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 23°C (69.8 to 73.4° 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 78.4°F.

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 °F. 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 5° 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°F 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%
6/28/1988 7:00	15,745	73%	9/13/1988 7:00	10,446	<57%	10/15/1989 7:00	16,013	74%	10/21/2000 7:00	15,314	72%
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 du

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).

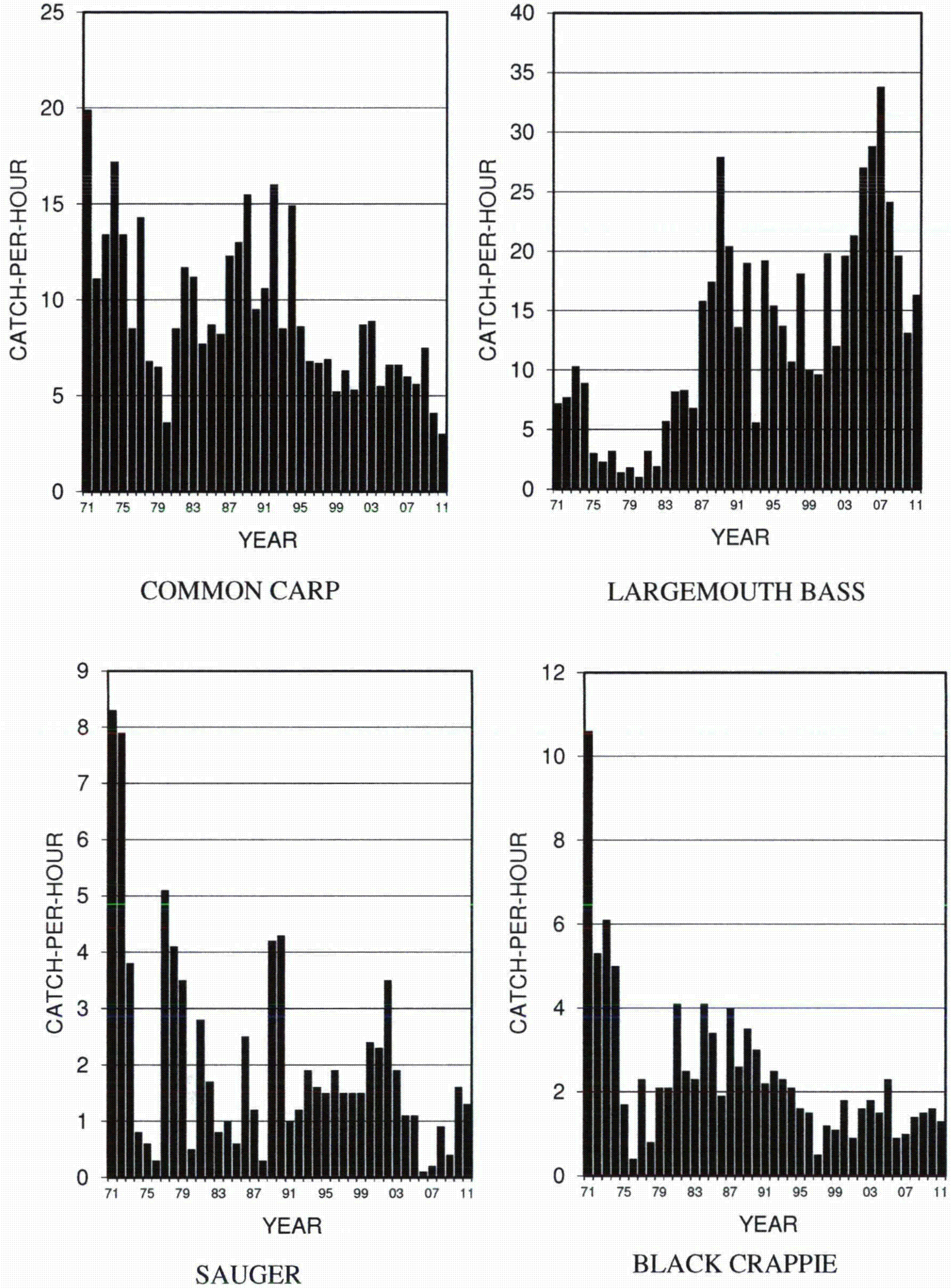


Figure C-1. Catch-per-Effort (All Locations) of Fish Collected by Electrofishing near Quad Cities Station, 1971-2011

