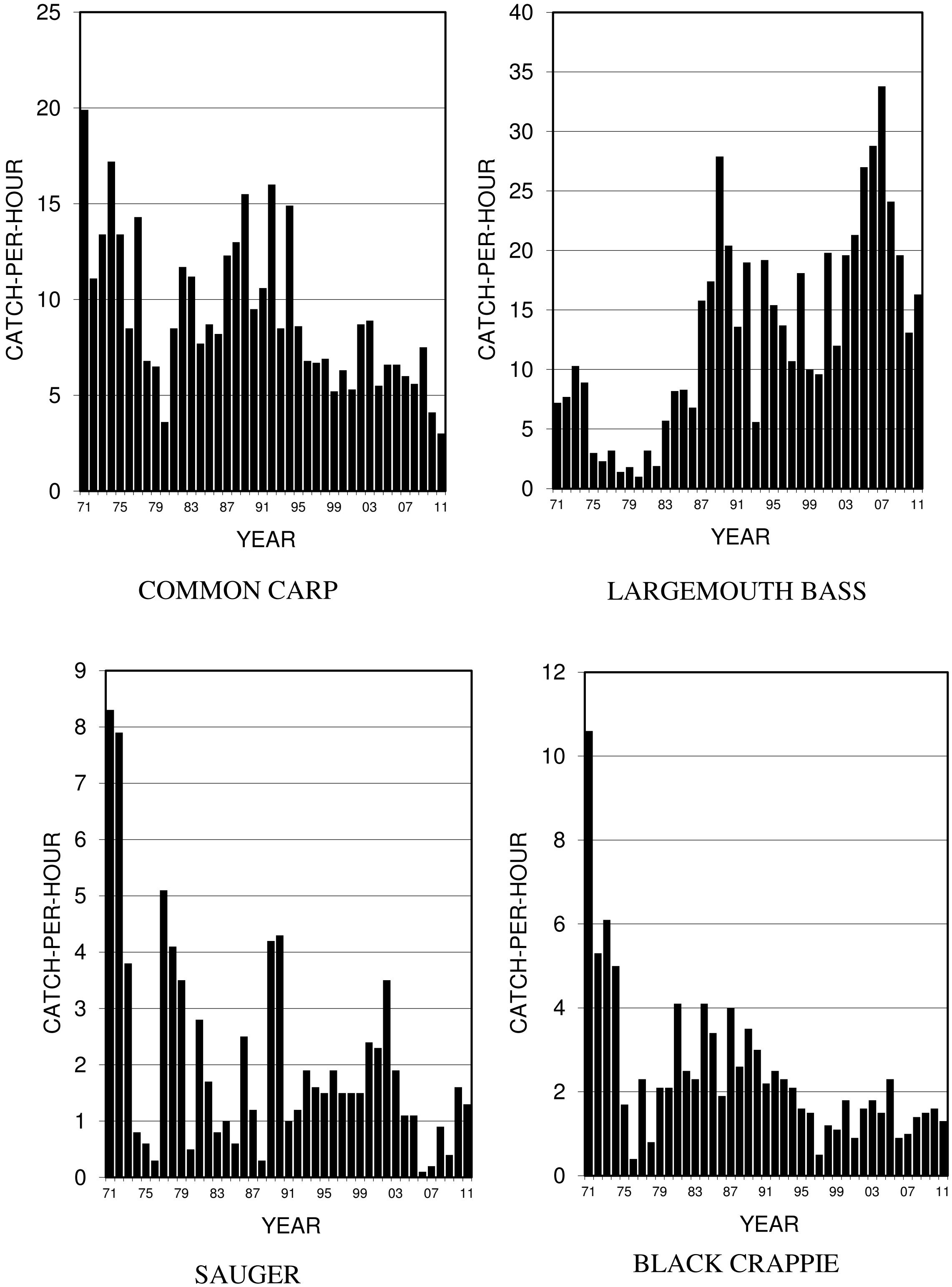
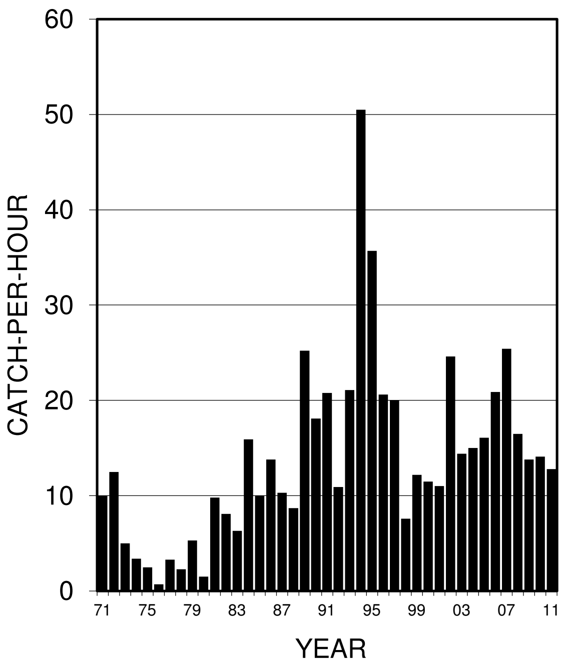
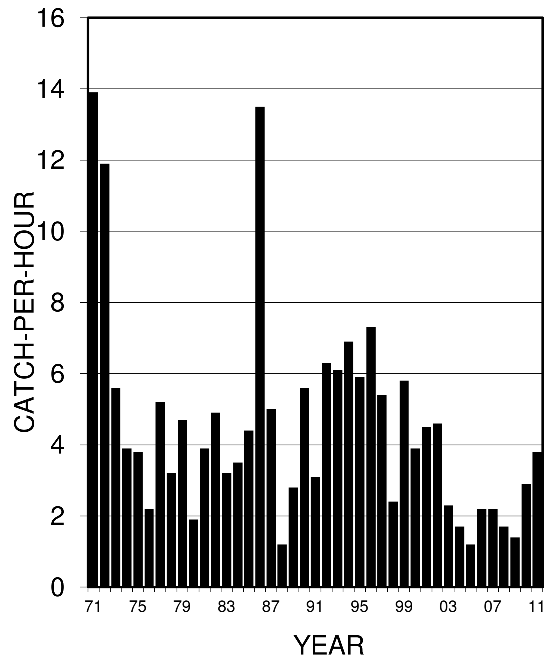


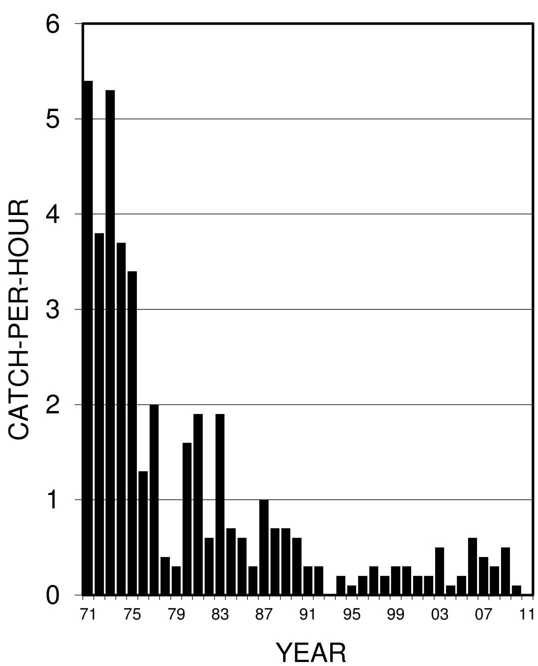
Figure C-1. Catch-per-Effort (All Locations) of Fish Collected by Electrofishing near Quad Cities Station, 1971-2011



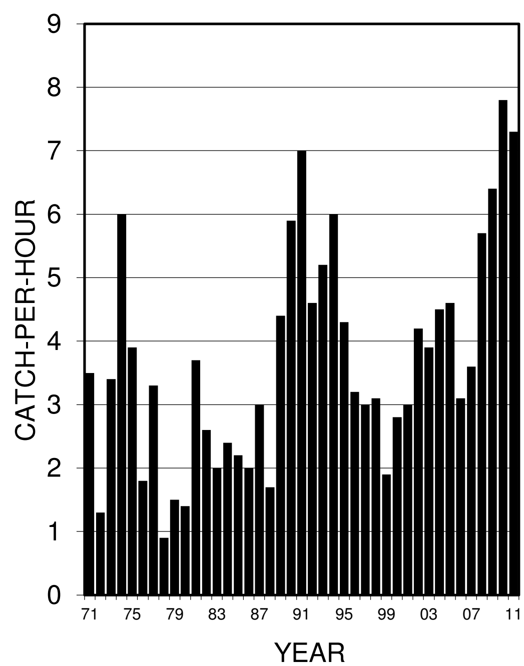
FRESHWATER DRUM



RIVER CARPSUCKER

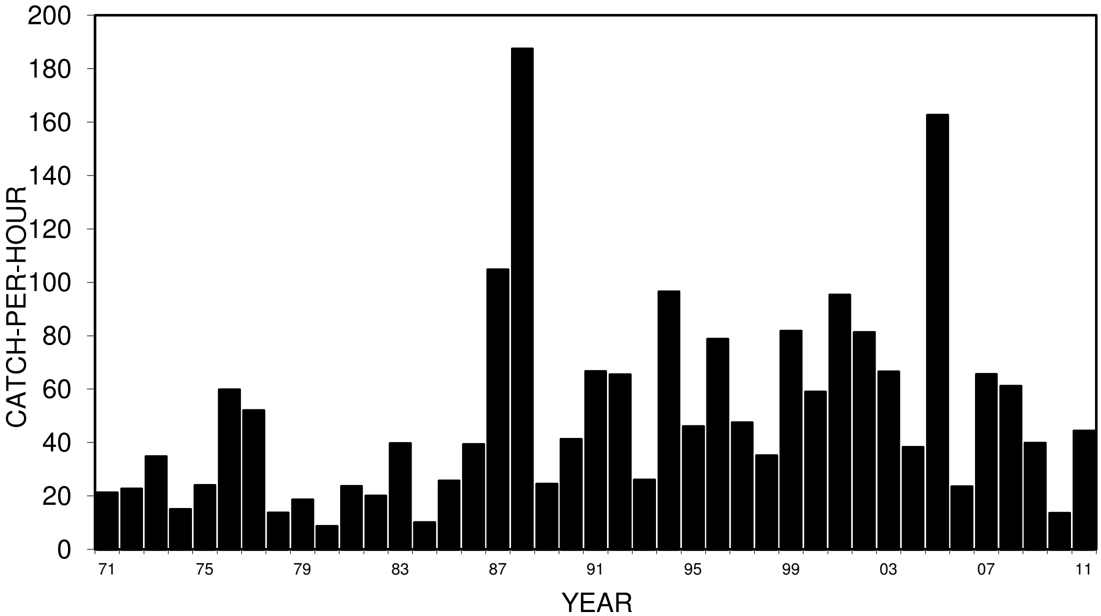


WHITE CRAPPIE

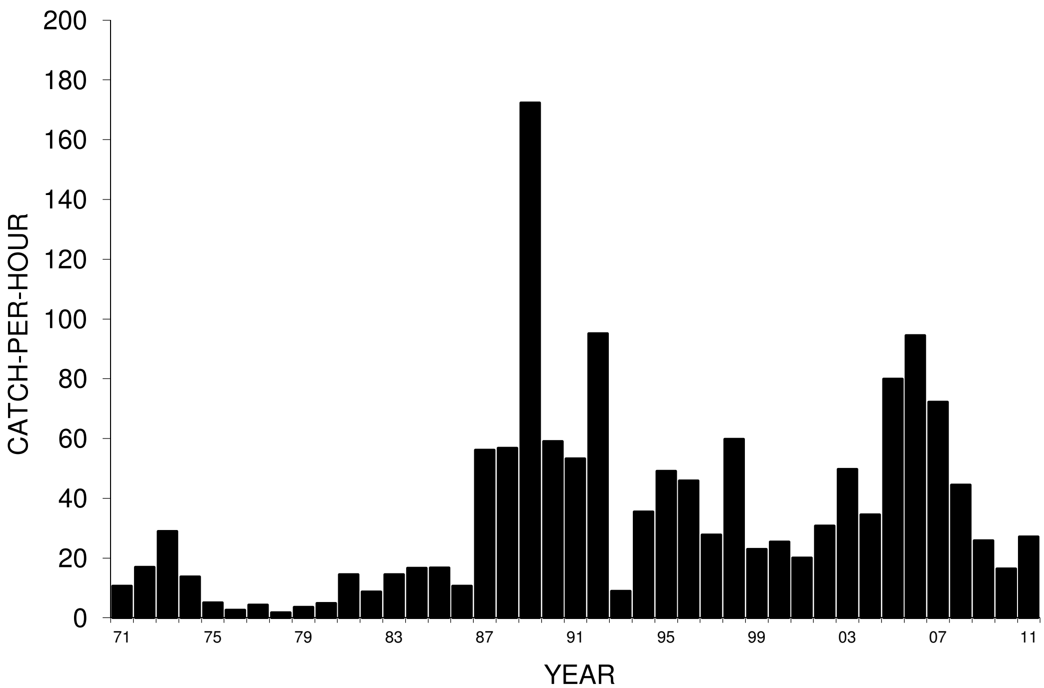


CHANNEL CATFISH

Figure C-1 (continued). Catch-per-Effort (All Locations) of Fish Collected by Electrofishing Near Quad Cities Station, 1971-2011



