PECO NUCLEAR
A Unit of PECO Energy

Nuclear Group Headquarters
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Kennett Square, PA 19348

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NPDES Permit No. PA009723

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555

Subject: Peach Bottom Atomic Power Station, Units 2 and 3
Submittal of Environmental Reports

Reference: Letter from G. A. Hunger, Jr. (PECO Energy Company)
to USNRC dated May 2, 1997

Dear Sir/Madam:

This letter is being submitted in accordance with the Peach Bottom Atomic Power Station (PBAPS), Units 2 and 3, Environmental Technical Specifications, Section 1.4.2.2.b, which stipulates that a written report, including an evaluation of the environmental impact resulting from a change, shall be forwarded to the NRC in the event of changes or additions to permits and certificates required for the protection of the environment.

The referenced letter informed the NRC of a variance to the PBAPS National Pollutant Discharge Elimination System (NPDES) permit concerning cooling tower operation. The variance, issued by the Pennsylvania Department of Environmental Protection (PA DEP), allowed for a three year study of zero tower operations. This study resulted in two reports, which are attached for your information.

The first report titled "A Report on the Thermal Conditions and Fish Populations in Conowingo Pond Relative to Zero Cooling Tower Operation at the Peach Bottom Atomic Power Station – February 2000" details results of the thermal field investigation and fish population assessment conducted in the Conowingo Pond for the period June through October 1999. Overall, the study concluded that zero tower operation has no discernible effect on the indigenous fish population of the Conowingo pond.

C001

The second report titled "Assessment of Cooling Tower Operation at Peach Bottom Atomic Power Station on Potential Fish Habitat – June 2000" details the results of an evaluation of zero cooling tower operations on potential fish habitat in the Conowingo Pond. This assessment was performed by Normandeau Associates at the request of the Pennsylvania Fish and Boat Commission. The report concludes that zero tower operation has minimal impact on fish habitat and is compatible with the existence of a balanced, indigenous fish population of the Conowingo Pond.

If you have any questions, please do not hesitate to contact us.

Very truly yours,

James A. Hutton
Director - Licensing

Attachments

cc: H. J. Miller, Administrator, Region I, USNRC
A. C. McMurtray, USNRC Senior Resident Inspector, PBAPS
R. R. Janati, Commonwealth of Pennsylvania

A REPORT ON THE THERMAL CONDITIONS AND FISH POPULATIONS IN CONOWINGO POND RELATIVE TO ZERO COOLING TOWER OPERATION AT THE PEACH BOTTOM ATOMIC POWER STATION (JUNE-OCTOBER 1999)

NPDES Permit No. PA009723

PREPARED FOR:
PECO Energy Company
2301 Market Street
Philadelphia, Pennsylvania 19101

PREPARED BY:
Normandeau Associates, Inc.
1921 River Road
Drumore, Pennsylvania 17518

FEBRUARY 2000

NORMANDEAU ASSOCIATES
ENVIRONMENTAL CONSULTANTS

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EXECUTIVE SUMMARY

In 1996, PECO Energy sponsored a study to determine whether the number of cooling towers in operation at Peach Bottom Atomic Power Station (PBAPS) can be curtailed without adversely affecting the integrity of the balanced, indigenous fish community of Conowingo Pond. Results of that study (Normandeau Associates, 1997a), which was coordinated with agency personnel primarily from the Pennsylvania Department of Environmental Protection, Pennsylvania Fish and Boat Commission, and Maryland Department of Natural Resources, suggested that the station could be operated with zero towers without adversely affecting the balanced fish community in Conowingo Pond. As a result of that study, PECO was issued a permit amendment to operate PBAPS with no cooling towers. However, to address agency concerns of the relatively high river flow and low water temperature conditions in 1996, PECO proposed a three (3) year monitoring program (1997 through 1999) to increase the probability of observing potential effects over a wide range of flow and temperature conditions. The principal components of the monitoring program were subsequently incorporated in the permit amendment. As in 1997 and 1998, monitoring in 1999 (the third and final year of study) was conducted monthly in June-October. The investigation included two components: relative abundance and distribution of fishes as measured by a variety of gears and evaluation of thermal conditions. Sampling was conducted at selected locations that had been monitored historically. A complete set of sampling within the one week per month consisted of the following: 48 h of trap netting, one set of seine collections, trawling at transect and zone locations, electrofishing, and two thermal mapping surveys.

The ambient water temperatures (as measured at PBAPS intakes) ranged from 54.4 to 86.5°F and varied between months due to changing natural hydrological and meteorological conditions. Temperatures were highest in July, followed by August, June and September, and lowest in October. Compared to previous study years, ambient inlet temperatures in summer 1999 were higher, exceeded 80°F longer (nearly 56 consecutive days), with daily values ≥83°F on 35 days versus 3 and 13 days, respectively in 1997 and 1998.

River inflows in 1999 were lower than in the historical period (1952-1998). Record low river flows for May and June occurred in 1999, while those in July and August 1999 were the lowest for those months in the last 33 years. River flows in summer 1999 were substantially lower than those experienced in 1996, and lower than the low inflow conditions in 1997 and 1998. Overall, compared to the historical period, the fish community in Conowingo Pond experienced near-worst summer conditions in 1999.

Water temperatures at the point of discharge were mostly 19 to 20°F above the Holtwood inflow temperatures and the ambient inlet temperatures.

The heated effluent from PBAPS quickly dissipated within about 2 miles downstream of the discharge structure. The effluent affected the top 5 to 15 ft of the water column primarily along the western shoreline downstream to western and mid-pond areas at the PA/MD State Line. Except in surface and near surface waters, rise in temperatures (above the PBAPS inlet) at the State Line were generally less than 4°F. The overall pattern of vertical distribution of temperature in the water column at locations along the west shore in 1999 was similar to that observed in 1995 (also a period of low river flow and high ambient water temperature) when a minimum of three cooling towers operated.

Despite high water temperature and record low river inflow conditions in summer 1999, DO values in the vicinity of PBAPS were good and reflected seasonal, spatial, and diurnal variations observed historically.

A total of 15,328 fish representing 45 species plus one striped bass hybrid and 11 unidentified *Lepomis* spp. was collected. The most fish (5,507) were collected in June and the least (1,596) in August. The number of species collected per month was similar and ranged from 35 (July, August, and September) to 37 (June and October). Overall, spotfin shiner was the most abundant species in July, August, September, and October while gizzard shad dominated the catch in June.

As in 1997 and 1998, the 1999 fisheries data for all gears revealed that most of the monthly catch per effort (CPE's) for the common and Environmental Protection agency designated species were within or above the historic range; CPE's among species and between stations were variable, likely due to differences

in year class strength, and no thermally stressed fish were observed. Overall, zero tower operation had no discernible effect on the integrity of the balanced, indigenous fish community of Conowingo Pond.

TABLE OF CONTENTS

EXECUTIVE SUMMARY ES-1
1.0 INTRODUCTION AND BACKGROUND 1
2.0 METHODS 2
2.1 General Scheme 2
2.2 Thermal Plume and Dissolved Oxygen (DO) Profiling 2
2.3 Fisheries Sampling and Reconnaissance Surveys 2
2.3.1 Electrofishing 3
2.3.2 Seine 3
2.3.3 Trap Net 3
2.3.4 Trawl 3
2.3.5 Reconnaissance Surveys 4
2.4 Data Analysis 4
3.0 RESULTS 15
3.1 Study Conditions 15
3.1.1 Natural River Flow and Temperature 15
3.1.1.1 River Flow 15
3.1.1.2 River Temperature 15
3.1.2 PBAPS Operational and Thermal Conditions 16
3.1.2.1 Power Output 16
3.1.2.2 Inlet (Intake) Temperatures 16
3.1.2.3 Condenser Outlet and Discharge Temperatures 16
3.2 Thermal and Dissolved Oxygen Conditions in Conowingo Pond 17
3.2.1 Thermal Conditions 17
3.2.2 Dissolved Oxygen (DO) Conditions 18
3.2.3 Diurnal Variations in DO 18
3.3 Fisheries (Overall) 34
3.3.1 Electrofishing 34
3.3.2 Seine 34
3.3.3 Trap Net 35
3.3.4 Trawl Zones 36
3.3.4.1 Zone 405 36
3.3.4.2 Zone 408 36
3.3.5 Trawl Transects 36
3.3.6 Reconnaissance Surveys 37
4.0 SUMMARY AND CONCLUSIONS 65
5.0 LITERATURE CITED 67
APPENDIX A – MONTHLY FLOW DURATION CURVES (JUNE-OCTOBER, HISTORICAL (1952-1998) VERSUS 1997, 1998, AND 1999) AND JOINT OCCURRENCE OF DAILY WATER TEMPERATURE AND RIVER FLOW (JUNE-OCTOBER, HISTORICAL (1956-1998), 1997, 1998, AND 1999

LIST OF TABLES

Table 2-1 Description of thermal mapping locations sampled in the vicinity of PBAPS, June-October 1999.

Table 2-2 Location of electrofishing stations sampled in Conowingo Pond, June-October 1999.

Table 2-3 Location of seine stations sampled in Conowingo Pond, June-October 1999.

Table 2-4 Location of trap net stations sampled in Conowingo Pond, June-October 1999.

Table 2-5 Location of stations 451 to 456 in trawl zone 405 and stations 481 to 486 in trawl zone 408 in Conowingo Pond sampled in June-October 1999.

Table 2-6 Location of trawl transect stations sampled in Conowingo Pond, June-October 1999.

Table 3-1 Summary of the mean and range of daily plant power output, temperature conditions, and river flows and temperatures (measured at Holtwood Dam) during thermal and fish population surveys conducted at zero tower operations at PBAPS, June-October 1999.

Table 3-2 Monthly mean river flow and water temperature at Holtwood Dam, May-October 1952-1998, and in 1995, 1996, 1997, 1998, and 1999.

Table 3-3 Joint occurrence of daily water temperature and river flow at Holtwood Dam, June-October 1956-1998, 1997, 1998, and 1999.

Table 3-4 Comparison of average monthly measured versus model-predicted condenser ΔT at the Peach Bottom Atomic Power Station with both units operating at maximum power achievable, spring to fall 1993-1998, and 1999.

Table 3-5 Selected weekly thermal profile conditions at locations sampled in Conowingo Pond, June-October 1999.

Table 3-6 Comparison of the mean profile water temperatures at western sampling stations on transects located downstream of the PBAPS discharge in August and September 1995 and 1999.

Table 3-7 Selected weekly DO profiles at transect locations in Conowingo Pond, June-October 1999.

Table 3-8 Scientific and common names of fishes collected in 1998 in Conowingo Pond, June-October 1999.

Table 3-9 Number and percent composition of fishes collected by all gear types per month in Conowingo Pond, June-October 1999.

Table 3-10 Number and percent composition of fishes collected by DC Electrofisher per month in Conowingo Pond, June-October 1999.

Table 3-11 Monthly catch per effort (number per 30 minutes) for fishes collected by a DC Electrofisher in Conowingo Pond, June-October 1999.

Table 3-12 Catch per effort (number per 30 minutes) for fishes collected by DC Electrofisher at stations in Conowingo Pond, June-October 1999.

Table 3-13 Comparison of the monthly catch per effort (number per 30 minutes) for the common and Environmental Protection Agency designated, representative, important species collected at electrofishing stations in Conowingo Pond in June-October.

Table 3-14 Number and percent composition of fishes collected by 10 x 4 ft seine per month in Conowingo Pond, June-October 1999.

Table 3-15 Monthly catch per effort (number per collection) for fishes collected by a 10 x 4 ft seine in Conowingo Pond, June-October 1999.

Table 3-16 Catch per effort (number per collection) for fishes collected by 10 x 4 ft seine at stations in Conowingo Pond, June-October 1999.

Table 3-17 Diversity and evenness values for fishes taken by seine per month in Conowingo Pond, June-October 1999.

Table 3-18 Index of percent similarity of species composition between seine stations during zero tower operation in Conowingo Pond, June-October 1999.

Table 3-19 Index of percent similarity of species composition per month in Conowingo Pond, June-October 1999.

Table 3-20 Comparison of the monthly catch per effort (number per collection) for the common and Environmental Protection Agency designated, representative, important species collected at seine stations in Conowingo Pond in June-October.

Table 3-21 Number and percent composition of fishes collected by trap net per month in Conowingo Pond, June-October 1999.

Table 3-22 Monthly catch per effort (number per 24 h) for fishes collected by trap net in Conowingo Pond, June-October 1999.

Table 3-23 Catch per effort (number per 24 h) for fishes collected by trap net at stations in Conowingo Pond, June-October 1999.

Table 3-24 Comparison of the monthly catch per effort (number per 24 h) for the common and Environmental Protection Agency designated, representative, important species collected at trap net stations in Conowingo Pond in June-October.

Table 3-25 Number and percent composition of fishes collected by a 16 ft semi-balloon trawl per month in trawl zone 405, Conowingo Pond, June-October 1999.

Table 3-26 Monthly catch per effort (number per 10 min haul) for fishes collected by a 16 ft semi-balloon trawl in trawl zone 405, Conowingo Pond, June-October 1999.

Table 3-27 Catch per effort (number per 10 min haul) for fishes collected by a 16 ft semi-balloon trawl at stations in trawl zone 405, Conowingo Pond, June-October 1999.

Table 3-28 Comparison of the monthly catch per effort (number per 10 min haul) for the common and Environmental Protection Agency designated, representative, important species collected at trawl zone 405 in Conowingo Pond in June-October.

Table 3-29 Number and percent composition of fishes collected by a 16 ft semi-balloon trawl per month in trawl zone 408, Conowingo Pond, June-October 1999.

Table 3-30 Monthly catch per effort (number per 10 min haul) for fishes collected by a 16 ft semi-balloon trawl in trawl zone 408, Conowingo Pond, June-October 1999.

Table 3-31 Catch per effort (number per 10 min haul) for fishes collected by a 16 ft semi-balloon trawl at stations in trawl zone 408, Conowingo Pond, June-October 1999.

Table 3-32 Comparison of the monthly catch per effort (number per 10 min haul) for the common and Environmental Protection Agency designated, representative, important species collected at trawl zone 408 in Conowingo Pond in June-October.

Table 3-33 Number and percent composition of fishes collected by a 16 ft semi-balloon trawl per month at trawl transects in Conowingo Pond, June-October 1999.

Table 3-34 Monthly catch per effort (number per 10 min haul) for fishes collected by a 16 ft semi-balloon trawl at trawl transects in Conowingo Pond, June-October 1999.

Table 3-35 Catch per effort (number per 10 min haul) for fishes collected by a 16 ft semi-balloon trawl at stations on trawl transects in Conowingo Pond, June-October 1999.

Table 3-36 Comparison of the monthly catch per effort (number per 10 min haul) for the common and Environmental Protection Agency designated, representative, important species collected at trawl transect stations in Conowingo Pond in June-October.

LIST OF FIGURES

Figure 2-1 Thermal profiling locations in the vicinity of PBAPS.
Figure 2-2 Map of Conowingo Pond showing distribution of electrofishing stations.
Figure 2-3 Map of Conowingo Pond showing distribution of seine stations.
Figure 2-4 Map of Conowingo Pond showing distribution of trap net stations.
Figure 2-5 Map of Conowingo Pond showing distribution of stations in trawl zones 405 and 408.
Figure 2-6 Map of Conowingo Pond showing distribution of stations in trawl transects 2, 4, and 7.
Figure 3-1 Duration curve of average daily river flows at Holtwood Dam in June-October 1952 to 1998 and in 1997, 1998, and 1999.
Figure 3-2 Duration curve of daily average river temperatures at Holtwood Dam in June-October 1956 to 1998 and in 1997, 1998, and 1999.
Figure 3-3 Weekly mean percent of power output and condenser ΔT at PBAPS, June-October 1999.
Figure 3-4 Weekly mean temperatures at Holtwood Dam and PBAPS inlet, June-October 1999.
Figure 3-5 Average daily condenser outlet and canal outfall temperatures at PBAPS, June-October 1999.
Figure 3-6 Weekly mean canal outfall ΔT at PBAPS, June-October 1999.
Figure 3-7 Weekly mean surface and bottom DO at transects sampled in the vicinity of PBAPS, June-October 1999.
Figure 3-8 Comparison of AM versus PM DO at the surface and bottom at transects sampled in the vicinity of PBAPS in July through August 1999.

1.0 INTRODUCTION AND BACKGROUND

In 1996 PECO Energy sponsored a study to determine whether the number of cooling towers in operation at Peach Bottom Atomic Power Station (PBAPS) can be curtailed without adversely affecting the integrity of the balanced, indigenous fish community of Conowingo Pond. The study was coordinated with the Pennsylvania Department of Environmental Protection (PADEP), Pennsylvania Fish and Boat Commission (PFBC), Maryland Department of Natural Resources (MDNR), U.S. Fish and Wildlife Service (USFWS), and the Susquehanna River Basin Commission (SRBC). The primary reason for initiating the study was that the existing cooling tower operations were deemed conservative. They were based on a condenser design discharge water ΔT of 20.8°F and the fishes were assumed to be in a trapped situation at PBAPS. The investigation occurred in June through October 1996 at three discrete cooling tower (zero, one, and two) operations and consisted of two components: relative abundance and distribution of fishes as measured by a variety of gears and evaluation of near-field and far-field thermal conditions. The results of the 1996 study (Normandeau Associates, 1997a) were presented and discussed with concerned resource agencies. The consulted agencies concurred with the conclusion that no meaningful differences occurred in the relative abundance, distribution or species composition in each of the three tower operating scenarios (zero, one and two towers); fish populations at zero and two tower operation were similar. The report concluded that the integrity of a balanced, indigenous fish community in Conowingo Pond can be maintained at zero tower operation.

Based on the results of the 1996 study, PECO requested that the PADEP eliminate the need for operation of any cooling towers. However, recognizing agency concerns with regards to conditions studied in 1996 (relatively high river flows and cool water temperatures), and that operational changes should not pose undue biological risks over the long term, PECO submitted a long-term monitoring plan at zero (no) cooling tower operation. This Study Plan (Normandeau Associates, 1997b), incorporated agency's comments and recommendations, provided for a three year monitoring program (1997-1999). The selected monitoring duration increased the probability of observing the potential effects of a wide range of conditions, and included contingencies in the unlikely event of unusual thermally-related fish activity. The PADEP approved and incorporated the Study Plan in an amendment for zero tower operation, in the Station's NPDES permit.

This report presents the results of thermal profiling and fish community monitoring in Conowingo Pond in June through October 1999; the final year of the three year monitoring program. Results of 1997 and 1998 monitoring were reported earlier (Normandeau Associates 1998, 1999).

2.0 METHODS

2.1 General Scheme

The basic technical approach involved sampling at selected stations in Conowingo Pond at zero cooling tower operations within one week in each month (June through October 1999). Fish sampling occurred once and thermal plume mapping twice each sampling week. All surveys were conducted at prevailing river flow and temperature conditions in the last full week of each month and were completed in 4 to 5 days.

Sampling effort was concentrated in the vicinity of PBAPS to better delineate the effects, if any, of zero tower operation on relative abundance and distribution of fishes. A similar approach, with concurrence of resource agencies, was taken in 1974-1976 to delineate the areas of fish avoidance in the vicinity of PBAPS and then again in 1993, 1995 and 1996 summer to evaluate thermal effects. The same field sampling protocols utilized during the pre-operational and post-operational periods and in 1997-1998 were used in 1999. A general description of the thermal mapping and fisheries protocols employed are provided below.

In addition to fisheries collections, reconnaissance surveys of the areas upstream and downstream of the discharge were conducted in July and August, in conjunction with weekly dissolved oxygen surveys requested by the PFBC. The surveys were conducted to document any potential fish stress as a result of zero tower operation, particularly in light of the hundreds of thousands of additional fish lifted into the Pond via operation of the fish passage facilities at Conowingo Dam.

2.2 Thermal Plume and Dissolved Oxygen (DO) Profiling

Synoptic boat based surveys were conducted twice each fisheries sampling week to delineate the spatial extent of the thermal plume. These surveys were usually conducted at the beginning and end of each sampling week; one survey was conducted in an upstream to downstream direction and the other downstream to upstream. As shown in Table 2-1 and Figure 2-1, most transects selected for this monitoring were located downstream of the PBAPS discharge. Additionally, as requested by the PFBC, two sets of DO profiles (AM and PM) were taken one day a week (July and August) at selected locations (east shore, mid-pond and west shore stations) on the Fishing Creek, Burkins Run, and Williams Tunnel transects to provide an indication of near-field diurnal variation in DO. Most AM profiles were initiated between 0600-0800 hr, while the PM profiles were conducted between 1400-1700 h.

At each transect location, water temperature and dissolved oxygen (DO) were measured at 5 ft intervals from the surface to bottom using Yellow Springs Instrumentation (YSI, Model 57 meters). The meters were calibrated/checked at each transect (the DO probes against the known solubility of oxygen in air saturated water, and the thermistors against an NIST certified traceable thermometer). Instrument operation and maintenance quality control checks were performed initially and at monthly intervals throughout the study. Measurements were recorded on standardized field forms (DO to the nearest 0.1 mg/l and water temperature to the nearest 0.2-0.3°C).

DO and water temperature measurements on each sampling date were also complemented with daily temperature and river flow data (obtained from Holtwood Dam located about 7 miles upstream of PBAPS) and daily operational data from PBAPS (power level, condenser inlet and outlet temperatures, and temperature at the discharge canal outfall to Conowingo Pond). As in the case of fish sampling, extensive monitoring of thermal conditions (via hourly measurements and boat-based surveys) occurred during the pre-operational and post-operational periods. Detailed statistical analyses of these data, establishing the magnitude of natural variations and temperature rise due to power plant discharge, are provided in Purdy and Silver (1975a,b,c,d).

2.3 Fisheries Sampling and Reconnaissance Surveys

Fishes were sampled by seine, trawl, and trap net at selected locations with emphasis on locations clustered in the vicinity of PBAPS (Tables 2-2 through 2-6; Figures 2-2 through 2-6). These locations were also sampled during the pre- and post-operational periods (1966-1973 and 1974-1987, 1993, 1995, 1996, 1997 and 1998, respectively). Similarly, electrofishing occurred at sites that had been sampled earlier.