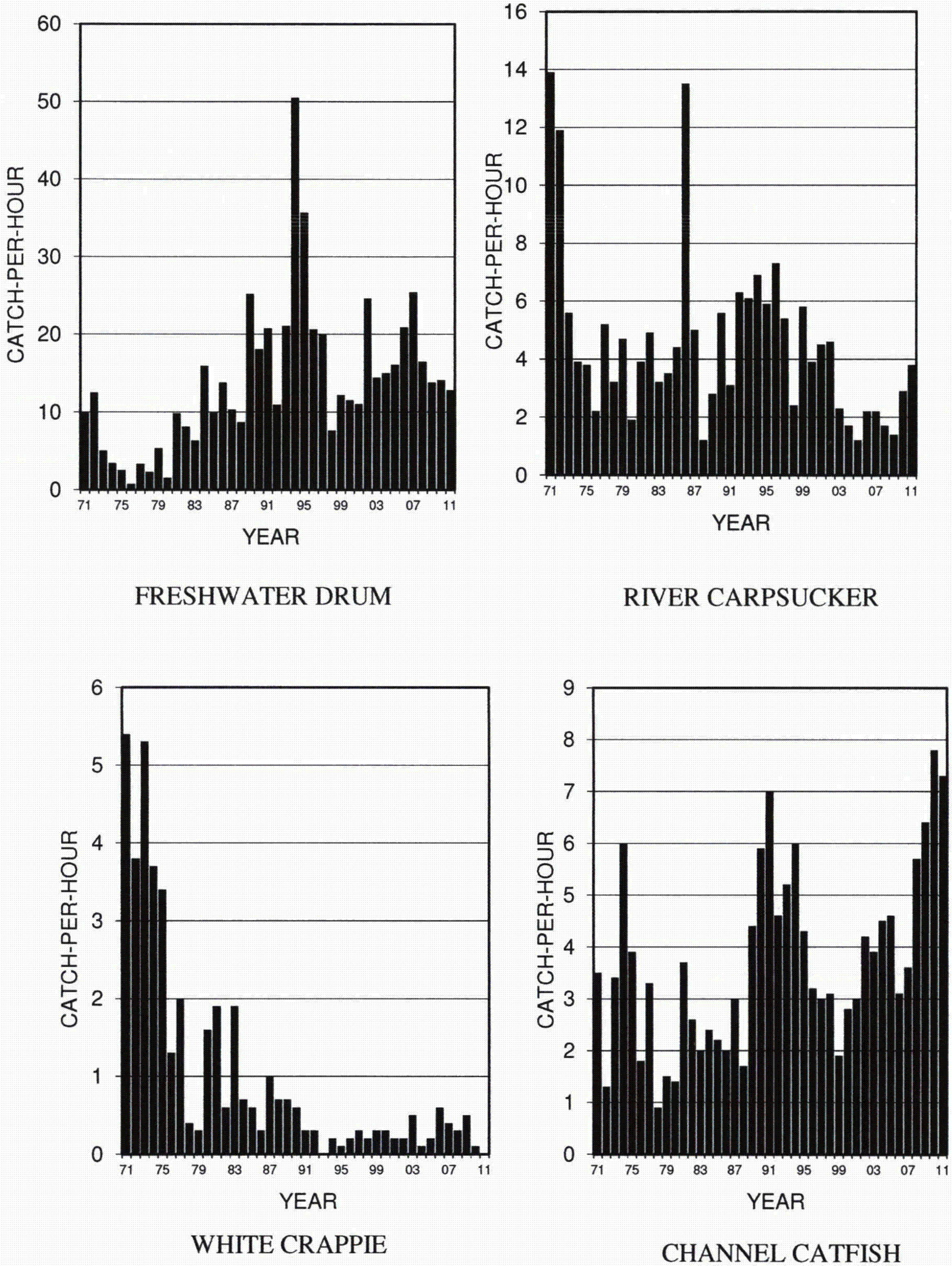
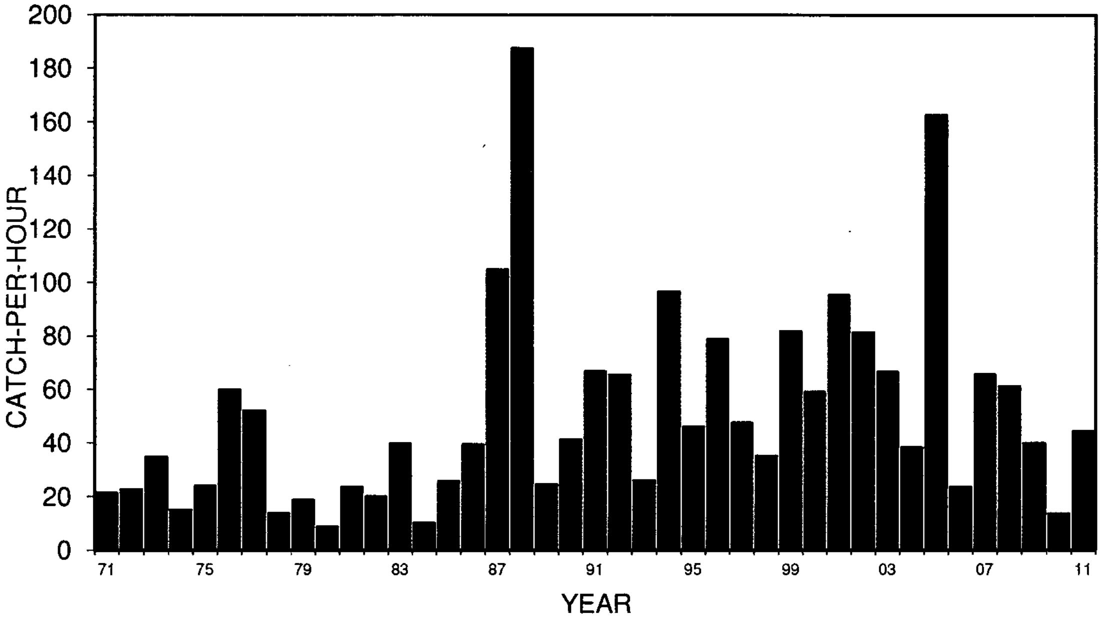
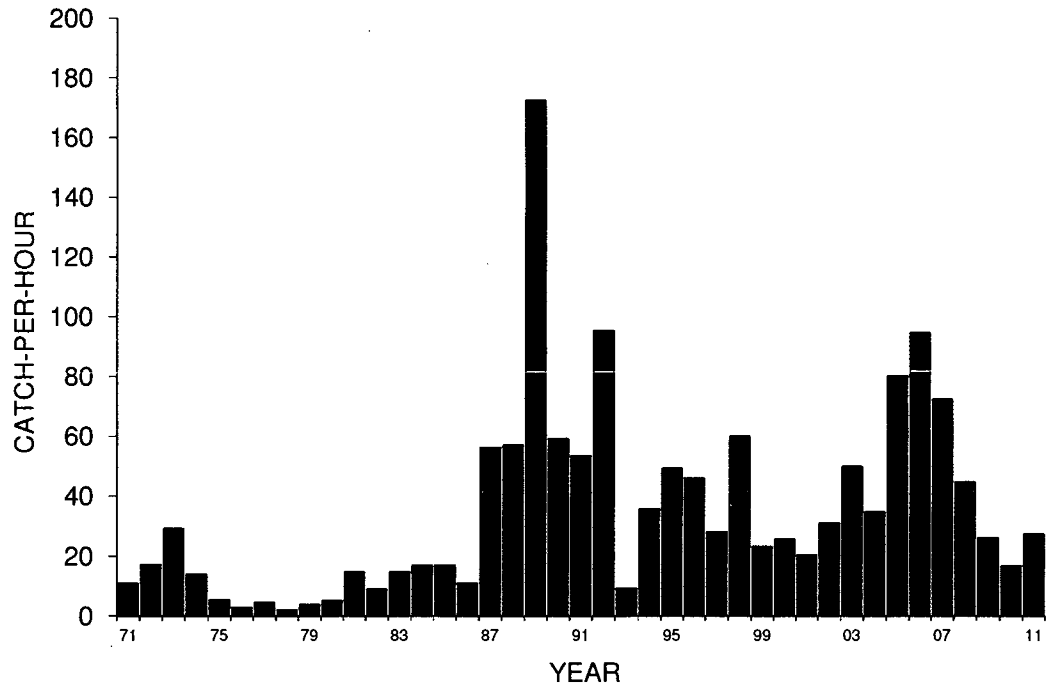


Figure C-1 (continued). Catch-per-Effort (All Locations) of Fish Collected by Electrofishing Near Quad Cities Station, 1971-2011



