APPENDIX B

Biothermal Assessment:
Prospective Demonstration

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1. INTRODUCTION

1.1 Regulatory Background and Project Objective

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

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

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

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

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

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

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

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

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

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

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

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

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

1.2 Project Background

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

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

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

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

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

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

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

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

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

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

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

1.3 General Approach to the Biothermal Modeling

1.3.1 Selection of Species to be Evaluated

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

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

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

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

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

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

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

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

1.3.2 Selection of Plant and River Conditions Evaluated

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

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

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

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

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

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

2. BIOTHERMAL ASSESSMENT METHODS

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

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

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

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

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

2.1 Basic Steps to the Biothermal Modeling Process

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

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

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

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

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

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

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

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

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

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

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

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

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

3. RESULTS OF THE BIOTHERMAL ASSESSMENT

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

3.1 Growth

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

3.1.1 Process of Determining Potential Growth Effects

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

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

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

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

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

3.1.2 Findings of the Growth Assessment

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

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

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

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

3.2 Thermal Avoidance and Habitat Loss

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

3.2.1 Process of Determining Potential for Thermal Avoidance

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

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

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

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

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

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

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

3.2.2 Findings of the Thermal Avoidance Assessment

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

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

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

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

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

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

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

3.3 Potential for Chronic Mortality from Prolonged Exposure

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

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

3.3.1 Process of Determining Potential Chronic Mortality

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

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

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

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

3.3.2 Findings of the Chronic Mortality Assessment

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

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

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

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

4. CONCLUSIONS OF THE BIOTHERMAL ASSESSMENT

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

5. TABLES

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

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

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

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

Notes:

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

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

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

Notes:

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

[2] See Attachment 1.

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

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

Notes:

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

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

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

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

Notes:

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

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

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

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

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

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

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

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

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

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

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

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

Table 8. Summary of Predicted Area-weighted Chronic Mortality

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

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

6. FIGURES

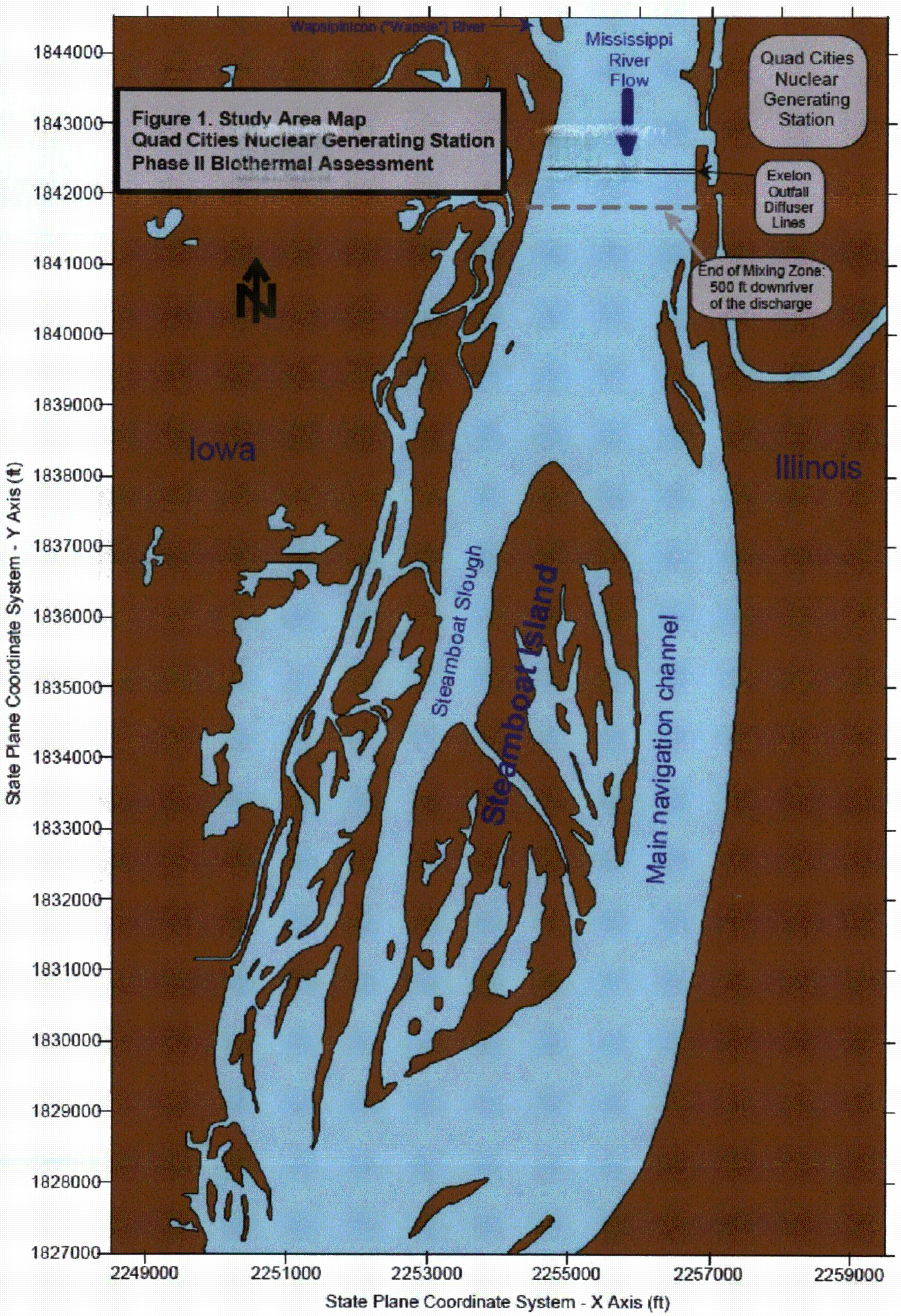
Figure 1. Study Area Map
Quad Cities Nuclear Generating Station
Phase II Biothermal Assessment
Wapsipinicon ("Wapsie") River
Mississippi River Flow
Quad Cities Nuclear Generating Station
Exelon Outfall Diffuser Lines
End of Mixing Zone: 500 ft downriver of the discharge
Iowa
Illinois
Steamboat Slough
Steamboat Island
Main navigation channel
State Plane Coordinate System - Y Axis (ft)
State Plane Coordinate System - X Axis (ft)
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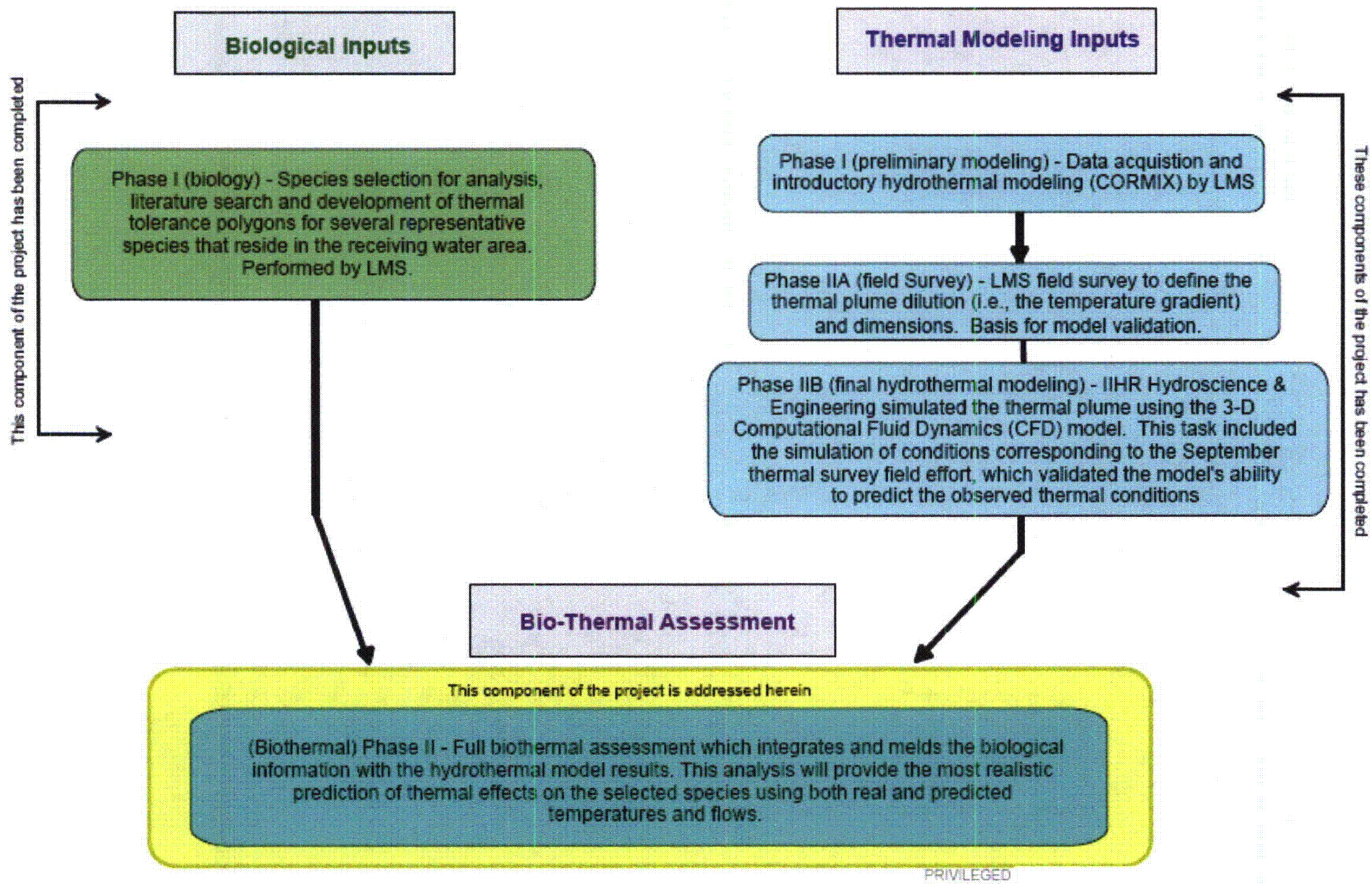
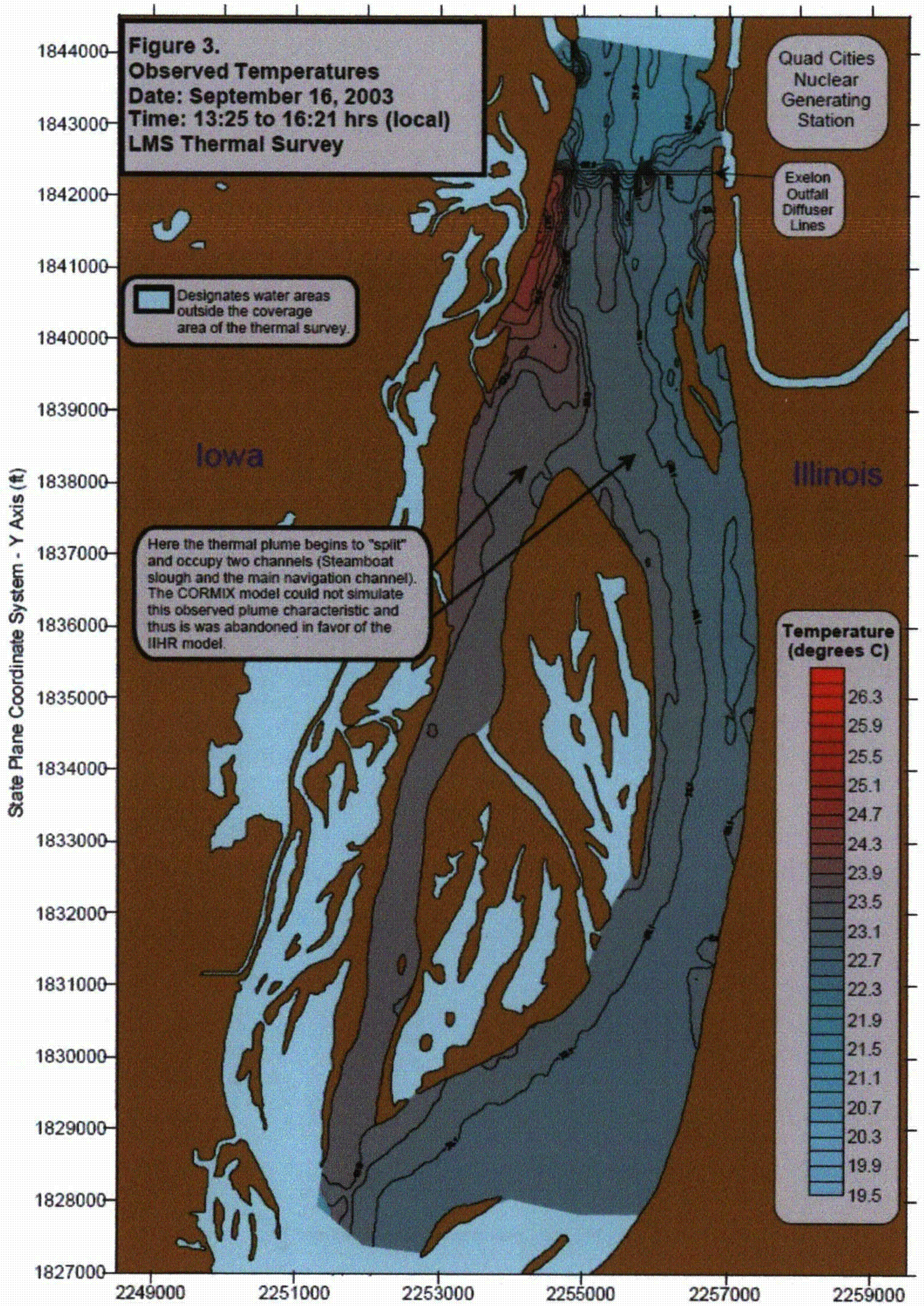
Figure 2. Quad Cities Generating Station - Overview of Project Tasks
Biothermal Assessment of the Thermal Plume's Effect in the receiving waters of the Mississippi River