GIZZARD SHAD



BLUEGILL

Figure C-1 (continued). Catch-per-Effort (All Locations) of Fish Collected by Electrofishing Near Quad Cities Station, 1971-2011

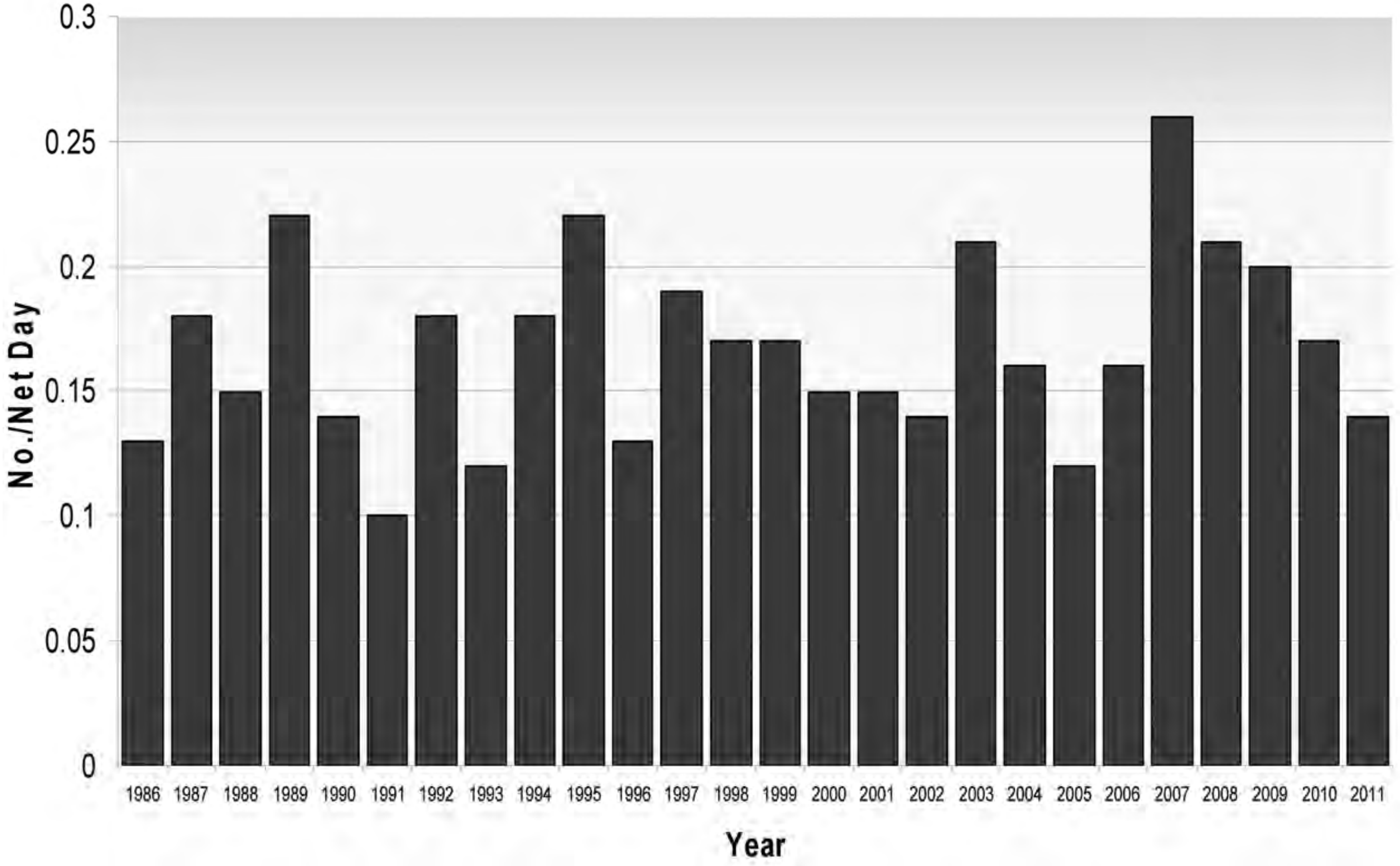


Figure C-2. Flathead Catfish CPE Collected by Hoop Net Near Quad Cities Station, 1986-2011

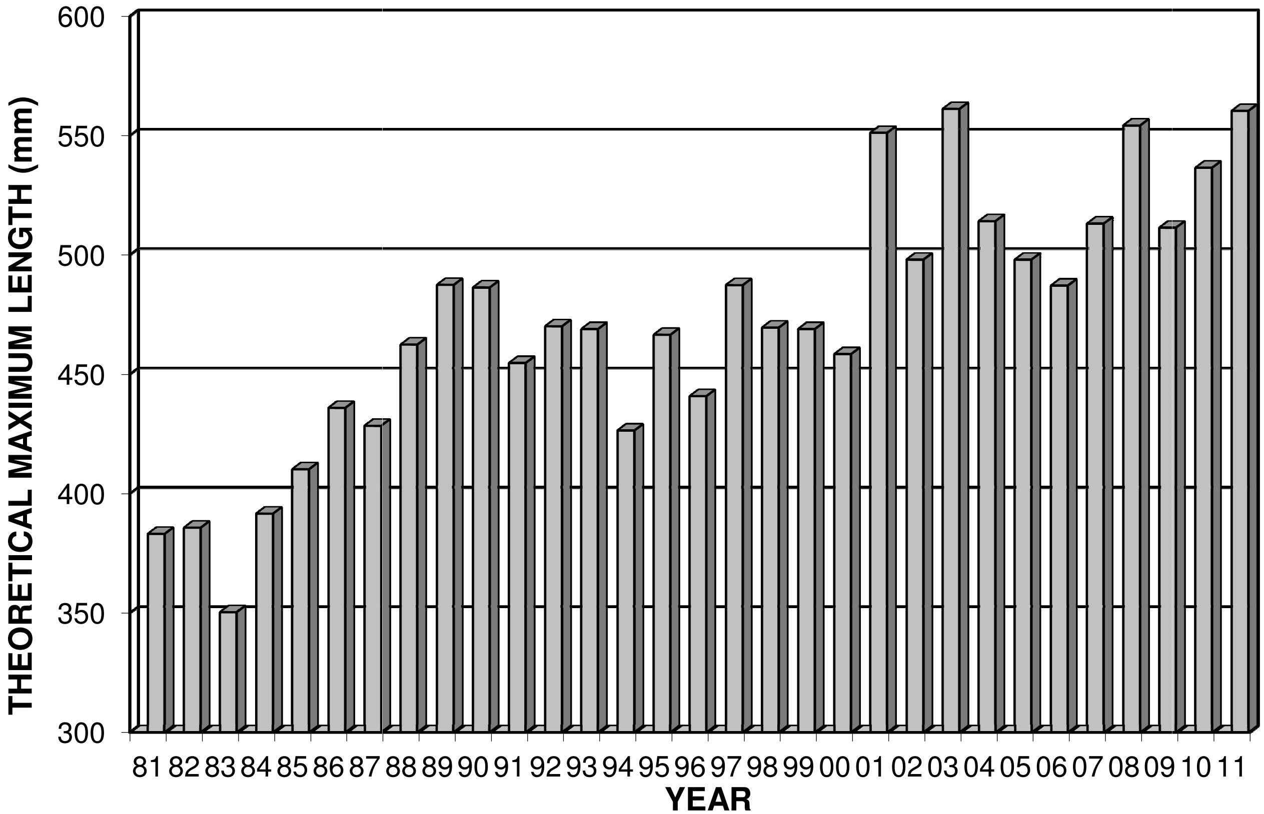


Figure C-3. Theoretical Maximum Length (mm) for Freshwater Drum from Pool 14 of the Mississippi River, 1980-2011

APPENDIX D

Quad Cities Nuclear Station Operations

TABLE OF CONTENTS

1. LOCATION

Exelon Generating Company's Quad Cities Nuclear Station (QCNS) is located in Rock Island County, Illinois on the east bank of the Mississippi River, approximately 3 miles north of Cordova, Illinois, 20 miles northeast of the Quad Cities Metropolitan Area of Davenport, Iowa, Rock Island, Moline, and East Moline, Illinois and 7 miles southwest of Clinton, Iowa. The Station is located on Pool 14 of the Mississippi River, at approximate River Mile 506.5 above the confluence of the Ohio River (Figures D-1 and D-2).

2. FACILITY OVERVIEW

QCNS is a dual unit nuclear-fueled steam electric generating facility. The QCNS site consists of approximately 920 acres. In addition to the two nuclear reactors and the associated reactor and turbine buildings, the site includes intake and discharge canals, ancillary buildings, switchyards, a training facility, fish hatchery and a retired spray canal now used to raise game fish for release into the Mississippi and other local rivers. QCNS began low power testing in 1972 and began commercial operation in 1973. The original forty year operating license allowed for operation of the station until 2012. In 2003, QCNS applied for a twenty-year extension to the original operating license. QCNS was granted a twenty-year license extension in 2004. The station's operating license now expires in 2032.

3. ELECTRICAL GENERATING SYSTEM

Both QCNS Unit-1 and Unit-2 nuclear reactors are boiling water reactors (BWR) that utilize forced circulation boiling water, which produces steam that turns turbines to generate electricity. QCNS's original operating license limited each reactor to a core thermal output of 2,511 megawatts thermal (MWt). In December 2000, Exelon submitted an application to the NRC for a change in the operating license for an increase of the rated core thermal power for each QCNS reactor of 17.8 percent, an extended power uprate (EPU) level from 2,511 to 2,957 MWt. In December 2001, the NRC granted Exelon a license amendment allowing an increase in power level to 2,957 MWt for both units. The EPU for both units was completed in 2002. The station's maximum combined thermal output is currently licensed at 5,914 MWt and will not increase as a result of the requested ATS. Heat rejection is a function of the MWt produced by the reactors. Exelon understands that any increase of QCNS output capacity above 2957 MWt per reactor will require a NPDES permit modification. Additionally, any increase of QCNS output capacity above 2957 MWt per reactor would also require an NRC operating license change. QCNS electrical generating capacity is described in terms of megawatts electric (MWe). Issuance of the requested ATS will not result in an increase to plant generating capacity. If Exelon realizes future increases in plant efficiency (i.e. station produces more MWe from the reactor maximum 2957 MWt capacity), then a permit modification will not be necessary, assuming the heat rejection does not increase. It should also be noted that water withdrawals from and discharges of cooling water to the Mississippi River will not increase as a consequence of the new ATS.