GIZZARD SHAD



BLUEGILL

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

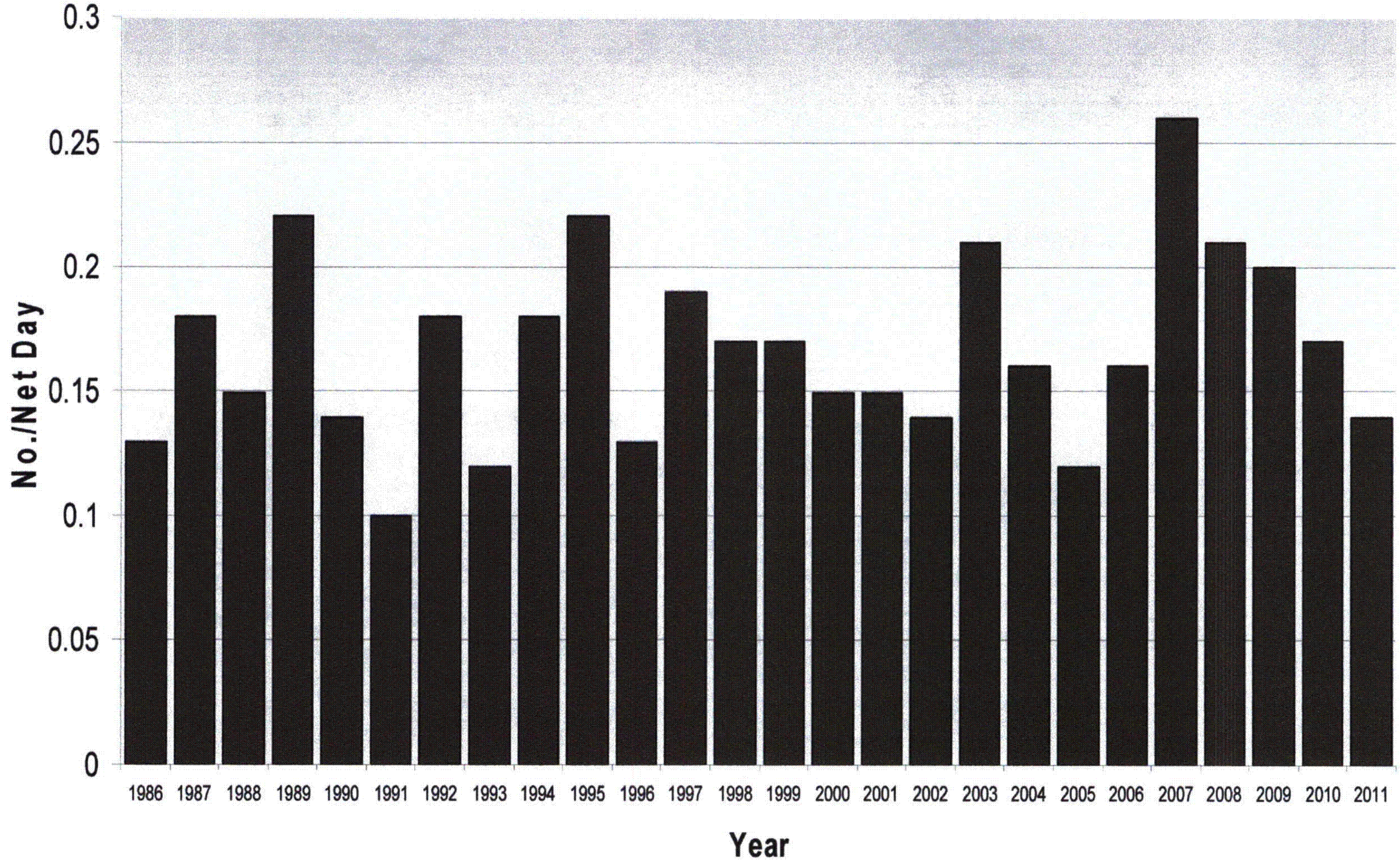


Figure C-2. Flathead Catfish CPE Collected by Hoop Net Near Quad Cities Station, 1986-2011

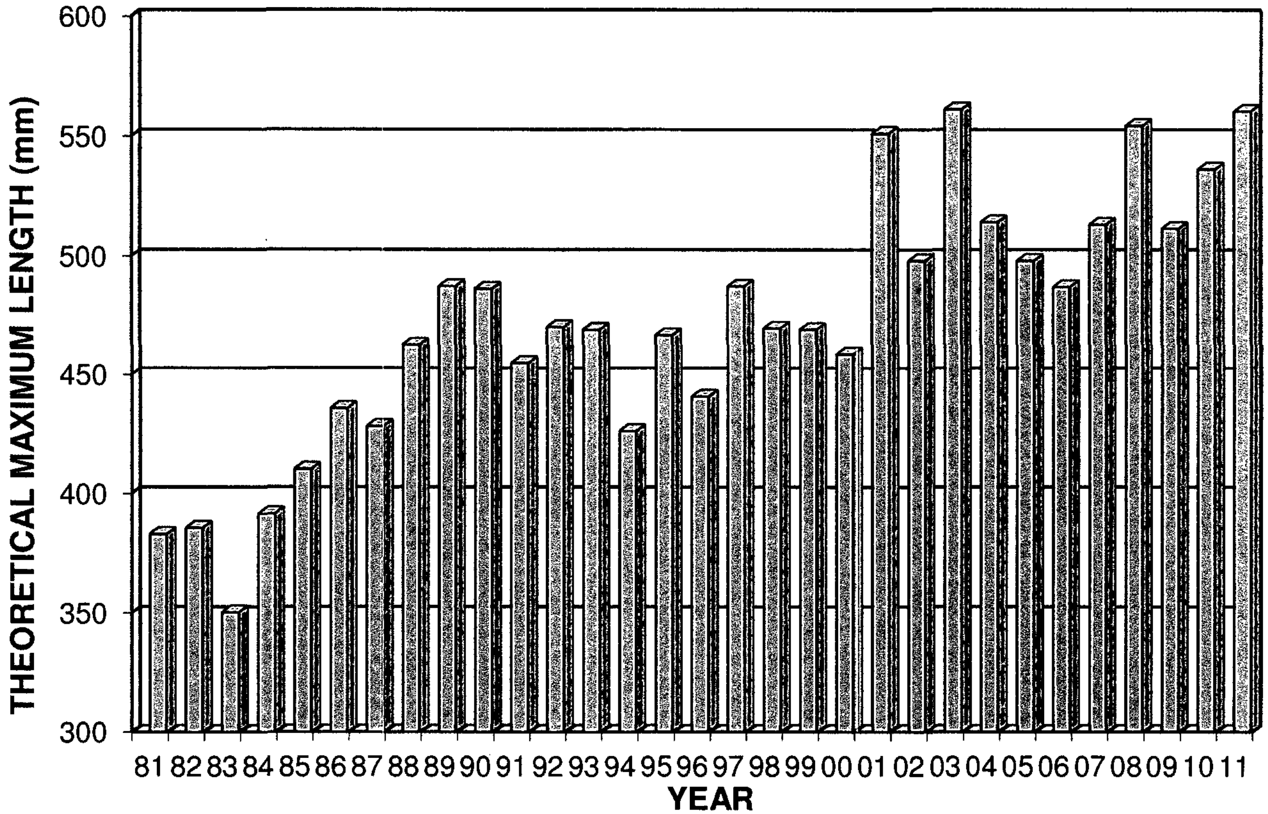


Figure C-3. Theoretical Maximum Length (mm) for Freshwater Drum from Pool 14 of the Mississippi River, 1980-2011

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 0.7°F 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

Commonwealth Edison (1975). 316 (a) and 316 (b); Demonstration for the Quad Cities Nuclear Generating Station.

Commonwealth Edison (1981). Supplement to 316 (a) and 316 (b); Demonstration for the Quad Cities Nuclear Generating Station.