Sampling with each gear type occurred once during the monthly sampling week. A complete sampling event consisted of the following: one set of seine collections; 48 hours of trap netting; trawl collections at Zones 405 and 408 and Transects 2, 4, and 7; and one set of electrofishing. A description of each gear type and the disposition of the catch are given below.

2.3.1 Electrofishing

Electrofishing was conducted at night at four stations (Table 2-2; Figure 2-2). Stations 161 and 190 are influenced by the thermal discharge from PBAPS. The electrofishing system consisted of a Coffelt VVP-15 variable voltage pulsator, powered by a 3.5 kW generator, and mounted in a 18 ft aluminum boat equipped with flood lights. Fishes were collected using pulsed DC current to minimize fish injury.

Data recorded for each station included weather, date, time (start and end), air and surface water temperatures, voltage, and amperage. Sampling at each location consisted of a 30 minute run and was typically completed in one pass. The boat-mounted boom shocker was maneuvered slowly through the site, as close to shore as possible. Stunned fish were netted at the bow and placed in a live well. Large stunned specimens of common carp and quillback were not netted, but were counted by the netting crew and recorded. At the end of 30 minutes, the boat was returned to the center of the station, and the catch processed. Each fish was identified to species, fork length (FL) measured to the nearest mm, and released. When a collection contained more than 10 specimens of a single species, they were measured to the nearest 10 mm FL. If a collection contained more than 50 specimens of a single species, a subsample of 50 specimens was selected for individual processing, and the remainder counted and released.

2.3.2 Seine

Seining was conducted at seven shoreline stations (Table 2-3; Figure 2-3). Station 214 is located within the PBAPS thermal plume. Data recorded at each station included weather, date, time (start and end), air and surface water temperatures, and estimated water depth. A 10 x 4 ft straight seine with ¼ inch mesh was used. The seine was deployed and moved parallel to shore for a short distance, then moved into shore to trap fish. Since size and habitat of seine stations varied, effort was made to collect a representative qualitative sample based on complete coverage of all available habitats, rather than a specific number of hauls at each station.

All specimens were identified, counted, and released near the capture site. Specimens that were too small to accurately identify in the field to the species level were only identified to the genus level. This was particularly pertinent to small sunfishes and clupeids.

2.3.3 Trap Net

Trap nets were set at four locations (Table 2-4; Figure 2-4). Station 110 is within the PBAPS thermal plume. Data recorded at each station included weather, date, time (set and retrieve), Secchi disc transparency, air temperature, water temperature at the surface, 5 ft, 10 ft, and bottom, and water depth. The trap net consisted of a 3 x 6 ft trap with a 3 x 50 ft lead of ½ inch square mesh. Trap nets were set with the lead perpendicular to the shoreline. After 24 hours the nets were retrieved, the catch removed and processed, and reset for a second 24 hour period. All specimens in each collection were identified, measured to the nearest mm FL, and released. When a collection contained more than 10 specimens of a single species, they were measured to the nearest 10 mm FL. If a collection contained more than 50 specimens of a single species, a subsample of 50 specimens was selected for individual processing, with the remainder counted and released.

2.3.4 Trawl

Trawl surveys were divided into zones and transects. Two zones (405 and 408) and three transects (2, 4, and 7) were sampled (Figures 2-5 and 2-6). Zone 405 is affected by the thermal discharge while Zone 408 is considered a control (non-affected). Each zone consisted of three near-shore and three off-shore locations, while each transect was composed of an east shore, mid-pond, and west shore station. Transect Station 371 is influenced by PBAPS discharge. A description of all stations is found in Tables 2-5 and 2-6. Data recorded during each survey included weather, date, time (start and end), Secchi disc transparency, air temperature, water temperature at the surface, 5 ft, 10 ft, and bottom, and water depth. A 16 ft semi-

balloon trawl with ¼ inch mesh liner in the cod end was used to sample the zone and transect stations. The trawl was deployed off the stern of the boat and hauled for 10 minutes in an upstream direction. A minimum of 7 minutes was required for the haul to be considered valid. After 10 minutes the trawl was retrieved, the boat was returned to the center of the station, and catch was removed from the net and processed. All specimens in each collection were identified, measured to the nearest mm fork length, and released. When a collection contained more than 10 specimens of a single species, they were measured to the nearest 10 mm FL. If a collection contained more than 50 specimens of a single species, a subsample of 50 specimens was selected for individual processing, with the remainder counted and released.

2.3.5 Reconnaissance Surveys

In conjunction with weekly DO profiling in July and August, fish reconnaissance surveys were conducted throughout Conowingo Pond, from near Holtwood Dam downstream to Conowingo Dam. These boat-based surveys were performed specifically to document occurrences of any unusual thermally related fish activity. The surveys were conducted as precautionary measures due to the co-occurrences of relatively low and warm river inflows, zero tower operation at PBAPS, and the introduction of nearly 1,200,000 fish into the Pond during spring operations at the Conowingo Dam fish passage facilities.

2.4 Data Analysis

Thermal and DO profiling, fisheries sampling, and related data were electronically processed and verified prior to analysis. For representation of average thermal conditions at transect locations during the fish sampling week each month, the profile data were pooled.

Fisheries data from each gear types were compiled and expressed as catch per unit effort (CPE) by station, and month. Seine catches were expressed as number of each species per collection, while trap net catches were expressed as number of each species captured per 24 hours. The trawl data (transects and zones) are presented as number of each species per 10 minute haul, with electrofishing data expressed as the number of fish captured per 30 minutes.

For delineating the potential effects of zero tower operation on the fish community structure, indices of diversity and similarity were calculated as had been done in earlier pre- and post-operational studies for PBAPS.

Species diversity indices (D) were calculated by the Shannon-Weaver (1948) method using the formula:

$$D = -\sum_{i=1}^{S} P_i \mathrm{Log}_2 P_i$$

where D is the species diversity index, S is the total number of species collected, and P_i is the proportion of a species in the sample. However, results are not directly comparable since the number of species vary between populations. In order to equalize all values so they are comparable, evenness values were also calculated using the formula:

$$H_{max'} = \log S$$

where S is the number of taxa.

Evenness values have a range from 0 to 1.0 with 1.0 being the maximum equality for a community.

Index of percent similarity (Whittaker and Fairbanks, 1958) was calculated to determine the similarity in species composition between stations and month. This index was calculated as follows:

$$PS_c = 100 - 0.5 \sum |a - b|$$

where PS is the percent similarity, a and b are percentages of a species at station A and B. Similarity values range from 0 (no similarity) to 100% (complete similarity). This index can be used to identify those stations that are most and least similar with respect to community structure.

Data analyses were performed utilizing SAS and Microsoft Excel software.

Table 2-1

Description of thermal mapping locations sampled in the vicinity of PBAPS, June through October 1999.

Location/ Station Number	Description	Mean Depth (ft)
	Holtwood Dam	
100	PP&L's water temperature monitor located off the upstream end of the skimmer wall (about 7 miles upstream of the PBAPS intakes)	-
	PBAPS	
001	Units 2 and 3 - condenser inlet water box temperature monitors	-
002	Units 2 and 3 - condenser outlet water box temperature monitors	-
009	Discharge canal - end of berm/outfall to Conowingo Pond	-
	Conowingo Pond	
Fishing Creek Transect (located approximately 1 mile upstream of PBAPS intake)		
101*	West shore, approximately 200 yards off Rollins Point	18
102*	Mid-pond, off the mouth of Fishing Creek	15
103*	East shore, approximately 200 yards off the mouth of Fishing Creek	5
Burkins Run Transect (located approximately 600 yards downstream of PBAPS outfall)		
201*	West shore, approximately 75 yards off the mouth of Burkins Run	13
202	About 500 yards off west shore mid-way between Stations 201 and 203	14
203*	Mid-pond off the mouth of Burkins Run	15
204	About 500 yards off the east shore mid-way between Stations 203 and 205	15
205*	East shore, approximately 75 yards off shore	5
William's Tunnel Transect (located approximately 1.2 mile downstream of PBAPS outfall)		
301*	West shore, approximately 75 yards off McClellan's Rock	23
302	About 600 yards off west shore, mid-way between Stations 301 and 303	16
303*	About 600 yards off east shore, mid-way between Stations 302 and 304	16
304*	East shore, approximately 75 yards off William's Tunnel	30
PA/MD Stateline Transect (located approximately 2 miles downstream of PBAPS outfall)		
401	West shore, approximately 75 yards off shore and 500 yards downstream of the mouth of Michael's Run	13
402	About 500 yards off west shore, mid-way between Stations 401 and 403	24
403	About 500 yards off east shore, mid-way between Stations 402 and 404	19
404	East shore, approximately 75 yards off Frazer Tunnel	40

* DO profiling (AM and PM) locations.

Table 2-2

Location of electrofishing stations sampled in Conowingo Pond, June through October 1999.

Station	Description
161	PBAPS discharge structure to approximately 500 yards downstream.
164	Southwest shoreline of Mt. Johnson Island.
165	East shoreline above Peters Creek.
190	Mouth of Michaels Run to 500 yards downstream.

Table 2-3

Location of seine stations sampled in Conowingo Pond, June through October 1999.

Station	Description
202	Southeast shore of Sicily Island.
203	West shore of Big Chestnut Island.
208	Peach Bottom Beach.
209	Broad Creek at the boat launch.
210	Conowingo Creek at the boat launch.
212	Fishing Creek at the first road bridge upstream from the mouth.
214	Beach at the mouth of Burkins Run.

Table 2-4

Location of trap net stations sampled in Conowingo Pond, June through October 1999.

Station	Description
104	100 yards directly off-shore from the PBAPS Unit 1.
107	At the mouth of Broad Creek.
108	50 yards above the mouth of Conowingo Creek.
110	Off Burkins Run (Stonewall Point).

Table 2-5

Location of Stations 451 to 456 in Trawl Zone 405 and Stations 481 to 486 in Trawl Zone 408 in Conowingo Pond sampled in June through October 1999. Trawls made at near-shore stations are indicated by odd numbers and off-shore stations by even numbers.

Station	Location
	Zone 405
451 & 452	From a point off Stonewall Point to a point at the terminus of the PBAPS Discharge Canal (as of 1970 construction). Sampling is done on the river side of the canal and not in the canal.
453 & 454	From a point approximately 50 yards upriver from the terminus of the PBAPS Discharge Canal (as of 1970 construction) to a point off the PBAPS Unit 1.
455 & 456	From a point off PBAPS Unit 1 to a point just above PBAPS Units 2 and 3.
	Zone 408
481 & 482	From a point approximately 300 yards below Peach Bottom Beach to a point off Peach Bottom Beach.
483 & 484	From a point off Peach Bottom Beach to a point off the former Ichthyological Associates dock.
485 & 486	From a point off the former Ichthyological Associates dock to a point off the mouth of Peters Creek.

Table 2-6

Location of trawl transect stations sampled in Conowingo Pond, June through October 1999.

Transect	Location
	Transect 2
321	Off PBAPS Unit 2.
322	Mid-pond between Mt. Johnson Island and PBAPS.
323	Below Mt. Johnson Island.
	Transect 4
341	Broad Creek.
342	Mid-pond off Broad Creek.
343	Wildcat Tunnel.
	Transect 7
371	Burkins Run (Stonewall Point).
372	Mid-pond between Burkins Run and the former Ichthyological Associates dock.
373	Ichthyological Associates Dock.

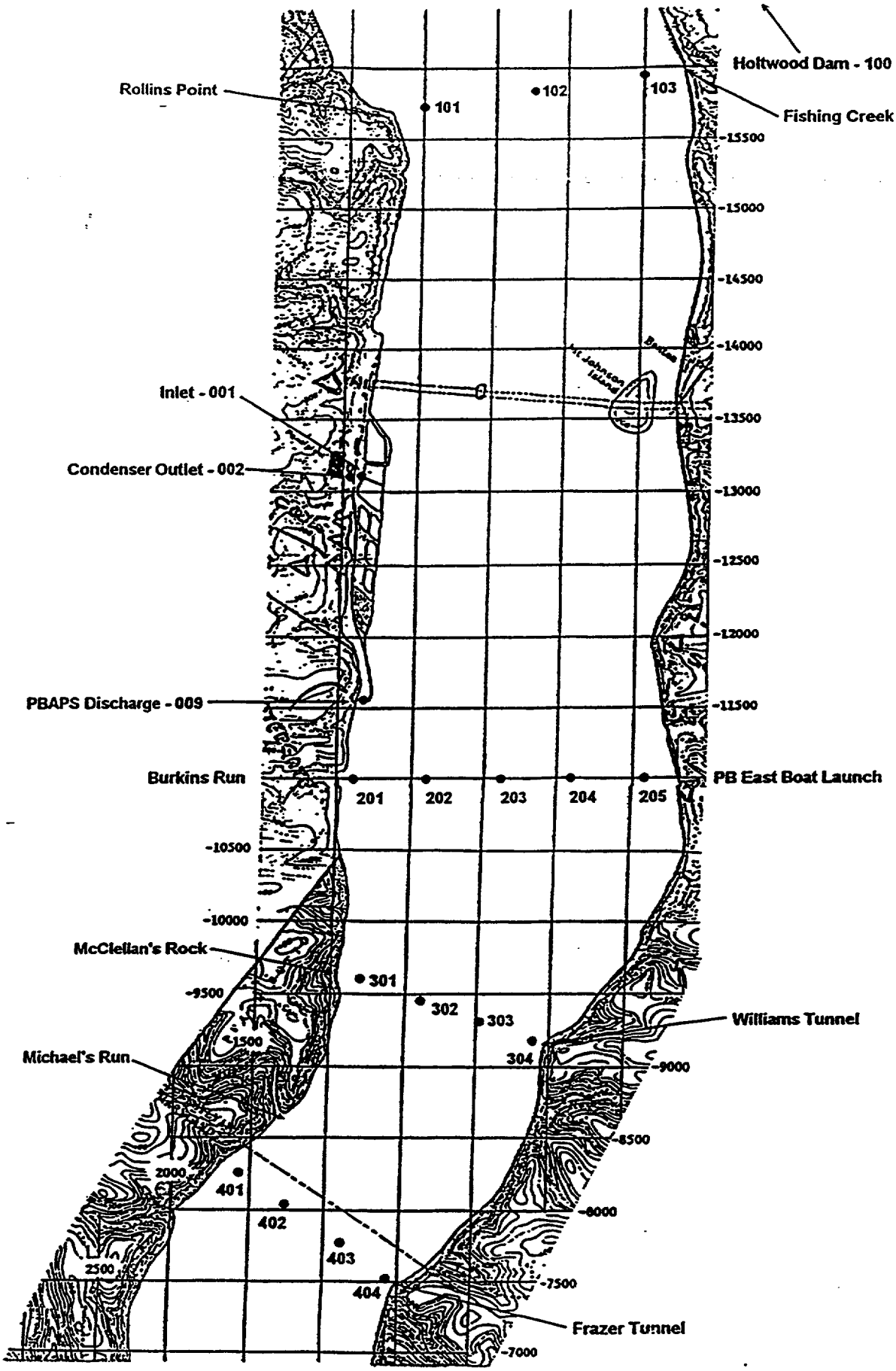


Figure 2-1

Thermal profiling locations in the vicinity of PBAPS.

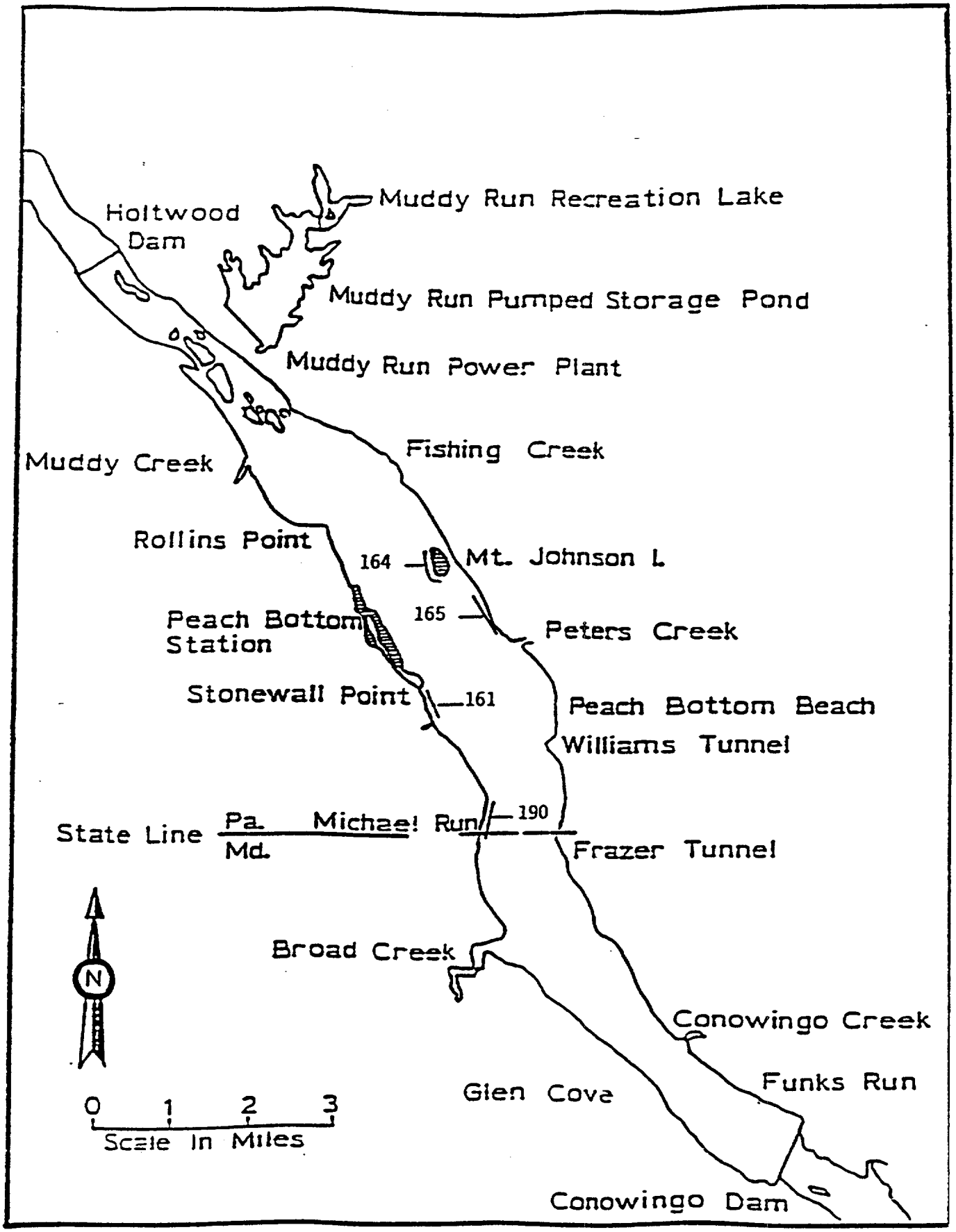


Figure 2-2 Map of Conowingo Pond showing distribution of electrofishing stations.

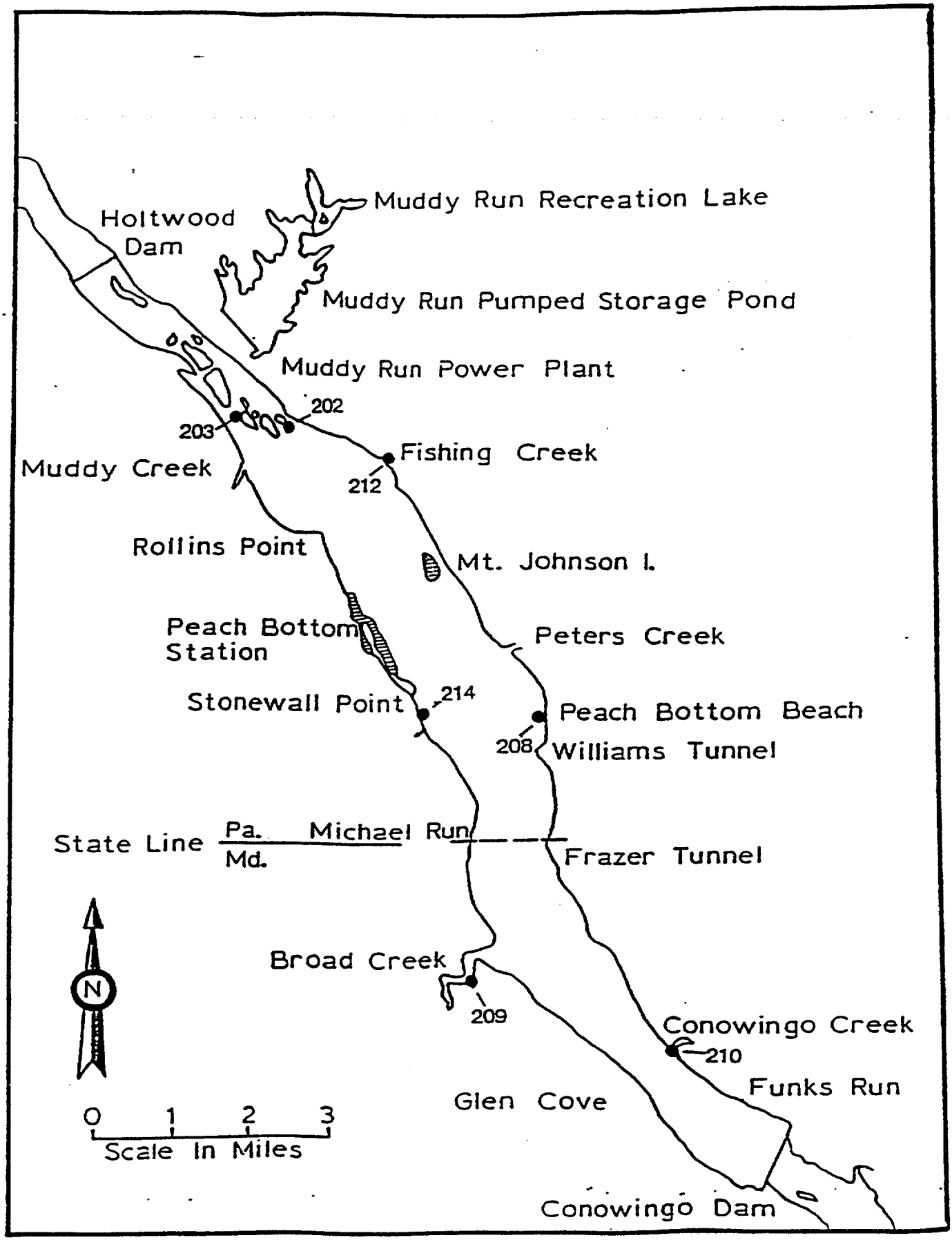


Figure 2-3 Map of Conowingo Pond showing distribution of seine stations.