Source: LMS Thermal Survey Report

Figure 4. Temperature Tolerance Polygon for Largemouth Bass

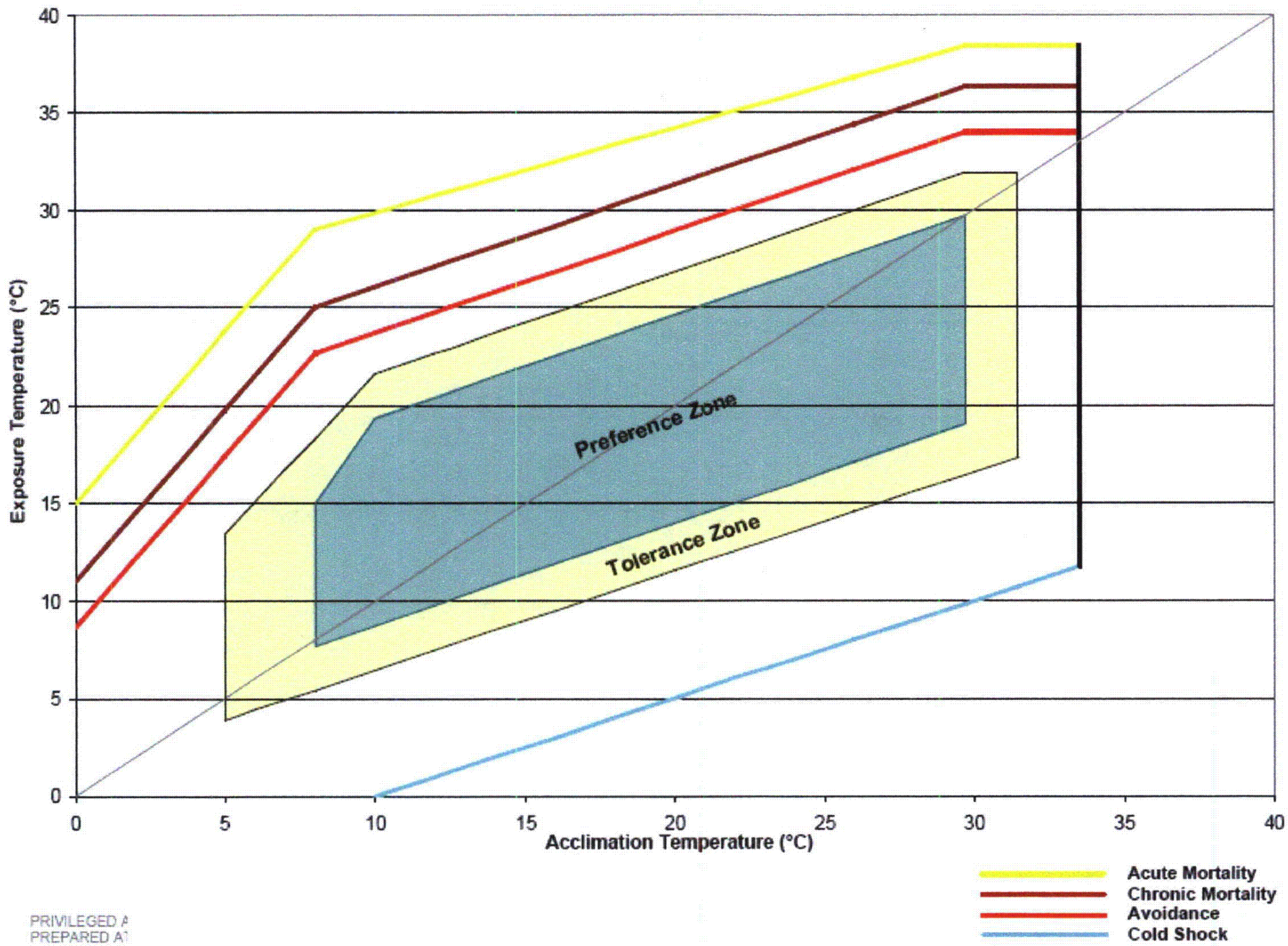


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Figure 5. Temperature Tolerance Polygon for Walleye

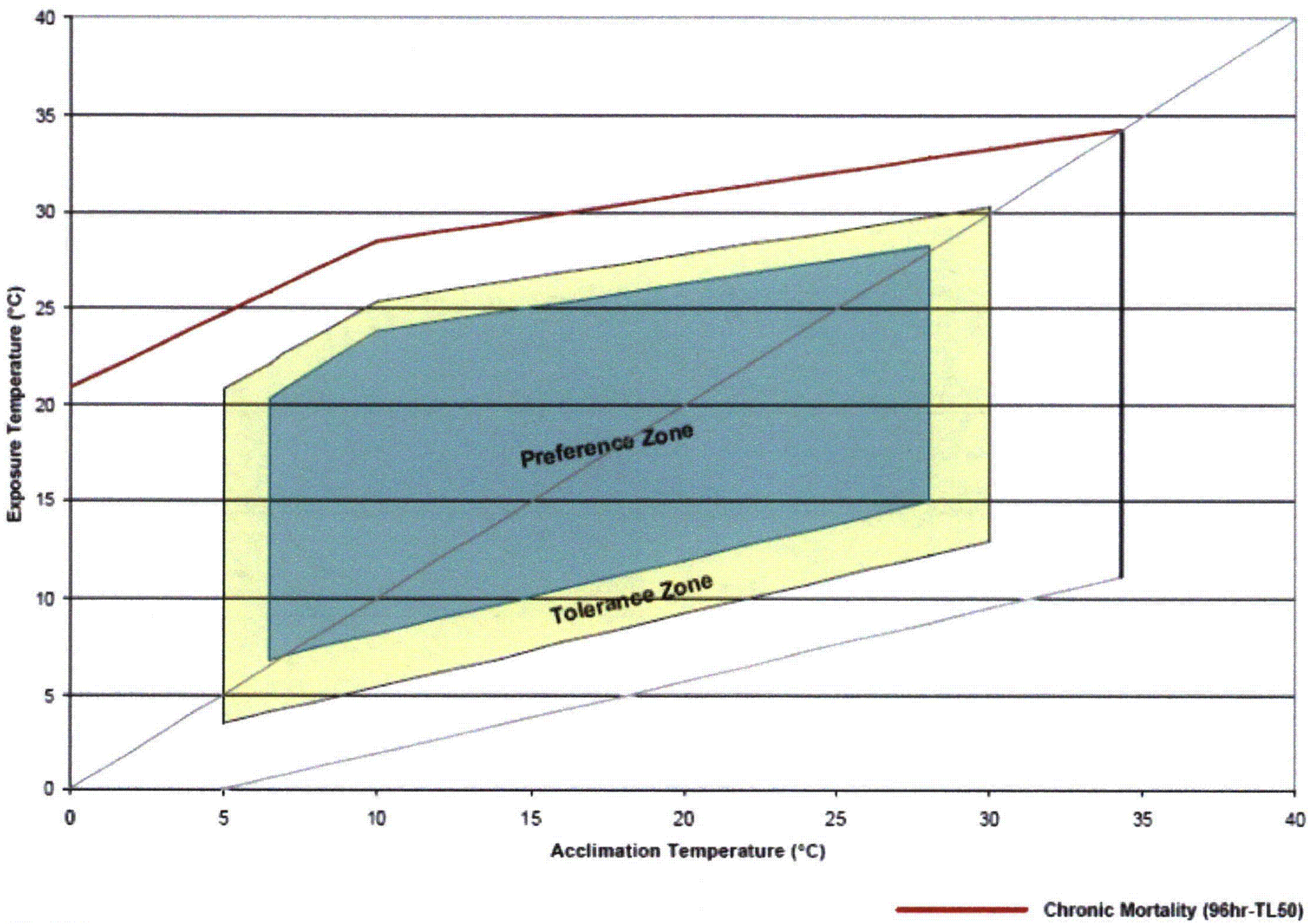

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Figure 6. Temperature Tolerance Polygon for Channel Catfish

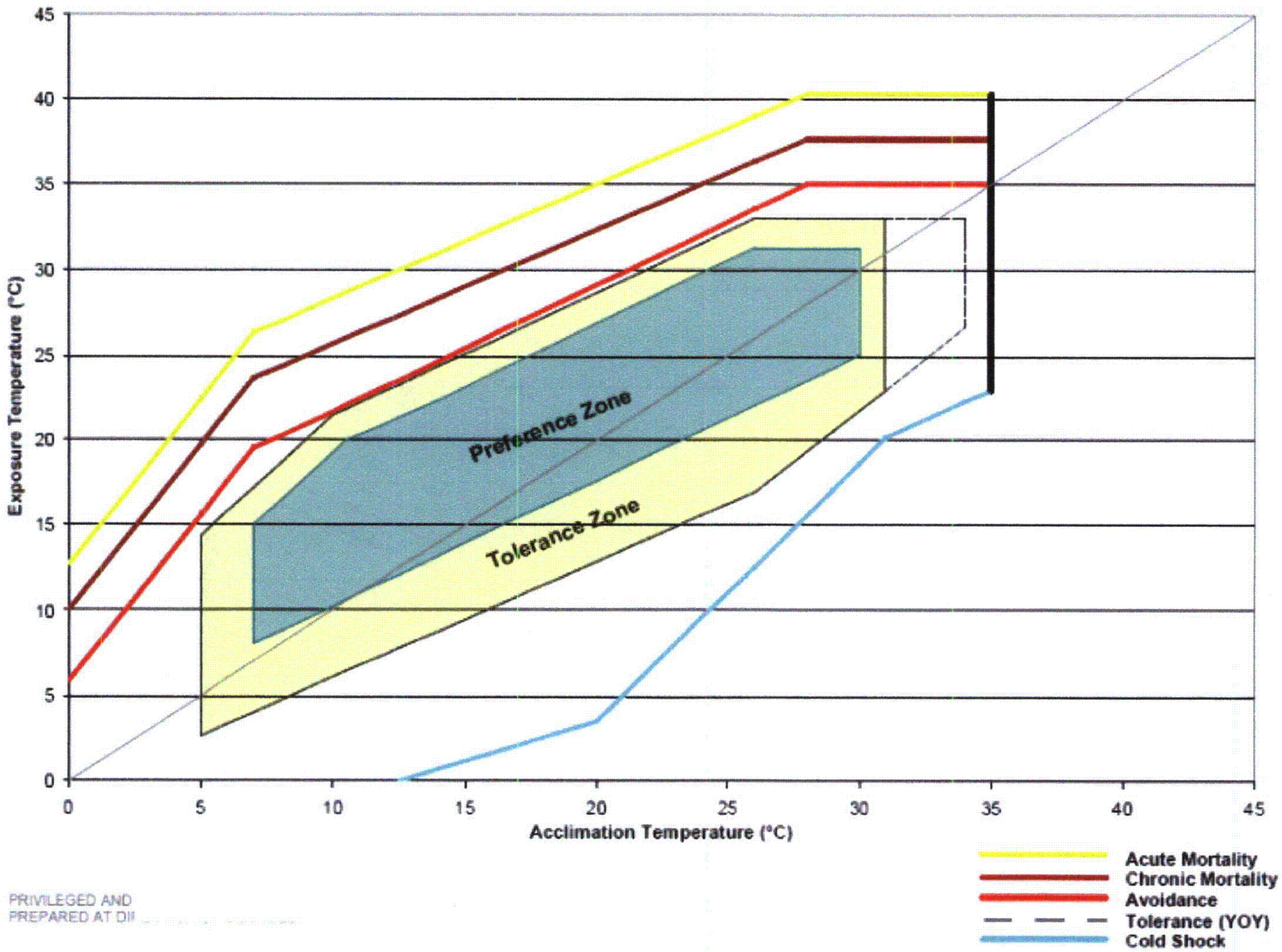

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Figure 7. Temperature Tolerance Polygon for Spotfin Shiner