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8. FIGURES

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

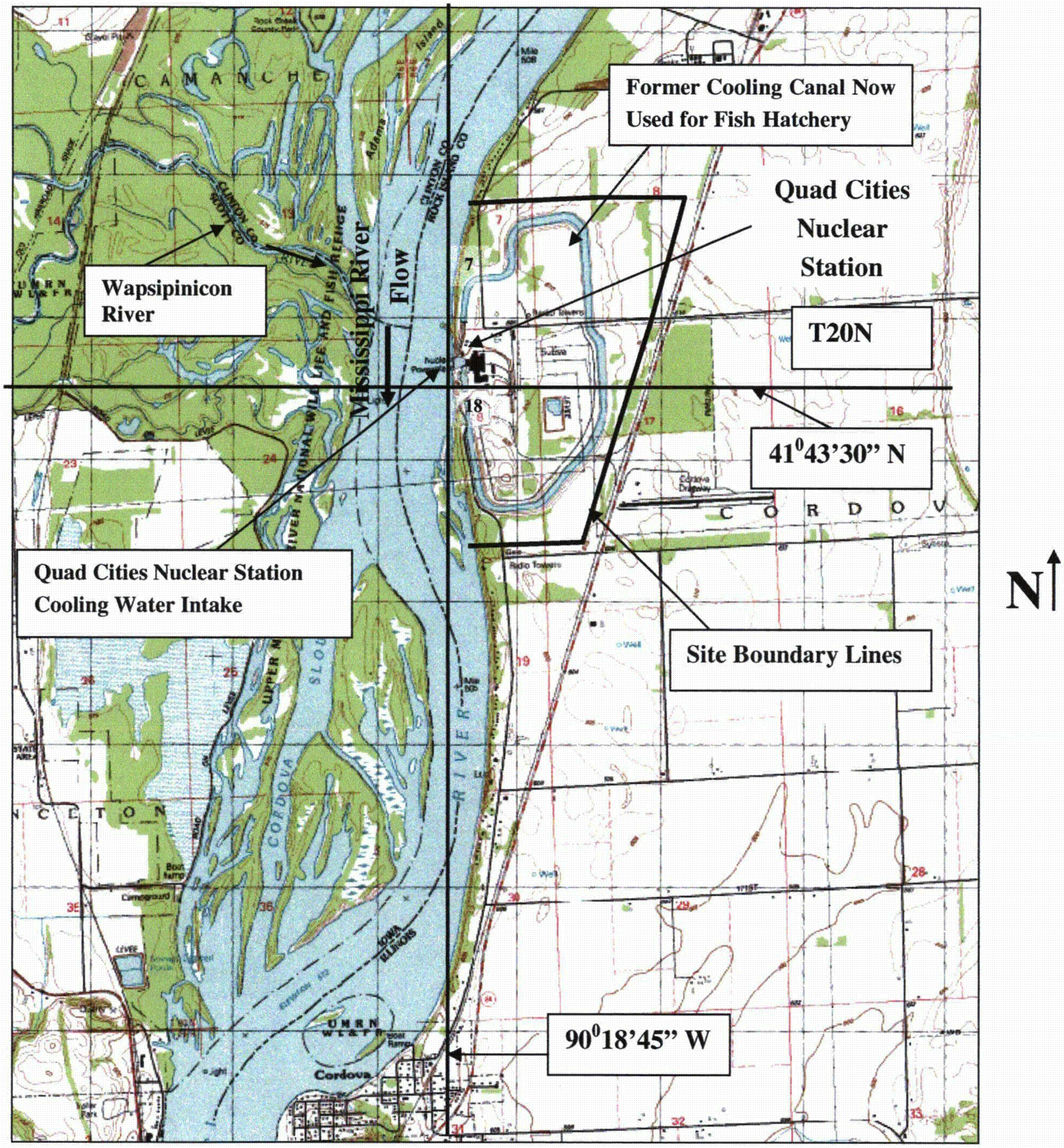

Figure D-2. Topographic Map of Quad Cities Nuclear Station located on Pool 14 of the Mississippi River at River Mile 506.5 (LMS, 2005)

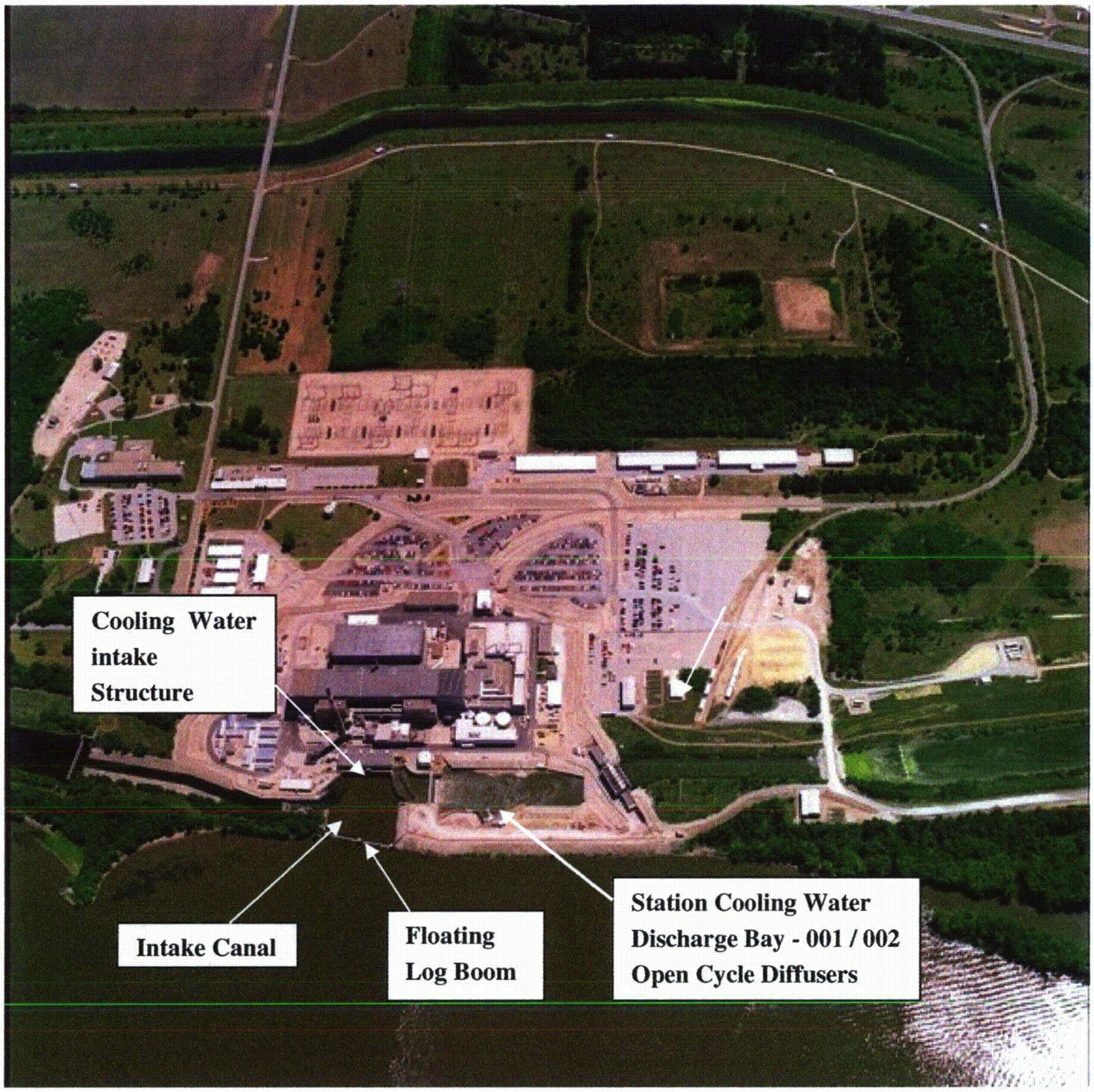

Figure D-3. Aerial View of Quad Cities Nuclear Station located on Pool 14 of the Mississippi Rive at River Mile 506.5 (LMS, 2005)