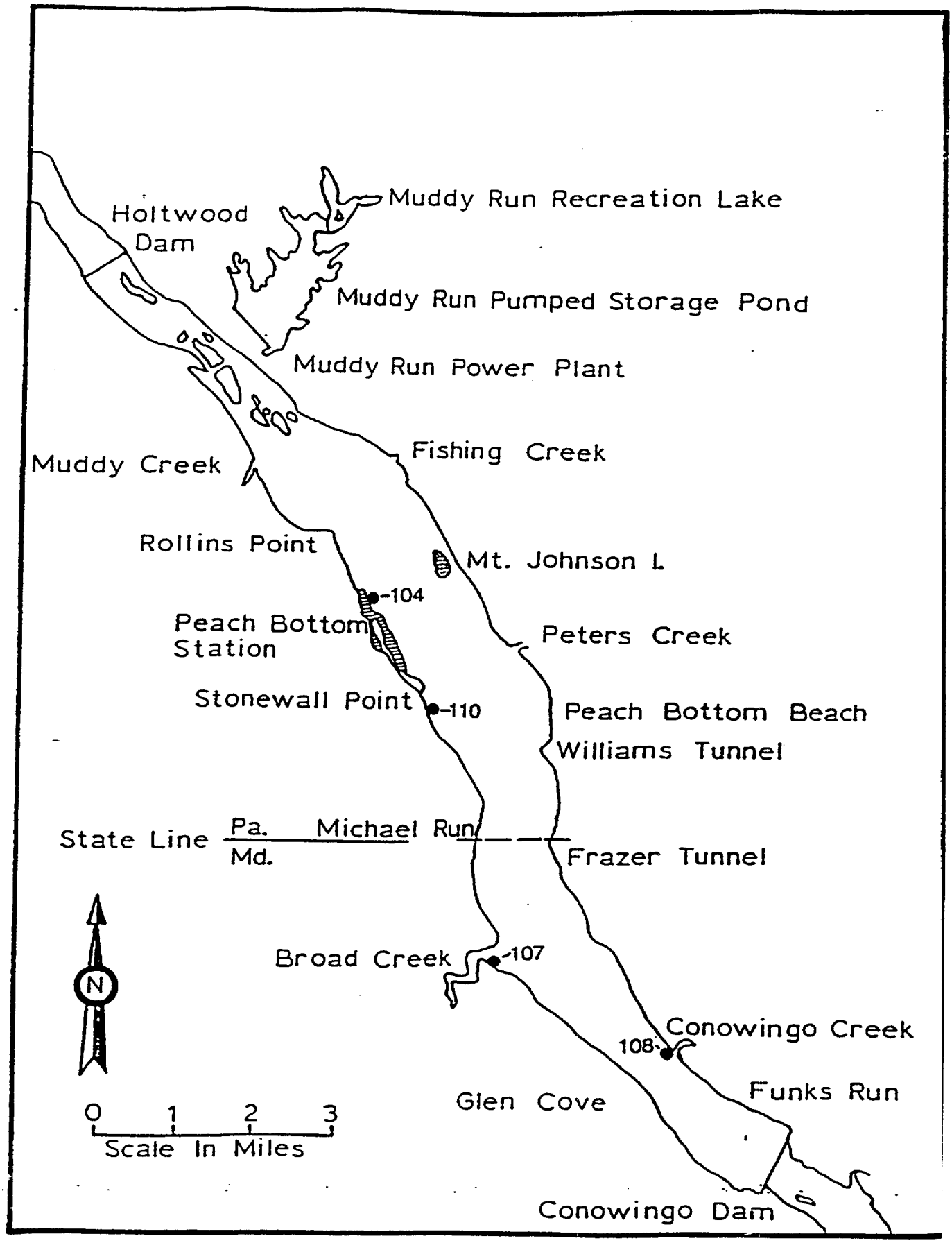


Figure 2-4 Map of Conowingo Pond showing distribution of trap net stations.

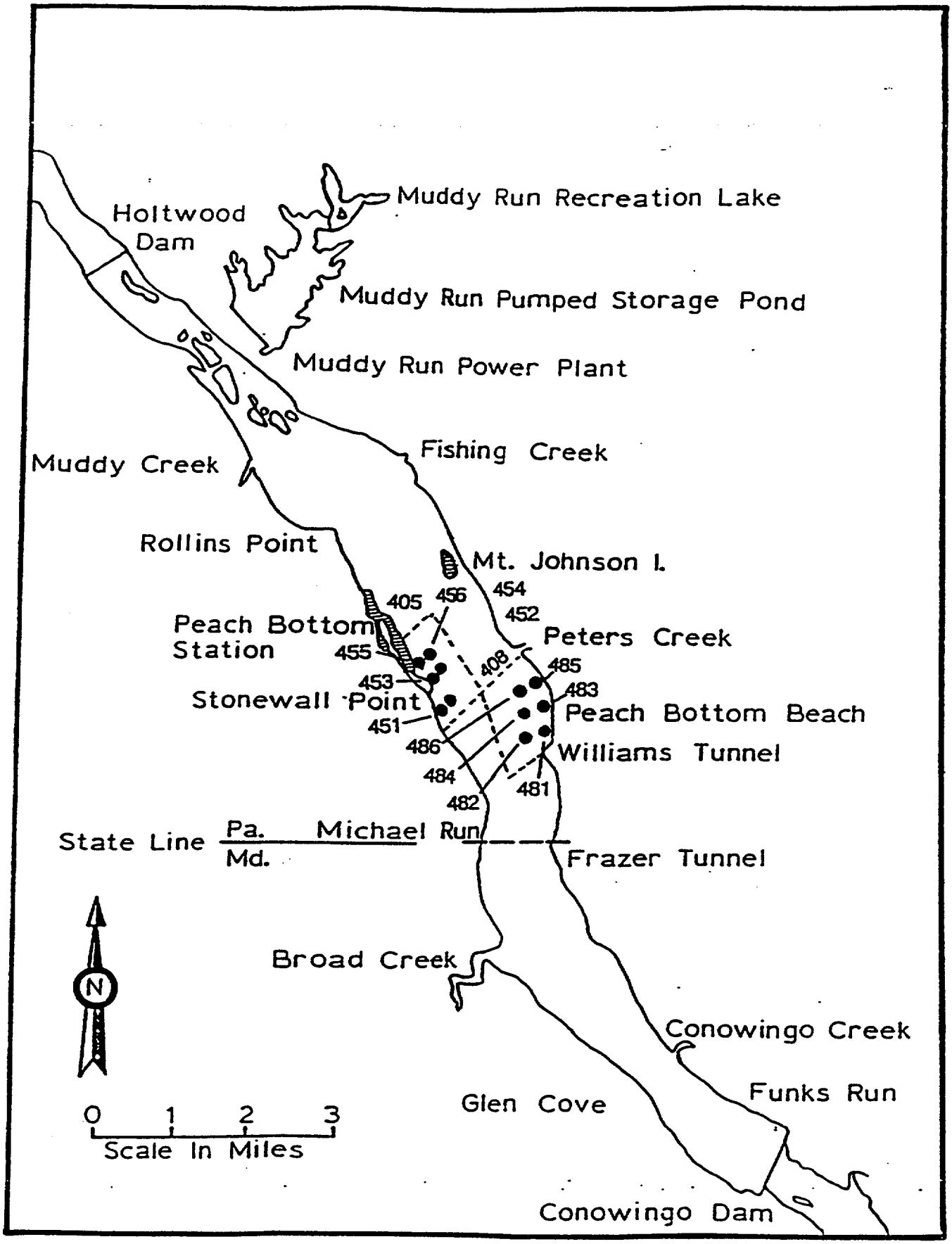


Figure 2-5 Map of Conowingo Pond showing distribution of stations in trawl zones 405 and 408.

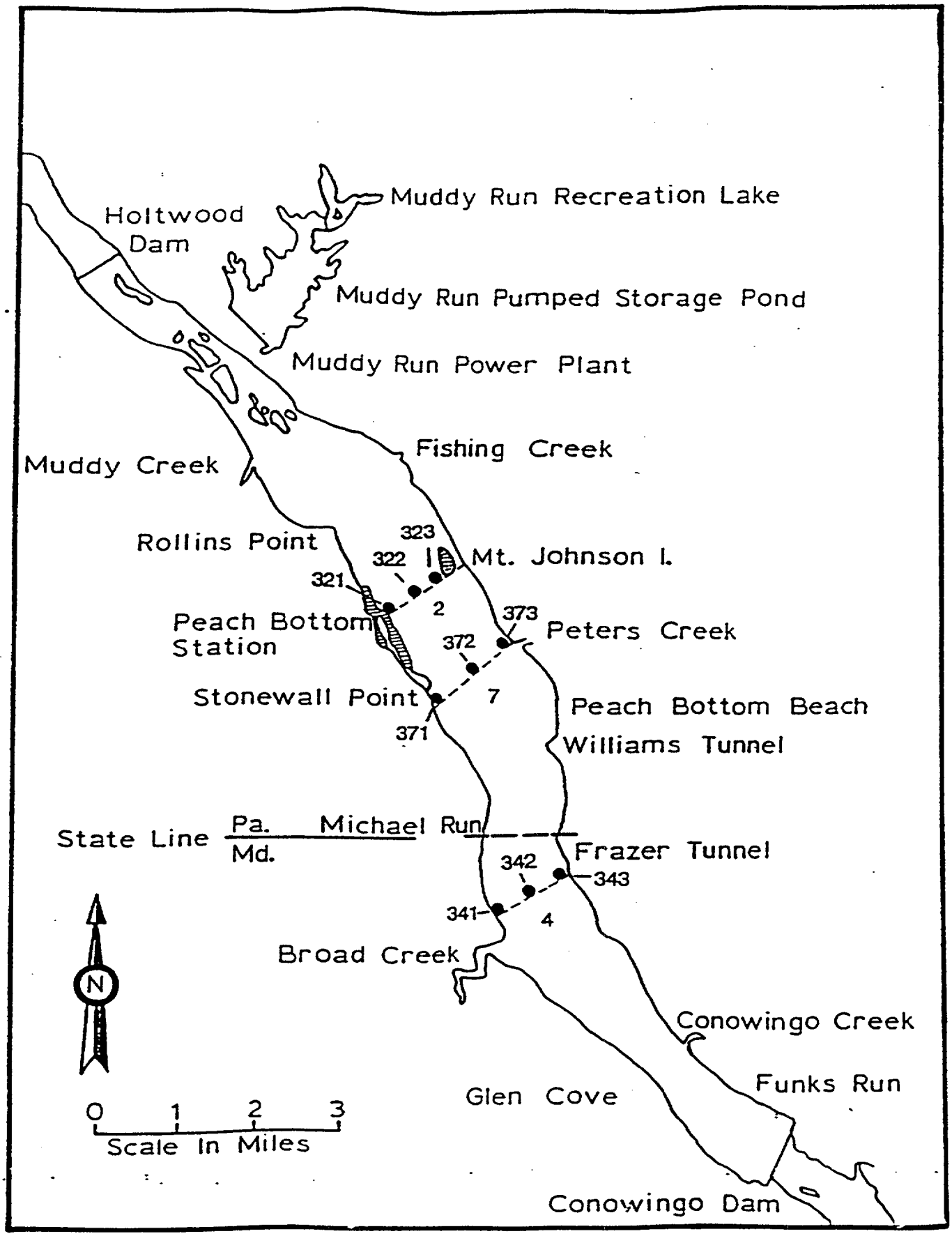


Figure 2-6 Map of Conowingo Pond showing distribution of stations in trawl transects 2, 4, and 7.

3.0 RESULTS

3.1 Study Conditions

Thermal profiling and fishery surveys were conducted at prevailing river temperatures and flows, and operational and thermal conditions at PBAPS. Table 3-1 provides a summary of the conditions experienced in each month. These conditions varied throughout the study.

3.1.1 Natural River Flow and Temperature

3.1.1.1 River Flow

During the study, average daily river flows, as measured at Holtwood Dam, ranged from 2,200 cfs (13 August) to 54,400 cfs (18 September), with the monthly mean value highest in September (26,430 cfs) and lowest in July (4,994 cfs; Table 3-1). Except in September and October, the mean river flow for each monthly survey week was ≤6,800 cfs in June-August. In September and October, the mean survey river flow was 26,780 and 10,840 cfs, respectively.

Compared to the historical flow record (1952-1998), average daily river flow in June 1999 was the lowest recorded for that month, as was that for May 1999 (Table 3-2). While not the lowest in the historical period, mean daily flows in July and August 1999 were the lowest for those months in the past 33 years, with flow for the period May-October 1999 the second lowest. Although river flows exceeded 20,000 cfs less than 25% of the time historically and in 1999; flows <10,000 cfs occurred nearly 65% in 1999 versus 42% of the time historically (Figure 3-1). The occurrence of flows <10,000 cfs in 1999 was similar to that in 1997 (the initial study year at zero tower operation) and greater than that in 1998 (the second study year). As in 1997 and 1998, river flows in 1999 were also much lower than flows in 1996 (the pilot study year for evaluating tower operation scenarios). River flows <10,000 cfs rarely occurred in 1996, with no values <7,500 cfs (Normandeau Associates, 1997a). Flow duration curves showing the historical versus 1997 to 1999 comparisons by month are provided in Appendix A.

3.1.1.2 River Temperature

Average daily river inflow temperatures, as measured at Holtwood Dam (Table 3-1), ranged from 53.2°F (31 October) to 85.9°F (8 July). Mean inflow temperatures were ≥80°F for the survey conducted in July (84.4°F), 74.9°F in June, 78.8°F in August, 65.6°F in September and 53.9°F in October. On a monthly basis, mean values were highest in July followed by August, June and September, and lowest in October.

Compared to the historical June-October record (1956-1998), average daily inflow temperatures in 1999 were slightly lower (Figure 3-2). In both periods, inflow temperatures exceeded 80°F nearly 32% of the time, while the occurrence of temperatures in the range of 65 to 80°F was higher in 1999, and higher historically for temperatures >85°F. Compared to 1997 and 1998, inflow temperatures were slightly cooler in 1999.

Because water temperature and river flow are important influencing variables, an analysis of their joint occurrence was performed to provide a perspective on conditions that fishes experienced historically, in 1999, and in 1997-1998. Table 3-3 provides the results of this analysis for the entire period of June through October. Appendix A shows the same analyses for each month.

Historically, although water temperatures ≥80°F occurred 35% of the time in June-October, they coincided with river flows <10,000 cfs nearly 21% of the time (Table 3-3). In 1999, the occurrence of water temperatures ≥80°F was less (32% of the time), but jointly occurred with river flows <10,000 cfs nearly 32% of the time. In contrast, these temperature and flow conditions jointly occurred less than 5% of the time in 1996 (Normandeau Associates, 1997a). In addition, the overall occurrence (and joint occurrence with flows <10,000 cfs) of water temperatures ≥80°F in June-October 1999 was greater than that which occurred in 1997, 1998, and in 1995 (the most recent period of high temperatures and near historic low river flows when cooling towers were in operation at PBAPS). In 1995, water temperatures ≥80°F occurred jointly with flows <10,000 cfs about 29% of the time (Normandeau Associates, 1997a).

3.1.2 PBAPS Operational and Thermal Conditions

3.1.2.1 Power Output

The average daily power output ranged from 0 to 200% (the sum of both units) during the study period (Table 3-1). The station was operated at the maximum level of power achievable based on available fuel supplies.

Figure 3-3 shows the weekly average power output in June-October 1999. Overall, maximum output (near 200%) declined in summer to near 150% in late September due to fuel depletion during the Unit 3 end of cycle coast down. . Except in early October when both units were shutdown, Unit 2 remained operational at 100% power during the Unit 3 refuel outage (30 September to 29 October). Full load (>195%) was restored by 1 November.

End of cycle coast down of one unit is an annual operational occurrence in spring to summer. As a result, the total power output of the station is less than the maximal 200% (Table 3-4).

3.1.2.2 Inlet (Intake) Temperatures

During the study, the daily average temperature at the PBAPS inlet ranged from 54.4°F (27 and 28 October) to 86.5°F (1 August) (Table 3-1). Overall, daily inlet temperatures were highest in July (79.7-86.3°F, with values >80°F on 30 of the 31 days) followed by August (76.6-86.5°F, with values >80°F on 21 days), and June (72.6-81.6°F, with values >80°F on 4 days) and lowest in October (54.4-66.9°F). Except for one day (2 July), inlet temperatures exceeded 80°F for a 56 consecutive day period (27 June-21 August). In July-August 1999 inlet temperatures ≥83°F occurred on 35 days compared to 3 and 13 days in 1997 and 1998, respectively (Normandeau 1998, 1999).

Compared to corresponding river inflow temperatures measured at Holtwood Dam, inlet temperatures followed a similar pattern, but were generally higher (1 to 4°F) in June to August, with differences less than 1°F in September and October (Figure 3-4).

3.1.2.3 Condenser Outlet and Discharge Temperatures

Condenser outlet temperatures reflect the warmest water available for discharge at PBAPS, the magnitude of which is dependent on the inlet water temperature and power output/heat loads. Excluding early October when both units were shutdown, daily condenser outlet water temperatures ranged from 68.3 to 107.2°F, with survey and monthly mean values highest in July, followed by August, June and September, and lowest in October (Table 3-1). Corresponding average daily condenser ΔT's were 12.3 to 24.0°F based on the number of units and circulating water pumps in operation. The ΔT's in late September and late October (Figure 3-3) were 4-6°F higher than normal due to the removal from service (for preventative maintenance) of one of the three Unit 3 main condenser circulating cooling water pumps. Following the shutdown of Unit 3, mean condenser ΔT's in October were 17-20°F when Unit 2 operated at 100% power and three circulating water pumps (which represents half the total condenser outflow volume when both units are operating). Compared to 1993-1998, the decline in condenser ΔT's and power levels (when the units operated with six pumps) in 1999 was less than that observed in 1993-1998 (Table 3-4). The power levels and subsequent condenser ΔT's remained higher in 1999 as coast down started later and condenser cooling (heat transfer) was not as efficient due the warm ambient (inlet) cooling water temperatures (83-87°F) in July-August.

Water temperatures at the end of the discharge canal (outfall) represent the warmest water discharged to Conowingo Pond, the magnitude of which is dependent on the station power output/heat load and the number of circulating water pumps operating. In 1999, the daily average temperature of water discharged to Conowingo Pond ranged from 66.7 to 106.5°F (Table 3-1).[1] Except for some minor

[1] As is evident in Table 3-1, some mean and/or range values given for the PBAPS discharge temperatures differ slightly from the corresponding condenser outlet value. These differences are attributed primarily to the measurement process for each location. Average daily condenser outlet temperatures reflect the mean of hourly measurements recorded to the nearest 0.1°F via multiple thermistors placed at the outlet side of unit condensers, while the discharge temperature is the average of six readings per day (each taken at 4 hr intervals and recorded to the nearest 1°F).

differences, the average daily discharge temperature generally approximated the average condenser outlet temperature throughout most of the study period (Figure 3-5). A summary of observed discharge ΔT's (canal outfall temperature minus the inlet temperature) is provided in Figure 3-6. Except in September and late October when only 5 circulating water pumps were in operation at power, discharge ΔT's generally were less than the predicted design ΔT of 20.8°F.

3.2 Thermal and Dissolved Oxygen Conditions in Conowingo Pond

3.2.1 Thermal Conditions

Thermal profiling was conducted on 11 weeks in June through October 1999 to evaluate the areas in Conowingo Pond affected by the thermal discharge. The number of locations profiled on each transect included three for Fishing Creek, five for Burkins Run, and four each at Williams Tunnel and the PA/MD State Line (Table 2-1; Figure 2-1). However, for brevity, only data from three locations on each transect downstream of the discharge are utilized in subsequent presentation and discussion. The locations selected were considered representative of thermal conditions observed across each transect: western area of Conowingo Pond, mid-pond, and eastern area. Respectively, the selected locations include Stations 201, 203, and 205 on the Burkins Run transect, Stations 301, 303, and 304 on the Williams Tunnel transect, and Stations 402, 403, and 404 on the PA/MD State Line transect. On the latter transect, Station 402 was considered more representative of thermal, flow, and depth conditions along the west shore than Station 401. Station 401 was shallower and slightly cooler, perhaps influenced by inflow from Michael's Run (located approximately 500 yds upstream).

The magnitude of the effect of the thermal discharge was evaluated by examining the differences in absolute temperature, or ΔT's (temperature at location/depth minus the corresponding PBAPS inlet temperature).