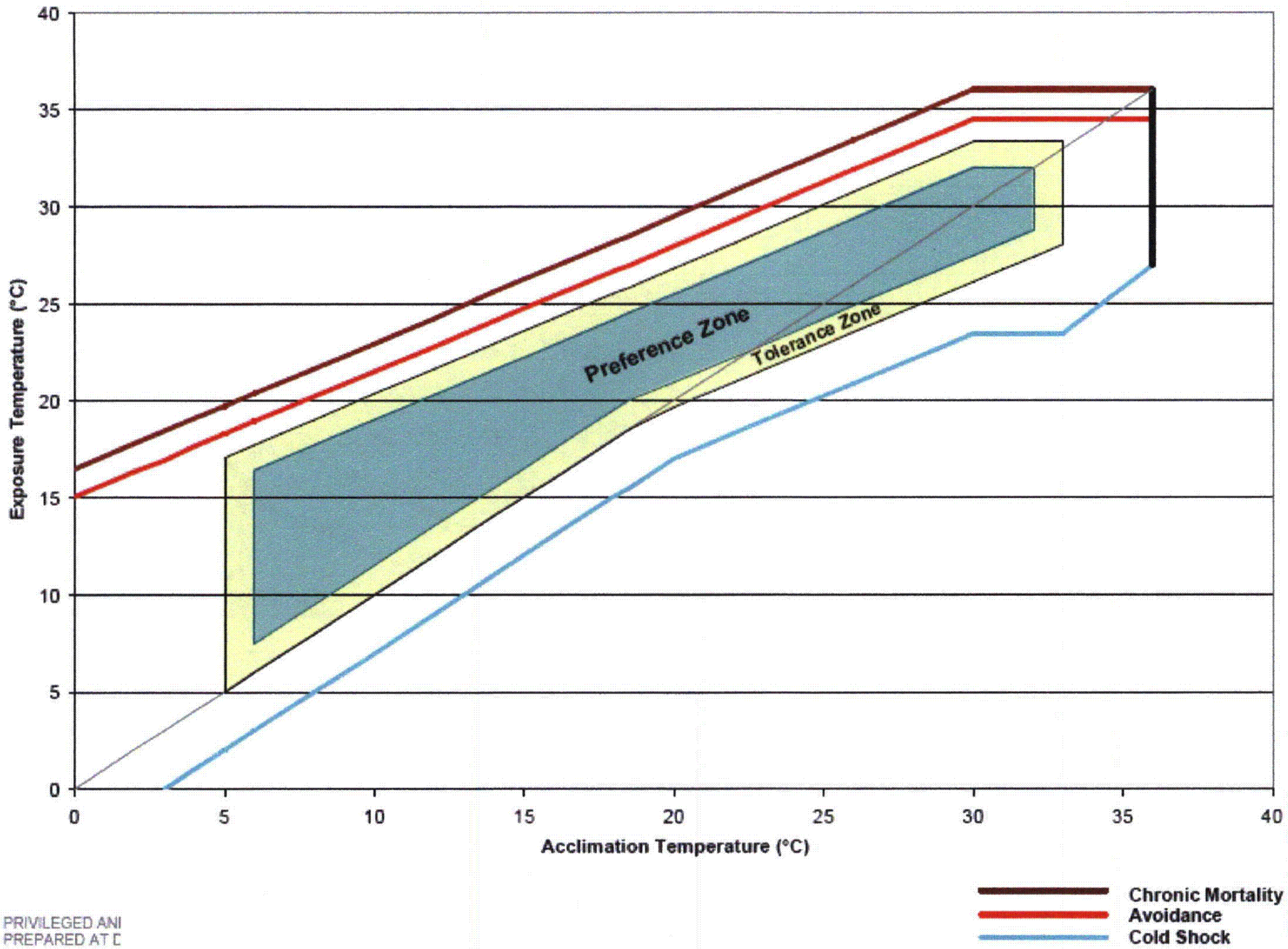

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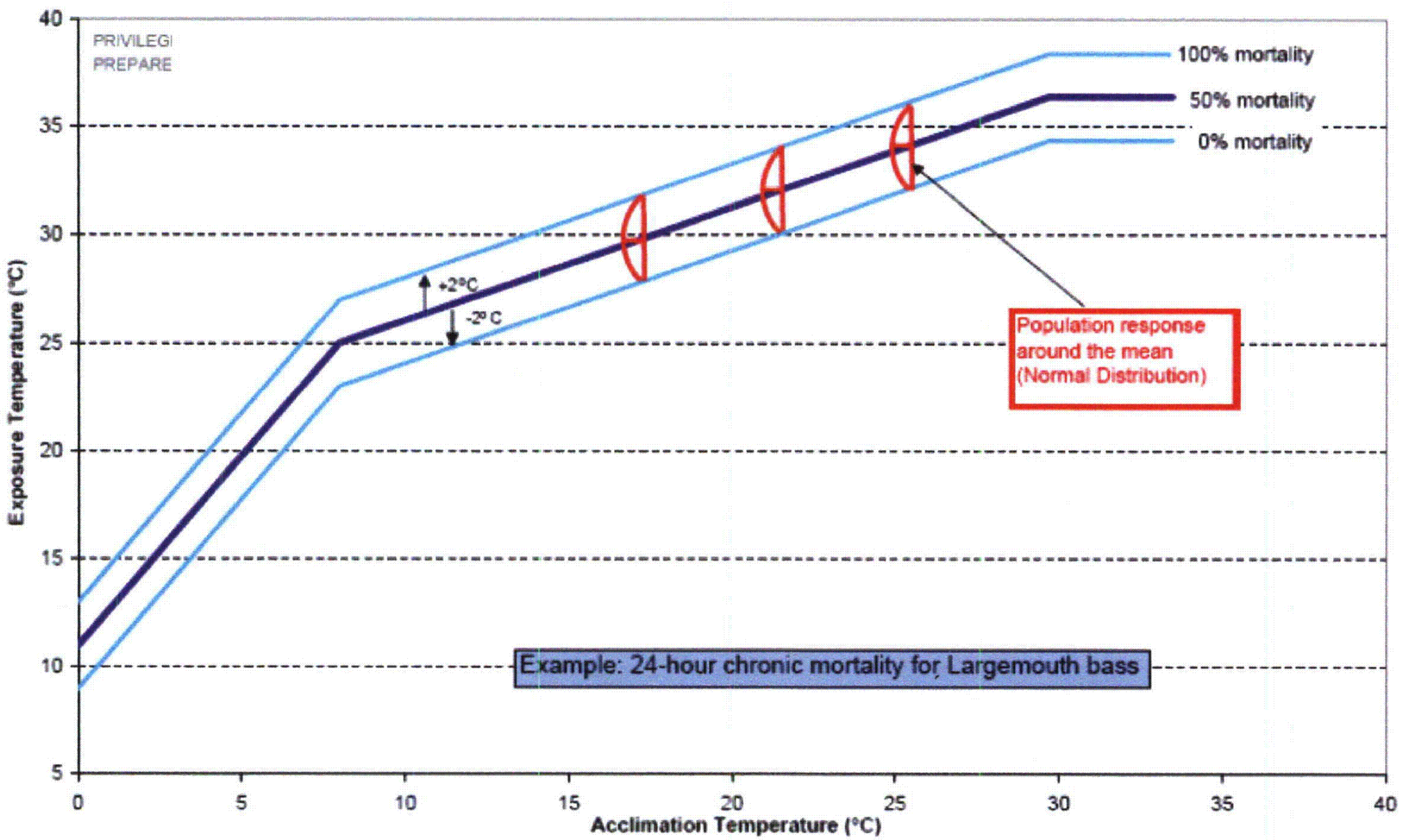
Figure 8. Range of Responses Modeled
(2°C above and below the mean)



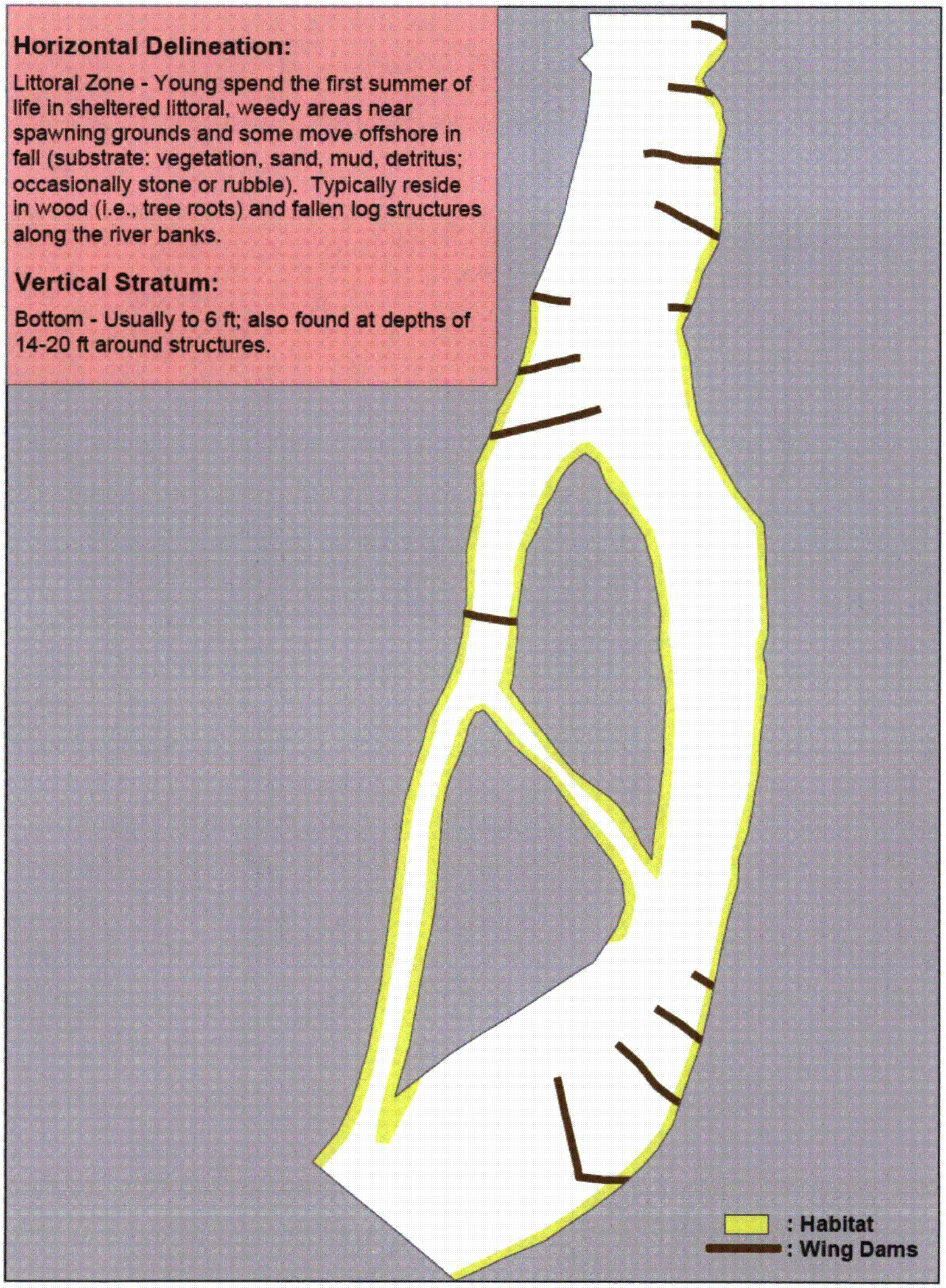


Figure 9A. Young-of-the-Year (YOY) Largemouth Bass habitat in the project study area (downriver of the Quad Cities Nuclear Generating Station's Thermal Discharge)

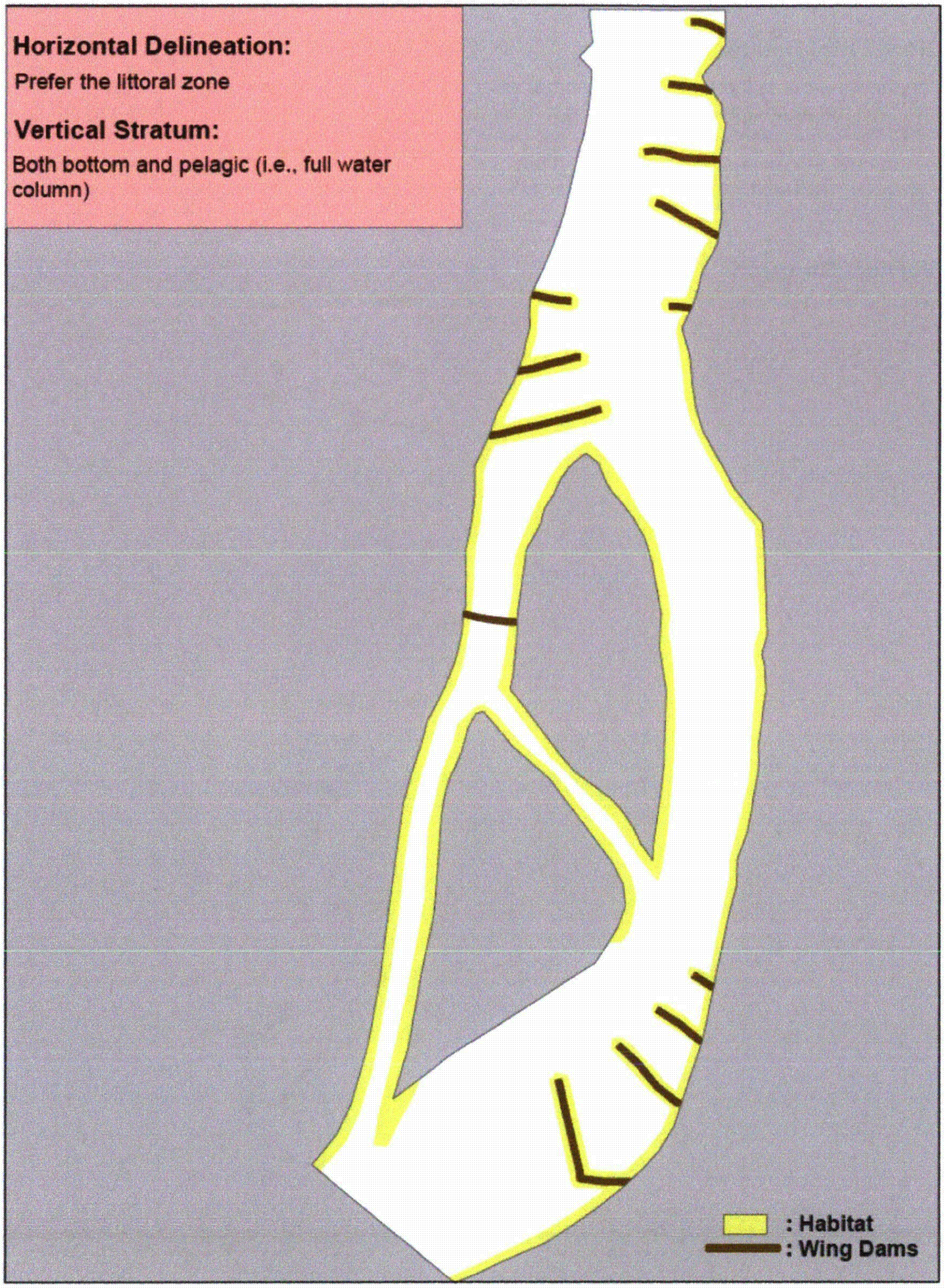


Figure 9B. Juveniles and adults Largemouth Bass habitat in the project study area (downriver of the Quad Cities Nuclear Generating Station's Thermal Discharge)