4. INTAKE SYSTEM

4.1 COMPONENTS AND OPERATING CONFIGURATIONS

The Cooling Water Intake Structure (CWIS) is located on the western side of the plant site. Condenser cooling water is withdrawn from the Mississippi River through a canal that is perpendicular to the river flow (Figure D-3). The canal is 235 feet long, 180 feet wide, and 12 feet deep where it meets the river. Intake velocity at the mouth of the canal is approximately one foot per second. A floating boom, extending to a depth of 33 inches, traverses the mouth of the canal to deflect floating material. At the other end of the canal is a trash rack consisting of a series of vertical metal bars spaced 2.5 inches apart that screens large pieces of debris from the intake. The CWIS is divided into six individual bays (three per unit). The individual bays are approximately 26 feet wide and each bay has two 10-foot wide sets of traveling screens fitted with 3/8-inch mesh to protect the circulating water pumps. Fish and other materials impinged on the traveling screens are washed off and collected in a trash basket. Each intake bay has one circulating water pump rated at 157,000 gallons per minute (gpm) and five of the six intake bays have one service water pump each rated at 13,800 gpm. The CWIS design also includes an ice melt line that provides a means to route a portion of heated discharge water back to the intake canal to prevent ice accumulation at the intake structure from impeding flow to system components.

The station’s maximum design cooling water flow is 2,253 cubic-feet-sec (cfs) or 1,011,000 gpm. The volume of water required varies with station power output and ambient river temperature. During the summer months, both units operate with all three circulating water pumps in operation and an average of three service water pumps, for an average summer cooling water flow of 2,191 cfs or 983,400 gpm. During the winter months, both units operate with two circulating water pumps in operation, an average of two service water pumps, and the ice melt line open for an average winter cooling water flow of 1,200 cfs or 538,570 gpm.

QCNS main condensers and piping configuration enable the station to reverse flow through each unit’s main condensers. Reversing flow is done to reduce the buildup of macro fouling (eel grass, leaves, etc.) on the condenser tube sheet. Another benefit to reversing condenser flow is that by reversing flow alternates hot ends of the condenser, which prevents mussels / marine growth from growing in the condenser and piping from the condenser.

4.2 BIOCIDE APPLICATION

4.2.1 Circulating Water System

The QCNS National Pollution Discharge Elimination System (NPDES) permit allows for biocide treatment of each unit's circulating water system (condenser cooling) a maximum 120 minutes per day with sodium bromide and/or sodium hypochlorite with a maximum instantaneous total residual chlorine/total residual oxidant (TRC/TRO) concentration of 0.05 ppm discharged to the river. Sodium hypochlorite is normally used as the sole biocide for treatment of the circulating water system. Circulating water treatment regime varies with the seasons. During winter months when river water temperatures are cooler, circulating water chlorination is 3 days per week for 60 minutes per day (one injection per day at approximately 3 gpm). As the river water warms with the onset of summer (June through September), chlorination is gradually increased to 7 days per week and 90 minutes per day (one injection per day for 90 minutes at approximately 5.5 gpm). The chlorination schedule is then gradually reduced during the fall until chlorination returns to 3 days per week and 60 minutes per day. Sodium bisulfite is used as a neutralizing agent prior to discharge to the river to ensure compliance with the TRC/TRO limit of 0.05 ppm.

Circulating water is also treated with a scale inhibitor (60% 1-Hydroxy Ethylidene-1,1-Diphosphonic Acid) continuously 365 days per year. Condenser water inlet is sampled weekly to determine scaling potential. The scale inhibitor injection rate is adjusted accordingly to prevent scaling. The minimum scale inhibitor injection rate is 15 ml per minute and the maximum is 150 ml per minute.

4.2.2 Service Water System

The QCNS service water system is treated with biocide, silt dispersant, and corrosion inhibitor. Injection rates vary with the seasons and water quality. Sodium hypochlorite is used as the sole biocide. Biocide is injected 24 hours per day and seven days a week when river temperatures are above 50^{o}F. Biocide injection rates vary from as low as 500 ml per minute during early spring and late fall to 1500 ml per minute during mid summer. A combination HEDP and poly acrylic acid is used for silt dispersant/scale inhibitor. Silt dispersant is injected 24 hours per day and seven days a week year around. Injection rates very from 20 ml per minute to as high as 200 ml per minute during periods of high river levels. Sodium hexa-meta phosphate (SHMP) is used for corrosion inhibition of carbon steel components. Corrosion inhibitor is injected 24 hours per day and seven days a week year around. Injection rates very from 50 ml per minute to as much as 200 ml per minute during periods of high river temperatures when biocide injection rates are maximized.

5. DISCHARGE SYSTEM

5.1 PHYSICAL DESCRIPTION

The circulating water effluent from both unit's main condensers and station service water system combine in the discharge bay, which is immediately south of the intake canal. The intake canal and the discharge bay are separated by a concrete retaining wall. The discharge bay is approximately 700 feet long by 150 feet wide. The combined effluent from the discharge bay is then distributed across the Mississippi River through a diffuser pipe system. The diffuser pipe system consists of two 16-foot diameter pipes buried in the river bed; the north pipe extends approximately 2,100 feet across the river, while the south pipe terminates about 390 feet before the end of the north pipe. Each diffuser pipe is fitted with 20 discharge risers of 36-inch diameter spaced at 19 feet 8 inches in the deep portion of the river, and 14 discharge risers (9 of which presently are closed) of 24-inch diameter spaced at 78 feet 8 inches in the shallow zone of the river. The diffuser pipe system was designed to achieve complete mixing of the condenser water with the river flow within a short distance downstream of the diffuser pipe.

5.2 THERMAL PLUME

As stated above, heated condenser cooling water is discharged into the Mississippi River by means of a diffuser pipe system which was designed to distribute the condenser cooling water across the river approximately in proportion to the transverse distribution of the ambient river discharge to achieve complete mixing within a short distance downstream of the diffuser pipes.

No heated water is discharged to the shallow portions of the river because the lower velocity of the shallow portion of the river does not provide effective dilution. Blind flanges close off the first nine 24-inch risers from the Illinois side of the river. The operational diffusers begin approximately 840 feet from the Illinois shore and proportionately distribute the discharge 1,200 feet across the deeper portion of the river.

Several temperature surveys (Iowa Institute of Hydraulic Research, Jain et al., 1971; Jain and Kennedy, 1990) have been conducted to determine the distribution of the temperature rise in the 500 feet downstream from the diffuser pipes. The surface area of the reach of the river between the diffuser pipes and the 500 feet downstream cross-section is 24.9 acres, slightly less than the 26 acres allowed by the State of Illinois as a mixing zone.

The diffuser-pipe system for QCNS has been investigated extensively, both through laboratory testing and collection and analysis of field data for a wide range of river discharges, with the plant operating at full load and at various partial loads.. At a river discharge of 13,800 cfs, the 7Q10 for Pool 14, the surface area with a temperature rise greater than 5°F is less than two acres when the plant is operating at rated capacity and is fully cooled through the diffuser-pipe system.

5.3 ALLOWANCE FOR EXCURSION HOURS

5.3.1 NPDES Permit Site Specific Standards

Regulatory allowance for exceeding the monthly temperature limits at the end of the mixing zone (commonly referred to as excursion hours) is incorporated into Special Condition 6 of the Station's most recently issued NPDES permit.

SPECIAL CONDITION 6. Discharge of wastewater must not alone or in combination with other sources cause the receiving stream to violate the following thermal limitations at the edge of the mixing zone:

A. Maximum temperature rise above the natural temperature must **not** exceed 5°F.

B. Water temperature at representative locations in the main river shall **not** exceed the maximum limits in the following table during more than (1) percent of the hours (87.6 hrs) in the 12-month period ending with any month. Moreover, at **no** time shall the water temperature at such locations exceed the maximum limits in the following table by more than 3°F. (Main river temperatures are temperatures of those portions of the river essentially similar to and following the same thermal regime as the temperatures of the main flow of the river.)

Month	**Temperature Limitation**
January	45°F
February	45°F
March	57°F
April	68°F
May	78°F
June	85°F
July	86°F
August	86°F
September	85°F
October	75°F

November	65°F
December	52°F

C. The area of diffusion of an effluent in the receiving water is a mixing zone, and that mixing zone shall **not** extend:

i) over more than 25 percent of the cross sectional area or volume of flow in the Mississippi River.

ii) more than 26 acres of the Mississippi River

The following data shall be collected and recorded:

1. Weekly determination of the river flow rate (daily when the river flows fall below 23,000 cfs).
2. Daily determination of the river ambient river temperature (at or upstream of station intakes).
3. Daily recording of station discharge rate.
4. Daily continuous recording of the temperature of the station discharge.
5. Daily determination of station load.
6. As deemed necessary according to the above data, daily determination of the cross-sectional average temperature at the 500 foot downstream cross-section in the river.

Compliance with the thermal limitations shall be demonstrated as follows:

1. When river flow is 21,000 cfs or greater and ambient river temperature is 5° F or more lower than the monthly limiting temperatures**,** the temperature monitoring curve[1] establishes that the permittee is in compliance for all power generation levels;
2. When river flow is less than 21,000 cfs and/or the ambient river temperature is within 5° F of the monthly limiting temperatures, the permittee shall demonstrate compliance using either:

   a. Plant load, river flow, ambient river temperature, and the temperature monitoring curve.

b. Field measurement[2] of the river cross-sectional average temperature taken 500 feet downstream of the diffusers.

In the event that compliance monitoring shows that the permittee has exceeded the monthly limiting temperature, the number of hours of such exceedance shall be reported on the permittee's Discharge Monitoring Report.

The following footnotes appear as part of Special Condition 6.

[1]The temperature monitoring curve identified as Figure 2 in December 2000 "Revised Temperature Monitoring Curve for Quad Cities Nuclear Generating Station" (Jain, 2000).

[2]When conditions such as ice formation render the Mississippi River inaccessible to marine activity, the Permittee may demonstrate compliance with thermal limitations of Special Condition 6 by using the most recent field measurement data collected at a river flow equal to or less than the flow for which field measurement data cannot be collected. The most recent field measurement data shall be normalized to the power production level for the day when the river was inaccessible (Illinois Environmental Protection Agency NPDES permit # IL0005037).

6. QUAD CITIES HISTORIC OPERATING DATA

6.1 STATION POWER OUTPUT

The station's maximum combined thermal output is currently licensed at 5,914 MWt. It should be noted that the retrospective studies supporting this 316(a) Demonstration are based on thermal discharge levels that QCNS produced in the 2002 through 2009 timeframe. Since then, the facility replaced turbines on both units (in 2010 and 2011) with more efficient systems. These new systems increased the heat-to-electrical conversion efficiency for the facility, and thereby reduced the thermal discharge from the facility to the Mississippi River by approximately 2.6% or 0.7ºF from the 2002 through 2009 levels. Consequently, this 316(a) demonstration provides support for plant operating levels up to 2.6% above current levels.

Both QCNS reactors are on 24 month refuel cycles. Once every 24 months, each unit is shutdown to refuel the reactor and perform extensive maintenance activities. Each refueling shutdown averages 20-30 days. The QCNS refuel outages are alternated such that every year, one of the units is shutdown for refueling. Other than refueling shutdowns, both reactors are operated at full power except for occasional down-powers for surveillance testing or short duration shutdowns to resolve equipment issues.

In 2006, power output of both units was limited to between 50 and 100% for three days due to extreme low river flows combined with high ambient river temperatures. Power output reduction was required to maintain the stations discharge within thermal limits established by IEPA Provisional Variances Order 07-01 and 07-03.

6.2 COOLING WATER SYSTEMS OPERATIONS

The station began operation in January 1972, when low power testing was initiated. Following low power testing in early April 1972, startup testing began and was continued until August 1972. From January until August 1972, cooling water was withdrawn from the Mississippi River, circulated through the condenser cooling system and discharged through a shoreline-jet discharge canal (the current discharge bay was open to the river, west of the lift station).

As the result of litigation filed against Commonwealth Edison (Exelon) regarding the station's thermal discharge, an agreement requiring closed-cycle cooling by May 1, 1975 was signed in 1972 by Commonwealth Edison Company, the Attorney General of the State of Illinois, the Izaak Walton League of America, and the United Automobile Workers of America.

A diffuser system was installed in the Mississippi River in 1972 as an interim mode of discharge until the spray canal (closed-cycle cooling) was completed. This diffuser system consists of two 16-foot diameter multi-riser manifolds that are buried in the riverbed. Open cycle, two-pipe diffuser operation began in August 1972, at which time the use of the side-jet discharge was permanently discontinued. The diffuser mode of operation continued until May 1, 1974.