Table 3-5 provides these differences by locations and depths for selected weeks in June through October 1999. Overall, the influence of the heated discharge from PBAPS, which dissipated rapidly within the two miles downstream to the State Line, was most evident at the West location on the Burkins Run transect, followed by the West and Mid-pond location on the Williams Tunnel transect. In addition, the heated effluent was limited to the top 5 to 15 ft of the water column, with the warmest water at the surface, at affected locations. Except at the West location on the Burkins Run transect, temperature differences between depths greater than 5 to 15 ft usually were within 2 to 4°F of that at the inlet. The highest temperatures in the water column occurred at the Burkins Run West surface location (ΔT's varied from 7.5 to 13.9°F), with ΔT's at the bottom typically 2 to 4°F less than those at the surface. Compared to the PBAPS inlet values, surface values at locations across the State Line transect were 2.1 to 7.1°F higher, with ΔT's in most weeks ≤4°F. The differences in ΔT's among other locations and depths on transects downstream of the PBAPS discharge as well as the locations on the upstream transect (Fishing Creek), generally were <3°F.

Table 3-6 provides a general comparison of profile water temperatures measured at common locations (west shore) downstream of the PBAPS in August and September in 1995 (when a minimum of three towers operated and when high water temperatures coincided with low river flows) and in 1999 (zero tower operation). In August, daily river flows most often were <6000 cfs and daily intake temperatures >81°F in both years. In September 1995, daily temperatures were higher and daily inflows lower than observed in 1999. The prevailing river flows in August 1999 were the lowest experienced in August in the past 33 years, whereas those in 1995 were the second lowest. In August, discharge temperatures were higher at zero tower operation (1999) versus multiple tower operation (1995). However, the general effect of the higher discharge temperature on the vertical distribution of temperature at locations downstream of the discharge was not as readily apparent. Overall, at zero tower operation (1999) temperature profiles at downstream locations (particularly at Williams Tunnel and the State Line locations) were similar to those under multiple tower operations (1995). Although the mean discharge temperature in September was the same in both years, water temperatures at locations downstream of the discharge were lower in 1999 due to the higher and cooler inflow conditions.

3.2.2 Dissolved Oxygen (DO) Conditions

DO profiling was conducted in conjunction with thermal surveys, and in July through August included two sets of profiles (AM and PM) on a weekly basis at west, mid-pond, and east locations on three transects (Fishing Creek, Burkins Run, and Williams Tunnel) as requested by the PFBC. The locations used in subsequent presentation are the same as those selected above for thermal profiling. As appropriate, corresponding values at depth from locations on a given transect were pooled to represent DO conditions and trends observed during the study period.

Figure 3-7 summarizes weekly DO (surface and bottom) conditions. Overall, DO varied seasonally and was higher at the surface than at the bottom, trends commonly observed in the historical period (RMC, 1985) and in temperate waters. In most weeks, surface DO values were >7 mg/l, differences between transects usually were <1 mg/l, and DO was not consistently higher or lower at any given transect (Table 3-7). However, corresponding bottom DO values were lower in June-August, particularly at the deeper water stations along the east shore on Williams Tunnel and the State Line transects. During this period, mean bottom DO was <5 mg/l, while values exceeded 5 mg/l at other times. At the Fishing Creek transect (located upstream of PBAPS) and Burkins Run transect (located just downstream of the PBAPS discharge) DO values in bottom waters remained >5 mg/l throughout the study period. Overall, bottom DO was consistently higher at the Burkins Run and Fishing Creek transects, and lowest at the State Line transect.

Although mean bottom DO was usually lower than corresponding surface values (Table 3-7), the magnitude of difference in most weeks was <2 mg/l at the Fishing Creek Transect, <1 mg/l Burkins Run Transect, while differences exceeded 3 mg/l at the Williams Tunnel and State Line transects. The weekly mean value for each of these transects reflected the contribution of the low bottom DO in the deeper waters primarily along the eastern shore (Station 304 on the Williams Tunnel transect and 404 on the State Line transect). Overall, DO in bottom and near bottom waters at theses locations in summer 1999 generally was lower than conditions observed in 1997 and 1998 (Normandeau 1998,1999). The lower DO conditions in 1999 were attributed to the extended period of record low inflows in May-August.

3.2.3 Diurnal Variations in DO

In July through August the weekly survey included two sets of profiles (AM and PM) at selected locations on the Fishing Creek, Burkins Run and the Williams Tunnel transects to evaluate diurnal variations. These profiles were taken to evaluate the potential near-field effects of zero tower operation on diurnal variations in DO. Figure 3-8 provides a comparison of the AM and PM mean DO values at the surface and bottom on sampled transects. Throughout the period, surface PM values were higher than corresponding AM values at transects located downstream of the PBAPS discharge (Burkins Run and Williams Tunnel), while the same occurred in most sampled weeks at the upstream Fishing Creek transect. Generally, the difference between surface AM and PM values was within 1 to 3 mg/l, with slightly higher values at transects located downstream of the PBAPS discharge. During most survey weeks, diurnal variation in DO was also evident in bottom waters. However, the difference between AM and PM values at the bottom was usually less than that observed in surface waters.

Overall, under the warm water temperature and record low river flow conditions experienced in summer 1999, DO conditions in the study area were good and reflected seasonal, spatial, and diurnal variations observed under similar flow and temperature conditions historically (RMC, 1985).

Table 3-1

Summary of the mean and range of daily plant power output, temperature conditions, and river flows and temperatures (measured at Holtwood Dam) during thermal and fish population surveys conducted at zero tower operations at PBAPS, June-October 1999.

	June	July	August	September	October
Survey Period (Week of)	20 Jun	25 Jul	22 Aug	19 Sep	24 Oct
Power Output (%)[1]					
Survey Mean	200	199	190	180	129
Survey Range	199-200	198-200	183-193	179-181	102-184
Monthly Mean	197	198	193	172	92
Monthly Range	168-200	169-200	165-199	80-189	0-196
Inlet Temperature (°F)					
Survey Mean	76.3	85.1	79.1	65.2	54.5
Survey Range	74.7-78.0	84.7-86.3	78.7-79.5	64.6-66.1	54.4-54.8
Monthly Mean	77.2	83.6	82	71.7	59.4
Monthly Range	72.6-81.6	79.7-86.3	76.6-86.5	64.6-79.3	54.4-66.9
Condenser Outlet Temperature (°F)					
Survey Mean	96.7	105.7	98.6	87.9	71.2
Survey Range	95.1-98.4	105.2-107.2	98.2-99.1	87.1-89.5	68.3-76.7
Monthly Mean	97.6	104.2	102.2	91.1	74.5
Monthly Range	93.4-102.2	100.1-107.2	96.1-107.0	79.3-98.5	65.1-81.0
Discharge (Outfall) Temperature (°F)					
Survey Mean	96.3	104.9	98.1	87.8	70.9
Survey Range	94.7-97.8	104.3-106.5	97.8-98.5	86.5-89.0	68.5-75.7
Monthly Mean	96.9	103	101.6	91.1	74.7
Monthly Range	93.2-101.0	98.7-106.5	96.3-105.8	81.2-97.6	66.7-80.8
Actual ΔT (°F)[2]					
Survey Mean	20.4	20.6	19.5	22.7[4]	16.6
Survey Range	20.4-20.5	20.5-20.9	19.0-19.8	22.0-24.0[4]	13.6-22.1[4]
Monthly Mean	20.5	20.6	20.2	19.4	15.0
Monthly Range	18.9-21.8	19.7-20.9	19.0-21.1	12.3-24.0[4]	0.2-23.3[4]
Design ΔT (°F)[3]	20.8	20.8	20.8	20.8	20.8
River Flow (cfs)					
Survey Mean	6,160	3,720	6,800	26,780	10,840
Survey Range	5,000-7,400	3,600-3,900	5,400-10,100	21,900-30,300	10,100-11,800
Monthly Mean	7,010	4,994	5,158	19,687	19,329
Monthly Range	4,400-11,600	3,400-7,500	2,200-15,200	3,700-54,400	8,900-42,100
River Temperature (°F)					
Survey Mean	74.9	84.4	78.8	65.6	53.9
Survey Range	74.5-75.1	84.3-84.7	78.2-79.4	64.6-66.5	53.6-54.5
Monthly Mean	76.6	82.7	80.8	71.6	59
Monthly Range	72.9-79.3	78.0-85.9	76.3-84.5	64.4-78.9	53.2-67.4

1 The total station percent power output (Unit 2 & Unit 3). Maximum station output is 200% when both units operate at 100% power. The values in June through September reflect the maximum output achievable due to end of cycle coast down for Unit 3. Unit 3 was shutdown for refueling on 30 September and restored to near 100% power load in late October.

2 Actual ΔT (condenser outlet temperature minus inlet temperature) measured during the study.

3 Design condenser ΔT criteria for both units operating at 100% power with six circulating water pumps.

4 One Unit 3 circulating pump was out of service; a total of only 5 pumps were operational for 11 days at the end of September, and 7 days in late October. This resulted in a ΔT that was 4-6°F higher than what would have occurred with all pumps operating.

Table 3-2

Monthly mean river flow and water temperature at Holtwood Dam, May-October 1952-1998, and in 1995, 1996, 1997, 1998, and 1999.

Period	May	June	July	August	September	October	May-October
				Flow (cfs)			
1995 *	22,752	20,223	15,545	5,745	3,703	23,997	15,364
1996	82,229	28,833	26,368	15,942	39,813	52,487	41,017
1997	30,968	24,710	8,794	7,613	7,897	7,068	14,489
1998	75,255	26,430	22,184	7,019	4,843	7,461	23,955
1999	19,939 **	7,010 **	4,994	5,158	19,867	19,329	12,708 **
1952-1998	49,239	29,935	16,940	12,042	13,331	18,766	23,504
				Water Temperature (°C)			
1995 *	65.3	76.1	80.6	84.3	76.8	64.6	74.6
1996	61.6	77.0	79.3	81.3	72.6	59.3	71.8
1997	62.8	75.8	83.4	80.9	74.4	63.2	73.4
1998	65.6	74.5	80.0	81.3	76.7	65.6	74.0
1999	67.8	76.6	82.7	80.8	71.6	59.0	73.1
1952-1998	63.8	74.9	81.1	80.9	75.0	62.5	73.0

* 1995 is the most recent period of high water temperatures and near record low river flows when cooling towers were in operation at PBAPS.

** Mean daily river flows in May and June 1999 set a new record low for those months, while the flows for July and August 1999 were the lowest in the last 33 years.

Table 3-3

Joint occurrence of daily water temperature and river flow at Holtwood Dam, June-October 1956-1998, 1997, 1998, and 1999.

Daily Average River Flow (cfs)	Daily Average Temperature (°F) 40-49 No.	40-49 Pct.	50-59 No.	50-59 Pct.	60-69 No.	60-69 Pct.	70-79 No.	70-79 Pct.	80-85 No.	80-85 Pct.	>85 No.	>85 Pct.	Total No.	Total Pct.
						1956-1998								
< 2,500	.	.	.	.	8	0.12	11	0.17	10	0.16	9	0.14	38	0.59
2,500-4,999	.	.	22	0.34	102	1.59	219	3.42	277	4.33	108	1.69	728	11.37
5,000-7,499	.	.	59	0.92	170	2.65	283	4.42	334	5.22	138	2.15	984	15.37
7,500-9,999	.	.	35	0.55	151	2.36	267	4.17	361	5.64	71	1.11	885	13.82
10,000-14,999	.	.	67	1.05	174	2.72	481	7.51	479	7.48	41	0.64	1,242	19.39
15,000-19,999	.	.	49	0.77	116	1.81	461	7.20	228	3.56	7	0.11	861	13.44
20,000-29,999	1	0.02	42	0.66	124	1.94	483	7.54	138	2.15	1	0.02	789	12.32
30,000-39,999	.	.	19	0.30	71	1.11	227	3.54	42	0.66	.	.	359	5.61
40,000-50,000	2	0.03	27	0.42	34	0.53	103	1.61	13	0.20	.	.	179	2.80
> 50,000	20	0.31	74	1.16	119	1.86	118	1.84	8	0.12	.	.	339	5.29
Total	*23*	*0.36*	*394*	*6.15*	*1,069*	*16.69*	*2,653*	*41.43*	*1,890*	*29.51*	*375*	*5.86*	*6,404*	*100.00*
						1997								
< 2,500	.	.	.	.	.	.	.	.	.	.	.	.	0	.
2,500-4,999	.	.	.	.	1	0.65	.	.	6	3.92	.	.	7	4.58
5,000-7,499	.	.	7	4.58	17	11.11	16	10.46	15	9.80	5	3.27	60	39.22
7,500-9,999	.	.	.	.	4	2.61	11	7.19	14	9.15	2	1.31	31	20.26
10,000-14,999	.	.	.	.	5	3.27	6	3.92	16	10.46	1	0.65	28	18.30
15,000-19,999	.	.	.	.	.	.	10	6.54	3	1.96	.	.	13	8.50
20,000-29,999	.	.	.	.	3	1.96	4	2.61	.	.	.	.	7	4.58
30,000-39,999	.	.	.	.	3	1.96	.	.	.	.	.	.	3	1.96
40,000-50,000	.	.	.	.	2	1.31	.	.	.	.	.	.	2	1.31
> 50,000	.	.	.	.	2	1.31	.	.	.	.	.	.	2	1.31
Total	*0*	.	*7*	*4.58*	*37*	*24.18*	*47*	*30.72*	*54*	*35.29*	*8*	*5.23*	*153*	*100.00*
						1998								
< 2,500	.	.	.	.	.	.	.	.	.	.	.	.	0	.
2,500-4,999	.	.	.	.	.	.	22	14.38	2	1.31	.	.	24	15.69
5,000-7,499	.	.	3	1.96	8	5.23	7	4.58	22	14.38	2	1.31	42	27.45
7,500-9,999	.	.	.	.	9	5.88	2	1.31	13	8.50	.	.	24	15.69
10,000-14,999	.	.	.	.	5	3.27	.	.	10	6.54	.	.	15	9.80
15,000-19,999	.	.	.	.	5	3.27	4	2.61	1	0.65	.	.	10	6.54
20,000-29,999	.	.	.	.	2	1.31	11	7.19	6	3.92	.	.	19	12.42
30,000-39,999	.	.	.	.	2	1.31	10	6.54	3	1.96	.	.	15	9.80
40,000-50,000	.	.	.	.	.	.	2	1.31	2	1.31	.	.	4	2.61
> 50,000	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Total	*0*	.	*3*	*1.96*	*31*	*20.26*	*58*	*37.91*	*59*	*38.56*	*2*	*1.31*	*153*	*100.00*
						1999								
< 2,500	.	.	.	.	.	.	.	.	3	1.96	.	.	3	1.96
2,500-4,999	.	.	.	.	.	.	12	7.84	28	18.30	.	.	40	26.14
5,000-7,499	.	.	.	.	.	.	27	17.65	15	9.80	1	0.65	43	28.10
7,500-9,999	.	.	1	0.65	.	.	9	5.88	2	1.31	.	.	12	7.84
10,000-14,999	.	.	10	6.54	.	.	6	3.92	.	.	.	.	16	10.46
15,000-19,999	.	.	5	3.27	8	5.23	2	1.31	.	.	.	.	15	9.80
20,000-29,999	.	.	1	0.65	12	7.84	1	0.65	.	.	.	.	14	9.15
30,000-39,999	.	.	.	.	4	2.61	1	0.65	.	.	.	.	5	3.27
40,000-50,000	.	.	.	.	2	1.31	.	.	.	.	.	.	2	1.31
> 50,000	.	.	.	.	2	1.31	1	0.65	.	.	.	.	3	1.96
Total	*0*	.	*17*	*11.11*	*28*	*18.30*	*59*	*38.56*	*48*	*31.37*	*1*	*0.65*	*153*	*100.00*

Table 3-4

Comparison of average monthly measured versus model-predicted condenser ΔT at the Peach Bottom Atomic Power Station with both units operating at maximum power achievable (and six circulating water pumps), Spring to Fall 1993-1998, and 1999. N represents the number of days.

Month	N	Total Power Output (%)	Condenser ΔT (°F) Predicted	Observed	Difference
			1993-1998		
April	41	195	20.8	19.4	1.4
May	129	189	20.8	18.8	2.0
June	173	184	20.8	17.9	2.9
July	168	178	20.8	17.4	3.4
August	159	170	20.8	16.7	4.1
September	74	163	20.8	16.0	4.8
October	30	190	20.8	18.7	2.1
			1999		
April	4	200	20.8	20.7	0.1
May	31	200	20.8	21.1	-0.3
June	30	197	20.8	20.5	0.3
July	31	198	20.8	20.6	0.2
August	31	193	20.8	20.2	0.5
September [a]	19	177	20.8	18.4	2.4
October [b]	--	--	20.8	--	--

a Due to the operational loss of one Unit 3 circulating water pump, only 5 pumps were operational on 11 days in late September.

b Unit 3 was in outage from 30 September until restored to near 100% power in late October. During the Unit 3 outage, Unit 2 operated at 100% power on 16 days; condenser ΔT's were 12.3 to 15.7°F on those days..

Table 3-5

Selected weekly thermal profile conditions (expressed as ΔT = temperature at location/depth minus the corrsesponding PBAPS Inlet temperature) at locations sampled in Conowingo Pond, June-October 1999. (For transect locations W = western area; M = mid-pond; and E = eastern area)

		Week of																				
		20 June*			11 July			25 July*			8 August			22 August*			19 September*			24 October*		
	Depth	W	M	E	W	M	E	W	M	E	W	M	E	W	M	E	W	M	E	W	M	E
Holtwood Dam	-	-1.4	-	-	-0.8	-	-	-0.4	-	-	-2.1	-	-	-0.1	-	-	-0.1	-	-	-2.2	-	-
Fishing Creek	0	-2.1	-1.1	-0.4	-2.9	-1.5	-0.6	-1.6	0.0	1.3	-2.3	0.4	-0.3	-2.5	-1.6	-2.0	-0.5	-0.3	-0.1	-1.0	-0.6	-0.6
	5	-2.9	-1.3	-	-2.9	-1.5	-0.6	-2.1	-0.3	-	-2.3	0.4	-	-2.4	-1.6	-	-0.5	-0.4	-	-1.5	-1.1	-0.8
	10	-3.4	-	-	-2.9	-	-1.0	-2.0	-2.1	-	-2.3	0.4	-	-2.5	-	-	-0.5	-	-	-1.6	-1.1	-
	15	-3.6	-	-	-2.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Bottom	-3.6	-3.3	-4.0	-2.9	-1.9	-1.0	-2.1	-2.3	0.4	-2.3	-0.7	-0.7	-2.5	-2.3	-4.1	-0.6	-0.4	-0.6	-1.6	-1.1	-0.8
PBAPS Inlet	-	**76.2**	-	-	**82.1**	-	-	**84.9**	-	-	**82.9**	-	-	**79.0**	-	-	**65.8**	-	-	**54.6**	-	-
PBAPS Discharge	-	19.8	-	-	19.7	-	-	19.6	-	-	19.6	-	-	19.1	-	-	23.1	-	-	14.7	-	-
Burkins Run	0	11.9	4.5	4.4	11.1	3.9	1.7	11.9	4.5	3.3	13.9	6.7	6.5	9.5	0.5	1.6	12.6	0.6	0.6	7.5	0.4	-0.4
	5	10.4	2.1	-	10.2	3.5	-	11.9	4.2	-	13.0	5.3	-	8.8	0.2	-	10.5	0.6	-	7.3	0.3	-
	10	9.3	1.0	-	8.9	-1.1	-	10.4	-	-	-	0.4	-	-	-	-	-	-	-	6.5	0.0	-
	15	-	-1.2	-	-	-	-	-	-	-	-	-0.5	-	-	-	-	-	-	-	-	-	-
	Bottom	9.0	-1.2	3.5	7.9	-2.4	1.7	9.2	1.6	2.0	12.1	-0.5	4.7	8.1	-1.8	1.4	4.0	-0.2	0.3	6.3	0.0	-0.7
Williams Tunnel	0	8.1	6.7	5.8	8.8	4.3	3.9	9.6	6.5	4.7	9.4	8.3	6.7	8.3	6.1	5.9	8.9	4.1	1.1	5.5	1.6	1.3
	5	6.9	6.3	5.8	6.6	4.3	3.9	8.3	6.3	4.7	7.6	7.1	6.5	7.0	5.4	5.7	2.7	0.8	0.7	1.5	1.1	1.2
	10	5.7	4.6	5.1	2.6	3.5	2.5	5.8	4.6	4.2	5.1	4.9	4.9	5.7	4.6	4.8	1.0	-0.1	0.1	0.7	0.8	1.2
	15	4.0	-	4.0	-	-	2.1	3.8	-	2.9	-	-	2.2	2.8	-	2.3	0.2	-	-0.1	0.7	0.8	0.9
	20	0.7	-	1.4	-	-	-	-	-	-0.7	-	-	1.3	2.0	-	-	-	-	-	-	-	0.8
	25	-	-	-	-	-	-	-	-	-1.7	-	-	0.4	-	-	-	-	-	-	-	-	0.8
	Bottom	0.0	-0.5	-0.4	1.7	2.5	-1.9	2.0	2.1	-2.7	3.1	0.9	-0.1	0.7	1.4	0.3	0.2	-0.2	-0.3	0.7	0.8	0.6
PA/MD State Line	0	3.9	4.0	4.2	3.5	2.1	2.1	5.6	4.6	4.8	7.1	4.0	4.0	5.3	4.3	4.0	5.8	5.6	4.2	4.2	3.8	2.3
	5	3.6	3.7	3.7	2.1	2.1	2.1	5.1	4.6	4.8	4.0	3.8	3.6	4.3	4.3	4.0	3.1	3.7	3.6	4.1	3.5	2.3
	10	3.6	3.5	3.6	2.1	2.1	1.9	4.7	4.4	4.2	3.5	3.3	3.3	4.2	4.3	3.9	1.3	1.8	2.7	3.7	3.1	2.3
	15	3.6	-	2.5	1.9	-	1.7	4.5	-	3.7	3.1	3.1	2.7	4.2	-	3.7	0.7	-	2.4	3.3	2.6	2.3
	20	2.2	-	0.2	-	-	1.7	-	-	2.9	2.9	-	2.7	2.5	-	3.3	0.3	-	1.3	3.3	-	1.9
	25	0.3	-	-0.6	-	-	1.6	-	-	1.1	-	-	2.2	-	-	2.2	-	-	0.9	-	-	1.8
	30	-	-	-1.5	-	-	-1.1	-	-	-0.5	-	-	1.7	-	-	1.2	-	-	0.6	-	-	1.6
	35	-	-	-1.5	-	-	-1.3	-	-	-0.9	-	-	1.3	-	-	-	-	-	-	-	-	1.6
	40	-	-	-	-	-	-1.3	-	-	-2.3	-	-	1.1	-	-	-	-	-	-	-	-	1.5
	Bottom	0.3	2.6	-1.8	1.4	1.9	-1.3	2.4	1.8	-0.3	0.4	3.1	0.9	1.6	3.7	0.4	0.1	1.1	0.0	3.1	2.3	1.5

* Fish sampling survey week

** The absolute temperatures (°F) measured at the PBAPS Inlet (included for reference).

Table 3-6

Comparison of the mean (and range) profile water temperatures (F) at western sampling stations on transects located downstream of the PBAPS discharge in August and September, 1995 and 1999.