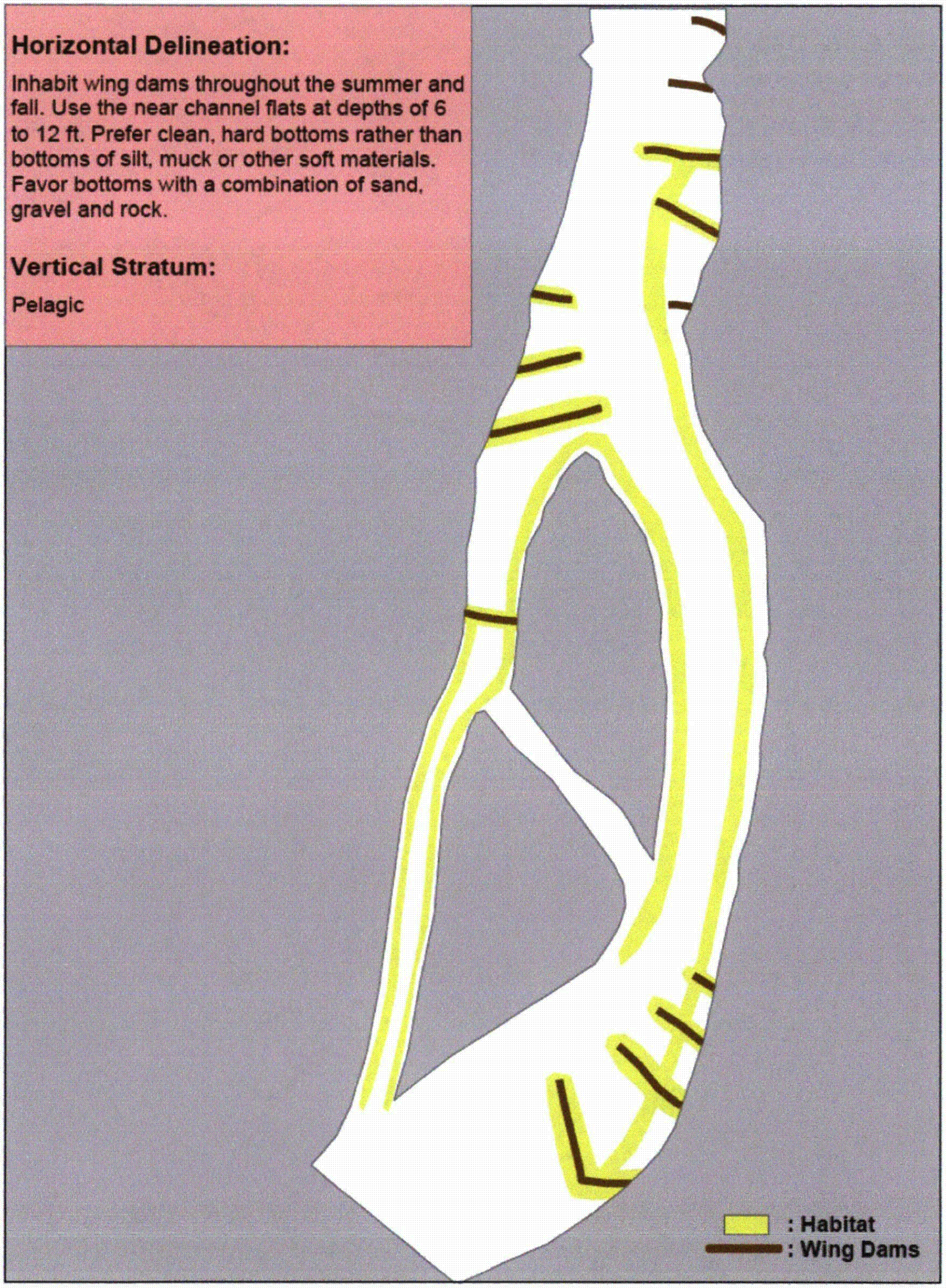


Figure 10. Juveniles and adults Walleye habitat in the project study area (downriver of the Quad Cities Nuclear Generating Station's Thermal Discharge)

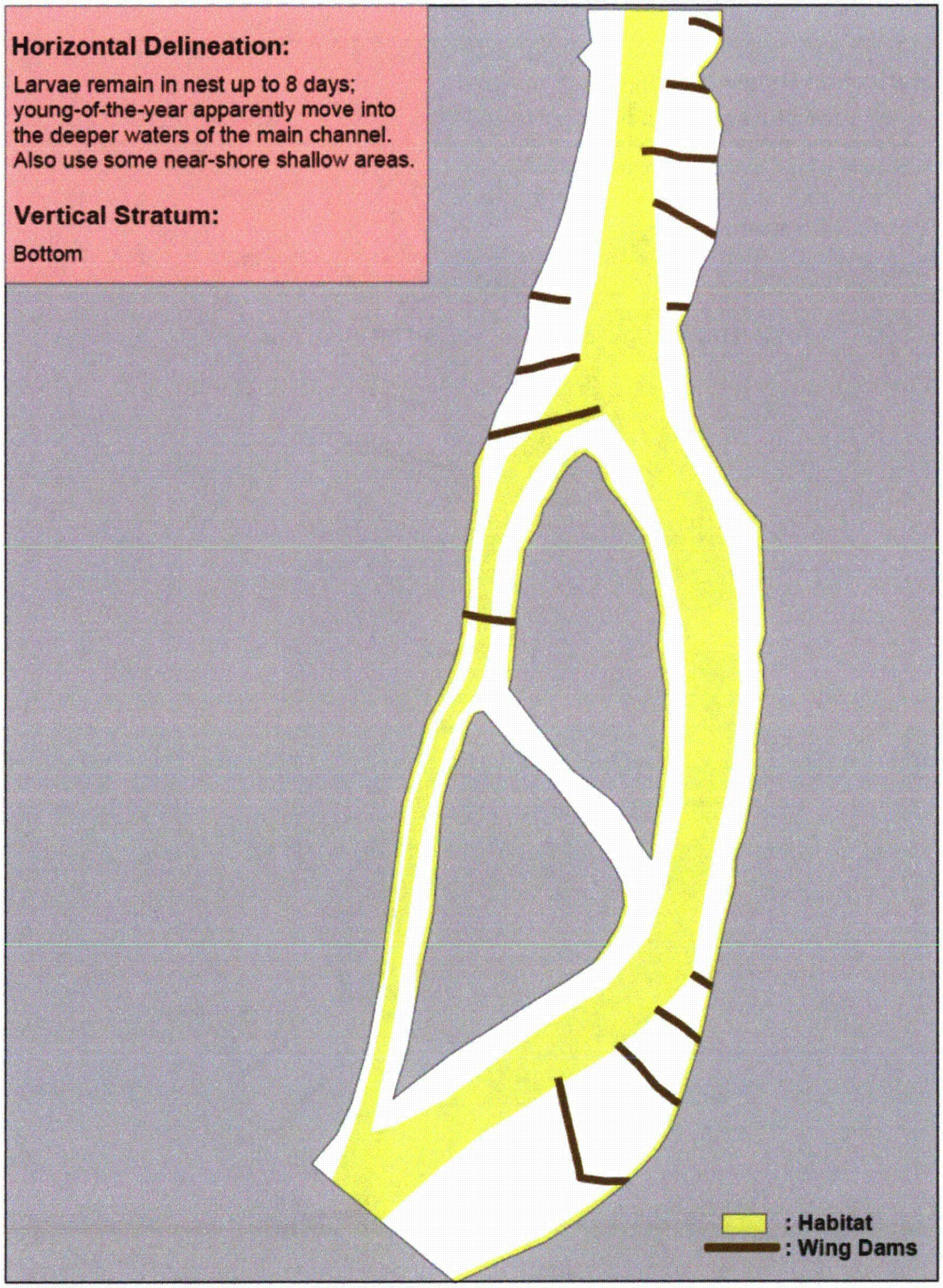


Figure 11A. Young-of-the-Year (YOY) Channel Catfish habitat in the project study area (downriver of the Quad Cities Nuclear Generating Station's Thermal Discharge)

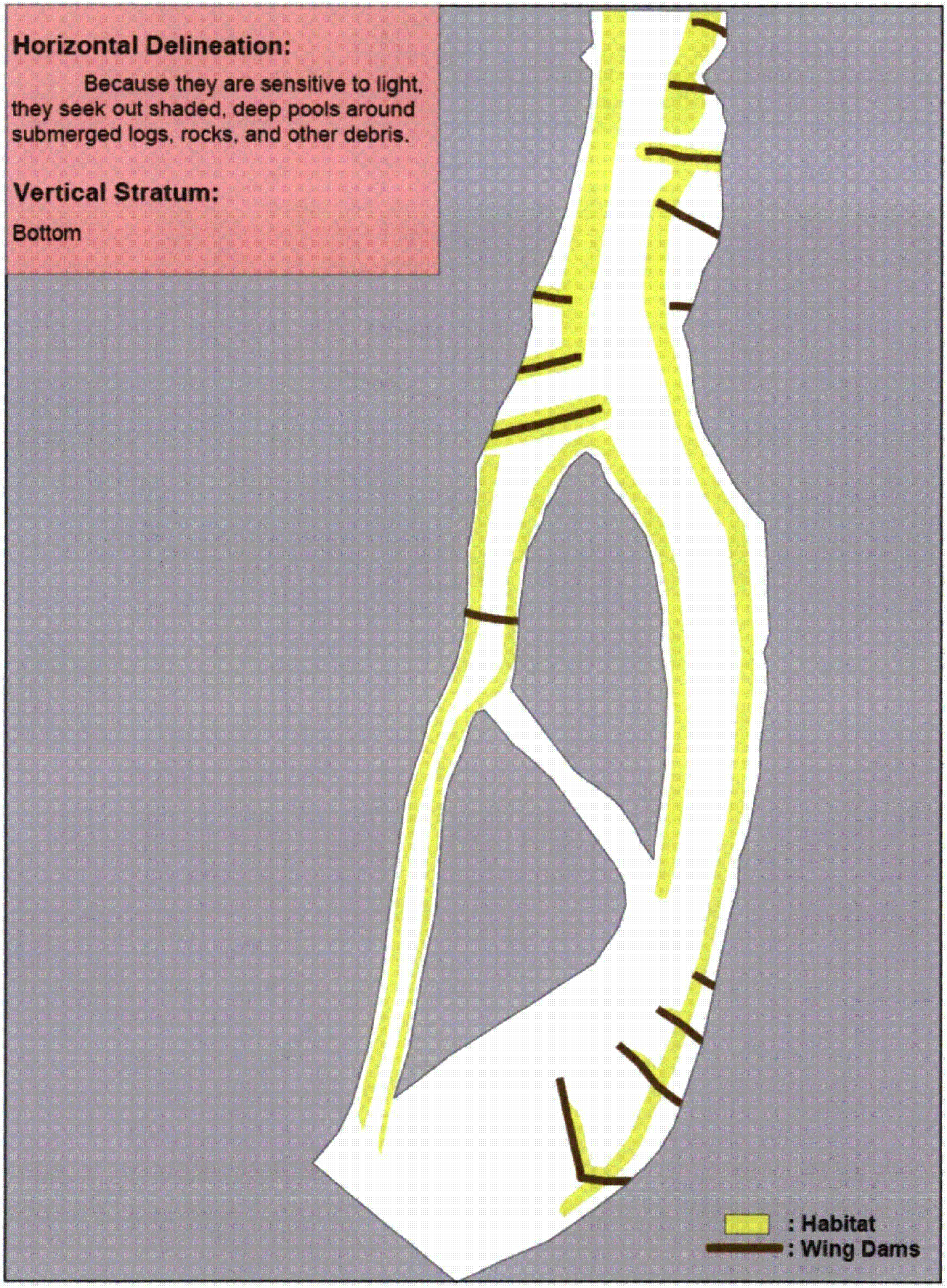


Figure 11B. Juveniles and adults Channel Catfish habitat in the project study area (downriver of the Quad Cities Nuclear Generating Station's Thermal Discharge)

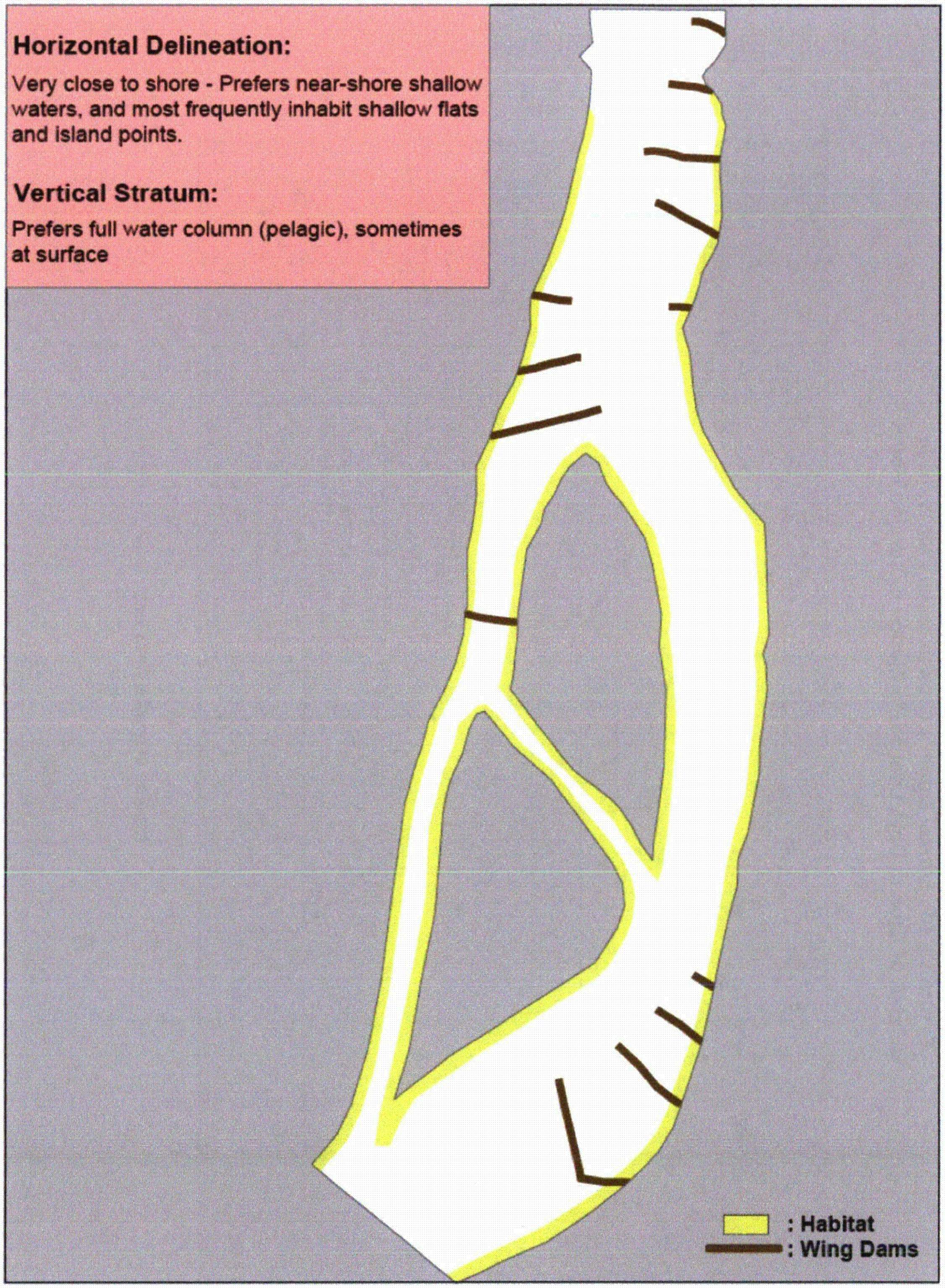


Figure 12. Juveniles and adults Spotfin Shiner habitat in the project study area (downriver of the Quad Cities Nuclear Generating Station's Thermal Discharge)