In accordance with the agreement, operation of the spray canal commenced on May 1, 1974, with the station operating with the equivalent of one unit discharging cooling water to the canal and one unit discharging directly to the river. This mode of operation continued until May 1, 1975, when cooling water from both units was routed to the canal (closed-cycle). Electrical energy to operate the spray canal (328 spray pumps and 5 lift pumps) required approximately 29 megawatts electricity (MWe). Similarly, the warm water returning from the spray canal reduced turbine efficiency and resulted in significant loss of production of electricity during summer months. Due to these combined losses of electricity available to the grid during operation of the spray canal during the summer months, Commonwealth Edison sought relief from operating in the closed-cycle mode from the various stakeholders.

Closed-cycle operation continued until August 2, 1979 when the station received a new NPDES permit that allowed partial open-cycle operation of the condenser cooling system at times when the temperature of the water returning from the spray canal to the intake exceeded 93°F. Operation of the station in the partial open-cycle mode was also subject to an interim modification effective August 27, 1979 by the parties listed above to the closed-cycle agreement which allowed the station to operate in partial open-cycle mode to avoid substantial capacity losses.

Operation in the partial open-cycle mode continued until December 23, 1983 when the station commenced the current full open cycle mode of operation via the diffuser pipes. The open-cycle agreement was signed on October 11, 1983 between the above-mentioned parties and approval from the IEPA for open-cycle mode of operation was received on December 23, 1983.

6.3 INTAKE TEMPERATURE

Ambient intake river temperatures range from 32°F during winter months up to 88°F degrees during July and August. Average high temperatures for July and August are in the upper 70's to low 80's. During 1990 to 2000, maximum ambient river temperatures at the Quad Cities Station intake exceeded 86°F on five occasions (July 14, 15, 16, 1995, when Mississippi River flow was 45,000 cfs and July 30, 31, 1999, when Mississippi River flow was 94,000 cfs). In 2001, daily maximum ambient temperatures in the Mississippi River at the Quad Cities Station intake gradually increased from 76.9°F on July 3rd to a high of 87.8°F on August 8th. For eight days, maximum ambient river temperatures at the Quad Cities Station intake exceeded 86°F. During that time, the station used 57.5 hours of the 87.6 excursion hours allowed. As in prior years, use of the excursion hours during 2001 was related to the ambient upstream river temperatures approaching and exceeding 86°F. In 2001, river flows ranged from 37,000 cfs to 124,000 cfs which was higher than normal, thereby reducing the number of excursion hours used. In 2005, a total of 42.5 of the allotted 87.6 excursion hours were used during July as daily maximum ambient river temperatures ranged from 85°F to 86°F for a seven day period and flows ranged from 40,000 cfs to 28,000 cfs.

During July and August 2006, extreme drought conditions existed and ambient temperatures in the Mississippi River exceeded Exelon's discharge limit of 86°F reaching 88°F. Between July 16 and August 6, the Station used 223 excursion hours (117 excursion hours in July and 106 excursion hours in August), authorized by emergency provisional variances issued by Illinois EPA. The ambient river temperature entering the intake exceeded 86°F on July 31 and remained above 86°F until August 3. River flows during July and August 2006 ranged from 28,000 cfs down to 12,600 cfs.

6.4 DIFFERENTIAL TEMPERATURE

With both units operating at full power, station discharge temperature differential from ambient inlet river temperature ranges from 28°F during summer months when each unit operates with three circulating water pumps to 48°F during winter months when each unit is has two circulating water pumps operating and the ice melt line open.

6.5 TRANSIT TIME

With both units operating at full power and all six circulating water pumps operating, time of passage from the intake structure to the entrance of the diffuser pipes is approximately 150 seconds. Total time of passage from intake structure to the furthest diffuser port is approximately 700 seconds. The circulating water temperature rise profile versus time of passage from intake to when the cooling water approaches ambient river temperature varies from approximately 325 seconds for the diffuser port closest to the Illinois shore to 750 seconds for the diffuser port closest to the Iowa shore (Commonwealth Edison 1975, 1981).

7. REFERENCES

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8. FIGURES

Figure D-1. Vicinity Map of Quad Cities Nuclear Station (LMS, 2005)

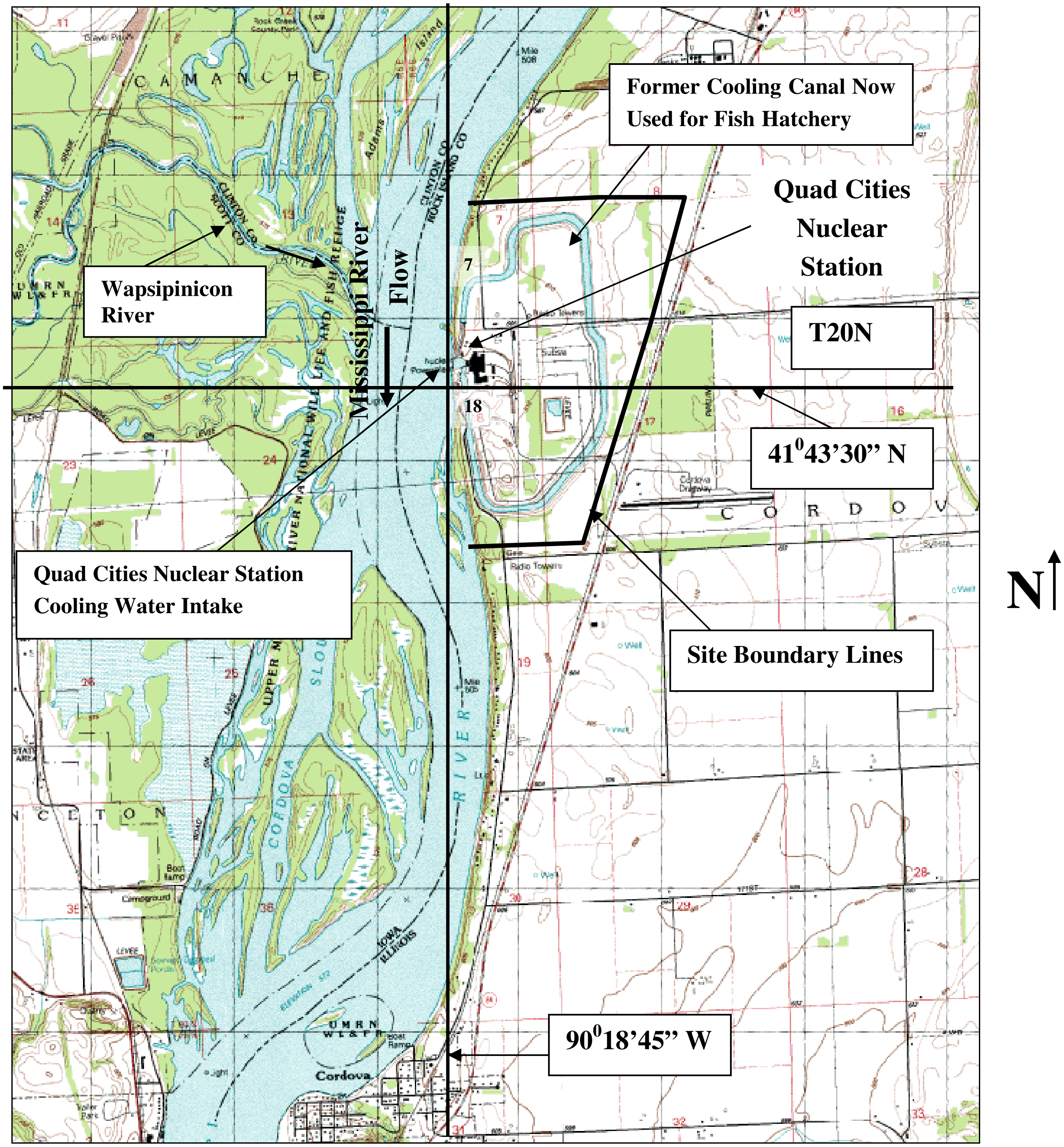

Figure D-2. Topographic Map of Quad Cities Nuclear Station located on Pool 14 of the Mississippi River at River Mile 506.5 (LMS, 2005)

Figure D-3. Aerial View of Quad Cities Nuclear Station located on Pool 14 of the Mississippi Rive at River Mile 506.5 (LMS, 2005)

APPENDIX E

Data Collection Programs

TABLE OF CONTENTS

1. INTRODUCTION

1.1 Technical Advisory Committee

The Quad Cities Steering Committee was established to review, monitor and make recommendations on the Long-Term Monitoring Program, which consists mainly of the river sampling programs discussed herein, both past and present. The Steering Committee consists of entities that were involved in the original operational agreement, the local, state and federal resource agencies, and technical consultants who conduct and oversee the sampling activities. The group meets annually to review data collected during the previous year and to discuss any changes to the scope of work for the upcoming year.

1.2 Data Collection Programs

Studies to identify and quantify potential impacts of Station operation on the biota of Navigation Pool 14 were initiated in 1971. To date, the program includes one year of pre-operational and 40 years of operational investigations. The earliest studies considered a wide scope of potential biological effects. Many of the initial concerns have been resolved and recent efforts have focused on the well being of fish populations in Pool 14. Recent studies (1978-2008) were developed in cooperation with the Iowa and Illinois Departments of Natural Resources and the Illinois Environmental Protection Agency. The emphasis on fish reflects the continued belief that if any long-term impacts should occur, this component of the biota is most likely to exhibit detectable changes. Further, the emphasis recognizes the importance of the local commercial fishery.

Following an extensive review of data developed during the operational history of Quad Cities Nuclear Station (QCNS), parties to the original closed-cycle agreements of 1972 and 1979 completed a new agreement on 11 October 1983. This agreement allowed open-cycle operation of the Station contingent upon continued biological monitoring of the biota in Pool 14. Subsequent to the new agreement, the NPDES permit issued for Quad Cities Nuclear Station on 22 December 1983 allows for open-cycle operation.

The monitoring program currently performed represents a continuation of studies designed to evaluate potential effects of open-cycle operation on the fish community of Pool 14. The present program includes the accumulation of a long-term database on species abundance as well as studies to quantify important aspects of the population dynamics of selected species that may be potentially affected by Station operation. Four separate studies are conducted, representing a continuing multi-year effort: Channel and Flathead Catfish Studies, Long-Term Fisheries Monitoring, Freshwater Drum Life History and Population Dynamics, and Impingement Monitoring. A fall stock assessment study was added to the existing program to evaluate the effects of annual hybrid striped bass and walleye stocking efforts that were initiated in 1984. Hydrological data for Pool 14 are included, because this information has direct bearing on interpretation of reported results.

2. NUTRIENTS

Nitrogen and phosphorus are essential nutrients, which in excess can be detrimental to aquatic health (U.S. Geological Survey, 2003). Nitrogen and phosphorus are abundant in the drainage basin because of the widespread use of commercial and animal-manure fertilizers. In fact, the quantity of nitrogen and phosphorous lost from the land to the stream (“yields”) in the Upper Mississippi River Basin (UMRB) is higher than in any other portion of the Mississippi River Basin. Specifically, elevated nutrients accelerate photosynthesis, which produces nuisance growth or "blooms" of algal or other plant biomass that can be detrimental in several ways. First, they are unsightly, degrading the aesthetics and can impede recreational uses. Second, excessive plant growth can damage habitats for other biota and impair the general ecological health of the aquatic ecosystem. Lastly, is the effect that excessive growth of algae and other plants has on the concentrations of dissolved oxygen in the water column. When these plants die, their decomposition consumes oxygen rapidly that results in low concentrations of dissolved oxygen (hypoxia). Low dissolved oxygen concentrations can and are highly stressful or even fatal to fish and other biota in the river.