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 37°C, 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 15.2°C 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 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 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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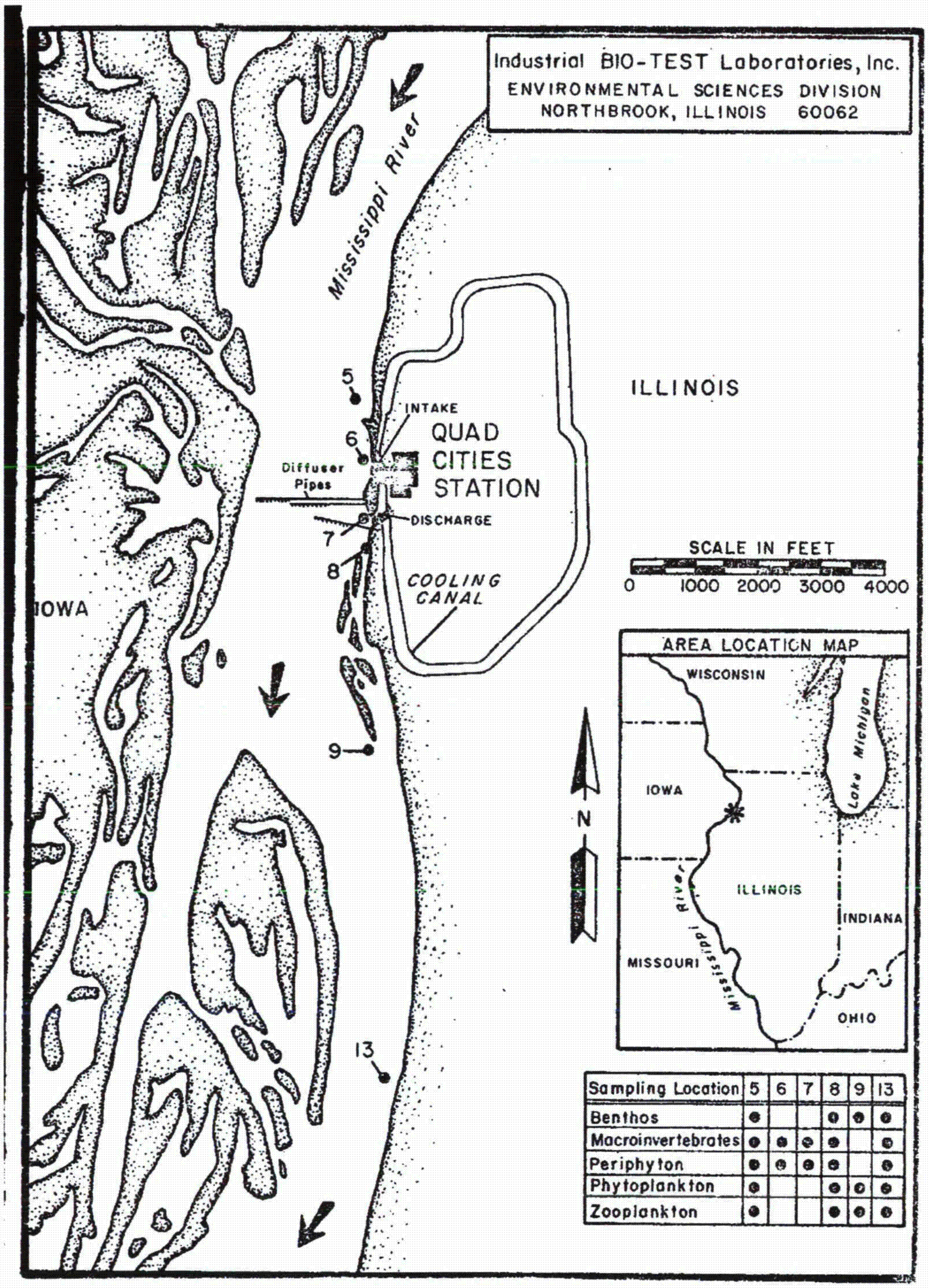
11. FIGURES



Sampling Location	5	6	7	8	9	13
Benthos	●			●	●	●
Macroinvertebrates	●	●	●	●		●
Periphyton	●	●	●	●		●
Phytoplankton	●			●	●	●
Zooplankton	●			●	●	●

Figure E-1. Historical sampling locations for the biological monitoring studies at Quad Cities Nuclear Station