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

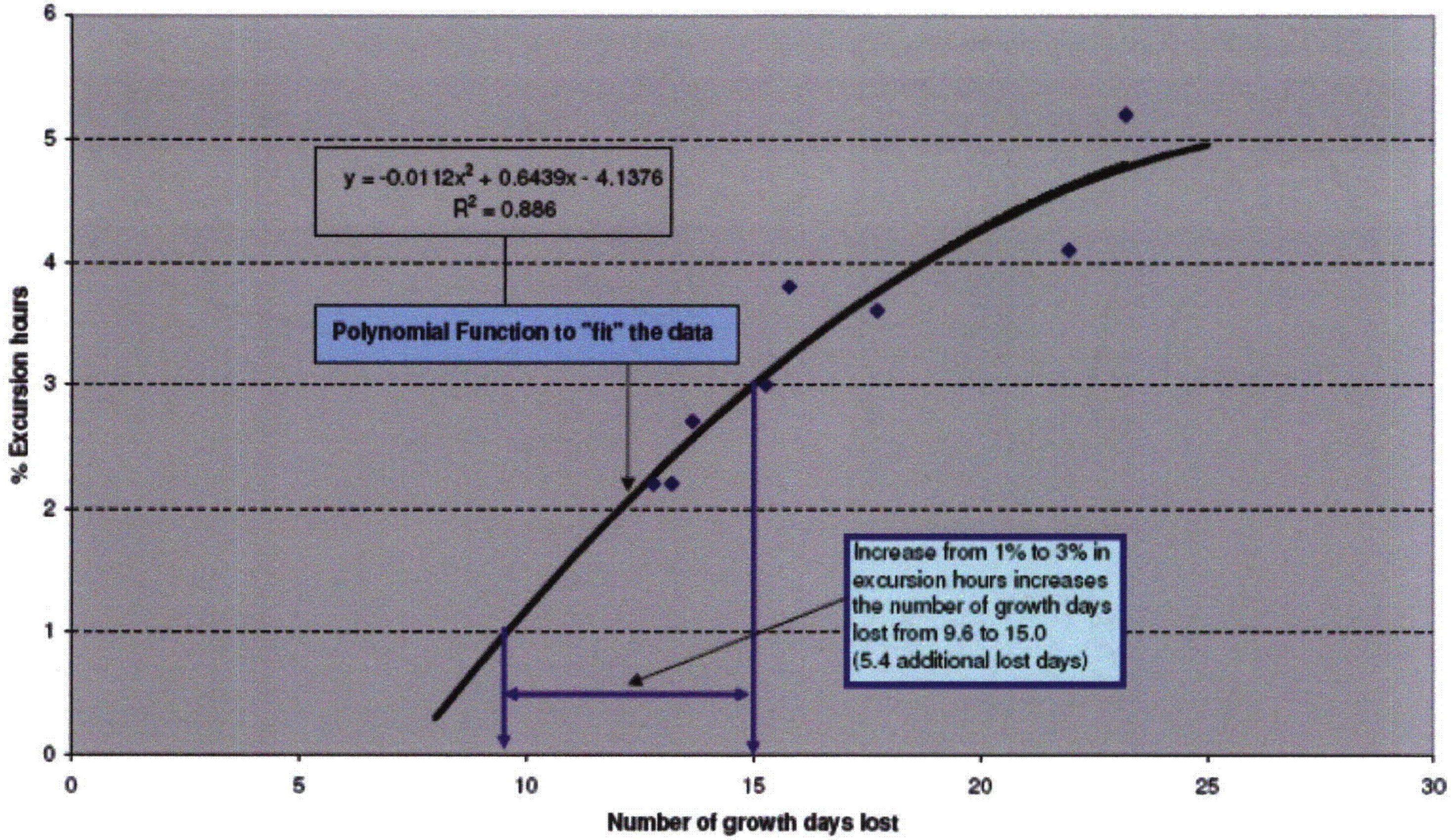


Figure 14. Daily Time-Series of Percent Habitat Avioded
Largemouth Bass - Adults and Juveniles

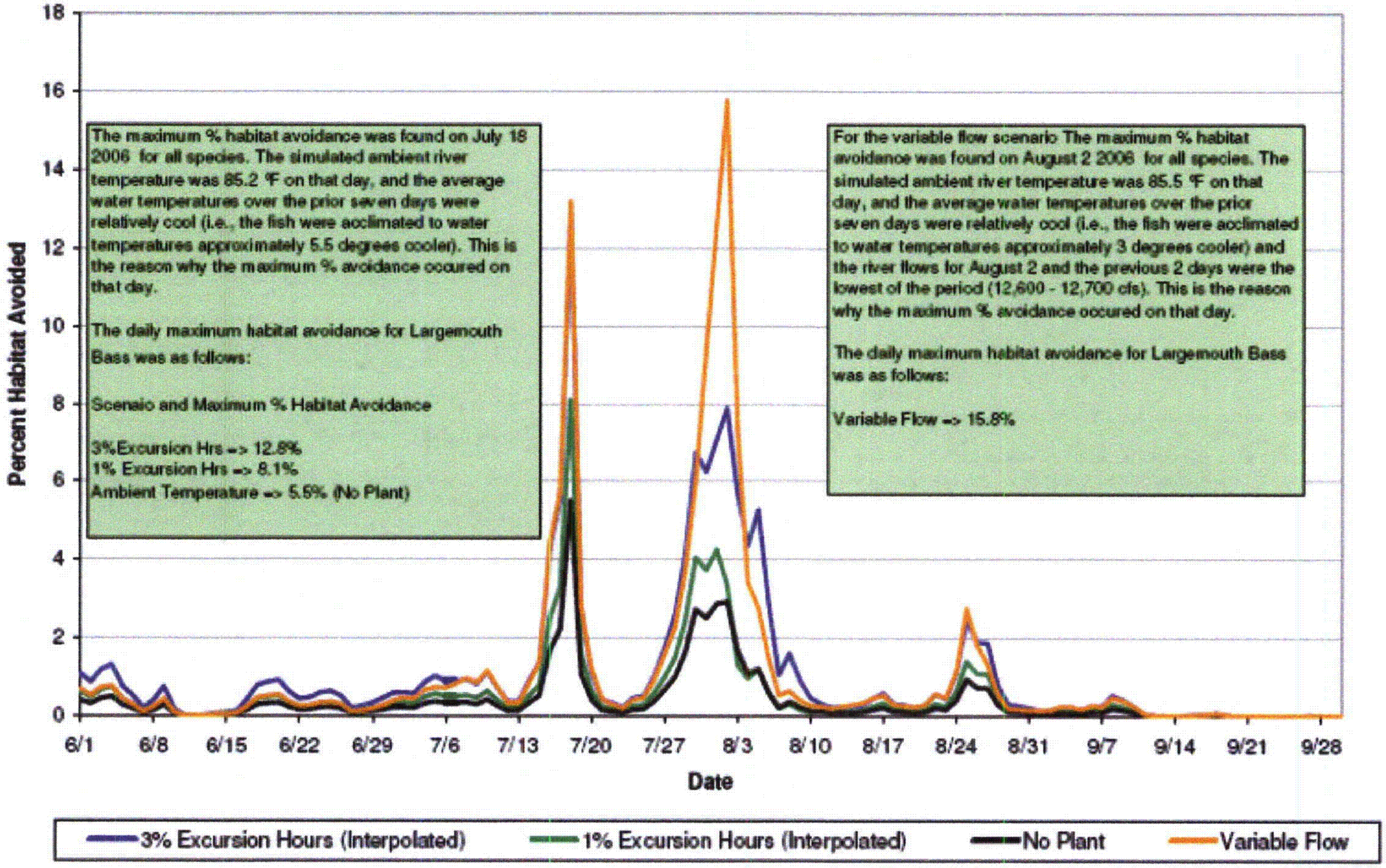


Figure 15. Daily Time-Series of Percent Habitat Avioded
Spotfin Shiner - Adults and Juveniles