Upper Mississippi River (UMR) water quality data were compiled from federal, state and local agencies that conducted monitoring on the river over a twenty year period from 1980 to 1999 (Sullivan et al., 2002). Three sites from pool 14 are included in these data. The major objectives of this effort were to increase coordination and cooperation among monitoring agencies, develop a unified database of relevant water quality information, and to use these data to produce a systemic assessment of the water quality of the UMR. This effort was particularly important for the Mississippi River, which forms the boundary with five states and is monitored and managed by many federal, state, and local resource agencies. The river reach for this evaluation extends from Anoka, Minnesota (just upstream of the Twin Cities) to the Ohio River, a distance of 872 river miles (RM). Two databases were compiled. The first database includes field and laboratory inorganic chemistry data from samples collected near or in the main channel of the river. The primary focus of the assessment was on water quality data collected during the summer

(June 1 to September 15), which resulted in the creation of a summer data subset of the entire compiled database (universe). The second database includes fish contaminant data on polychlorinated biphenyls (PCBs), chlordane, and mercury collected throughout the UMR. These later data were primarily obtained by agencies responsible for providing fish consumption advice for sport anglers fishing the Mississippi River.

3. THERMAL STUDIES

Numerous thermal studies have been conducted at the Quad Cities Nuclear Station since the facility began operation in 1972. The most relevant include:

- A Study to Evaluate The Effects of The Quad Cities Nuclear Generating Station On Navigation Pool No. 14 Of The Mississippi River, October 1982.
- Hydrothermal Model Study of Diffuser Pipe System at Quad Cities Nuclear Generating Station, July 1990.
- Evaluation of the Quad Cities Nuclear Generating Station Diffuser Pipe System at Low River Flows, July 1990.
- Hydrothermal modeling – IIHR Hydroscience & Engineering simulated the thermal plume using a three-dimensional (3-D) Computational Fluid Dynamics (CFD) model. The IIHR modeling effort included the following major components (as detailed in the IIHR Report), 2004

    - Inclusion of relevant river-training structures, namely wing dams and the cross-channel closure dam in the Steamboat Slough, in the model bathymetry to better reflect real-world conditions. The resultant model grid contained nearly 2 million points.
    - Simulation of conditions corresponding to the LMS September 2003 thermal survey field effort, which validated the model's ability to predict the observed thermal conditions.
    - Simulation of station operations at maximum power for a series of relatively low Mississippi River flows.
    - Provision of temperature, depth, and velocity results from the multiple simulations to LMS to serve as input for the biothermal model.

- Supplementary Thermal Analysis was conducted to relate measured sediment temperatures to the hydrothermal modeling, July 2007.

The first study listed above was a base study used to evaluate the open-cycle change and the second and third studies address the thermal issues that were experienced during the drought years of the late 1980's. The last two were expansions of the low flow analysis conducted in 1990 modeling and were used in biological evaluations.

3.1 Evaluation of Operation of Diffuser Pipes in Navigation Pool No. 14 of the Mississippi River

An investigation was undertaken to develop strategies and associated diffuser pipe modifications to enable Quad Cities Nuclear Station to operate at full load during periods of low flow. The investigation was conducted in three major phases: development of an optimum configuration of the diffuser pipe systems by analyzing the QCNS thermal-plume data; evaluation of the cooling potential of the cooling canal; and trend analysis of the river-water discharge and temperature data.

3.2 Hydrothermal Model Study of Diffuser Pipe System at Quad Cities Nuclear Generating Station

This investigation was concerned with optimizing the sizes of the orifice plates for the risers of the diffuser pipe system at QCNS to achieve uniform mixing of the condenser water discharge with the Mississippi River flow. An undistorted model at a scale of 1:50 was used to investigate the temperature distribution in the 500-ft downstream section of the river. A series of tests with different orifice plate sizes were conducted to determine the optimum sizes of the orifice plates. Model tests with the optimum diffuser were carried out to develop the new temperature monitoring curves for two to six circulating pumps. A simple procedure for monitoring the thermal plume in the field was developed.

4. PHYTOPLANKTON COMMUNITY

Phytoplankton studies were conducted in conjunction with and at the same locations as zooplankton studies from August 1972 through August 1973 (Figure E-1). During this period, both reactor units were in the open cycle operation mode with the two diffuser pipes employed to diffuse waste heat into the river (ComEd, 1975).

Composite phytoplankton samples were collected, preserved, and transported, and transported to a laboratory where abundance, biomass, chlorophyll *a,* and carbon fixation rates were determined. Analysis of variance was preformed to identify differences in phytoplankton productivity between the intake location and the discharge location and between river locations above and below the diffuser pipe discharge system.

5. ZOOPLANKTON COMMUNITY

Zooplankton entrainment studies were conducted at Quad Cities Nuclear Station from mid-September 1972 through early August 1973, a period of which full thermal, mechanical and chemical stresses of entrainment could be assessed, since both reactor units were in operation in the open cycle mode with the two diffuser pipes employed to diffuse waste heat into the river (ComEd, 1975).

Samples were collected with a filter-pump system near the surface from the Station intake and from the discharge bay where condenser water entered the diffuser pipes. River locations were sampled about 1,600 feet upstream of and at approximately 375, 4,000, and 8,000 feet downstream of the diffuser pipes (ComEd, 1975). Motile and non-motile zooplankters were examined under a microscope within 20 minutes and at four-hour intervals after sample collections. Zooplankton observed during the first (20 minute) period were initially recorded as motile or non-motile rather than living or dead to allow for possible recovery from temporary shock resulting from condenser passage. However, since there was no clear indication of delayed mortality or recovery from the immediate effects of condenser passage throughout the study, those organisms observed to be non-motile 20 minutes after collection were reported as dead. The percentage of dead zooplankton due to condenser passage was calculated by subtracting the percent intake of upstream mortalities from the percentage of downstream mortalities.

6. BENTHIC INVERTEBRATES

Drifting benthic invertebrates were sampled monthly from late March to early July 1972, primarily at the edge of the channel offshore of the Station.

6.1 Local Mussel Surveys

In 2004, Exelon established a monitoring program using quantitative and qualitative techniques for freshwater unionids near the QCNS thermal discharge diffuser. All of these mussel sampling programs were conducted via scuba and conducted by Ecological Specialists, Inc. The most recent surveys were conducted in 2008. The purpose of the monitoring program is to provide data and information regarding the unionid community, to evaluate the effects QCNS discharge has had on the community, and to establish the baseline unionid community characteristics for comparison with community characteristics observed following the issuance of alternate thermal standards.

Quantitative samples are used to estimate density, relative abundance, age structure and mortality, which then provide spatial and temporal comparisons of unionid communities for management and impact analysis. A standard quantitative sample consisted of 90-0.25m^2, 15cm deep quadrat samples taken randomly within the bed using GIS and plotted on a GPS Depthfinder. All materials are hoisted to the boat in a 6mm bag where the contents are removed and identified accordingly. All live mussels were returned to the river after processing.

Qualitative sampling involved a visual and tactile search for unionids by a diver and by design can be biased towards large and sculptured animals. The qualitative sampling consisted of a 5-minute interval to collect all mussels at each location along with pertinent water quality information. Usually 25 sites were selected for the sample within the bed and all live mussels were returned to the river after processing.

Three unionid beds occur in the vicinity of QCNS: the Steamboat Slough (SS) Bed, located approximately 675 to 1,125 meters downstream of the QCNS mixing zone; the Upstream (UP) Bed, located approximately 730 to 1,130 meters upstream of the QCNS diffuser; and the Cordova Bed, located about 3,000 meters downstream of QCNS. Ecological Specialists, Inc. (ESI) monitored each of these unionid beds in 2004, 2005, 2006, and 2007. In 2007, the monitoring program added 400 meter sections of three additional beds to further evaluate unionid community characteristics among and within unionid beds. The three additions were: the Albany Bed located approximately 14,000 to 14,400 meters upstream of the diffuser, Hansons Slough (HS) Bed located approximately 5,000 to 5,400 meters upstream of the diffuser, and Woodwards Grove (WG) Bed located approximately 10,500 to 10,900 meters downstream of the diffuser (ESI 2009).

Upstream Bed

The Upstream Bed habitat has remained consistent among monitoring events (July 2004, July and October 2005, August and September 2006, October 2007). The Upstream Bed is located near the mouth of the Wapsipinicon River and upstream of QCNS diffuser discharge (Figure E-2). Substrate in the bed is a mixture of sand, silt, and clay, with sand being the major constituent. However, substrate constituents varies considerably among sample points (CV [coefficient of variation] exceeding 100 except for sand) (ESI 2009).

Steamboat Slough Bed

The Steamboat Slough Bed is located approximately 750 meters downstream of the QCNS mixing zone (Figure E-2). In previous years, the northern portion of the sampling area was downstream and riverward of a small island. This island was absent in 2007. Substrate in the Steamboat Slough Bed was primarily sand in 2004 and 2005, but in 2006 silt increased from <10% to >20%, forming a layer over the sand. Substrate in 2007 was nearly equal parts sand and silt, with silt forming a layer over the sand (ESI 2009).

Cordova Bed

The Cordova Bed is one of the Essential Habitat Areas designated in the *L. higginsii* recovery plan (USFWS, 2004). This bed has historically harbored a dense and diverse unionid community. The Cordova Bed differs from the Upstream and Steamboat Slough beds in that it occurs along a slight outside bend in the river and its substrate is coarser (higher percentages of gravel, cobble, shell) (ESI 2009).

Albany Bed

Albany Bed was the most upstream bed sampled. The bed extends upstream from Albany, IL (near RM 513) to Cattail Slough (near RM 516). Although very long, the bed is narrow, extending an average of only about 40 meters from the bank into the river. The bed is most similar to the Cordova Bed in habitat characteristics. Sampled substrate was primarily zebra mussel shells mixed with cobble, gravel, and sand. Silt was more apparent near the bank (ESI, 2009).

Hansons Slough Bed

The Hansons Slough Bed (HS Bed) is located approximately 4,600 to 6,400 meters upstream of the QCNS diffuser. The bed extends from approximately RM 509.1 to 510.1. The bed is within the upstream portion of Hansons Slough and within a dike field, similar to the Steamboat Slough Bed. However, the Hansons Slough Bed is shallower (0.6 to 2.7 meters) with sandier substrate (primarily fine sand similar to Upstream Bed) (ESI, 2009).

Woodwards Grove Bed

The Woodwards Grove Bed is located approximately 8,300 to 10,900 meters downstream of the QCNS diffuser. The bed extends from approximately RM 499.5 to RM 500.8 along the Iowa bank within a slight outside bend. Other than zebra mussels, substrate was primarily silt and clay closer to the bank, turning to finer sand riverward (ESI, 2009).

7. FISH MONITORING

This program currently contains four different study plans for monitoring the fish community near Quad Cities Nuclear Station on Pool 14 of the Mississippi River. Bottom trawling and cove rotenone studies were discontinued after 1995 and 1984, respectively.

The study plans are:

- Adult and juvenile fish long-term monitoring
- Freshwater drum life history and population dynamics study
- Channel catfish, flathead catfish, walleye and sauger studies
- Stocking assessment

7.1 Adult and Juvenile Fish Long-term Monitoring

Adult and juvenile fish monitoring has been conducted in the area of the Station since 1971. The program was modified several times during 1971 to 1977 to address specific objectives related to Station operation. In 1978, results of the previous years' studies were reviewed and those sampling techniques, electrofishing and trawling, and sample locations that had the greatest continuity since 1971 were selected to be included in the long-term monitoring program. Locations were selected based on their continuity to evaluate trends in the species composition and dominant species of Pool 14. At the suggestion of the Iowa Department of Natural Resources (IDNR), an additional collection method (haul seine) was added to provide relative abundance estimates for several species deemed not to have been adequately collected in previous studies. The haul seine also provides a means of estimating standing stocks for several species utilizing the side channel and slough habitats. Hoop nets were added in 1982 as an additional collection method. The entire data base (1971-1994) was re-evaluated in 1995 when it was determined that bottom trawling and hoop netting no longer provided useful information intended for adult and juvenile fish monitoring. Consequently, both of these elements were dropped from the long-term monitoring program beginning in 1996.

The current objectives of the long-term program are to:

- Continue the program established in 1978 to monitor long-term trends of the fish community and its dominant species in Pool 14 of the Mississippi River and

- Estimate standing stock of those species vulnerable to the haul seine.

Electrofishing sampling is currently conducted with a boat at three locations upstream and five locations downstream of the diffuser pipes (Figure E-3). Sampling is conducted once weekly each of the first two weeks in June, July, August and September. Therefore, 64 samples are scheduled to be collected annually and approximately 1,600 samples have been collected since the return to open cycle cooling in 1984. Water temperature and conductivity are measured at 0.5 meters below the surface during the collection of each electrofishing sample.