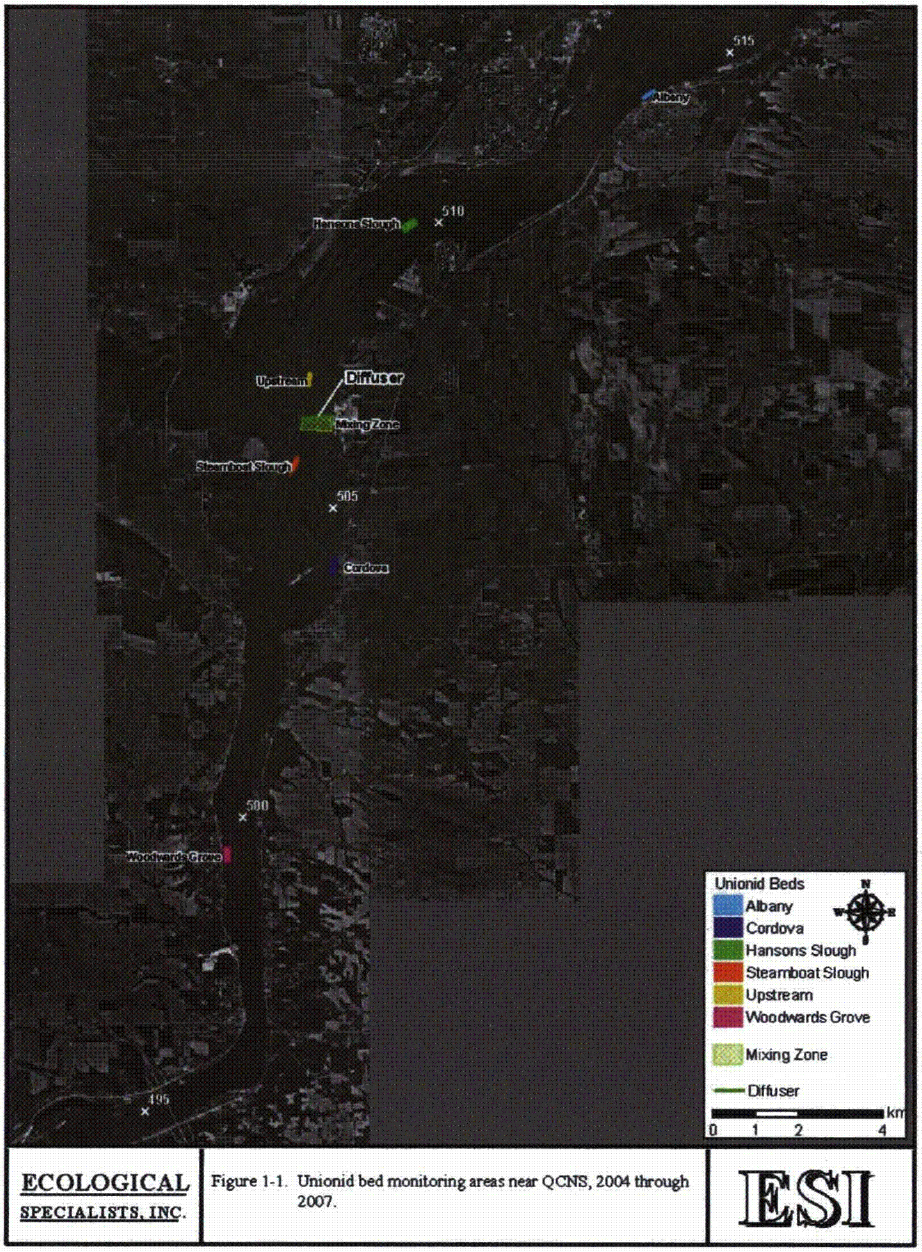


Figure E-2. Unionid Bed monitoring areas near QCNS, 2004-2007 (from Figure 1-1, ESI 2008).

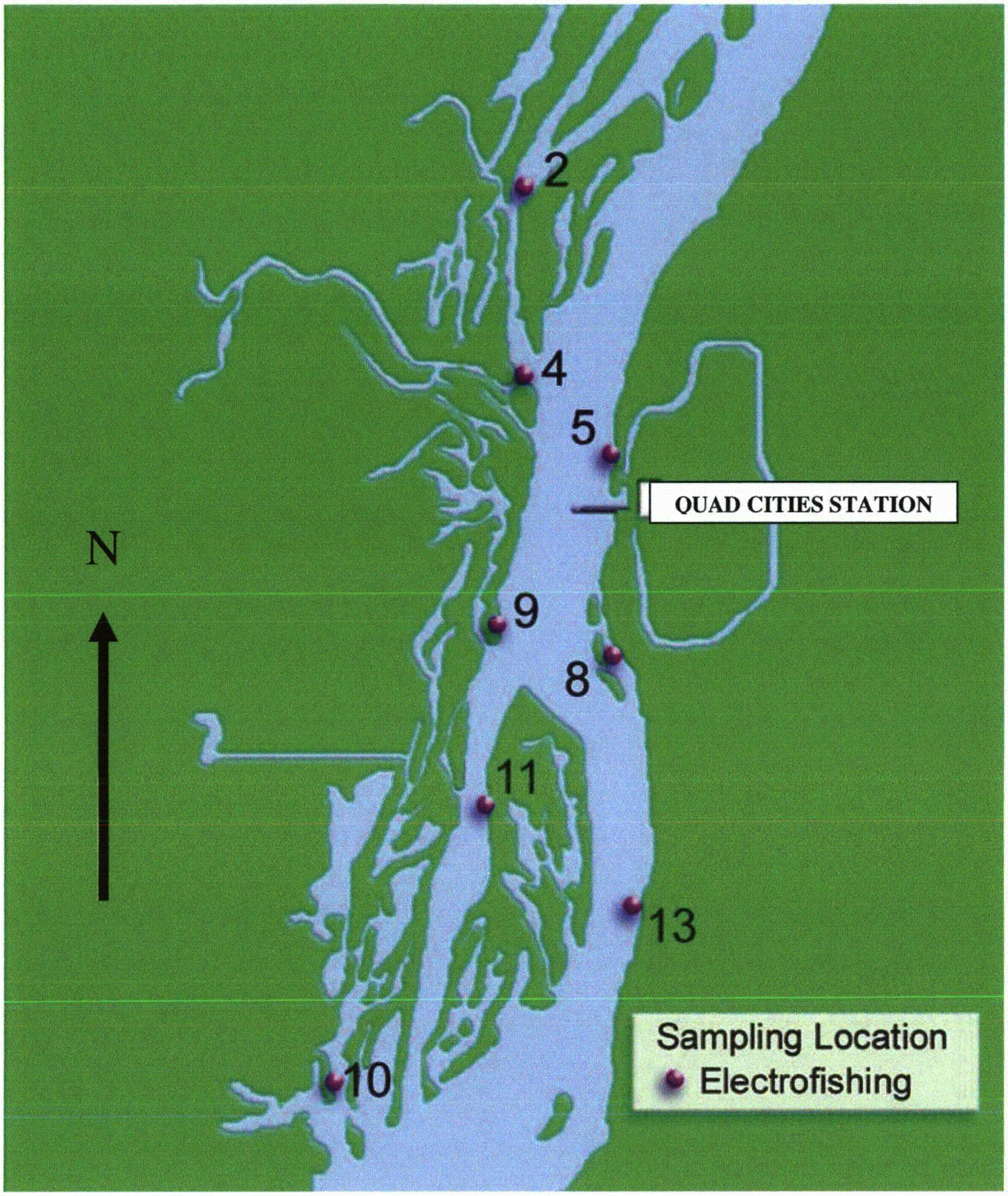


Figure E-3. Electrofishing locations in Pool 14 of the Mississippi River near the Quad Cities Nuclear Station