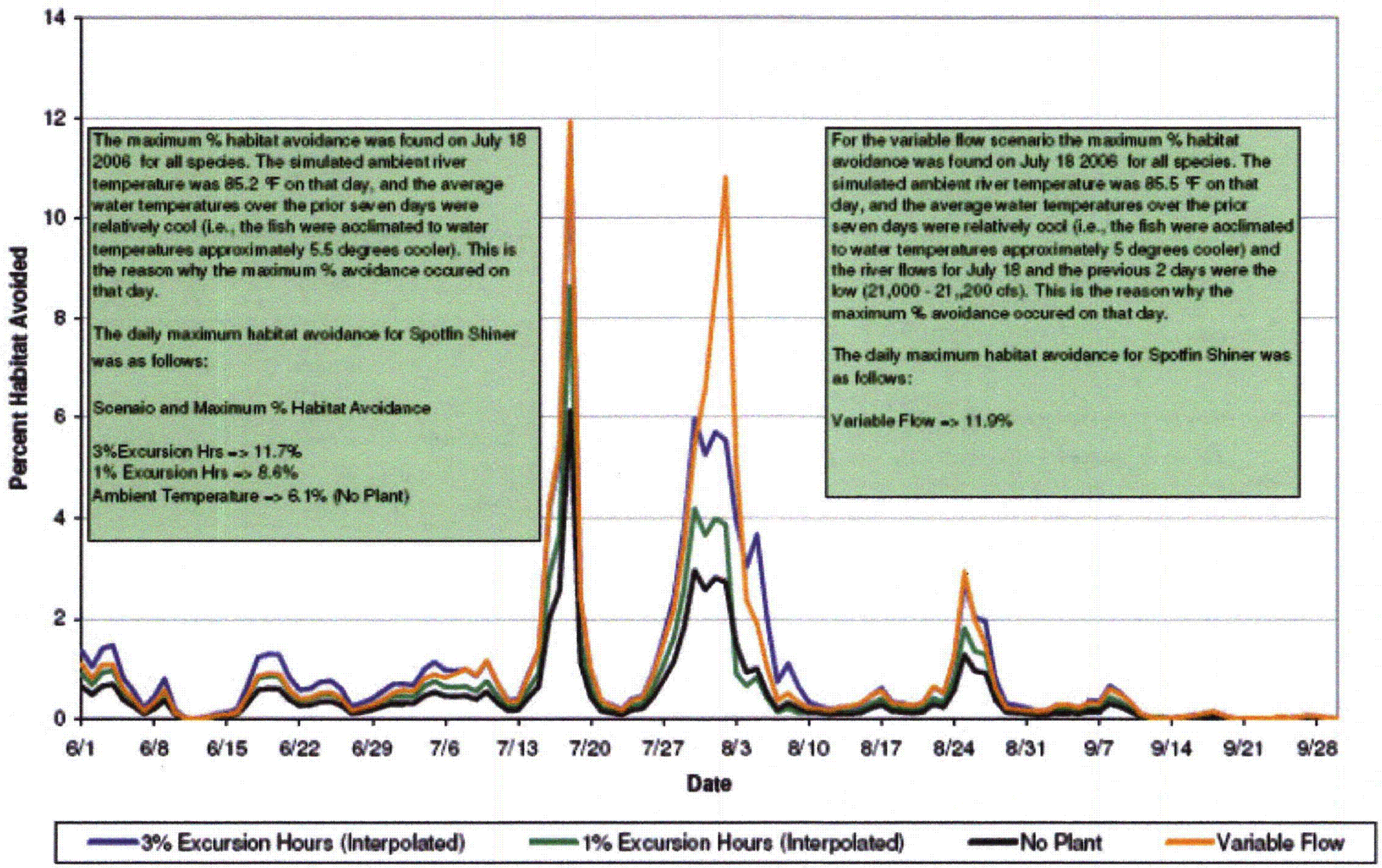
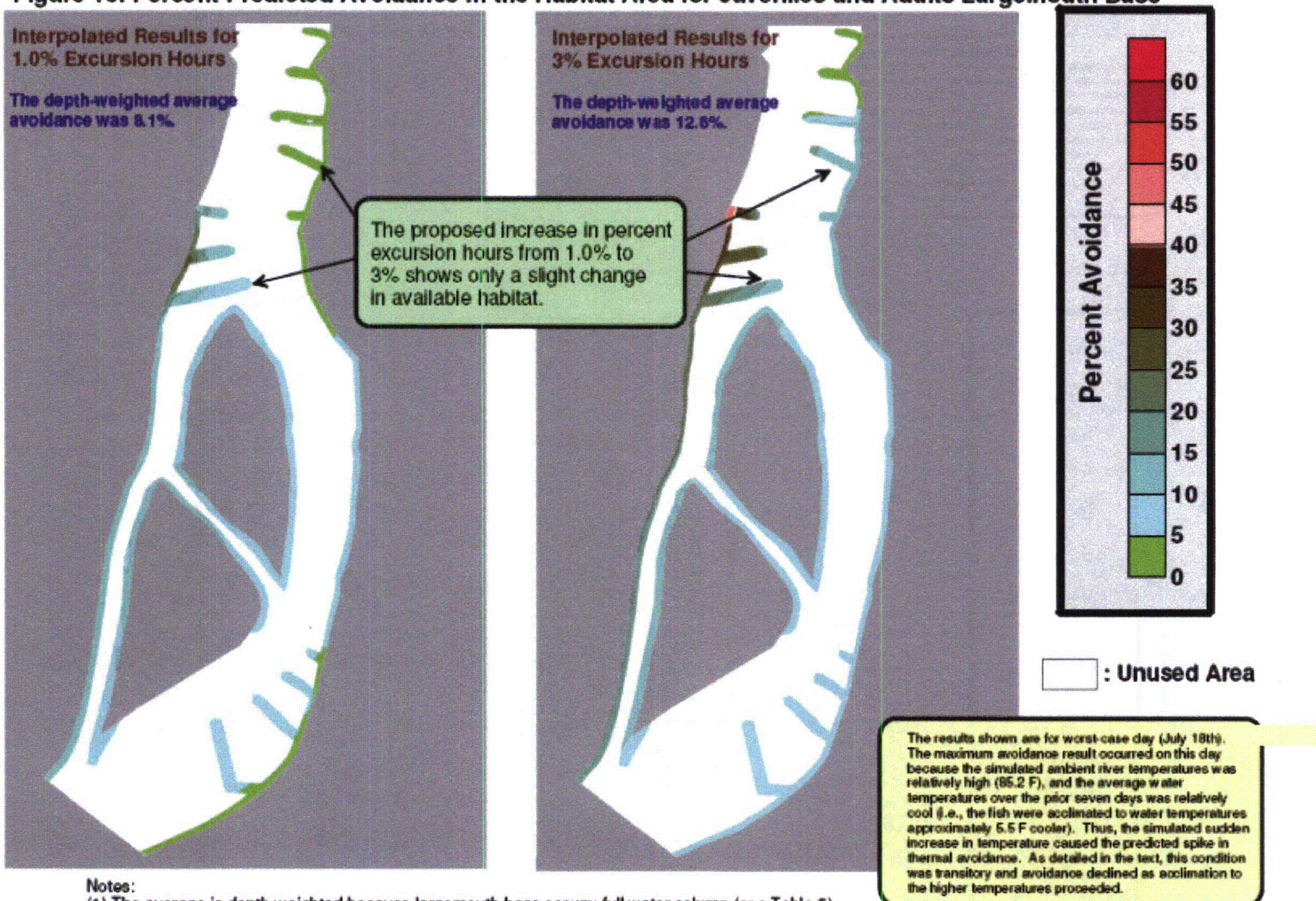
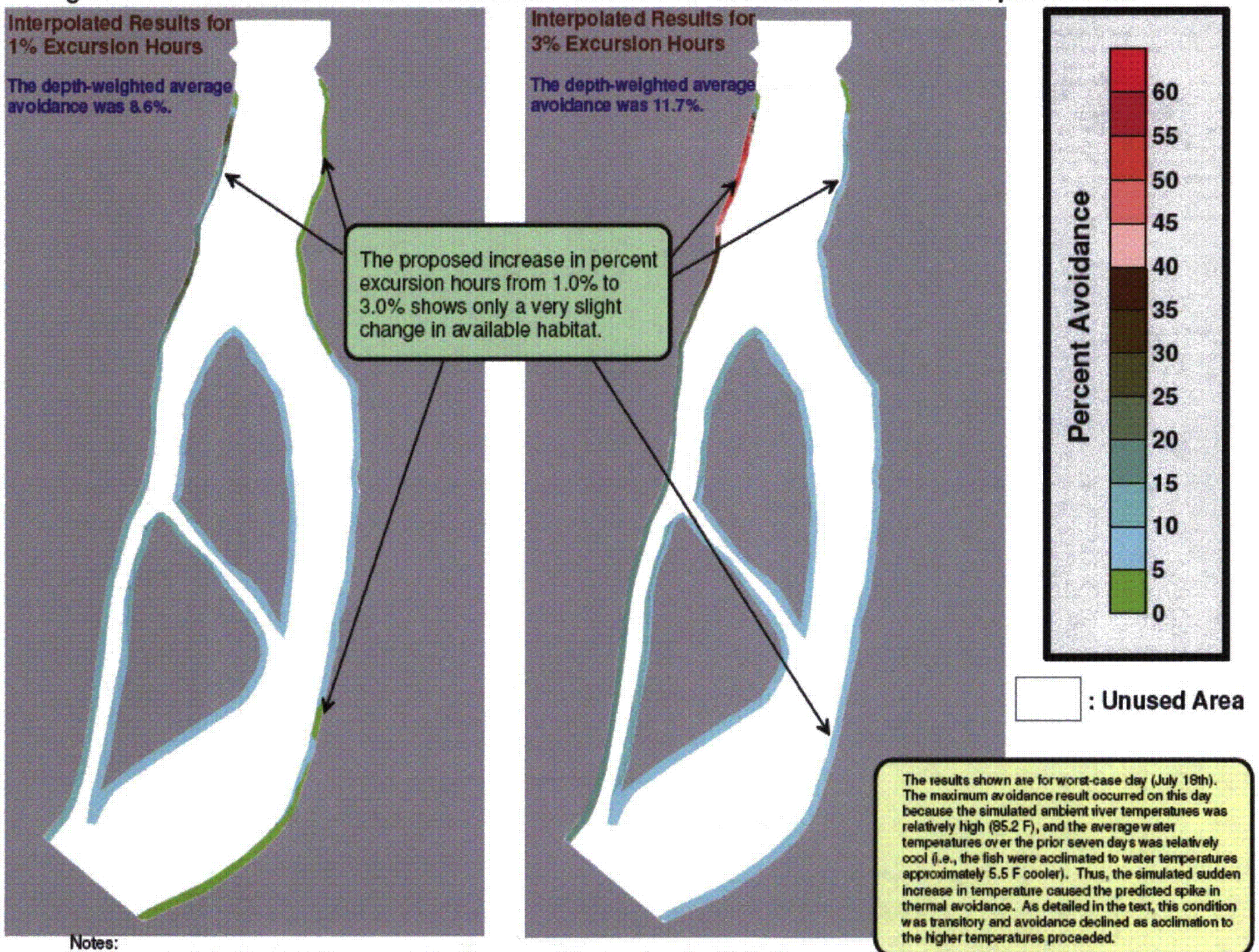


Figure 16: Percent Predicted Avoidance in the Habitat Area for Juveniles and Adults Largemouth Bass



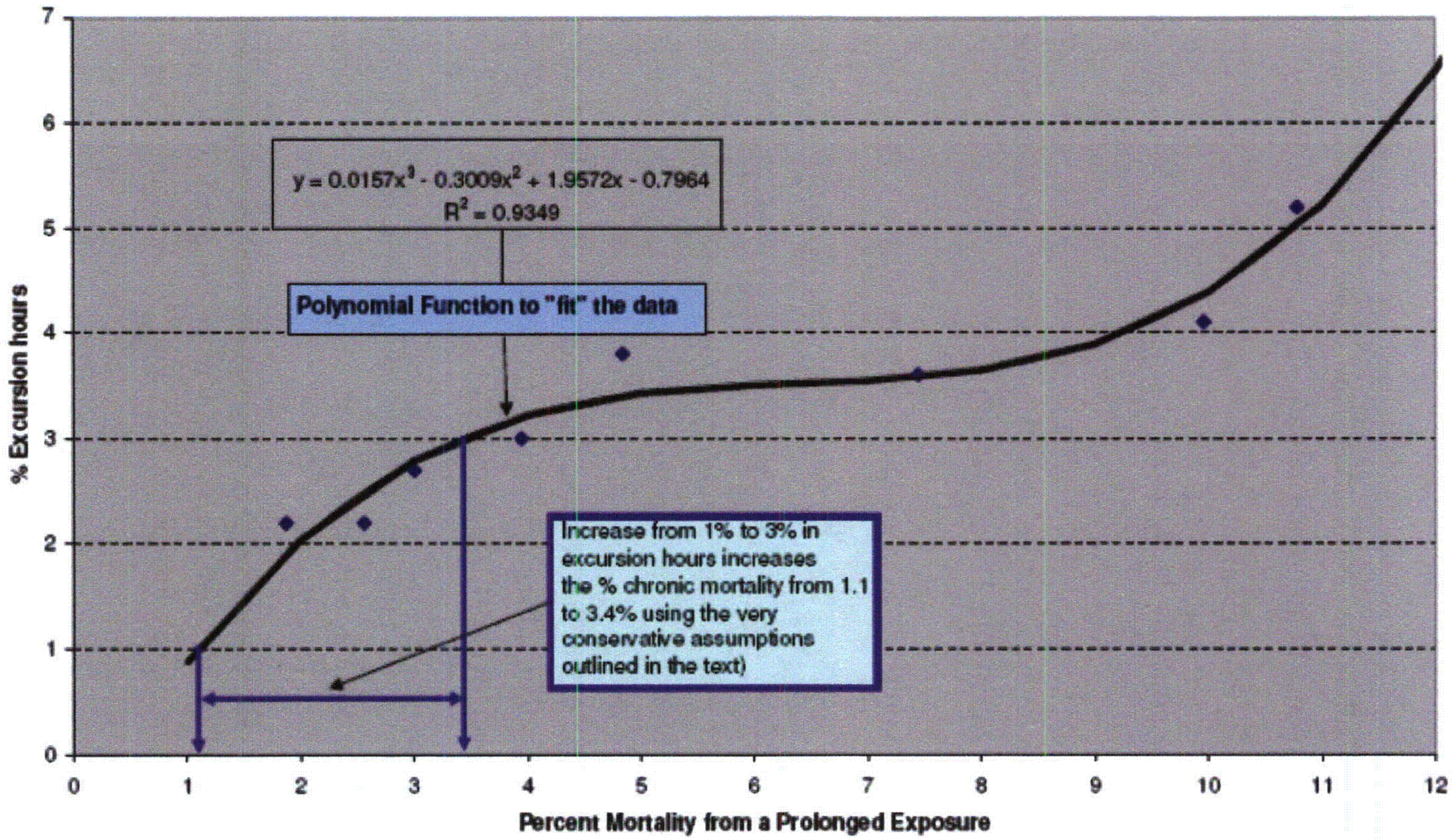
Notes:
(1) The average is depth-weighted because largemouth bass occupy full water column (see Table 5).
(2) The depth-weighted avoidance for largemouth bass under ambient conditions (i.e., no thermal disharge) was 5.5%

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



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

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



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ATTACHMENT 1

Background on the Selection of the Model Input Parameters

Attachment 1
Biothermal Assessment Report

Background on the Selection of the Model Input Parameters

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Note: The highlighted cells indicate a hypothetical permit violation.

[1] permit limit = 5°F

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

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

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

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

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

Notes:

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

Figure A1-1. Cumulative Frequency <= Flow

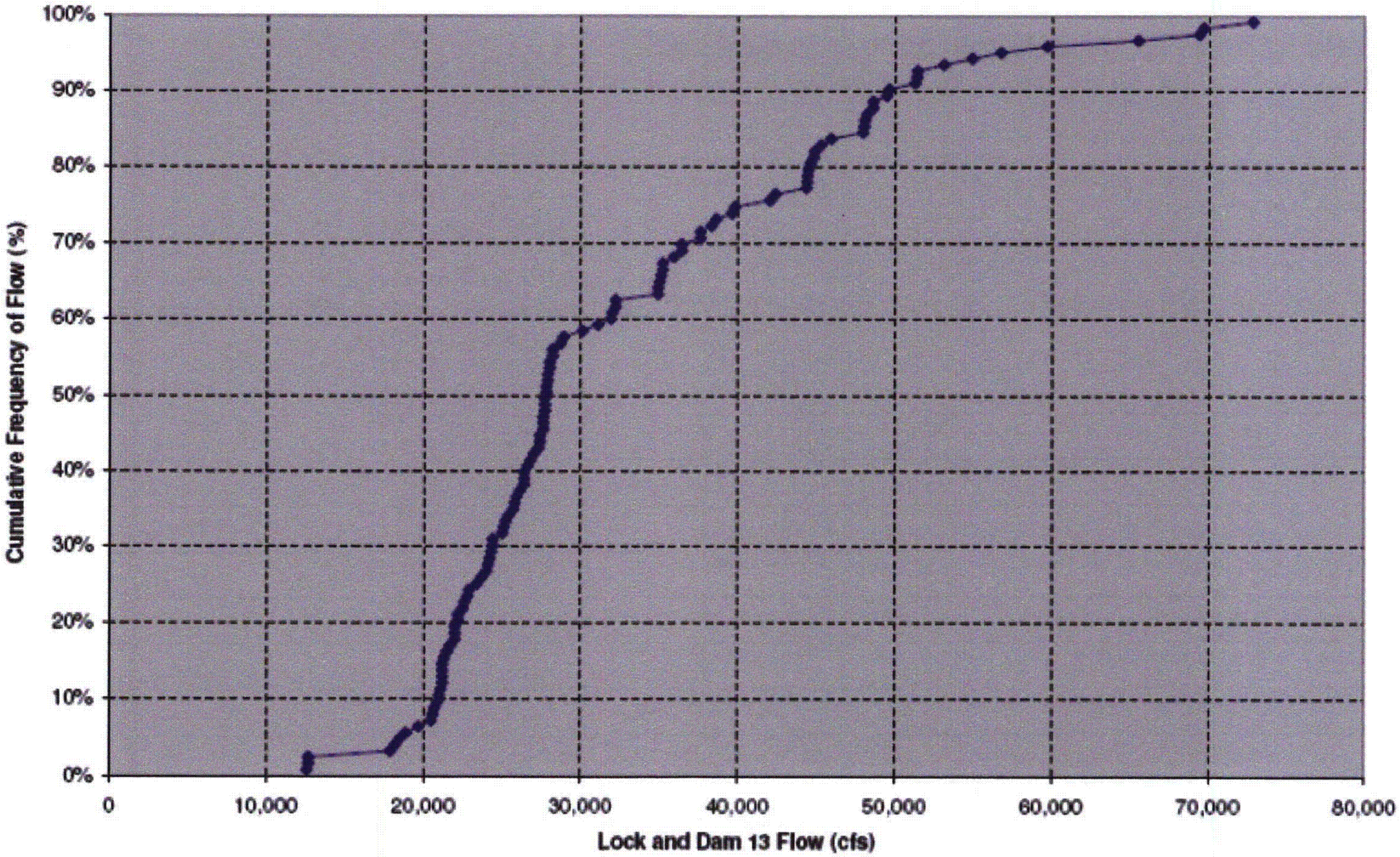


**Figure A1-2. Ambient River Water Temperatures for the Bio-thermal Assessment
2006 Observed Data at Lock and Dam 13 (provided by the USACE)**