		August *				September *			
		1995 **		1999 ***		1995 **		1999 ***	
	Depth	Mean	Range	Mean	Range	Mean	Range	Mean	Range
PBAPS Discharge		90.3	88.5-90.8	100.8	97.8-104.2	88.9	85.7-91.0	88.9	88.8-89.0
Burkins Run (201)	0	87.3	84.2-92.3	93.1	85.6-98.2	84.8	82.4-87.8	78.4	77.0-79.7
	5	87.1	84.2-92.3	91.9	84.2-96.8	84.7	82.4-86.9	76.3	75.6-77.0
	10	87.8	85.1-92.3	--	--	85.1	83.3-86.9	70.0	68.0-72.0
	15	87.4	85.1-91.4	--	--	84.2	83.3-86.0	--	--
	Bottom	86.6	84.2-89.6	90.6	82.8-95.0	84.5	82.4-86.9	69.8	68.0-71.6
Williams Tunnel (301)	0	88.7	87.8-89.6	90.5	86.4-95.9	--	--	74.7	73.8-75.6
	5	87.8	87.8-87.8	89.4	86.0-95.0	--	--	68.5	67.1-69.8
	10	86.9	86.0-87.8	87.4	83.8-91.0	--	--	66.8	66.2-67.5
	15	86.9	86.9-86.9	85.2	81.5-89.6	--	--	66.0	65.8-66.2
	Bottom	86.0	86.0-86.0	83.6	78.8-88.2	--	--	66.0	65.8-66.2
State Line (402)	0	83.5	82.4-86.0	86.9	84.2-90.0	81.7	78.8-84.2	71.6	69.8-73.4
	5	83.6	82.4-86.0	85.9	82.4-89.6	81.1	78.8-82.4	68.9	67.1-70.7
	10	--	--	85.7	82.2-89.6	--	--	67.1	66.2-68.0
	15	--	--	85.5	82.2-89.2	--	--	66.5	65.8-67.1
	Bottom	83.5	82.4-86.0	83.7	80.6-87.8	81.3	78.8-83.3	65.9	65.8-66.0

* In 1995, profiles were taken daily from 25-31 August and 1-12 September when PBAPS operated a minimum of 3 cooling towers. In 1999, profiles were taken on 5 days in August and 2 days in September during zero tower operation.

** In August and September 1995, daily river inflows were <6000 cfs on most days, with inlet temperatures typically >81°F in August and >75°F in September.

*** In 1999, daily inflows were <5000 cfs on most days in August, but >10,000 cfs in September. Inlet temperatures typically were >81°F in August and >68°F in September.

Table 3-7

Selected weekly DO profiles at transect locations (W = western area; M = mid-pond; and E = eastern area) in Conowingo Pond, June-October 1999.

		Week of																				
		20 June*			11 July			25 July*			8 August			22 August*			19 September*			24 October*		
	Depth	W	M	E	W	M	E	W	M	E	W	M	E	W	M	E	W	M	E	W	M	E
Fishing Creek	0	8.6	8.8	9.4	6.0	7.3	8.4	8.0	8.0	7.4	6.8	8.2	8.2	6.6	6.9	7.2	8.7	8.2	8.1	10.1	10.0	10.0
	5	7.0	8.6	-	5.9	7.3	8.4	7.0	7.9	-	6.9	8.2	-	6.5	6.9	-	8.6	8.2	-	10.0	9.9	10.0
	10	6.6	7.7	-	5.9	7.1	8.2	6.7	7.7	-	6.9	7.9	-	6.4	-	-	8.5	8.2	-	10.0	9.9	-
	15	6.3	-	-	5.8	-	-	-	-	-	6.9	-	-	6.4	-	-	-	-	-	10.0	-	-
	Bottom	6.0	5.1	10.2	5.7	7.1	8.1	6.2	5.6	7.3	6.9	6.6	8.1	6.4	5.8	7.1	8.5	8.2	8.1	10.0	10.0	9.9
Burkins Run	0	7.6	8.3	8.3	7.1	7.1	6.9	7.1	6.4	7.1	8.0	7.5	8.6	7.2	7.1	7.3	8.2	8.2	8.1	9.9	9.8	10.1
	5	7.7	6.5	-	7.1	7.0	-	7.2	6.1	-	8.0	6.9	-	7.1	6.8	-	8.2	8.2	-	9.9	9.7	-
	10	7.8	-	-	7.1	6.4	-	-	-	-	-	7.0	-	-	-	-	8.0	8.3	-	9.9	9.7	-
	15	-	-	-	-	-	-	-	-	-	-	7.3	-	-	-	-	-	-	-	-	-	-
	Bottom	7.9	5.1	6.8	7.1	6.1	6.9	7.1	5.3	6.0	8.0	7.1	6.6	7.0	6.0	6.4	8.0	7.8	8.0	9.9	9.7	10.1
Williams Tunnel	0	7.1	7.2	7.4	7.1	6.8	6.9	6.8	6.9	7.1	9.0	8.4	9.0	7.1	7.2	7.2	8.4	8.5	8.6	9.8	9.7	9.8
	5	6.8	7.0	7.3	6.8	6.7	6.8	6.6	6.8	6.8	8.6	8.0	8.8	6.8	6.9	7.1	8.4	8.5	8.6	9.7	9.7	9.8
	10	6.1	6.9	7.1	6.0	6.5	6.6	6.3	6.1	5.9	7.8	8.0	8.1	6.7	6.9	6.9	8.4	8.3	8.6	9.6	9.6	9.7
	15	5.8	5.1	6.4	-	-	6.2	4.7	-	3.6	-	-	4.5	6.5	-	6.7	8.5	-	8.6	9.6	9.5	9.7
	20	-	-	4.8	-	-	5.6	-	-	2.7	-	-	5.4	-	-	-	-	-	8.5	-	-	9.6
	25	-	-	1.0	-	-	4.6	-	-	2.2	-	-	5.0	-	-	-	-	-	8.5	-	-	9.6
	Bottom	3.4	4.0	3.5	4.5	5.9	3.7	2.9	3.2	1.2	6.1	5.0	4.1	5.4	5.3	5.5	8.0	8.2	8.3	9.7	9.5	9.5
PA/MD State Line	0	8.7	8.3	7.7	7.0	6.7	6.6	7.2	6.6	7.0	9.4	8.6	8.7	7.4	7.2	7.2	8.5	8.7	8.7	9.4	9.6	9.5
	5	8.5	8.2	7.7	6.7	6.6	6.5	6.9	6.1	6.8	8.0	8.5	8.6	7.3	7.2	7.1	8.4	8.6	8.6	9.4	9.6	9.5
	10	8.0	8.5	7.4	6.6	6.6	6.3	6.4	5.9	6.1	8.0	7.9	7.6	7.2	7.0	7.0	8.3	8.4	8.6	9.4	9.5	9.5
	15	7.7	6.5	5.8	6.4	-	6.1	6.2	-	5.5	7.0	6.9	6.4	7.2	6.4	6.6	8.5	8.1	8.6	9.3	9.5	9.5
	20	5.3	-	4.0	-	-	6.1	-	-	3.3	4.0	-	3.9	-	-	6.1	-	-	8.5	9.2	-	9.4
	25	-	-	2.9	-	-	6.1	-	-	1.6	-	-	3.1	-	-	6.0	-	-	8.5	-	-	9.4
	30	-	-	2.4	-	-	4.4	-	-	1.6	-	-	3.5	-	-	5.5	-	-	8.4	-	-	9.4
	35	-	-	2.2	-	-	4.3	-	-	0.6	-	-	3.9	-	-	-	-	-	8.5	-	-	9.3
	40		-	2.0	-	-	4.1	-	-	0.1	-	-	4.0	-	-	-	-	-	8.3	-	-	9.3
	Bottom	2.5	5.8	1.9	5.4	6.4	3.9	3.2	4.4	1.4	3.5	6.8	3.9	5.3	5.5	4.3	8.3	8.0	8.2	9.2	9.5	9.3

* Fish sampling survey week

Figure 3-1.

Duration curve of daily average river temperatures (F) at Holtwood Dam, in June – October 1952 to 1998 (historical) and in 1997,1998, 1999.

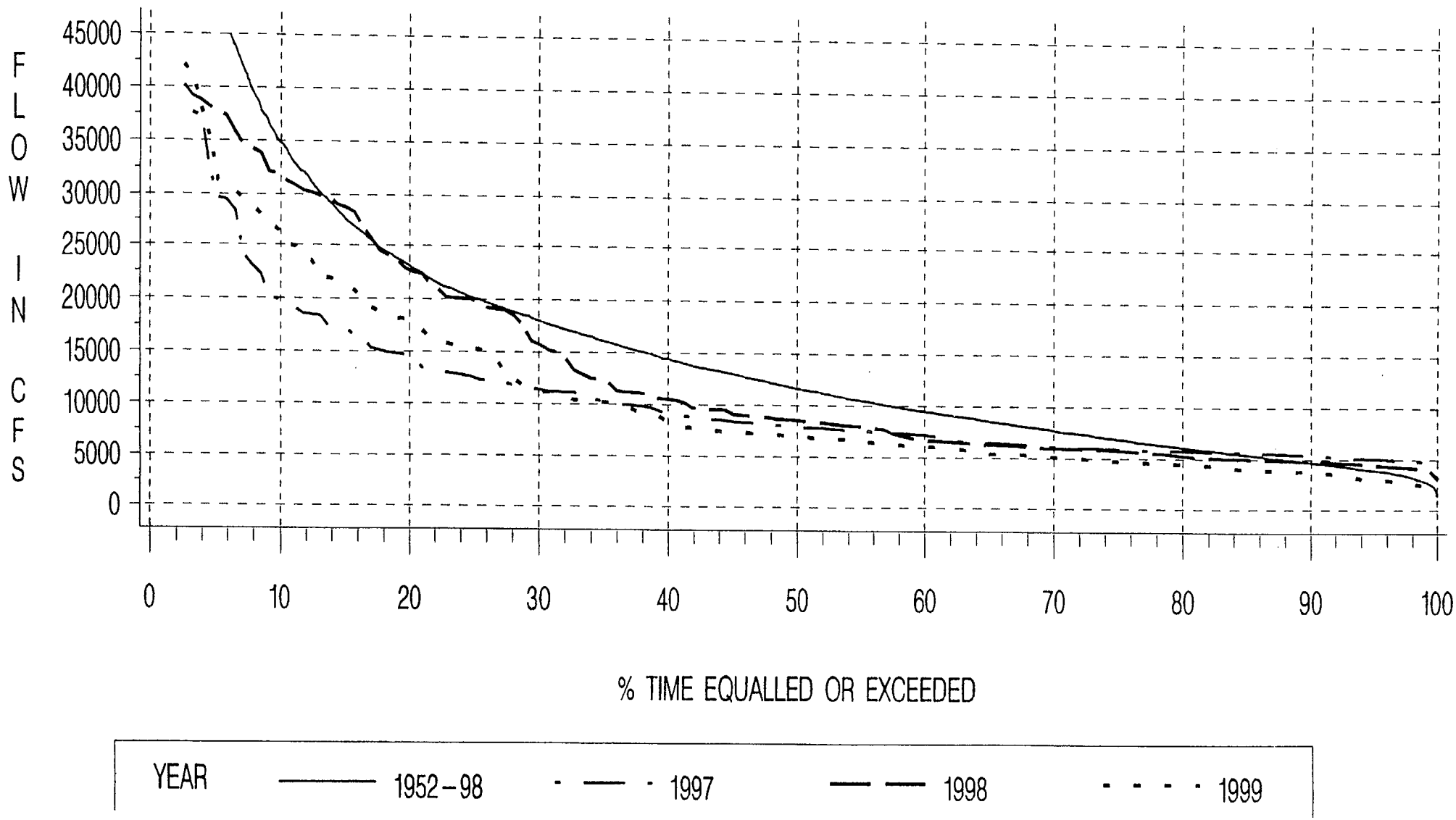
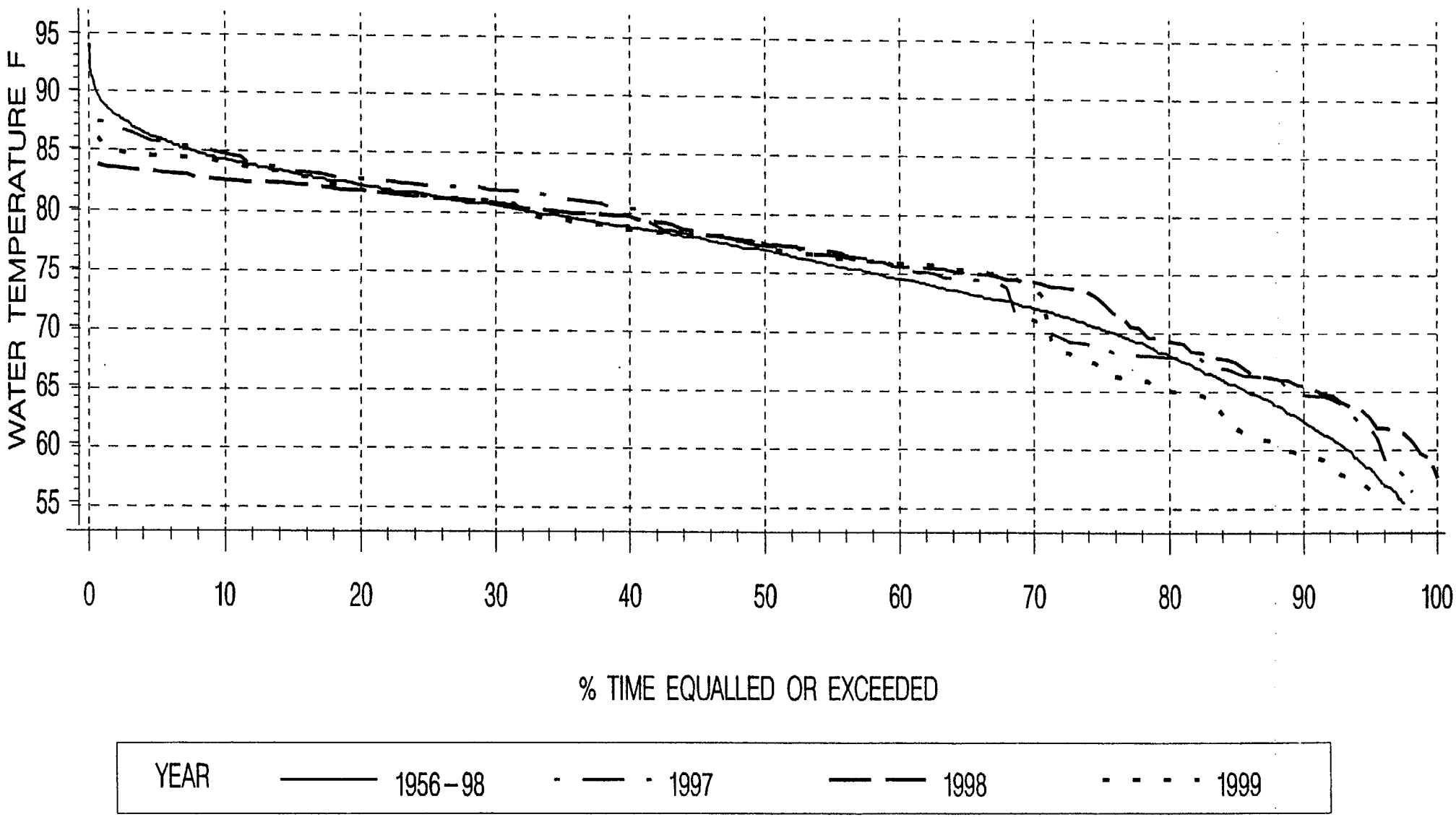


Figure 3-2.

Duration curve of daily average river temperatures (°F) at Holtwood Dam, in June – October 1956 to 1998 (historical) and in 1997,1998, 1999.



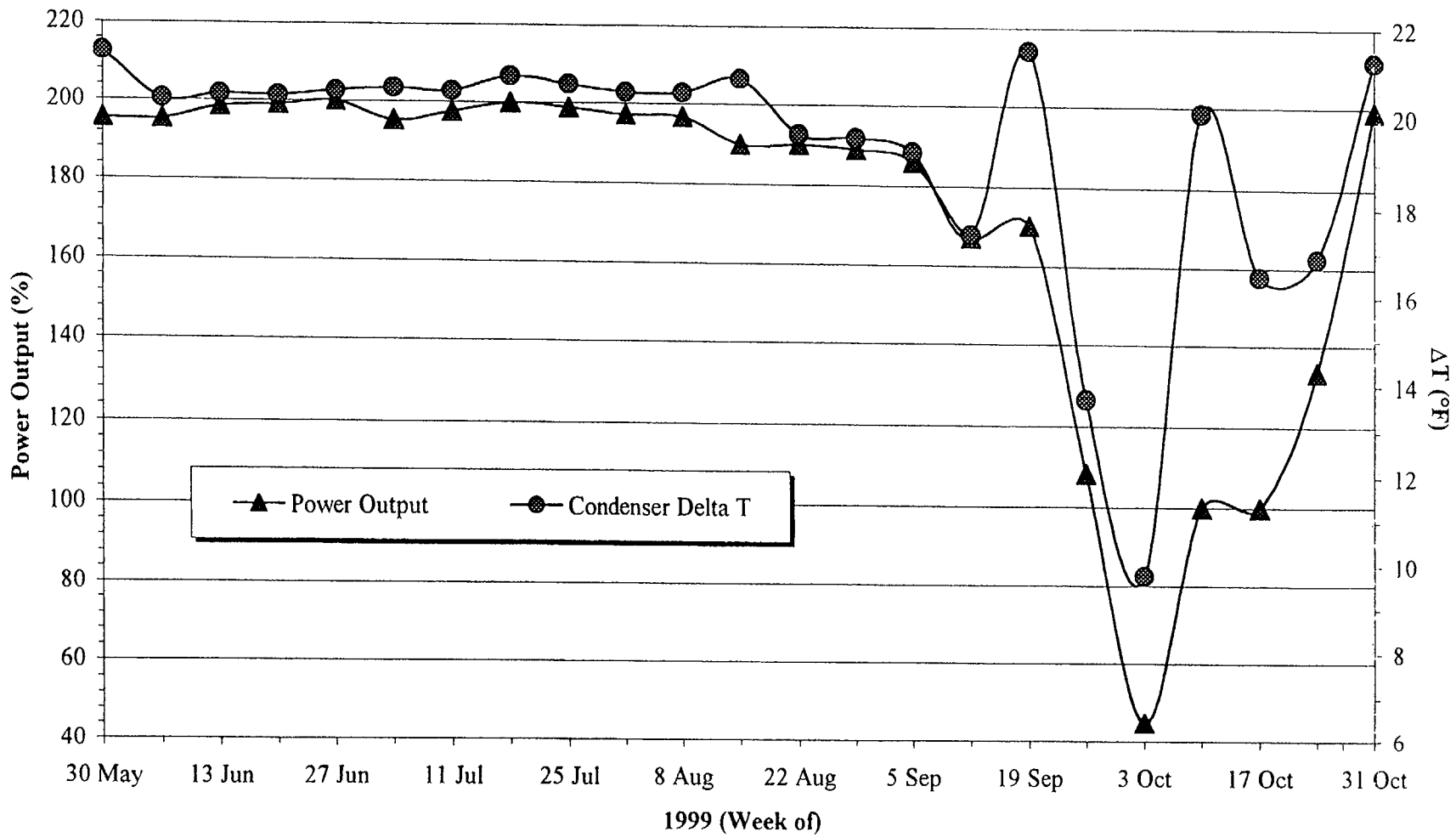


Figure 3-3

Weekly mean percent (%) power output and condenser ΔT (°F) at PBAPS, June-October 1999.