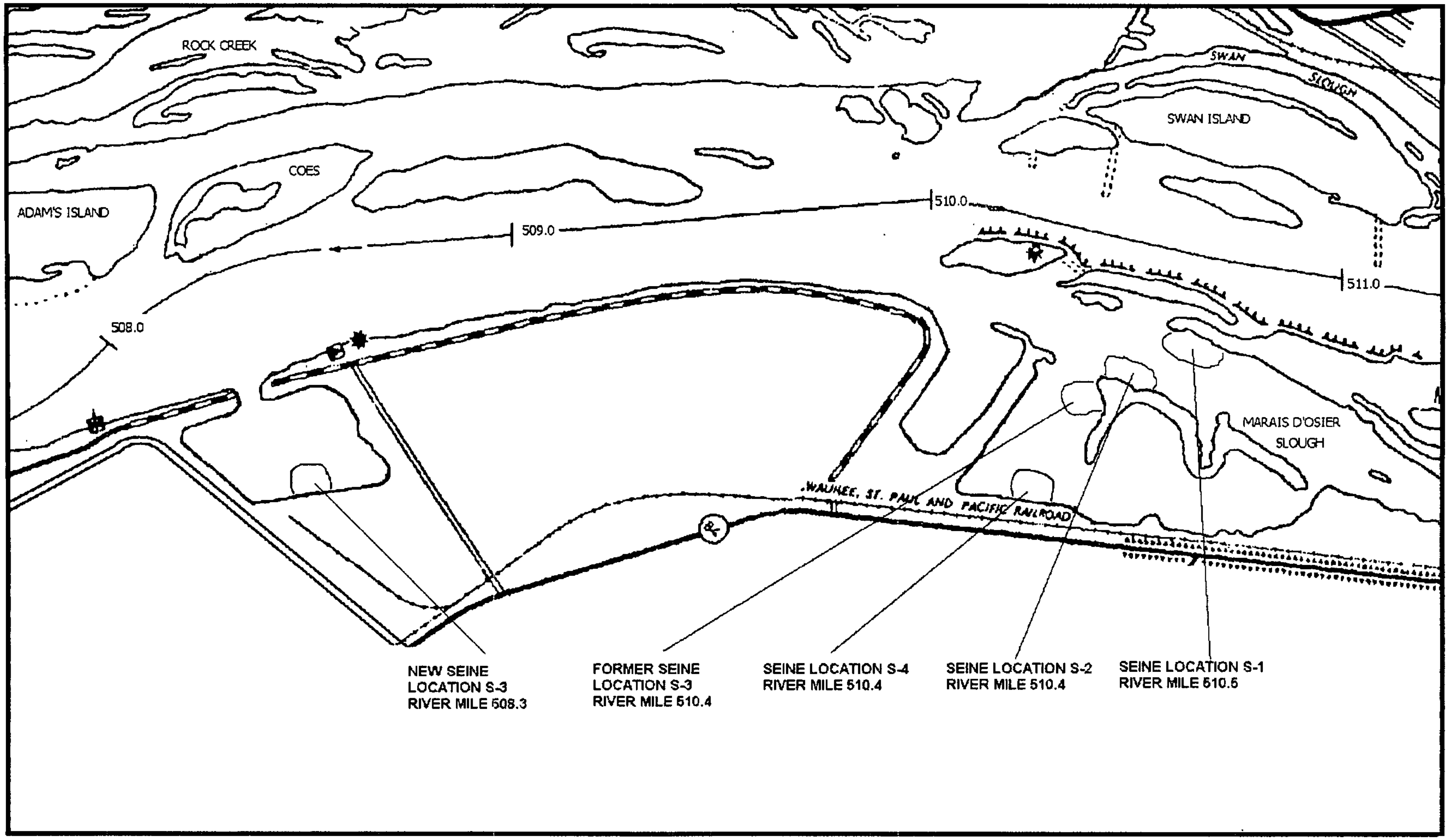


Figure E-4. Haul seining locations in Pool 14 of the Mississippi River near Quad Cities Nuclear Station

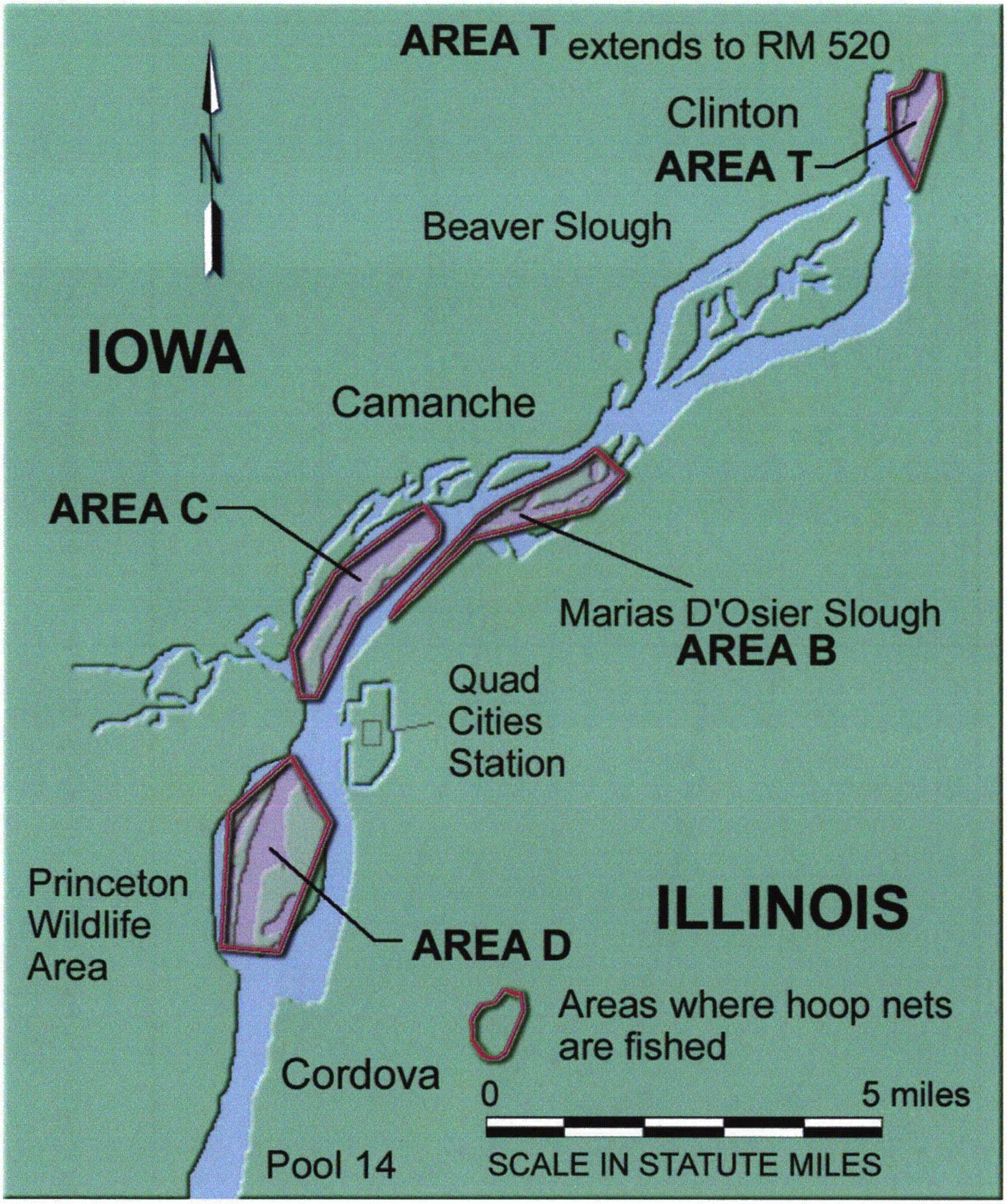


Figure E-5. Hoop net sampling locations in Pool 14 of the Mississippi River near Quad Cities Nuclear Station