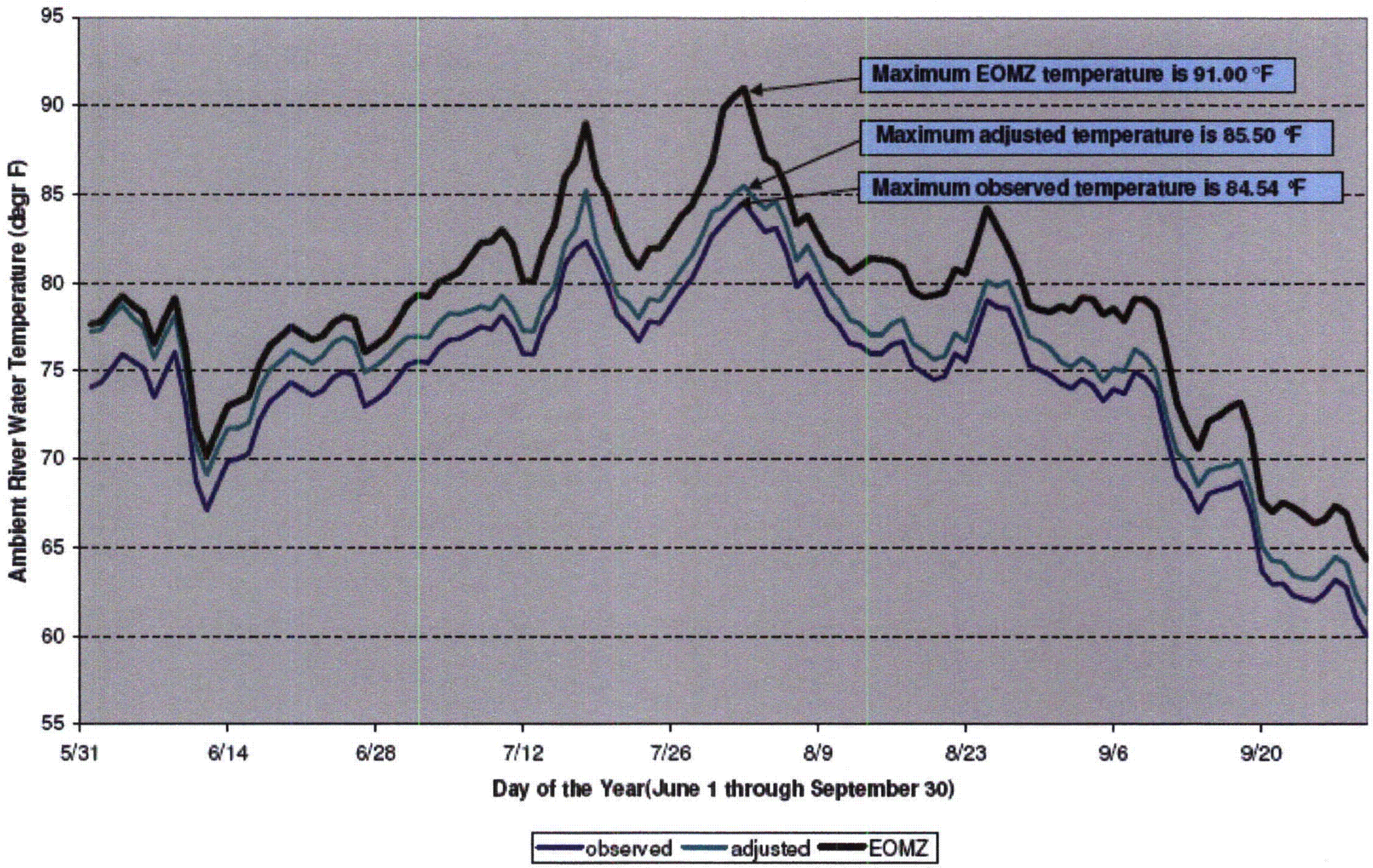
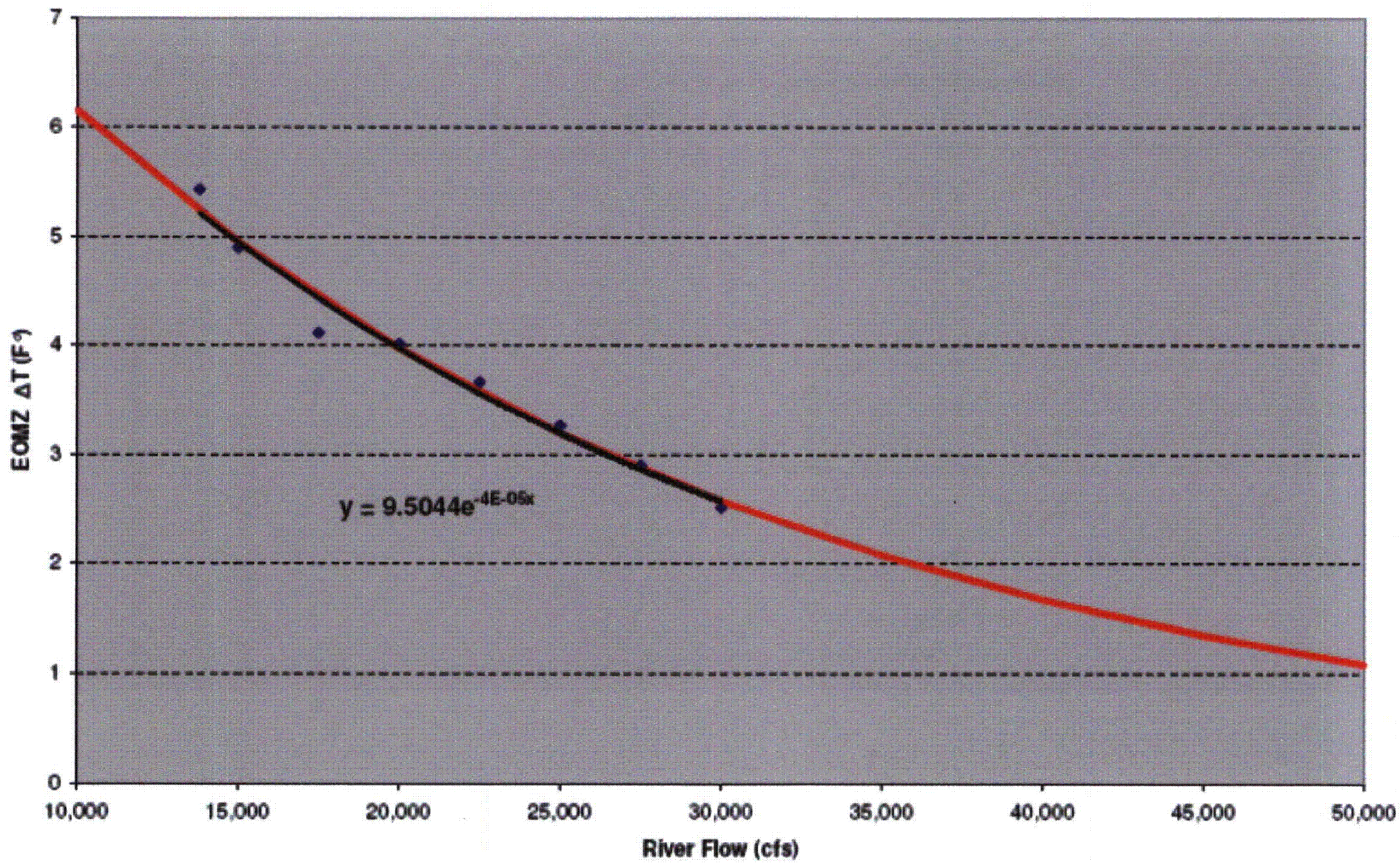


Figure A1-3. EOMZ ΔT vs River Flow



ATTACHMENT 2

Development of Thermal Tolerance Polygons

Attachment 2

Biothermal Assessment Report

Development of Thermal Tolerance Polygons

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

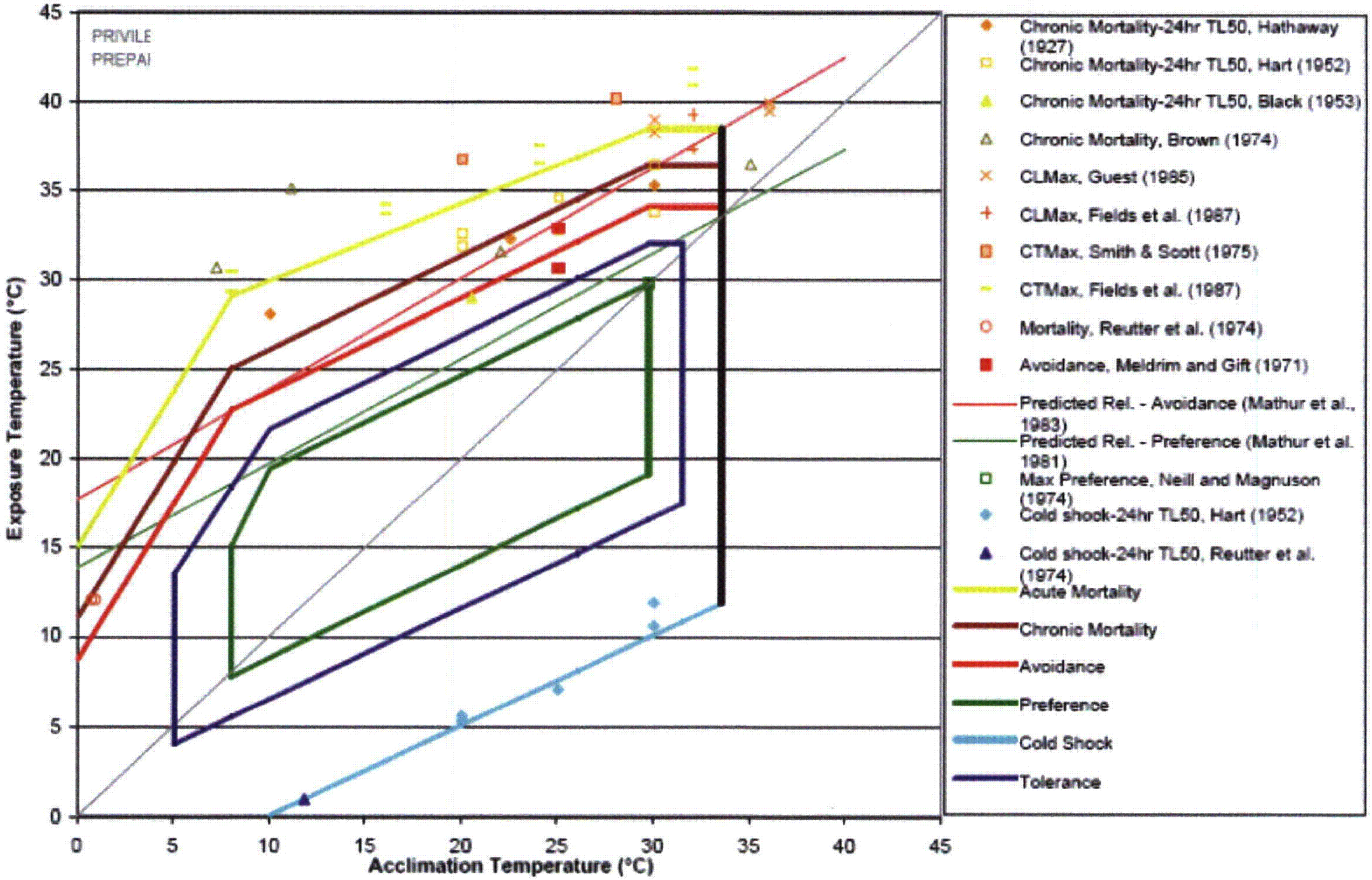


Figure A2-2. Temperature Tolerance Data & Polygon for Adult & Juvenile Channel Catfish