A commercial fisherman under contract directly to Exelon has been employed to sample by haul seine (1,000 ft x 20 ft of 1.5 in. bar mesh) at four selected locations (Figure E-4). Sampling is conducted on a weekly basis from mid-October to mid-November. One seine haul is made at each location each week, and a minimum of four seine hauls are made at each location during the sampling time period, weather and river conditions permitting. All four locations are three to six miles upriver of the diffuser pipes.

7.2 Freshwater Drum Life History and Population Dynamics Study

In 1978, at the recommendation of the Illinois Department of Natural Resources (ILDNR), an intensive study was initiated to determine whether Station operation was affecting population levels and growth of freshwater drum in Pool 14. Freshwater drum is the only species in Pool 14 that has a truly planktonic egg, and its larvae frequently represent the greatest percentage of ichthyoplankton drift. Thus, population levels may conceivably be affected by high percentages of its early life history stages being lost through entrainment. Impingement may also affect population levels because freshwater drum has the second highest impingement rate. Impingement is dominated by young-of-the-year freshwater drum with some older fish also impinged (Hazleton Environmental Sciences, 1979).

Since 1978, a variety of population parameters have been studied including population estimates, age class distribution, annual growth rates, fecundity, total annual mortality, and impingement exploitation rates. Refinements and adjustments to the freshwater drum life history program have been made during the past 31 years and the specifications described herein have evolved as a result.

The most recent modification to the freshwater drum life history program occurred in 1993. The fecundity analysis portion of the study was deleted on the basis that ten years of data were more than adequate to determine mean fecundity for the species and that no measurable changes in fecundity occurred as a result of Station operation.

The specific objectives of the continuing monitoring program include:

- Continuing to monitor freshwater drum adult population levels;
- Estimating age class distribution;
- Estimating total annual growth and mortality rates;
- And continuing to estimate standing crop throughout the study area and relate to impingement biomass as a means of assessing potential impingement impact.

Freshwater drum are collected in five areas (Figure E-5), both upstream and downstream of the diffuser pipes, using hoop nets from approximately May 1 through June 30. Exact sampling locations within each of the five areas vary to satisfy the objective of capturing as many freshwater drum as possible.

Weather permitting, all hoop nets (total of 72) are raised twice per week, which currently provides a total of 1,152 samples per year. Since 1984, over 30,000 samples have been collected in this program. Water temperatures are recorded for each sampling area.

Each drum larger than 150 mm is tagged and measured for total length to the nearest mm and weighed to the nearest gram (g). Location, river mile, and habitat where captured and released are also recorded. Age determination of freshwater drum is performed annually on a maximum of 600 otolith samples provided by the spring hoop-lead net sampling program. Length-frequency distributions for all freshwater drum captured during the spring survey are prepared for each collection period.

Growth rates of freshwater drum are evaluated using the length-weight regression and the von Bertalanffy (1938) growth equation. Length-weight relationships are based on all individuals selected for age analysis. Length-frequency and age data are fitted to the von Bertalanffy growth model. Comparisons of growth between years are made to determine if growth has changed, and comparisons of estimated growth are made with observed age-length data to determine any obvious inconsistencies.

7.3 Channel Catfish, Flathead Catfish, Walleye/Sauger Studies

Previous spring hoop and lead net studies, directed toward freshwater drum life history and population assessments, have also yielded considerable numbers of channel and flathead catfish. Consequently, ongoing life history studies were amended in 1983 to include a tagging study for channel and flathead catfish aimed at monitoring the extent of their movement and to provide an estimate of their standing crop in those same areas surveyed for freshwater drum. Population levels and standing crop of both species have increased in Pool 14 and the tagging studies have been discontinued. Both species continue to be monitored as part of the freshwater drum studies.

As a further supplement to the freshwater drum life history study and the catfish population study, a tagging program for walleye and sauger was initiated in 1984. Addition of this program to the monitoring effort was prompted by ILDNR's interest in habitat preference and utilization by walleye and sauger, and the need to develop a database on walleye in anticipation of future stocking activities in Pool 14. Too few fish of either species have been captured to date to satisfy program objectives. However, this effort is easily accommodated within the spring hoop and lead net program, and will be continued.

7.4 Fall Stock Assessment

In 1984, under the auspices of the IDNR and the ILDNR, the inactive spray canal surrounding the Station was converted into a game fish production facility through a grant to Southern Illinois University. Species chosen for rearing were hybrid striped bass and walleye, with annual stocking objectives of 175,000 advanced fingerlings of each species for Pools 13 & 14. Production of both species has been variable from year to year, but since 1984 in excess of 4.5 million walleye and 700,000 hybrid striped bass fingerlings have been stocked in the Mississippi River.

As a result of past stocking in Pool 14 and to provide information for future stockings, the need to monitor the results of these introductions was identified and the standard monitoring program was expanded to meet this need. Several basic elements of the long-term fisheries monitoring program (electrofishing, hoop netting and haul seining) document the relative contributions of these stocking efforts in habitats near Quad Cities Nuclear Station. However, both hybrid striped bass and walleye extensively utilize tailwater areas both upstream and downstream from the Station and historic monitoring programs have not included these areas.

Dialogue with IDNR and ILDNR resulted in the addition of a special fall tailwater electrofishing survey to the 1984 monitoring program. That effort was expanded over a broader time frame in 1985 and continues to be conducted.

Specific objectives of this post-stocking assessment program are to:

- Continue to expand the database regarding the relative abundance and size distribution of selected game fish species utilizing tailwater areas coincident with recruitment of game fish stocked in Pool 14 and

- Continue to define the age structure of walleye populations utilizing tailwater areas coincident with recruitment of stocked fingerling walleye.

Night electrofishing is conducted on a bi-weekly basis beginning in mid-September and extending into early-November. Four selected areas are sampled in each of the tailwaters below Lock and Dam 13 (Figure E-6) and Lock and Dam 14 (Figure E-7) during each sampling effort. Thirty-two samples are collected annually and approximately 784 samples have been collected since 1984.

Collection efforts are limited to walleye, sauger, white bass and hybrid striped bass. All walleye are closely examined for the presence of brand marks applied at the time of stocking. Data analysis includes tabular summaries of catch-per-unit-effort (no/species/hour), length-frequency distributions, and age-length distributions for walleye, as well as determinations of stocking contributions to individual year classes of walleye.

7.5 Bottom Trawls

Bottom trawling was conducted once per week during the first two weeks of June, July, August and September. Samples were collected within the main channel of the river from 1971 through 1995. Bottom trawl samples were collected at three locations each week (three fixed locations sampled eight times per season equaled 24 samples per year) using a 16-foot semi-balloon bottom trawl with a 0.25-inch cod-end inner liner. During the trawling program, approximately 600 trawl samples were collected. Each tow was conducted for seven minutes in a downstream direction within the navigation channel of the river. The trawl was towed at a constant speed of approximately 2 knots above ambient current velocity. Consequently, the distance covered by each tow varied with current velocity.

7.6 Rotenone Sampling

Fish standing crop estimates for selected slough habitats have been determined at various times using a cove rotenone sampling technique. Ten cove rotenone samples were collected at four separate locations in Pool 14 between 1977 and 1984. As a result of public displeasure and the belief that adequate standing crop data had been collected, rotenone surveys were discontinued after 1984.

8. ICHTHYOPLANKTON

8.1 River Studies

Ichthyoplankton monitoring was conducted in Pool 14 near the Quad Cities Nuclear Station from 1971 to 1985 and has provided information on species composition, temporal occurrence, and relative abundance of early life stages of fish in the pool. However, methods and, to a less extent, sample locations have been comparable only between 1975 and 1985. In 1978 an intensive larval sampling program was conducted during the period of peak larval abundance to better define diel, vertical, and horizontal differences in abundance, with special emphasis on the freshwater drum. Also in 1978, diel, vertical, and horizontal density differences by larval stages (yolk-sac, post-yolk-sac, and juveniles) were investigated for the first time.

In 1978 and 1979 sampling of fish eggs and larvae included single sample locations immediately below Lock & Dam 13, midway between the Station and Lock & Dam 13, and in the Marais D'Osier Slough. These three locations were used to indicate contributions of freshwater drum eggs and larvae to Pool 14 from Pool 13 and to determine where the area immediately above the Station was unique as a freshwater drum spawning and nursing area. Sampling at these locations was discontinued after 1979 because the objectives of the 1978 and 1979 programs were met.

From 1980 through 1983 only one location was sampled upstream of the intake. In previous years a minimum of three upstream locations were sampled. This adequately documented the diel, vertical, and horizontal differences in ichthyoplankton abundance. The return to an open-cycle operation in 1984 necessitated a more intensive ichthyoplankton sampling that included entrainment monitoring.

The sample design of the program used after the return to open cycle cooling in 1984 included sampling three locations (near Illinois bank, main channel, and near Iowa bank) on a transect that extended from a point upstream of the intake channel on the Illinois bank to a point upstream of the confluence of the Wapsipinicon River on the Iowa shoreline. Samples were collected one meter below the surface and one meter above the bottom at each river location and were also collected one meter below the surface at one location in the discharge bay. Samples were collected in quadruplicate at each location on a weekly basis for a period of 16 weeks beginning in mid-April. A total of 448 samples were collected annually during 1984 and 1985. These samples and results are the most indicative of current operations.

8.2 Entrained Ichthyoplankton Survival Study

Ichthyoplankton entrainment survival studies were conducted at Quad Cities Nuclear Station during 1978 with the Station operating in an open-cycle mode (LMS, 1986). These investigations were preformed only during a one-week period in late June, however.

Because of the short-term duration of the 1978 study, meaningful estimates of entrainment survival were developed only for freshwater drum and Cyprinidae (other than carp). To test entrainment survival predictions for the duration of the ichthyoplankton drift season, a relatively intensive study was preformed in 1984. This study was terminated following the 27 June 1984 collections because discharge canal water temperatures exceeded 37ºC, the point at which entrainment mortality is assumed to be 100%.

The only additional entrainment sampling at QCNS was conducted in 1985 for a study designed to develop an estimate of entrainment survival for walleye larvae (LMS, 1986).

8.3 Ichthyoplankton Diffuser Passage Survivability

The potential effects of exposure to an instantaneous increase of 15.2ºC as larvae pass the diffusers was evaluated (LMS, 2000b). Several conditions of this potential exposure are described below.

- The nearest diffuser open port to the Illinois shoreline is approximately 840 feet from the shore.
- The nearest open port to the Iowa shoreline is approximately 200 feet from the Iowa bank.
- The river width at the diffuser placement is approximately 2,200 feet.
- Ports are spaced 19-20 feet apart in the deeper portions of the river and 39-40 feet apart in the shallow zones.
- Ports are angled 20º from the bottom.
- This analysis was a worst-case approximation because it assumed that all organisms were exposed to the maximum temperature. This most likely is not true either vertically or horizontally.

- Duration of exposure to maximum temperature is not known; but several assumptions regarding incipient lethal temperatures (ILT), which are threshold temperatures for mortality, and incorporation of flow information permitted modeling that predicts mortality.
- Data were developed for total larvae, freshwater drum, and gizzard shad. These species are the two most abundant species collected in impingement samples at the Station (LMS, 2000b) and freshwater drum was selected as the indicator species for the Station's fish monitoring program beginning in 1980.
- Estimates of mortality were calculated for a variety of ambient river temperatures to determine the thresholds at which mortality begins to occur.

9. IMPINGEMENT

Fish impingement monitoring at Quad Cities Nuclear Station has been conducted since 1973. Specific objectives of the impingement program are as follows:

- Determine the species composition, number and biomass of fish impinged;

- Examine impinged freshwater drum, channel catfish, flathead catfish, walleye and sauger for tags, fin clips or brands;

- Compare impingement estimates with standing crop estimates developed in the adult and juvenile fish monitoring program.

Impingement sampling is conducted once each week (52 samples per year) over a 24 hour period. All fish collected in the screen wash basket are sorted to species, counted and weighed en masse. Individual impingement counts are expanded first to monthly and then to annual estimates.

From 1978 through 1983, a barrier net was deployed which spanned the Station's intake forebay in an effort to reduce fish impingement under a closed-cycle mode of operation. This net system proved effective in reducing impingement during closed-cycle operation because intake velocities near the river are very low under this operating mode (Nakato et al. 1979).