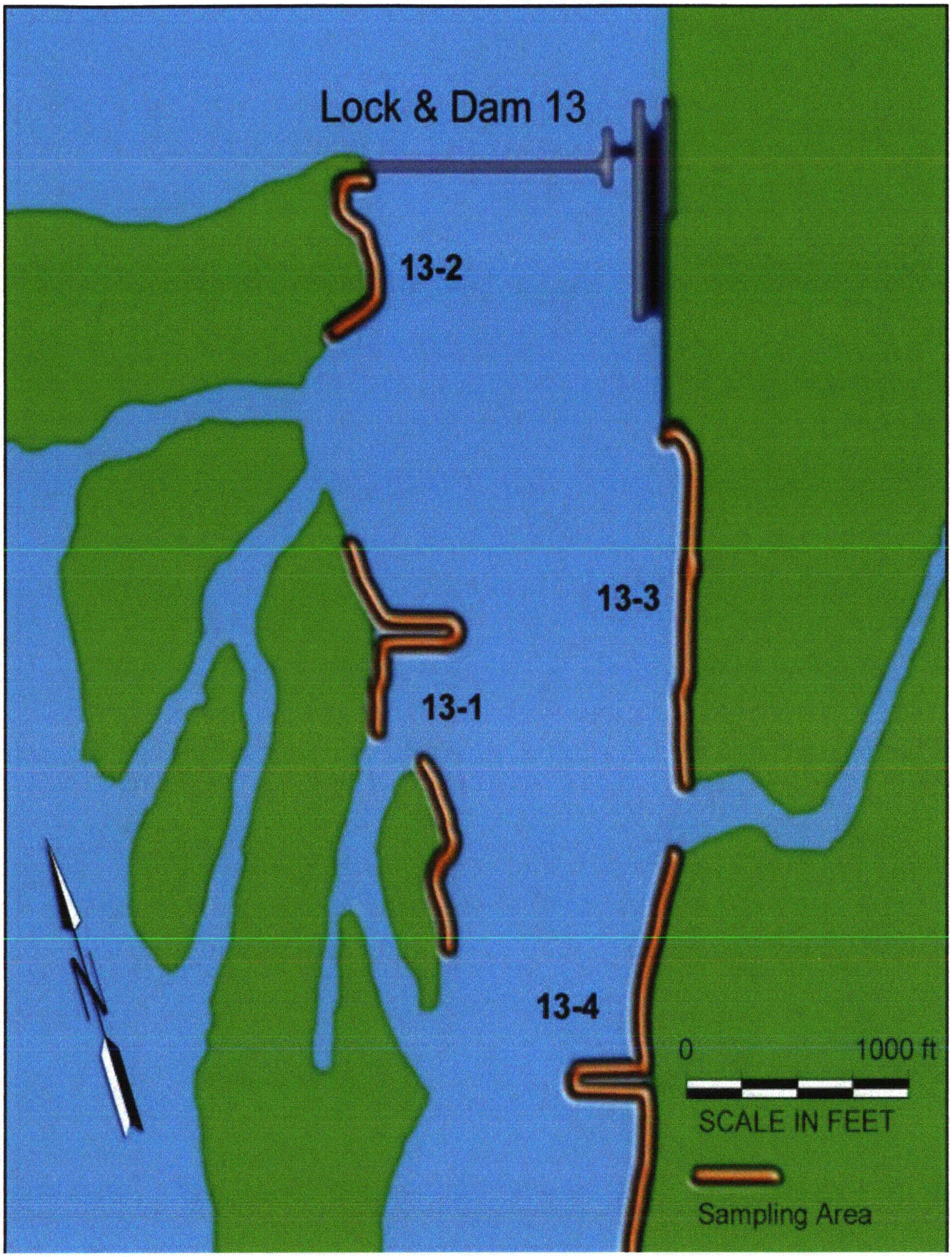


Figure E-6. Electrofishing sampling areas in the tailwater of Lock and Dam 13, Mississippi River

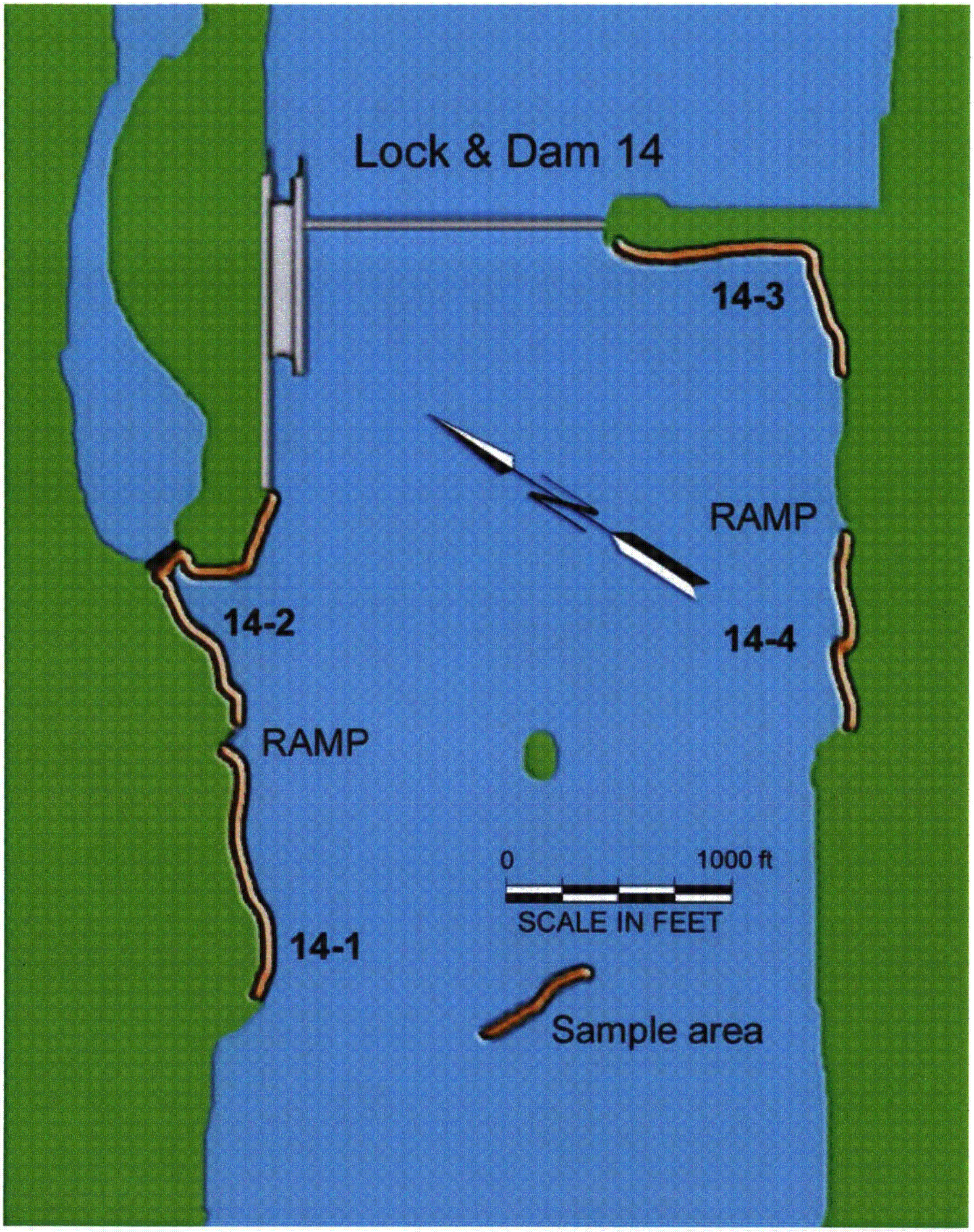


Figure E-7. Electrofishing sampling areas in the tailwater of Lock and Dam 14, Mississippi River