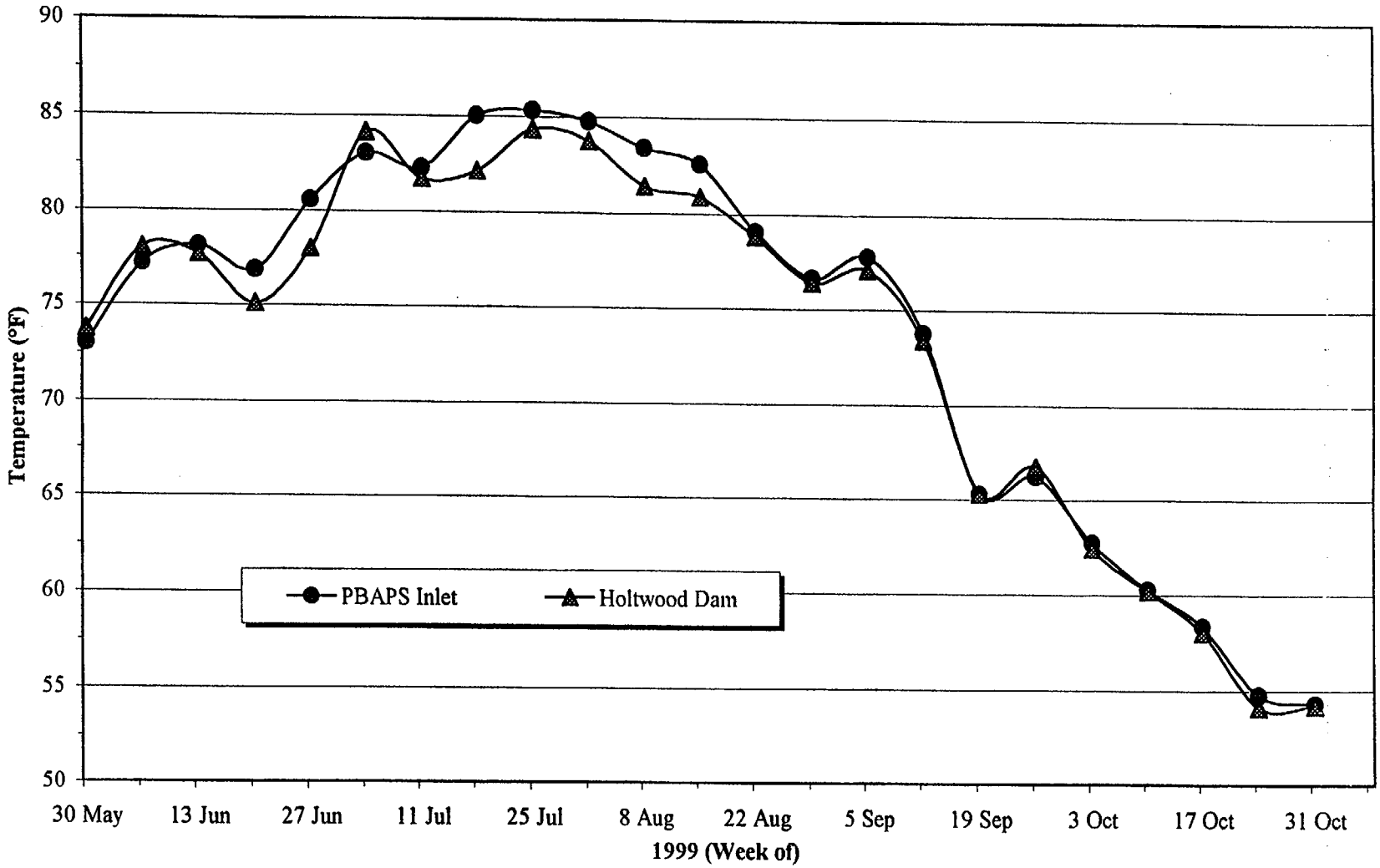


Figure 3-4

Weekly mean temperatures (°F) at Holtwood Dam and PBAPS inlet, June-October 1999.

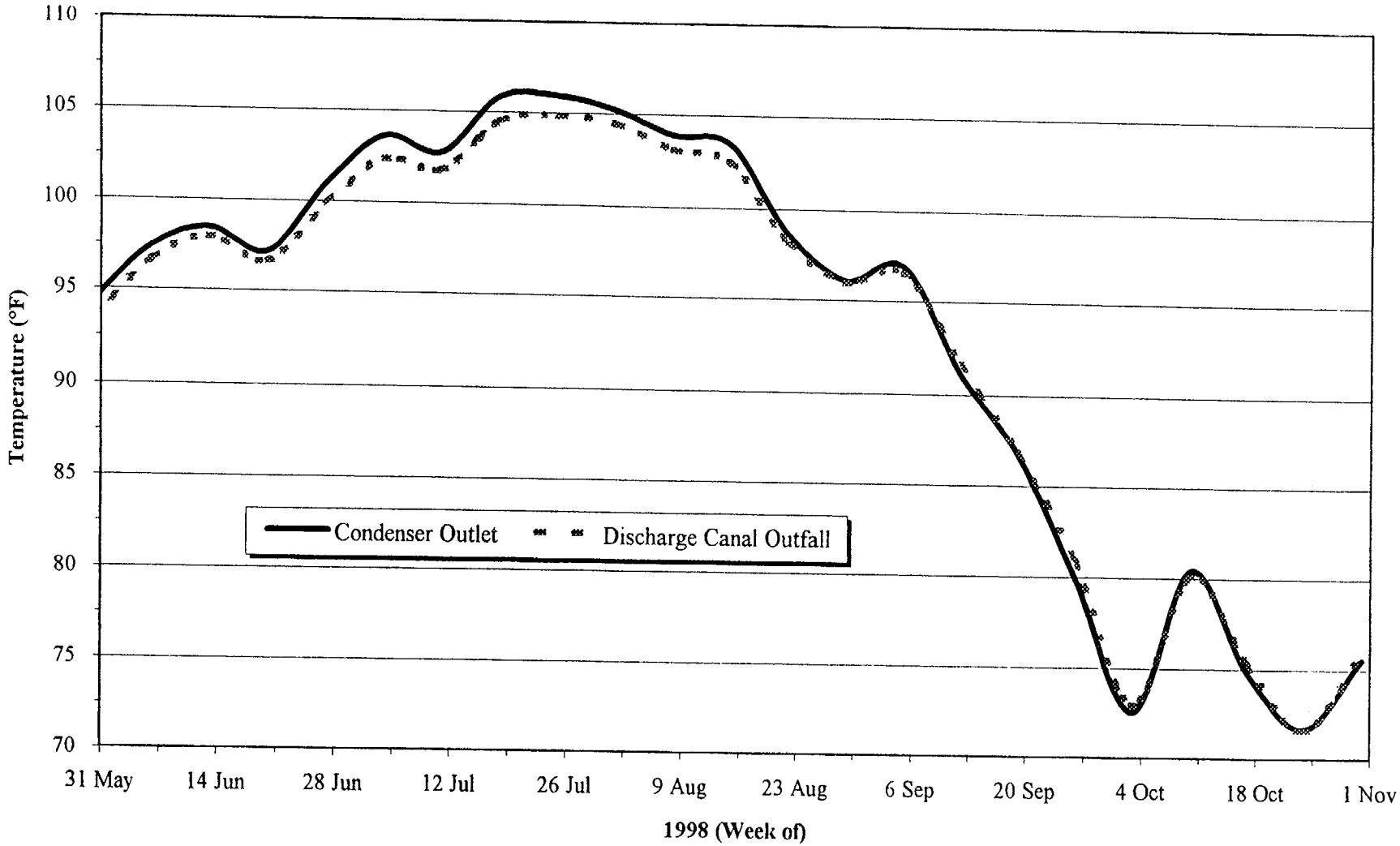


Figure 3-5

Average daily condenser outlet and canal outfall temperatures (°F) at PBAPS, June-October 1999.

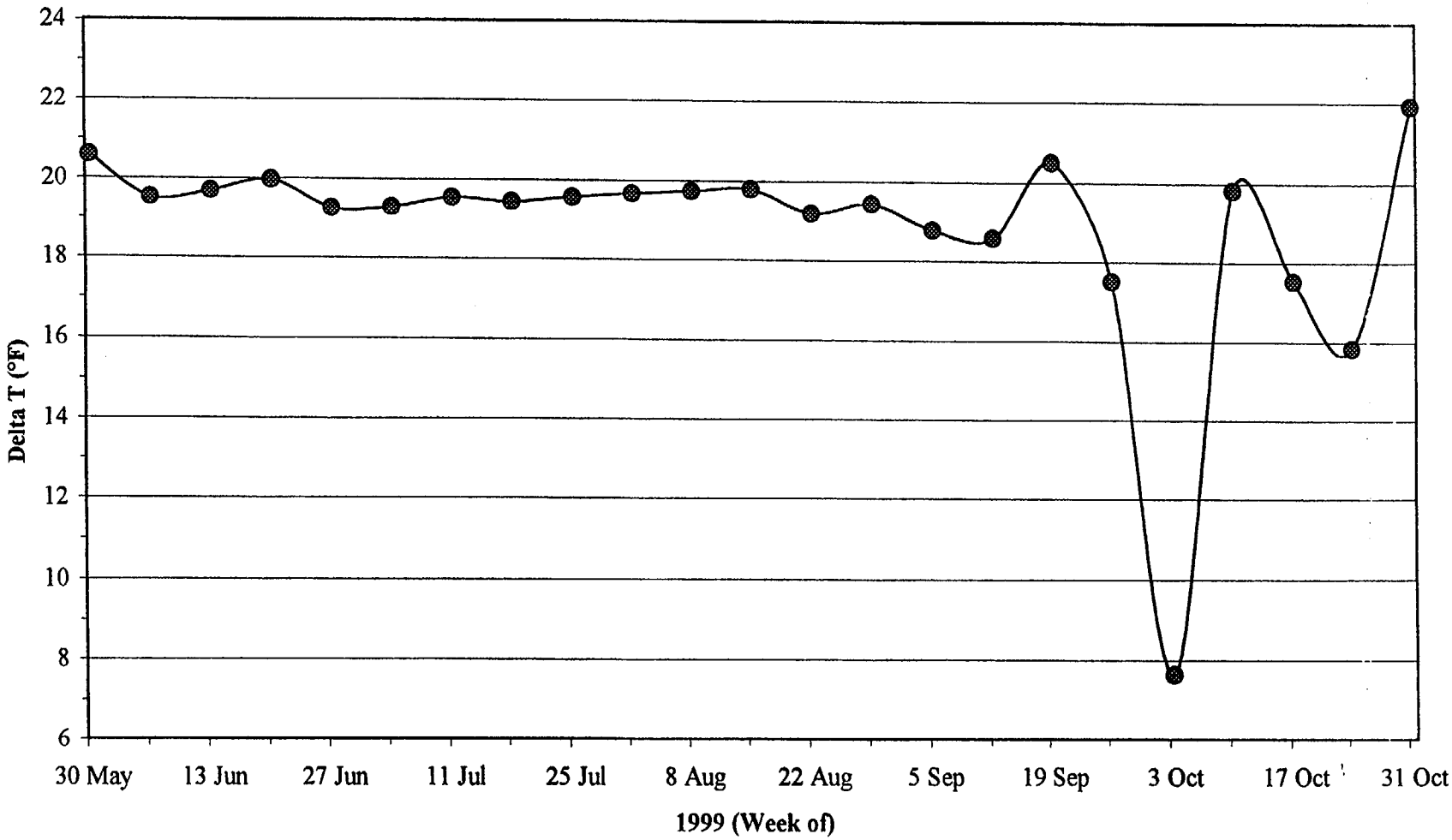
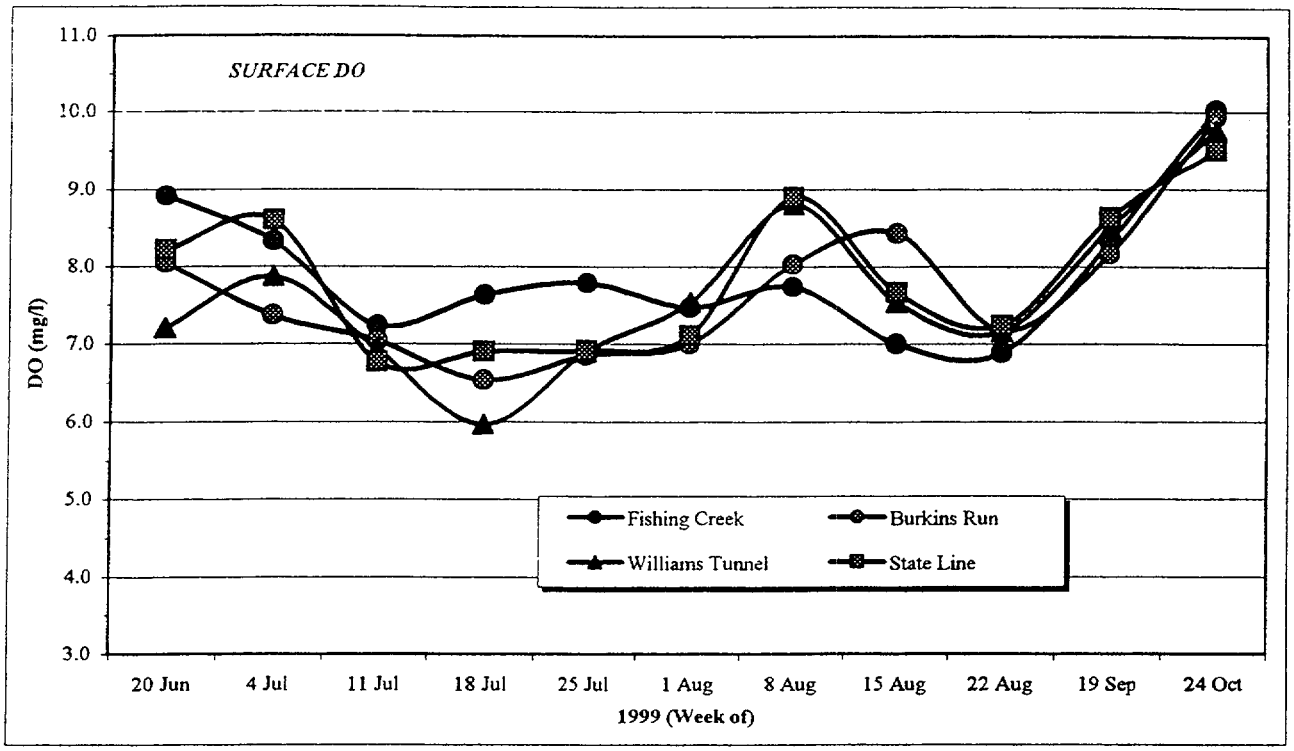


Figure 3-6

Weekly mean canal outfall ΔT (outfall °F minus inlet °F) at PBAPS, June-October 1999.



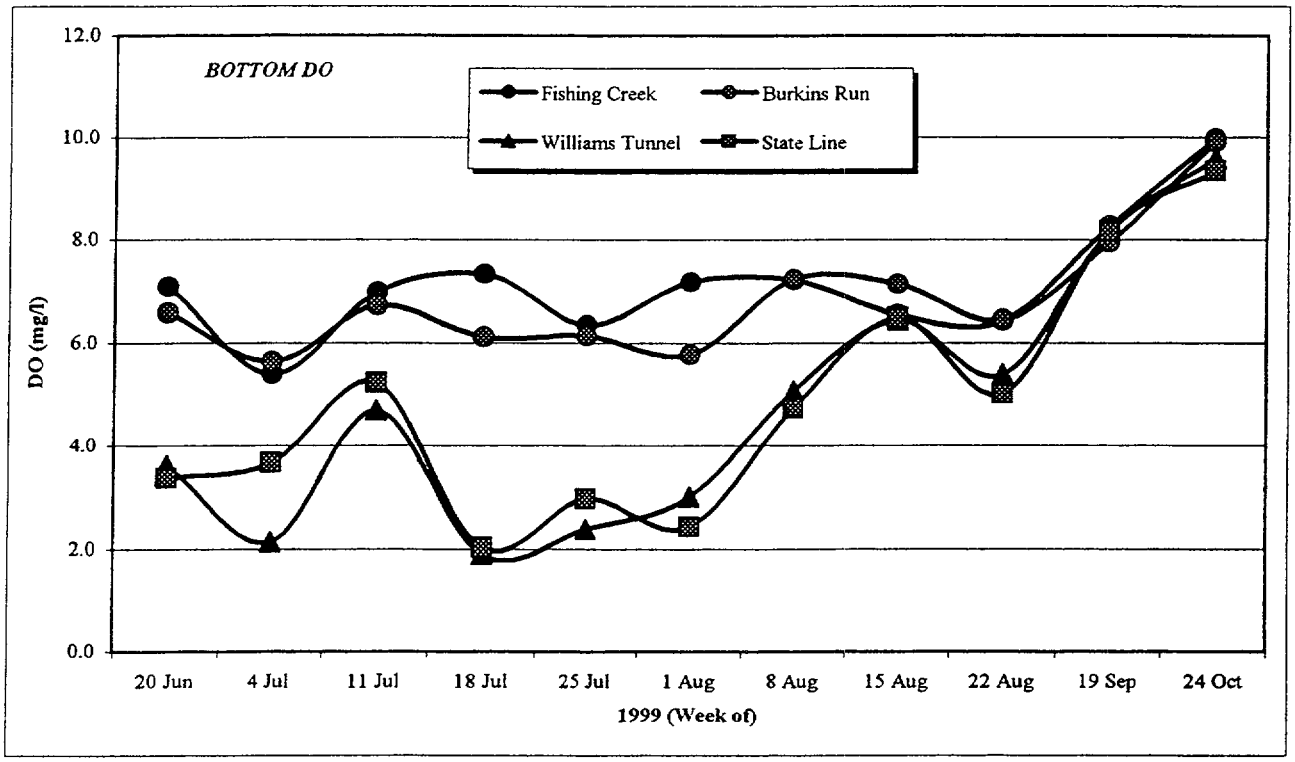
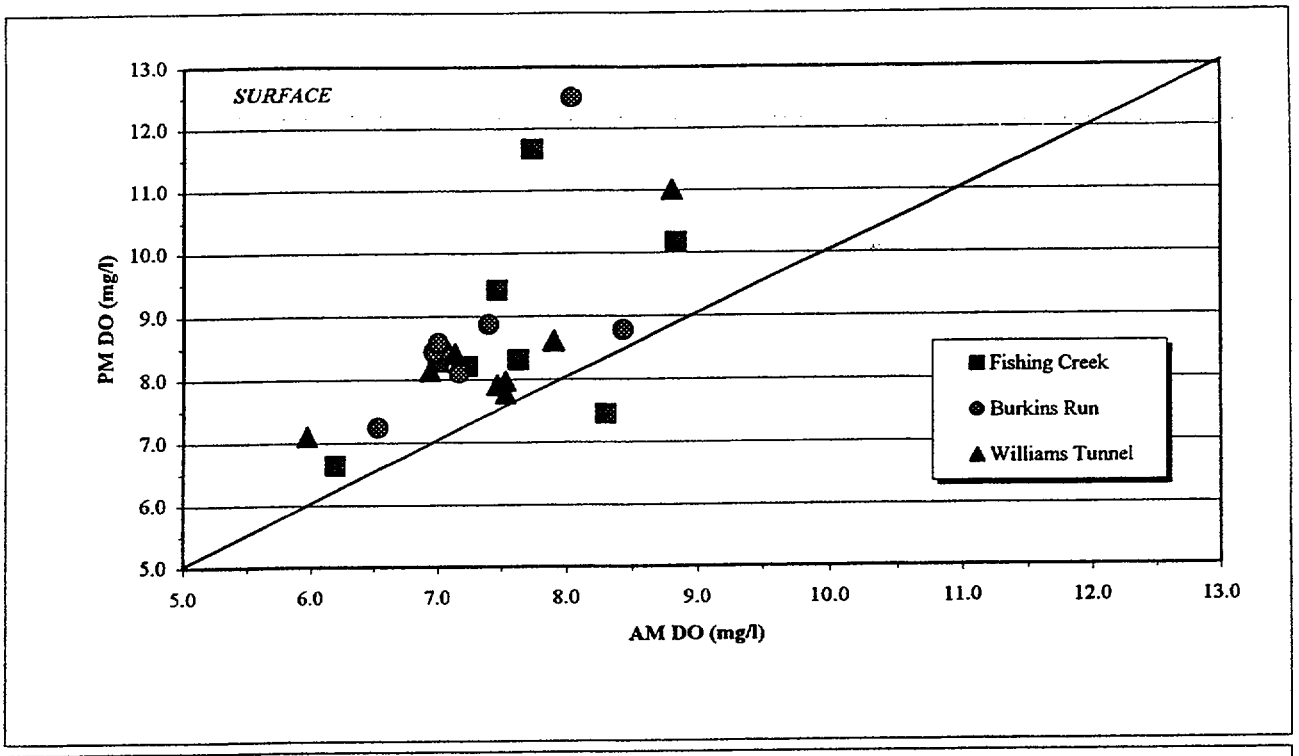


Figure 3-7

Weekly mean surface and bottom DO at transects sampled in the vicinity of PBAPS, June-October 1999.



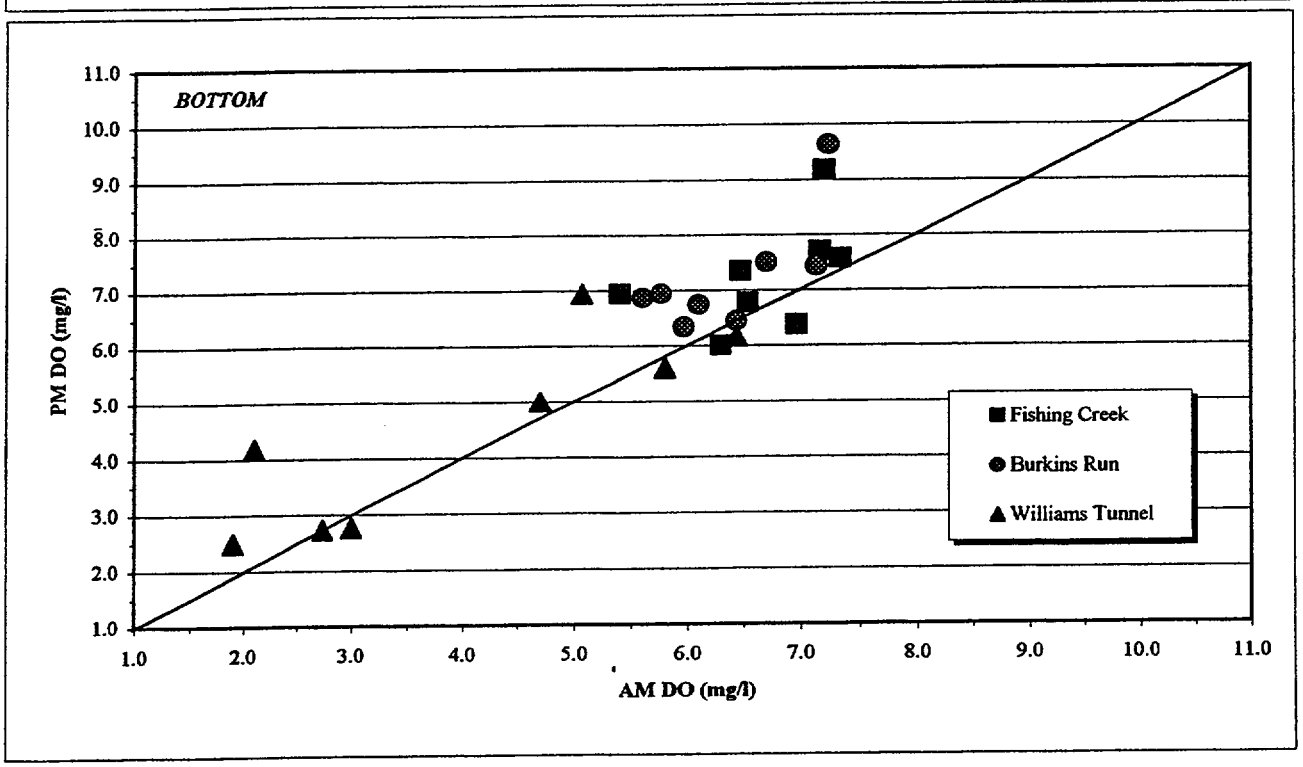


Figure 3-8

Comparison of AM versus PM DO (mg/l) at the surface and bottom at transects sampled in the vicinity of PBAPS in July through August 1999. Solid line represents line of equality.