From 1984 through 1989, a system of barrier nets was evaluated as a means of reducing impingement under open-cycle or partial open-cycle modes of operation. Experimentation with a river barrier net deployed from September to late-November was found it to be ineffective in reducing fish impingement. Similarly, the barrier net across the Station's intake was also found to be ineffective during its deployment from late-November through March. Under open-cycle or partial open-cycle modes of operation, intake velocities are sufficiently high that debris and dead fish accumulate on the nets rapidly and they cease to function as an effective barrier within 24 to 48 hours. Furthermore, the intake barrier net cannot be effectively maintained when ice forms, which coincides with peak fish impingement.

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11. FIGURES

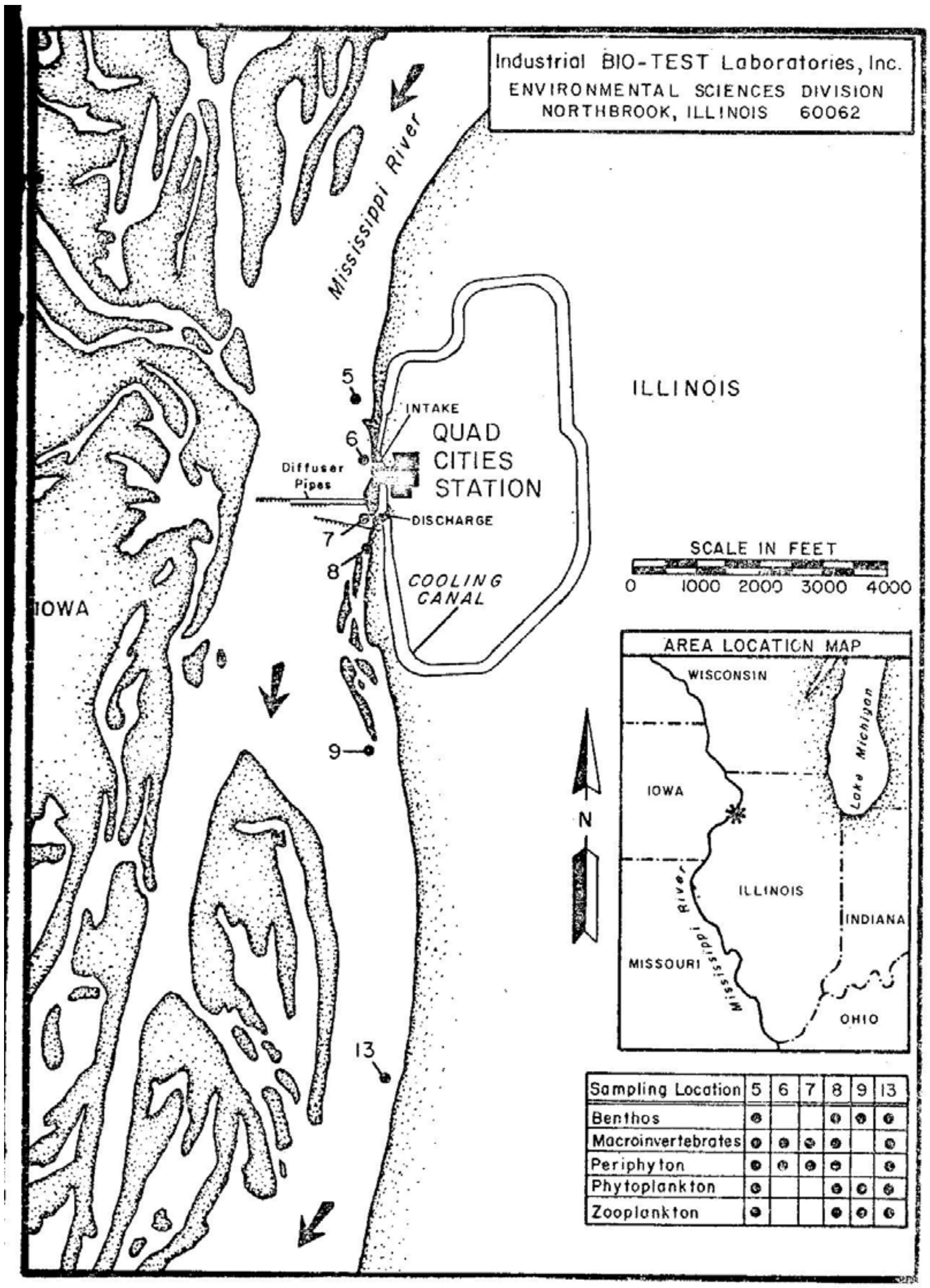

Figure E-1. Historical sampling locations for the biological monitoring studies at Quad Cities Nuclear Station

Figure E-2. Unionid Bed monitoring areas near QCNS, 2004-2007 (from Figure 1-1, ESI 2008).

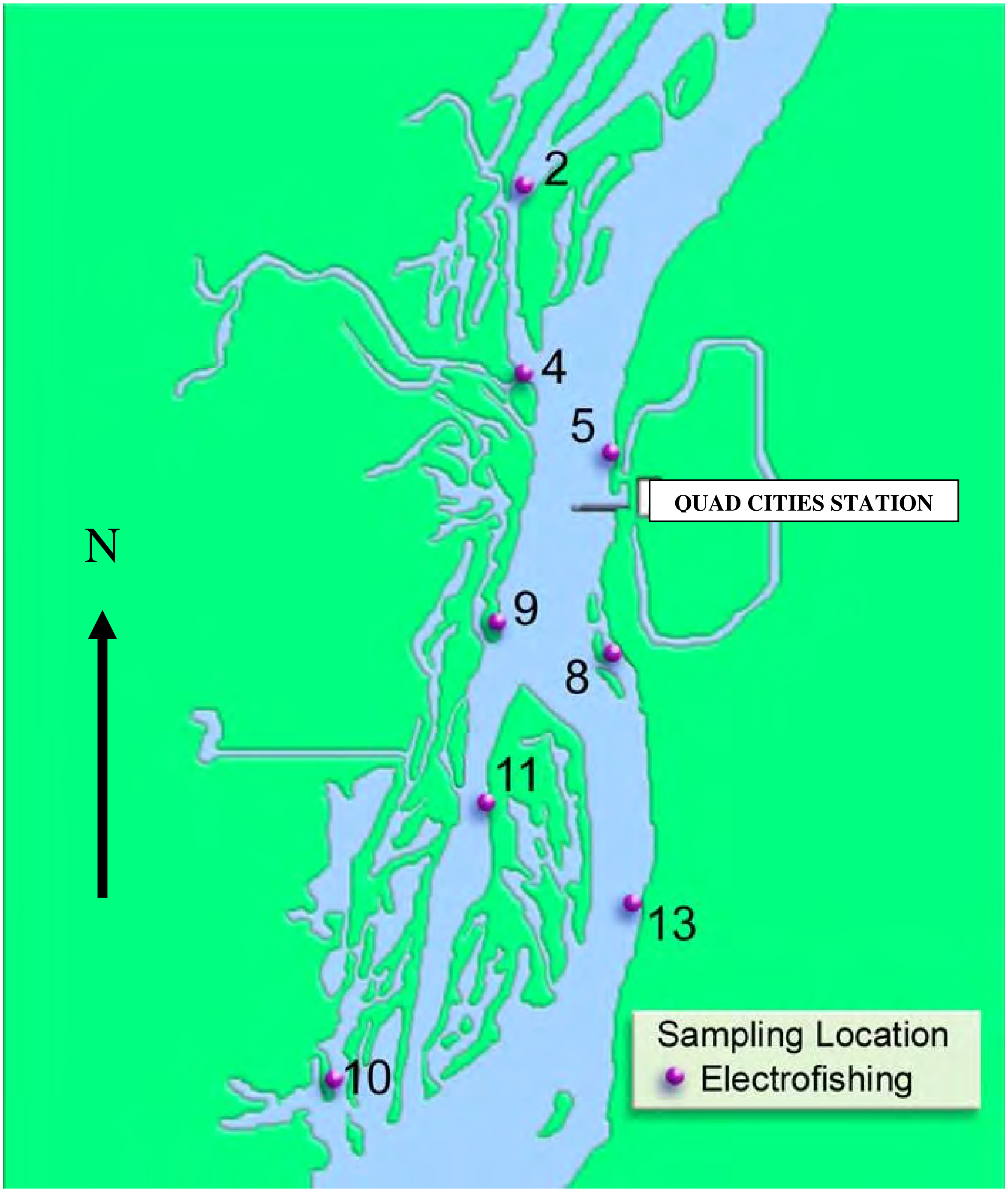

Figure E-3. Electrofishing locations in Pool 14 of the Mississippi River near the Quad Cities Nuclear Station

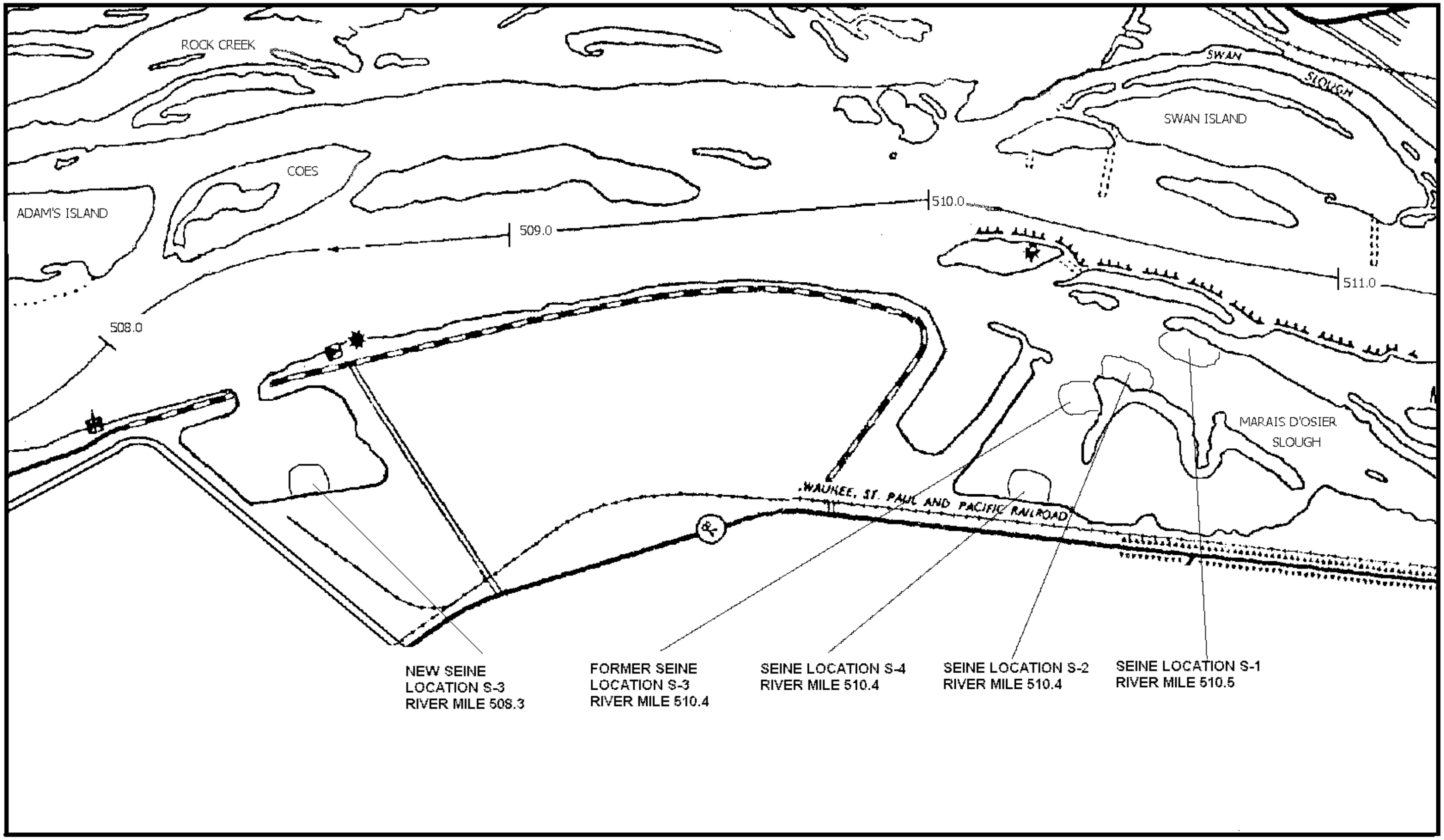

Figure E-4. Haul seining locations in Pool 14 of the Mississippi River near Quad Cities Nuclear Station