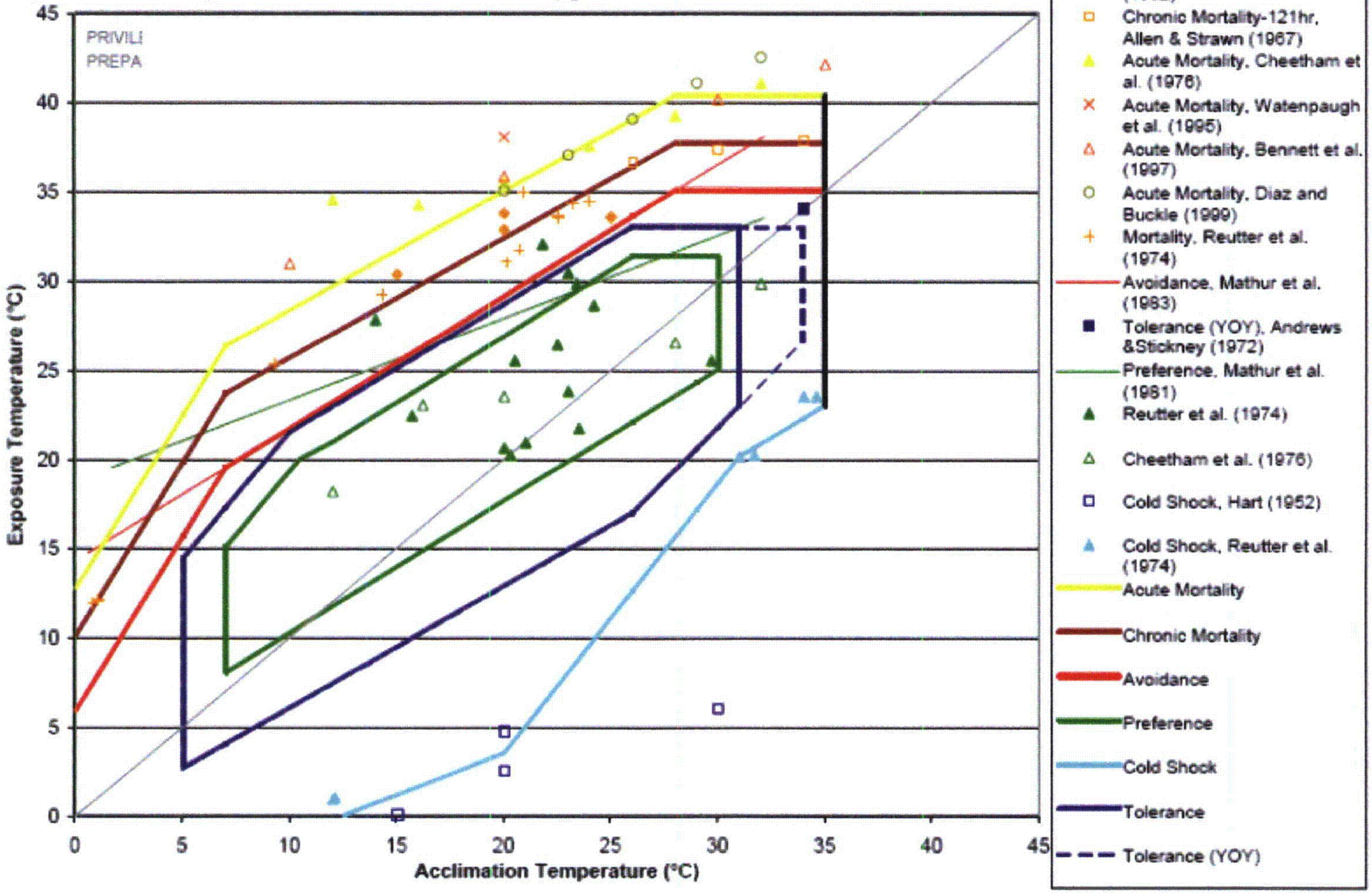


Figure A2-3. Temperature Tolerance Data & Polygon for Adult & Juvenile Walleye

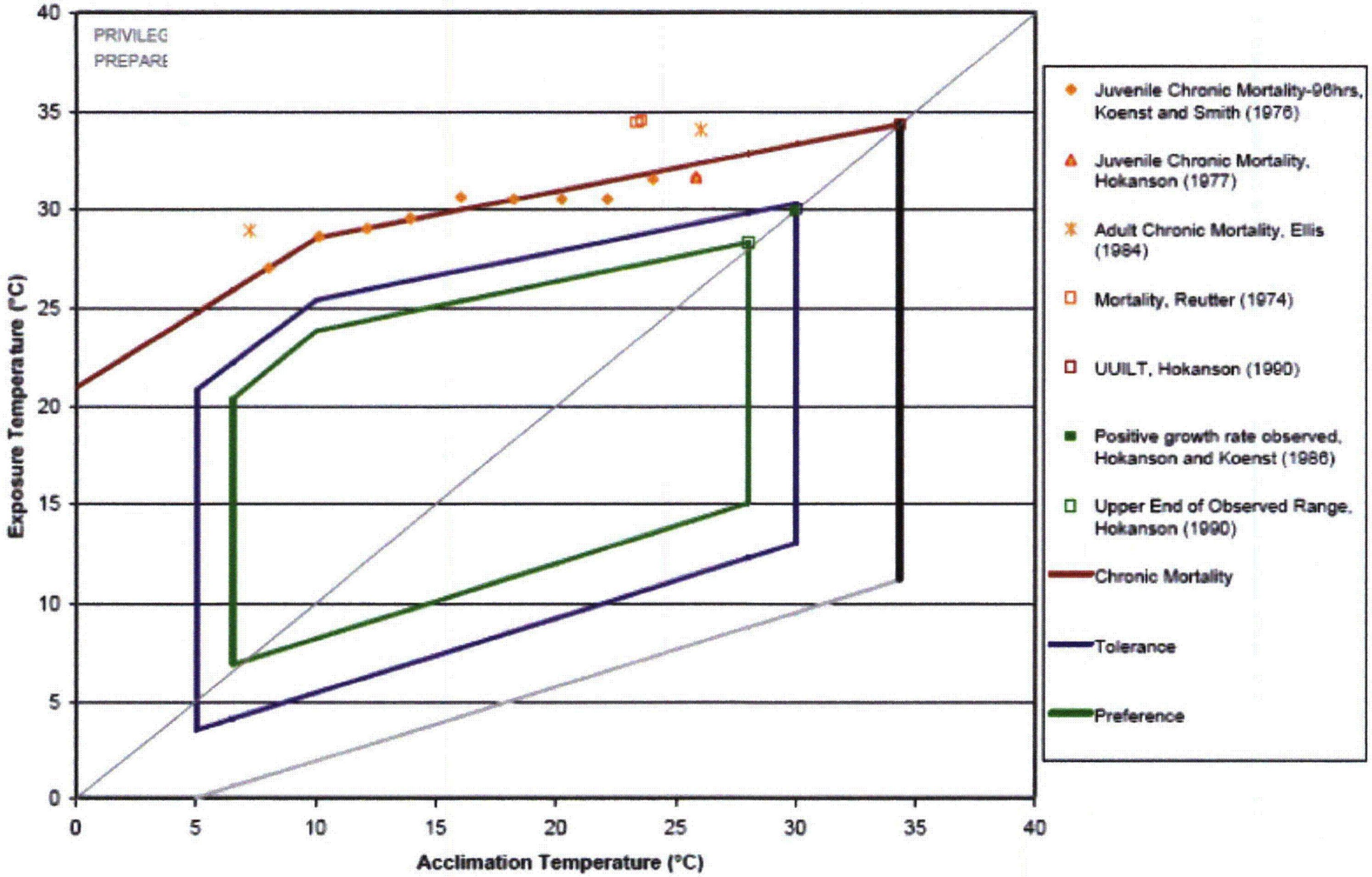
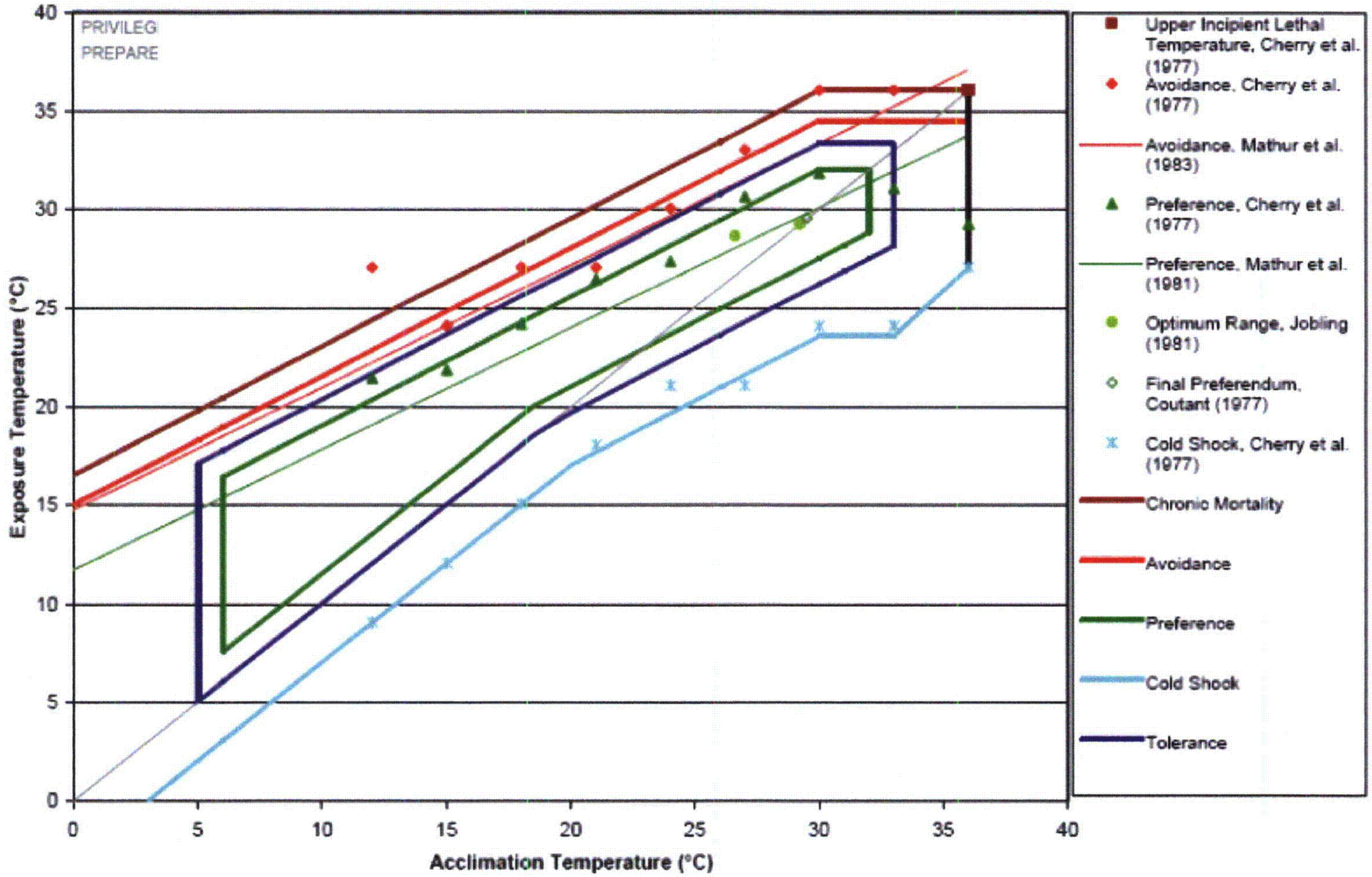


Figure A2-4. Temperature Tolerance Data & Polygon for Adult & Juvenile Spotfin Shiner



ATTACHMENT 3

Comparison of Walleye Abundance to River Water Temperature

Attachment 3

Biothermal Assessment Report

Comparison of Walleye Abundance to River Water Temperature

Introduction

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

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

Electro-fishing Methods

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

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

Data Analysis

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

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

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

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

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

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

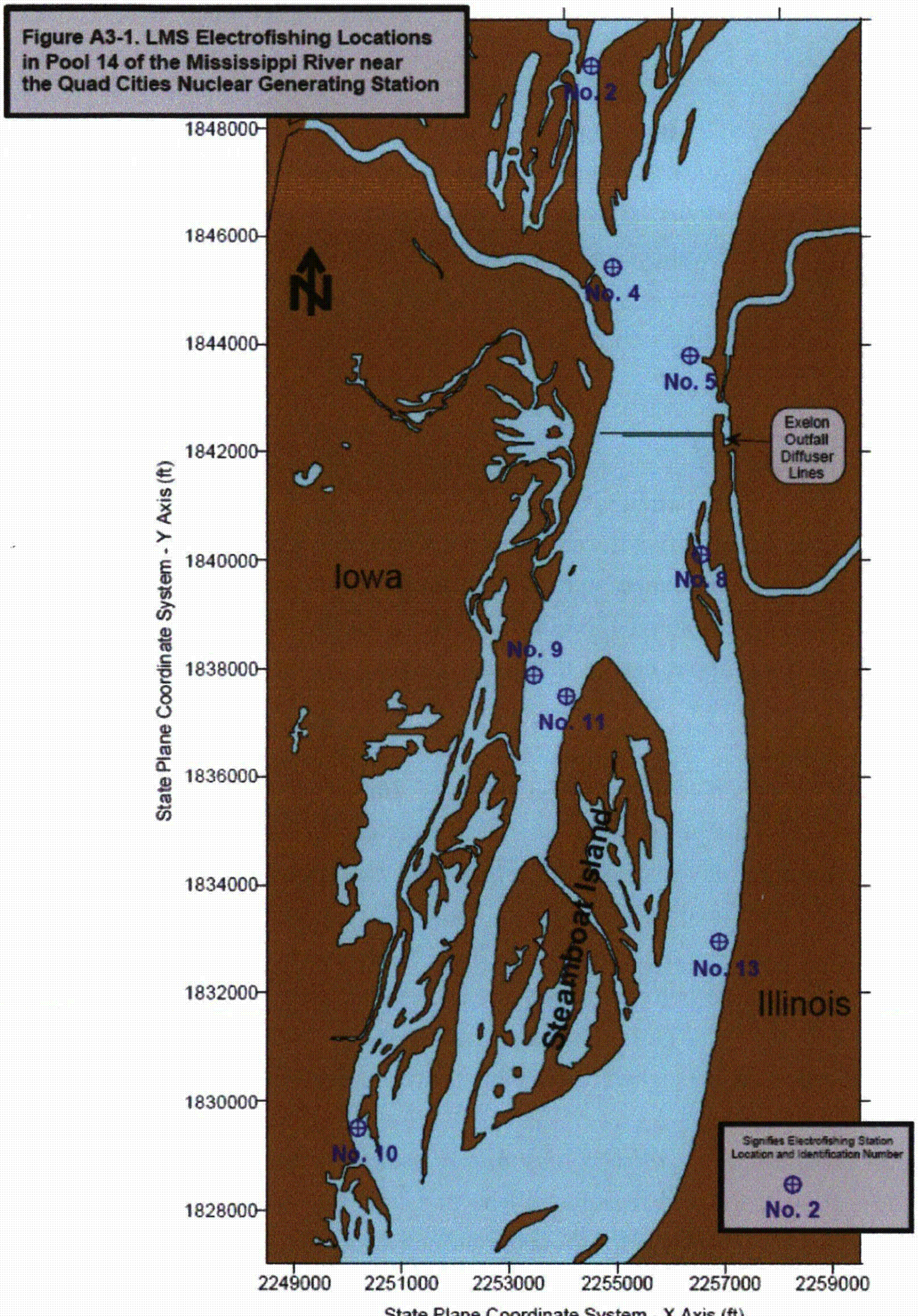
Observations made by the HDR field crews during the period of record indicate that walleye abundance at any of the fixed sampling locations seems to be driven by river stage. That is, low flows eliminate suitable habitat structure availability; and consequently, numbers of walleye collected decrease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

Conclusions

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

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

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



Preliminary Draft

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