3.3 Fisheries (Overall)

Sampling occurred on five occasions in June through October at zero cooling tower operation. A list of scientific and common names of species collected is found in Table 3-8.

A total of 15,328 fish representing 45 species plus one striped bass hybrid and 11 unidentified *Lepomis* spp. was collected (Table 3-9). Spotfin shiner, gizzard shad, channel catfish, bluegill, tessellated darter, bluntnose minnow, and smallmouth bass comprised 84% of the 1999 catch.

June accounted for the most fish (5,507) collected in a single month, while the least (1,596) was collected in August (Table 3-9). In 1998, July accounted for the fewest fish collected (3,525) while August accounted for the most fish (5,309). Number of species observed per month was similar and ranged from 35 (July, August, and September) to 37 (June and October). Spotfin shiner was the most abundant species in July, August, September, and October while gizzard shad dominated the catch in June.

3.3.1 Electrofishing

A total of 3,520 fish representing 26 species was collected (Table 3-10). Bluegill, smallmouth bass, gizzard shad, green sunfish, and largemouth bass comprised nearly 82% of the catch; all other species individually made up less than 4% of the total. Number of species between months varied and ranged from 13 (July) to 21 (September). The catch increased steadily from June, peaking in September, and declined in October.

The most common species collected during each month were similar. These were bluegill, smallmouth bass, gizzard shad and green sunfish. The species with the highest overall catch per effort (CPE) value was bluegill (49.35) while CPE values for smallmouth bass (31.40) and gizzard shad (30.60) were similar (Table 3-11).

Species CPE varied by month (Table 3-11). Bluegill, smallmouth bass, gizzard shad, and green sunfish ranked in the top five during all sample periods while spotfin shiner ranked among the top five in two of the five sample periods. The only other species that ranked in the top five was comely shiner during the August sample period. The highest CPE (345.25) for all species combined occurred in September and the lowest CPE (89.25) in June.

Overall, the number of species collected at each station varied slightly (Table 3-12). At stations 161 and 190 (both located within the influence of the thermal plume), 19 and 17 species were collected at each location, respectively. Stations 164 and 165 (outside the influence of the thermal plume) contributed 19 and 22 species, respectively. Generally, CPE values for bluegill were highest and nearly identical at stations 165 and 190 with gizzard shad having the highest CPE value for any species at station 164. Smallmouth bass had the highest CPE value at station 161.

Comparison of monthly CPE's for the 1997-1999 sampling effort and the historical data for common and important representative species are shown in Table 3-13. Little historical data were available for the period June through September; however, 76 of the 105 calculated monthly CPE's were within or above the range observed historically. White crappie CPE values for July through October were lower than the historical range, possibly due to variations in year class strength from year to year. Strong populations of gizzard shad, now bolstered by introductions from the Conowingo Dam East fish lift, may be outcompeting white crappie for available food during critical juvenile stages. High fluctuations in year class strength of white crappie have been observed historically. Smallmouth bass CPE values for June, July, August, and September were higher than those observed historically, while CPE values for largemouth bass were generally similar or above those values recorded historically.

3.3.2 Seine

A total of 6,714 fish representing 31 species plus eleven unidentified Lepomis spp. was collected (Table 3-14). Spotfin shiner, bluntnose minnow, and tessellated darter dominated the catch. These three species comprised over 81% of the total catch by seine; all other species individually made up less than 2.2% of the total. The lowest number of species collected (19) occurred in September while the highest number of species (25) occurred in June. The largest number of fish collected by seine (1,686) occurred in

September, whereas the lowest number collected (815) occurred in August. Spotfin shiner dominated the catch during all five sampling events. The number of species and specimens collected was variable over the sampling period. This was largely a factor of the mobility and growth of young fish.

The highest overall monthly CPE occurred in September (240.86) while the lowest value occurred in August (116.44; Table 3-15). Spotfin shiner was the most common species collected with a mean monthly CPE of 119.17. Bluntnose minnow and tessellated darter ranked second and third, respectively.

The number of species collected varied by station (Table 3-16). The most species (25) were collected at station 212 while the fewest (8) were collected at station 209. The total number of species collected was 31 plus eleven unidentified Lepomis spp. Spotfin shiner, bluntnose minnow, and tessellated darter were the most common species in the catch.

All monthly CPE values were within or above the historical range from 1997 to 1999 (Table 3-20). During the three year study, bluntnose minnow had CPE values higher than the existing range on six occasions while spottail shiner, largemouth bass, and tessellated darter had values greater than the existing range on at least three occasions. CPE values for smallmouth bass and pumpkinseed were each higher during one of the sample periods.

Diversity and evenness values by month are presented in Table 3-17. The values range from 0.370 (September) to 0.819 (June), similar to what was observed previously. Calculated diversity values were low due to the dominance of a few species, mainly spotfin shiner.

Percent similarity values between stations are found in Table 3-18. Variation in PS_C values was evident between stations. Station 212 appeared to be the least similar to the others, possibly due to habitat differences, since this station is located in Fishing Creek, unlike the others which are located within Conowingo Pond.

Percent similarity values between months are found in Table 3-19. The similarity in catch was high (>77%) between August, September, and October. Values for June were relatively low as compared to other months whereas July values were similar for each monthly comparison except for September.

3.3.3 Trap Net

A total of 656 fish representing 21 species was collected (Table 3-21). Five species comprised over 77% of the catch. They were white crappie, channel catfish, bluegill, gizzard shad, and common carp. Number of species collected ranged from 10 in June to 17 in September.

Overall catch per effort values ranged from 4.70 in June to 31.81 in September (Table 3-22). White crappie ranked first with a mean CPE of 3.65. Channel catfish and bluegill ranked second and third with mean CPE values of 2.77 and 2.57, respectively. By month, white crappie had the highest CPE values in September and October while bluegill, gizzard shad, and channel catfish were dominant in June, July, and August, respectively.

The number of species collected at each station was variable (Table 3-23). Number of species ranged from 11 collected at station 108 to 17 at station 110 which is located within the influence of the thermal plume. Gizzard shad and channel catfish were the dominant species collected at station 110 while white crappie dominated collections at stations 104, 107, and 108. Eight species were collected at all four stations. These were white crappie, channel catfish, bluegill, gizzard shad, common carp, green sunfish, largemouth bass, and pumpkinseed.

Most of the common and important representative species have monthly CPE values within the historical range from 1997 to 1999 (Table 3-24). Twenty-four of the 135 sample periods (17.8%) had CPE values less than the historical range. Monthly CPE values were generally lower for brown bullhead, channel catfish, pumpkinseed, and white crappie from July through September, while CPE values for bluegill, gizzard shad, smallmouth bass, largemouth bass, and walleye were consistently within the historical range during most sampling events.

3.3.4 Trawl Zones

3.3.4.1 Zone 405

A total of 741fish representing 15 species was collected in 1999 (Table 3-25). Channel catfish was the dominant species and accounted for more than 75% of the total catch. Channel catfish along with tessellated darter comprised nearly 92% of the catch. The remaining 13 species were collected in low numbers, infrequently, and represented slightly more than 8% of the total catch.

By month, the highest overall CPE value occurred in June (67.25) with lower values observed from July through October (Table 3-26). The lowest value (6.74) occurred in August, possibly due to the severe drought conditions the region experienced this summer. Except for tessellated darter in July, channel catfish had the highest CPE values of any species during each monthly sampling event.

The number of species collected per station varied and ranged from four at station 452 to 9 at station 455 (Table 3-27). Except for station 456, where tessellated darter dominated the catch, channel catfish was dominant at all other stations.

Monthly catch per effort values for the commonly collected species were within or greater than the range of the historical data from 1997 to 1999 (Table 3-28). The CPE values for tessellated darter were generally higher than the existing range from June through September with some higher CPE values for channel catfish, largemouth bass, and spottail shiner observed during July and August sampling periods.

3.3.4.2 Zone 408

A total of 840 fish of 14 species was collected (Table 3-29). Five species comprised 91% of the catch. They were gizzard shad, channel catfish, tessellated darter, bluntnose minnow, and bluegill. Gizzard shad dominated the catch in June with channel catfish dominant during July and August. Channel catfish, pumpkinseed, and bluegill were collected during each sampling event, whereas gizzard shad and tessellated darter were present in four of the five collections.

Overall monthly CPE values varied and ranged from 2.50 in September to 114.28 in June (Table 3-30). Strong numbers of gizzard shad and tessellated darters collected in June accounted for the higher CPE value observed. Catch per effort values were relatively strong in June but drastically decreased from July through October. Catch per effort values of certain species varied by station (Table 3-31). Gizzard shad, channel catfish, bluegill, and tessellated darter were present at all six stations whereas pumpkinseed and largemouth bass were collected at five of the six stations.

The relative abundance of all commonly collected species except for white crappie was generally within or above the historic range of monthly CPE values from 1997 to 1999 (Table 3-32). During the 3-year study period, monthly CPE values higher than the historic range were usually observed during June or July for bluegill, gizzard shad, smallmouth and largemouth bass, tessellated darter, and spottail shiner.

3.3.5 Trawl Transects

At trawl transect stations, a total of 2,857 fish representing 19 species was collected (Table 3-33). Three species, gizzard shad, channel catfish, and tessellated darter comprised more than 94% of the catch. Only one other species individually, bluegill, made up more than 1% of the catch. The remaining species were collected in low numbers and infrequently.

The number of species collected by month was similar and ranged from 8 in August to 13 in June (Table 3-34). The highest overall CPE (270.80) occurred in June with the lowest value (5.76) observed in October. Gizzard shad had the highest mean CPE overall and dominated the catch in June while channel catfish had the highest CPE values in July, August, and September. Bluegill had the highest CPE value in October.

The number of species collected at each station was generally similar (Table 3-35). Number of species ranged from four (Station 371) to 11 (Stations 343 and 373). Catch per effort values at each station were variable. Station 371 had the lowest CPE of any station. This was probably due to high current velocity precluding full utilization of the area by young-of the year fishes, which typically dominate trawl

catches. Channel catfish dominated the catch at stations 321, 342, 372, and 373 with gizzard shad most abundant at stations 323 and 341. Tessellated darter had the highest CPE values for stations 322 and 343.

The CPE of all commonly collected species (except for white crappie during four sampling events and one event each for channel catfish and spottail shiner) were within or above their historic range of values from 1997 to 1999 (Table 3-36). CPE values higher than historical values were observed often during the 3-year study for largemouth bass, tessellated darter, smallmouth bass, and gizzard shad.

3.3.6 Reconnaissance Surveys

Weekly fish reconnaissance surveys were conducted throughout Conowingo Pond in June through August, with three additional surveys conducted in August at river inflows <3,000 cfs. These boat-based surveys were performed to document occurrences of any unusual thermally related fish activity, particularly with the introduction of nearly 1,200,000 fish (including 950,000 gizzard shad) into the pond via spring fish passage operations at Conowingo Dam. These surveys revealed no unusual fish activity; no thermally stressed fish were observed. However, a total of 410 dead fish (comprised primarily of gizzard shad, followed by American shad, channel catfish and carp) was observed throughout the Pond. Nearly 60% of the dead fish (primarily gizzard shad, channel catfish, carp, and American shad) were observed in the four weeks surveyed in June. All were in various stages of decomposition, and mortality probably was due to post-spawning stress. During the low flow surveys in August, no dead fish were observed in the PBAPS discharge or downstream areas. Fish activity throughout this area in mid-July through August included predator species feeding on large schools of gizzard shad.

Table 3-8

Scientific and common names of fishes collected in Conowingo Pond, June-October 1999.

Clupeidae	**Herrings**
Alosa sapidissima	American shad
Dorosoma cepedianum	Gizzard shad
Cyprinidae	**Carps and minnows**
Campostoma anomalum	Central stoneroller
Clinostomus funduloides	Rosyside dace
Cyprinus carpio	Common carp
Notropis buccatus	Silverjaw minnow
Exoglossum maxillingua	Cutlips minnow
Notemigonus crysoleucas	Golden shiner
Notropis amoenus	Comely shiner
Luxilus cornutus	Common shiner
Notropis hudsonius	Spottail shiner
Notropis procne	Swallowtail shiner
Notropis rubellus	Rosyface shiner
Cyprinella spiloptera	Spotfin shiner
Notropis volucellus	Mimic shiner
Pimephales notatus	Bluntnose minnow
Rhinichthys atratulus	Blacknose dace
Rhinichthys cataractae	Longnose dace
Semotilus atromaculatus	Creek chub
Semotilus corporalis	Fallfish
Catostomidae	**Suckers**
Carpiodes cyprinus	Quillback
Catostomus commersoni	White sucker
Hypentelium nigricans	Northern hogsucker
Moxostoma macrolepidotum	Shorthead redhorse
Ictaluridae	**Bullhead catfishes**
Ameiurus catus	White catfish
Ictaluridae, continued	**Bullhead catfishes, continued**
Ameiurus natalis	Yellow bullhead
Ameiurus nebulosus	Brown bullhead
Ictalurus punctatus	Channel catfish
Cyprinodontidae	**Killifishes**
Fundulus diaphanus	Banded killifish
Percichthyidae	**Temperate basses**
Morone americana	White perch
M saxatilis x M chrysops	Striped bass x white bas
Centrarchidae	**Sunfishes**
Ambloplites rupestris	Rock bass
Lepomis sp	Lepomis sp
Lepomis auritus	Redbreast sunfish
Lepomis cyanellus	Green sunfish
Lepomis gibbosus	Pumpkinseed
Lepomis macrochirus	Bluegill
Micropterus dolomieu	Smallmouth bass
Micropterus salmoides	Largemouth bass
Pomoxis annularis	White crappie
Pomoxis nigromaculatus	Black crappie
Percidae	**Perches**
Etheostoma blennioides	Greenside darter
Etheostoma olmstedi	Tessellated darter
Perca flavescens	Yellow perch
Percina caprodes	Logperch
Percina peltata	Shield darter
Stizostedion vitreum	Walleye

Table 3-9

Number and percent composition of fishes collected by all gear types per month in Conowingo Pond, June-October 1999.

	June		July		August		September		October		Overall	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
American shad	0	0.00	0	0.00	0	0.00	0	0.00	1	0.05	1	0.01
Gizzard shad	2,188	39.73	283	11.76	260	16.29	166	4.56	122	5.59	3,019	19.70
Central stoneroller	2	0.04	0	0.00	0	0.00	0	0.00	0	0.00	2	0.01
Rosyside dace	8	0.15	6	0.25	13	0.81	32	0.88	8	0.37	67	0.44
Common carp	21	0.38	20	0.83	11	0.69	46	1.26	49	2.25	147	0.96
Cutlips minnow	1	0.02	4	0.17	1	0.06	0	0.00	1	0.05	7	0.05
Golden shiner	0	0.00	1	0.04	12	0.75	2	0.05	0	0.00	15	0.10
Comely shiner	15	0.27	13	0.54	63	3.95	14	0.38	43	1.97	148	0.97
Common shiner	21	0.38	14	0.58	10	0.63	7	0.19	3	0.14	55	0.36
Spottail shiner	15	0.27	37	1.54	0	0.00	7	0.19	20	0.92	79	0.52
Swallowtail shiner	2	0.04	3	0.12	2	0.13	0	0.00	0	0.00	7	0.05
Rosyface shiner	0	0.00	4	0.17	1	0.06	1	0.03	0	0.00	6	0.04
Spotfin shiner	647	11.75	794	33.00	558	34.96	1,427	39.22	882	40.44	4,308	28.11
Bluntnose minnow	325	5.90	402	16.71	41	2.57	35	0.96	82	3.76	885	5.77
Blacknose dace	9	0.16	0	0.00	3	0.19	8	0.22	3	0.14	23	0.15
Longnose dace	1	0.02	5	0.21	1	0.06	1	0.03	1	0.05	9	0.06
Creek chub	15	0.27	16	0.67	6	0.38	10	0.27	0	0.00	47	0.31
Fallfish	3	0.05	0	0.00	0	0.00	0	0.00	0	0.00	3	0.02
Silverjaw minnow	0	0.00	0	0.00	2	0.13	0	0.00	0	0.00	2	0.01
Mimic shiner	5	0.09	44	1.83	1	0.06	3	0.08	33	1.51	86	0.56
Quillback	54	0.98	9	0.37	8	0.50	6	0.16	7	0.32	84	0.55
White sucker	73	1.33	42	1.75	11	0.69	2	0.05	14	0.64	142	0.93
Northern hogsucker	0	0.00	0	0.00	0	0.00	0	0.00	4	0.18	4	0.03
Shorthead redhorse	8	0.15	9	0.37	5	0.31	5	0.14	14	0.64	41	0.27
White catfish	3	0.05	2	0.08	0	0.00	1	0.03	1	0.05	7	0.05
Yellow bullhead	2	0.04	1	0.04	2	0.13	5	0.14	4	0.18	14	0.09
Brown bullhead	4	0.07	2	0.08	6	0.38	16	0.44	1	0.05	29	0.19
Channel catfish	731	13.27	175	7.27	190	11.90	313	8.60	110	5.04	1,519	9.91
Banded killifish	1	0.02	1	0.04	0	0.00	0	0.00	1	0.05	3	0.02
White perch	0	0.00	0	0.00	1	0.06	7	0.19	1	0.05	9	0.06
Rock bass	4	0.07	8	0.33	8	0.50	25	0.69	33	1.51	78	0.51
Redbreast sunfish	11	0.20	0	0.00	1	0.06	2	0.05	2	0.09	16	0.10
Green sunfish	46	0.84	71	2.95	33	2.07	148	4.07	100	4.59	398	2.60
Pumpkinseed	21	0.38	23	0.96	30	1.88	73	2.01	37	1.70	184	1.20
Bluegill	130	2.36	118	4.90	138	8.65	669	18.39	313	14.35	1,368	8.92
Smallmouth bass	156	2.83	95	3.95	83	5.20	277	7.61	108	4.95	719	4.69
Largemouth bass	101	1.83	38	1.58	43	2.69	203	5.58	99	4.54	484	3.16
White crappie	5	0.09	13	0.54	13	0.81	87	2.39	36	1.65	154	1.00
Black crappie	0	0.00	0	0.00	0	0.00	1	0.03	1	0.05	2	0.01
Lepomis sp*	11	0.20	0	0.00	0	0.00	0	0.00	0	0.00	11	0.07
Tessellated darter	850	15.43	134	5.57	21	1.32	27	0.74	26	1.19	1,058	6.90
Yellow perch	2	0.04	1	0.04	0	0.00	1	0.03	4	0.18	8	0.05
Logperch	14	0.25	16	0.67	16	1.00	7	0.19	2	0.09	55	0.36
Shield darter	1	0.02	0	0.00	0	0.00	0	0.00	0	0.00	1	0.01
Walleye	0	0.00	1	0.04	1	0.06	3	0.08	14	0.64	19	0.12
Striped bass hybrid*	0	0.00	0	0.00	0	0.00	1	0.03	0	0.00	1	0.01
Greenside darter	1	0.02	1	0.04	1	0.06	0	0.00	1	0.05	4	0.03
Overall	*5,507*	*100*	*2,406*	*100*	*1,596*	*100*	*3,638*	*100*	*2,181*	*100*	*15,328*	*100*
Number of species	*37*		*35*		*35*		*35*		*37*		*45*	

* Not counted as separate species.

Table 3-10

Number and percent composition of fishes collected by DC electrofisher per month in Conowingo Pond, June-October 1999.