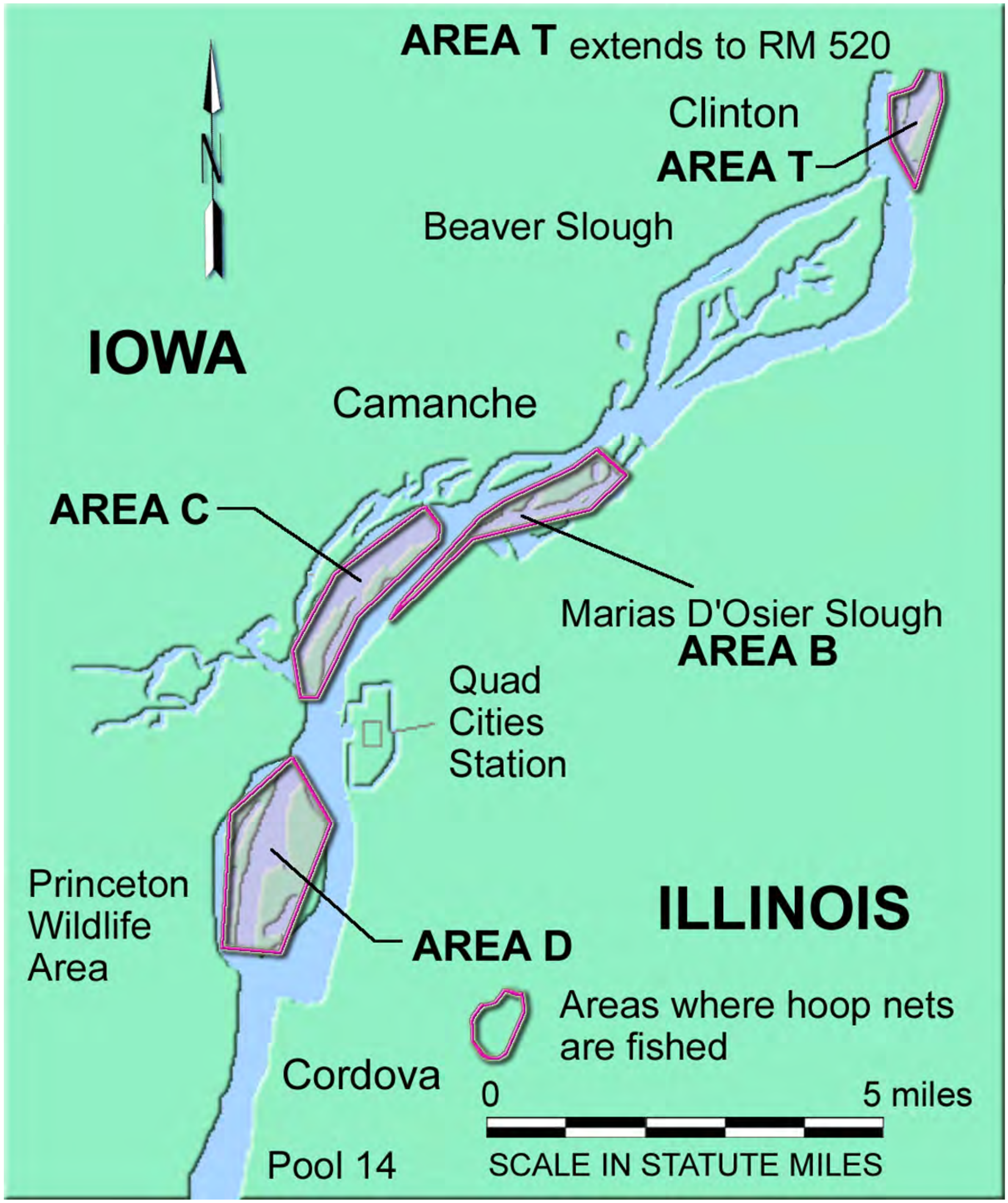

Figure E-5. Hoop net sampling locations in Pool 14 of the Mississippi River near Quad Cities Nuclear Station

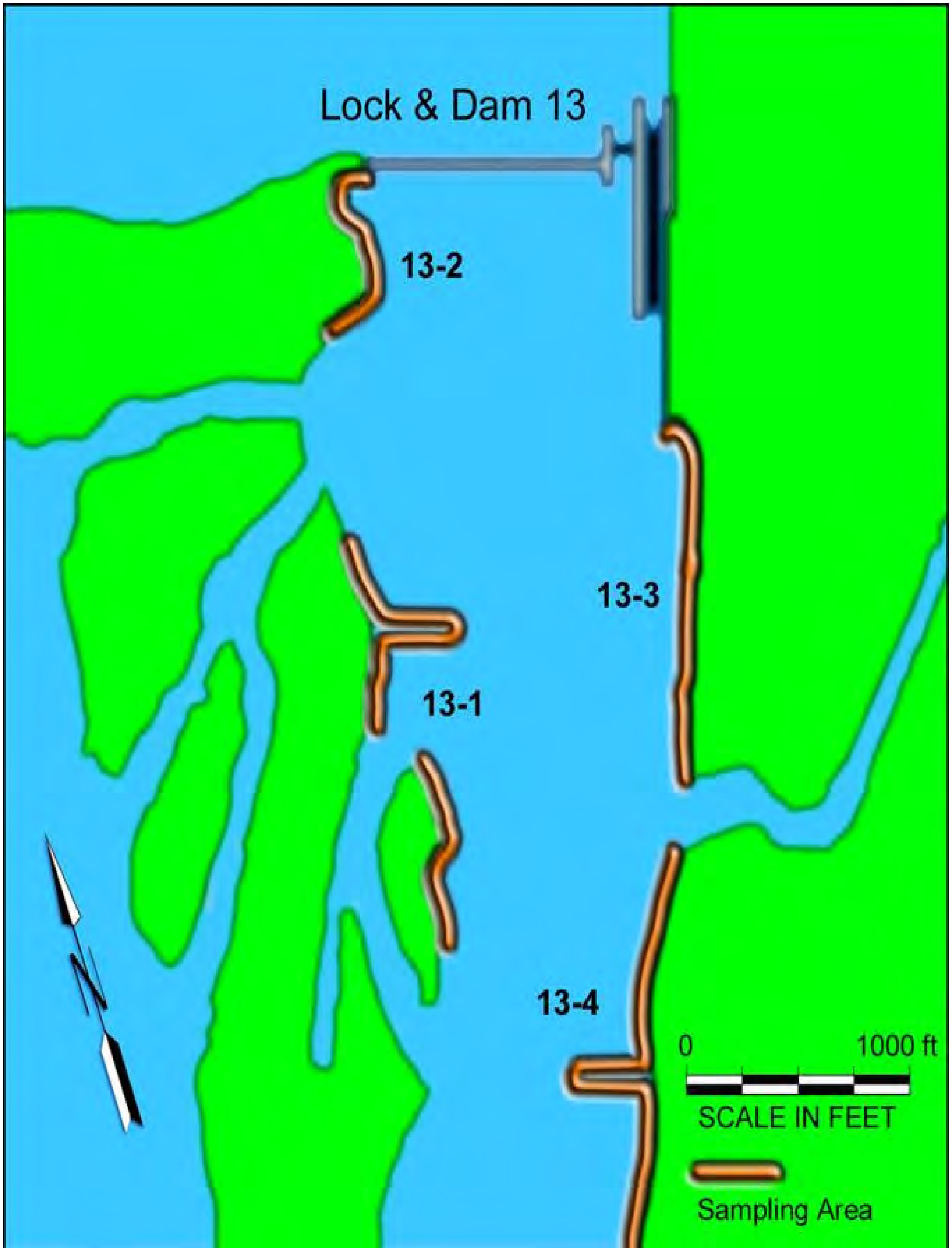

Figure E-6. Electrofishing sampling areas in the tailwater of Lock and Dam 13, Mississippi River

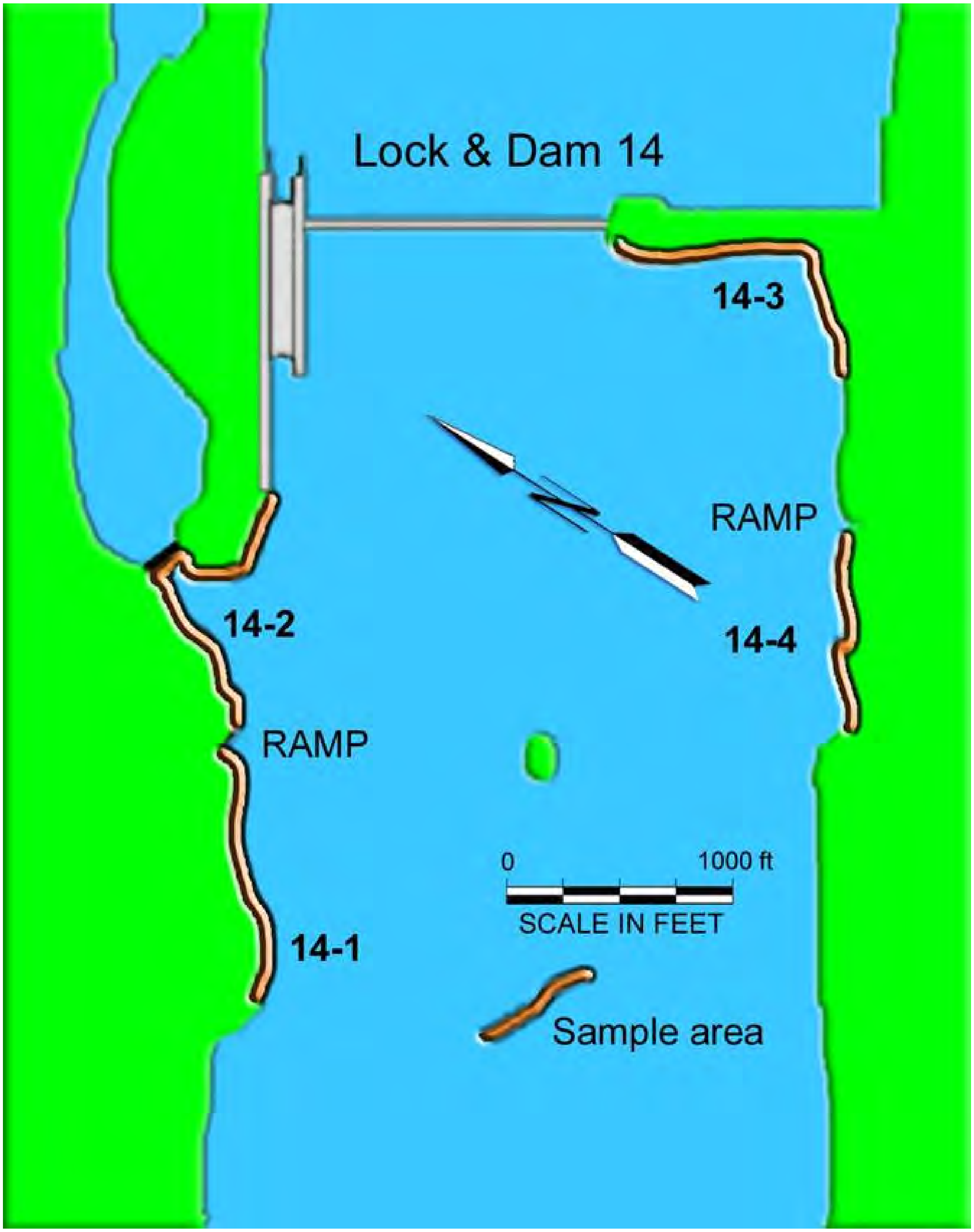

Figure E-7. Electrofishing sampling areas in the tailwater of Lock and Dam 14, Mississippi River