	June		July		August		September		October		Overall	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Gizzard shad	29	8.12	184	43.09	173	32.34	105	7.60	121	14.76	612	17.39
Common carp	1	0.28	7	1.64	5	0.93	11	0.80	27	3.29	51	1.45
Golden shiner	0	0.00	1	0.23	12	2.24	1	0.07	0	0.00	14	0.40
Comely shiner	14	3.92	1	0.23	49	9.16	14	1.01	43	5.24	121	3.44
Spottail shiner	1	0.28	0	0.00	0	0.00	2	0.14	1	0.12	4	0.11
Spotfin shiner	50	14.01	23	5.39	17	3.18	27	1.96	19	2.32	136	3.86
Bluntnose minnow	0	0.00	0	0.00	1	0.19	0	0.00	0	0.00	1	0.03
Quillback	0	0.00	0	0.00	8	1.50	2	0.14	7	0.85	17	0.48
White sucker	0	0.00	0	0.00	0	0.00	0	0.00	14	1.71	14	0.40
Shorthead redhorse	5	1.40	4	0.94	5	0.93	4	0.29	10	1.22	28	0.80
White catfish	0	0.00	0	0.00	0	0.00	1	0.07	0	0.00	1	0.03
Yellow bullhead	1	0.28	0	0.00	2	0.37	0	0.00	4	0.49	7	0.20
Brown bullhead	0	0.00	0	0.00	0	0.00	1	0.07	0	0.00	1	0.03
Channel catfish	27	7.56	17	3.98	26	4.86	18	1.30	23	2.80	111	3.15
Rock bass	3	0.84	8	1.87	6	1.12	18	1.30	16	1.95	51	1.45
Redbreast sunfish	11	3.08	0	0.00	1	0.19	2	0.14	1	0.12	15	0.43
Green sunfish	45	12.61	46	10.77	31	5.79	140	10.14	100	12.20	362	10.28
Pumpkinseed	1	0.28	0	0.00	5	0.93	38	2.75	7	0.85	51	1.45
Bluegill	48	13.45	36	8.43	117	21.87	555	40.19	231	28.17	987	28.04
Smallmouth bass	118	33.05	84	19.67	65	12.15	261	18.90	100	12.20	628	17.84
Largemouth bass	1	0.28	15	3.51	10	1.87	176	12.74	82	10.00	284	8.07
White crappie	0	0.00	0	0.00	0	0.00	2	0.14	2	0.24	4	0.11
Black crappie	0	0.00	0	0.00	0	0.00	1	0.07	0	0.00	1	0.03
Tessellated darter	1	0.28	0	0.00	0	0.00	0	0.00	0	0.00	1	0.03
Logperch	1	0.28	1	0.23	2	0.37	1	0.07	0	0.00	5	0.14
Walleye	0	0.00	0	0.00	0	0.00	0	0.00	12	1.46	12	0.34
Striped bass hybrid*	0	0.00	0	0.00	0	0.00	1	0.07	0	0.00	1	0.03
Overall	*357*	*100.00*	*427*	*100.00*	*535*	*100.00*	*1,381*	*100.00*	*820*	*100.00*	*3,520*	*100.00*
Number of species	*17*		*13*		*18*		*21*		*19*		*26*	

* Not counted as separate species.

Table 3-11

Monthly catch per effort (number per 30 min) for fishes collected by a DC electrofisher in Conowingo Pond, June-October 1999.

	June	July	August	September	October	Mean
Gizzard shad	7.25	46.00	43.25	26.25	30.25	30.60
Common carp	0.25	1.75	1.25	2.75	6.75	2.55
Golden shiner	0.00	0.25	3.00	0.25	0.00	0.70
Comely shiner	3.50	0.25	12.25	3.50	10.75	6.05
Spottail shiner	0.25	0.00	0.00	0.50	0.25	0.20
Spotfin shiner	12.50	5.75	4.25	6.75	4.75	6.80
Bluntnose minnow	0.00	0.00	0.25	0.00	0.00	0.05
Quillback	0.00	0.00	2.00	0.50	1.75	0.85
White sucker	0.00	0.00	0.00	0.00	3.50	0.70
Northern hogsucker	0.00	0.00	0.00	0.00	0.00	0.00
Shorthead redhorse	1.25	1.00	1.25	1.00	2.50	1.40
White catfish	0.00	0.00	0.00	0.25	0.00	0.05
Yellow bullhead	0.25	0.00	0.50	0.00	1.00	0.35
Brown bullhead	0.00	0.00	0.00	0.25	0.00	0.05
Channel catfish	6.75	4.25	6.50	4.50	5.75	5.55
Rock bass	0.75	2.00	1.50	4.50	4.00	2.55
Redbreast sunfish	2.75	0.00	0.25	0.50	0.25	0.75
Green sunfish	11.25	11.50	7.75	35.00	25.00	18.10
Pumpkinseed	0.25	0.00	1.25	9.50	1.75	2.55
Bluegill	12.00	9.00	29.25	138.75	57.75	49.35
Smallmouth bass	29.50	21.00	16.25	65.25	25.00	31.40
Largemouth bass	0.25	3.75	2.50	44.00	20.50	14.20
White crappie	0.00	0.00	0.00	0.50	0.50	0.20
Black crappie	0.00	0.00	0.00	0.25	0.00	0.05
Tessellated darter	0.25	0.00	0.00	0.00	0.00	0.05
Logperch	0.25	0.25	0.50	0.25	0.00	0.25
Walleye	0.00	0.00	0.00	0.00	3.00	0.60
Striped bass hybrid*	0.00	0.00	0.00	0.25	0.00	0.05
Overall	*89.25*	*106.75*	*133.75*	*345.25*	*205.00*	*176.00*
Number of species	*17*	*13*	*18*	*21*	*19*	*26*

* Not counted as separate species.

Table 3-12

Catch per effort (number per 30 min) for fishes collected by a DC electrofisher at stations in Conowingo Pond, June-October 1999.

	Station				
	161**	164	165	190**	Mean
Gizzard shad	16.60	68.80	11.60	25.40	30.60
Common carp	5.80	1.40	0.80	2.20	2.55
Golden shiner	0.00	0.00	0.20	2.60	0.70
Comely shiner	1.20	6.60	5.60	10.80	6.05
Spottail shiner	0.20	0.20	0.20	0.20	0.20
Spotfin shiner	2.20	7.80	11.20	6.00	6.80
Bluntnose minnow	0.00	0.00	0.20	0.00	0.05
Quillback	2.00	0.00	0.40	1.00	0.85
White sucker	2.00	0.20	0.60	0.00	0.70
Shorthead redhorse	2.60	1.60	0.40	1.00	1.40
White catfish	0.00	0.20	0.00	0.00	0.05
Yellow bullhead	0.40	0.80	0.20	0.00	0.35
Brown bullhead	0.20	0.00	0.00	0.00	0.05
Channel catfish	11.20	2.40	4.00	4.60	5.55
Rock bass	0.60	3.20	6.40	0.00	2.55
Redbreast sunfish	0.20	1.20	0.20	1.40	0.75
Green sunfish	9.80	14.20	26.60	21.80	18.10
Pumpkinseed	0.20	4.40	5.40	0.20	2.55
Bluegill	39.80	44.00	57.00	56.60	49.35
Smallmouth bass	47.00	28.60	33.60	16.40	31.40
Largemouth bass	36.00	8.80	7.60	4.40	14.20
White crappie	0.00	0.20	0.60	0.00	0.20
Black crappie	0.00	0.00	0.20	0.00	0.05
Tessellated darter	0.00	0.00	0.00	0.20	0.05
Logperch	0.00	0.20	0.80	0.00	0.25
Walleye	1.60	0.00	0.00	0.80	0.60
Striped bass hybrid*	0.20	0.00	0.00	0.00	0.05
Overall	*179.80*	*194.80*	*173.80*	*155.60*	*176.00*
Number of species	*19*	*19*	*22*	*17*	*26*

* Not counted as separate species.

** Located within the influence of PBAPS thermal effluent.

Table 3-13

Comparison of the monthly catch per effort (number per 30 minutes) for the common and Environmental Protection Agency designated, representative, important species collected at electrofishing stations in Conowingo Pond in June-October. "-"-designates a period when no effort was expended. Underlined CPEs are greater than historical values and italicized are less than historical values.

	June		July		August		September		October	
	N*	Range	N*	Range	N*	Range	N*	Range	N*	Range
					White crappie					
Pre-operational	-	-	-	-	-	-	-	-	-	-
Post-operational	3	0.00-1.18	3	0.92-1.50	4	1.00-3.07	2	3.0-3.58	8	1.25-33.00
1997		0.25		*0.25*		*0.25*		*1.25*		*0.75*
1998		0.25		*0.00*		*0.00*		*0.25*		*0.00*
1999		0.00		*0.00*		*0.00*		*0.50*		*0.50*
					Channel catfish					
Pre-operational	-	-	-	-	-	-	-	-	-	-
Post-operational	3	6.86-50.95	3	9.30-25.05	4	14.67-56.00	2	16.54-23.17	8	6.25-72.25
1997		*6.00*		10.75		56.25		26.75		12.75
1998		*5.50*		13.75		19.50		23.25		23.25
1999		*6.75*		*4.25*		*6.50*		*4.50*		*5.75*
					Bluegill					
Pre-operational	-	-	-	-	-	-	-	-	-	-
Post-operational	3	6.33-11.09	3	7.50-10.38	4	15.80-42.00	2	20.00-33.09	8	22.62-136.25
1997		*4.50*		*6.05*		20.75		37.00		*13.25*
1998		*6.00*		10.00		22.00		62.75		25.75
1999		12.00		9.00		29.25		138.75		57.75
					Gizzard shad					
Pre-operational	-	-	-	-	-	-	-	-	-	-
Post-operational	3	0.38-6.42	3	0.00-129.60	4	8.0-111.17	2	2.06-29.08	8	1.00-101.37
1997		1.50		46.50		11.50		34.25		34.50
1998		2.50		9.25		11.00		10.25		17.75
1999		7.25		46.00		43.25		26.25		30.25
					Smallmouth bass					
Pre-operational	-	-	-	-	-	-	-	-	-	-
Post-operational	3	9.80-15.67	3	13.0-15.17	4	12.67-20.58	2	18.43-19.67	8	12.88-64.75
1997		13.75		17.00		40.25		30.50		14.25
1998		17.75		19.75		32.00		38.75		25.50
1999		29.50		21.00		16.25		65.25		25.00
					Largemouth bass					
Pre-operational	-	-	-	-	-	-	-	-	-	-
Post-operational	3	0.43-2.42	3	0.30-1.67	4	0.60-3.83	2	3.69-9.17	8	1.04-98.75
1997		1.50		3.50		7.25		*3.50*		27.25
1998		3.75		1.50		2.25		*2.00*		13.50
1999		*0.25*		3.75		2.50		44.00		20.50
					Walleye					
Pre-operational	-	-	-	-	-	-	-	-	-	-
Post-operational	3	0.00-0.25	3	0.00-1.20	4	0.08-0.33	2	0.00-2.83	8	0.00-7.12
1997		0.00		0.00		*0.00*		0.00		0.75
1998		0.00		0.00		*0.00*		0.00		1.00
1999		0.00		0.00		*0.00*		0.00		3.00

* N= the number of years in the historical period (pre- or post-operational) that sampling occurred in a given month.

Table 3-14

Number and percent composition of fishes collected by 10 x 4 ft seine per month in Conowingo Pond, June-October 1999.

	June		July		August		September		October		Overall	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Gizzard shad	0	0.00	0	0.00	79	9.69	43	2.55	1	0.09	123	1.83
Central stoneroller	2	0.12	0	0.00	0	0.00	0	0.00	0	0.00	2	0.03
Rosyside dace	8	0.49	6	0.40	13	1.60	32	1.90	8	0.74	67	1.00
Common carp	0	0.00	0	0.00	0	0.00	0	0.00	1	0.09	1	0.01
Cutlips minnow	1	0.06	4	0.27	1	0.12	0	0.00	1	0.09	7	0.10
Comely shiner	1	0.06	12	0.81	14	1.72	0	0.00	0	0.00	27	0.40
Common shiner	21	1.28	14	0.94	10	1.23	7	0.42	3	0.28	55	0.82
Spottail shiner	1	0.06	35	2.36	0	0.00	2	0.12	17	1.57	55	0.82
Swallowtail shiner	2	0.12	3	0.20	2	0.25	0	0.00	0	0.00	7	0.10
Rosyface shiner	0	0.00	4	0.27	1	0.12	1	0.06	0	0.00	6	0.09
Spotfin shiner	597	36.31	770	51.89	541	66.38	1,400	83.04	863	79.54	4,171	62.12
Bluntnose minnow	254	15.45	401	27.02	40	4.91	35	2.08	82	7.56	812	12.09
Blacknose dace	9	0.55	0	0.00	3	0.37	8	0.47	3	0.28	23	0.34
Longnose dace	1	0.06	5	0.34	1	0.12	1	0.06	1	0.09	9	0.13
Creek chub	15	0.91	16	1.08	6	0.74	10	0.59	0	0.00	47	0.70
Fallfish	3	0.18	0	0.00	0	0.00	0	0.00	0	0.00	3	0.04
Silverjaw minnow	0	0.00	0	0.00	2	0.25	0	0.00	0	0.00	2	0.03
Mimic shiner	5	0.30	44	2.96	1	0.12	3	0.18	33	3.04	86	1.28
Quillback	54	3.28	8	0.54	0	0.00	0	0.00	0	0.00	62	0.92
White sucker	73	4.44	42	2.83	11	1.35	2	0.12	0	0.00	128	1.91
Northern hogsucker	0	0.00	0	0.00	0	0.00	0	0.00	4	0.37	4	0.06
Banded killifish	1	0.06	1	0.07	0	0.00	0	0.00	1	0.09	3	0.04
Green sunfish	0	0.00	0	0.00	1	0.12	4	0.24	0	0.00	5	0.07
Pumpkinseed	11	0.67	13	0.88	14	1.72	30	1.78	19	1.75	87	1.30
Bluegill	34	2.07	10	0.67	4	0.49	69	4.09	27	2.49	144	2.14
Smallmouth bass	25	1.52	9	0.61	16	1.96	15	0.89	8	0.74	73	1.09
Largemouth bass	85	5.17	9	0.61	24	2.94	12	0.71	7	0.65	137	2.04
Lepomis sp*	11	0.67	0	0.00	0	0.00	0	0.00	0	0.00	11	0.16
Tessellated darter	415	25.24	62	4.18	16	1.96	6	0.36	3	0.28	502	7.48
Logperch	13	0.79	15	1.01	14	1.72	6	0.36	2	0.18	50	0.74
Shield darter	1	0.06	0	0.00	0	0.00	0	0.00	0	0.00	1	0.01
Greenside darter	1	0.06	1	0.07	1	0.12	0	0.00	1	0.09	4	0.06
Overall	*1,644*	*100.00*	*1,484*	*100.00*	*815*	*100.00*	*1,686*	*100.00*	*1,085*	*100.00*	*6,714*	*100.00*
Number of species	*25*		*22*		*23*		*19*		*20*		*31*	

* Not counted as separate species.

Table 3-15

Monthly catch per effort (number per collection) for fishes collected by a 10 x 4 ft seine in Conowingo Pond, June-October 1999.

	June	July	August	September	October	Mean
Gizzard shad	0.00	0.00	11.29	6.14	0.14	3.51
Central stoneroller	0.29	0.00	0.00	0.00	0.00	0.06
Rosyside dace	1.14	0.86	1.86	4.57	1.14	1.91
Common carp	0.00	0.00	0.00	0.00	0.14	0.03
Cutlips minnow	0.14	0.57	0.14	0.00	0.14	0.20
Comely shiner	0.14	1.71	2.00	0.00	0.00	0.77
Common shiner	3.00	2.00	1.43	1.00	0.43	1.57
Spottail shiner	0.14	5.00	0.00	0.29	2.43	1.57
Swallowtail shiner	0.29	0.43	0.29	0.00	0.00	0.20
Rosyface shiner	0.00	0.57	0.14	0.14	0.00	0.17
Spotfin shiner	85.29	110.00	77.29	200.00	123.29	119.17
Bluntnose minnow	36.29	57.29	5.71	5.00	11.71	23.20
Blacknose dace	1.29	0.00	0.43	1.14	0.43	0.66
Longnose dace	0.14	0.71	0.14	0.14	0.14	0.26
Creek chub	2.14	2.29	0.86	1.43	0.00	1.34
Fallfish	0.43	0.00	0.00	0.00	0.00	0.09
Silverjaw minnow	0.00	0.00	0.29	0.00	0.00	0.06
Mimic shiner	0.71	6.29	0.14	0.43	4.71	2.46
Quillback	7.71	1.14	0.00	0.00	0.00	1.77
White sucker	10.43	6.00	1.57	0.29	0.00	3.66
Northern hogsucker	0.00	0.00	0.00	0.00	0.57	0.11
Banded killifish	0.14	0.14	0.00	0.00	0.14	0.09
Green sunfish	0.00	0.00	0.14	0.57	0.00	0.14
Pumpkinseed	1.57	1.86	2.00	4.29	2.71	2.49
Bluegill	4.86	1.43	0.57	9.86	3.86	4.11
Smallmouth bass	3.57	1.29	2.29	2.14	1.14	2.09
Largemouth bass	12.14	1.29	3.43	1.71	1.00	3.91
Lepomis sp*	1.57	0.00	0.00	0.00	0.00	0.31
Tessellated darter	59.29	8.86	2.29	0.86	0.43	14.34
Logperch	1.86	2.14	2.00	0.86	0.29	1.43
Shield darter	0.14	0.00	0.00	0.00	0.00	0.03
Greenside darter	0.14	0.14	0.14	0.00	0.14	0.11
Overall	*234.85*	*212.01*	*116.44*	*240.86*	*154.98*	*191.82*
Number of species	*25*	*22*	*23*	*19*	*20*	*31*

* Not counted as separate species.

Table 3-16

Catch per effort (number per collection) for fishes collected by a 10 x 4 ft seine at stations in Conowingo Pond, June-October 1999.

	Station							
	202	203	208	209	210	212	214*	Mean
Gizzard shad	0.80	0.00	0.00	0.00	0.00	23.60	0.20	3.51
Central stoneroller	0.00	0.00	0.00	0.00	0.00	0.40	0.00	0.06
Rosyside dace	0.00	0.00	0.00	0.00	0.00	13.40	0.00	1.91
Common carp	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.03
Cutlips minnow	0.00	0.00	0.00	0.00	0.00	1.40	0.00	0.20
Comely shiner	2.80	0.00	1.40	0.00	0.00	1.20	0.00	0.77
Common shiner	0.00	0.00	0.00	0.00	0.00	10.80	0.20	1.57
Spottail shiner	2.00	3.00	0.00	0.00	0.00	5.80	0.20	1.57
Swallowtail shiner	0.00	0.00	0.00	0.00	0.00	1.40	0.00	0.20
Rosyface shiner	0.00	0.00	0.00	0.00	0.00	1.20	0.00	0.17
Spotfin shiner	170.40	115.20	64.40	48.80	184.80	209.60	41.00	119.17
Bluntnose minnow	33.20	9.00	23.00	14.60	2.00	71.00	9.60	23.20
Blacknose dace	0.00	0.00	0.00	0.00	0.00	4.60	0.00	0.66
Longnose dace	0.00	0.00	0.00	0.00	0.00	1.80	0.00	0.26
Creek chub	0.00	0.00	0.00	0.20	0.00	9.20	0.00	1.34
Fallfish	0.00	0.00	0.00	0.00	0.00	0.60	0.00	0.09
Silverjaw minnow	0.00	0.00	0.00	0.00	0.00	0.40	0.00	0.06
Mimic shiner	7.60	8.20	0.20	0.00	0.00	1.20	0.00	2.46
Quillback	0.00	12.40	0.00	0.00	0.00	0.00	0.00	1.77
White sucker	0.00	0.00	0.00	0.00	0.00	25.60	0.00	3.66
Northern hogsucker	0.00	0.00	0.00	0.00	0.00	0.00	0.80	0.11
Banded killifish	0.00	0.00	0.20	0.00	0.00	0.00	0.40	0.09
Green sunfish	0.00	0.00	0.00	0.00	0.20	0.80	0.00	0.14
Pumpkinseed	0.00	0.20	0.40	5.80	3.20	6.60	1.20	2.49
Bluegill	0.00	0.60	0.00	4.60	2.20	10.80	10.60	4.11
Smallmouth bass	2.40	3.20	4.00	0.00	1.60	2.60	0.80	2.09
Largemouth bass	1.60	0.00	0.60	20.20	1.20	3.60	0.20	3.91
Lepomis sp**	0.00	0.40	1.20	0.20	0.40	0.00	0.00	0.31
Tessellated darter	27.40	8.20	5.80	4.80	0.20	54.00	0.00	14.34
Logperch	0.00	2.80	0.00	0.20	0.40	6.60	0.00	1.43
Shield darter	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.03
Greenside darter	0.00	0.60	0.00	0.00	0.20	0.00	0.00	0.11
Overall	*248.40*	*163.80*	*101.20*	*99.40*	*196.40*	*468.20*	*65.40*	*191.82*
Number of species	*10*	*11*	*9*	*8*	*10*	*25*	*12*	*31*

* Located within the influence of PBAPS thermal effluent.

** Not counted as separate species.

Table 3-17

Diversity and evenness values for fishes taken by seine per month in Conowingo Pond, June-October 1999.

Month	Diversity	Evenness
June	0.819	0.579
July	0.677	0.505
August	0.631	0.464
September	0.370	0.290
October	0.407	0.312

Table 3-18

Index of percent similarity of species composition between seine stations during zero tower operation in Conowingo Pond, June-October 1999.

	Station						
Station	202	203	208	209	210	212	214
202	100.00	83.93	85.62	67.93	71.14	72.00	77.94
203		100.00	76.66	60.31	73.26	59.22	70.20
208			100.00	69.80	66.76	67.66	79.49
209				100.00	53.98	69.17	70.54
210					100.00	49.89	67.58
212						100.00	64.94
214							100.00

Table 3-19

Index of percent similarlity of species composition per month in Conowingo Pond, June-October 1999.

	June	July	August	September	October
June	100.00	65.71	54.26	45.83	50.10
July		100.00	67.35	59.38	68.20
August			100.00	78.98	77.12
September				100.00	89.44
October					100.00

Table 3-20

Comparison of the monthly catch per effort (number per collection) for the common and Environmental Protection Agency designated, representative, important species collected at seine stations in Conowingo Pond in June-October. "-"-designates a period when no effort was expended. Underlined CPEs are greater than historical values and italcized are less than historical values.

	June		July		August		September		October	
	N*	Range	N*	Range	N*	Range	N*	Range	N*	Range
					White crappie					
Pre-operational	7	0-4.70	8	0-14.00	8	0-7.60	8	0-1.40	8	0-2.11
Post-operational	7	0-0.05	7	0-0.05	7	0	7	0-1.79	8	0-1.21
1997		0.00		0.00		0.00		0.00		0.00
1998		0.00		0.00		0.00		0.00		0.00
1999		0.00		0.00		0.00		0.00		0.00
					Channel catfish					
Pre-operational	5	0-1.60	8	0-0.31	8	0-0.60	8	0-0.90	8	0-0.18
Post-operational	7	0-0.08	7	0	7	0-0.07	7	0-0.57	8	0-0.43
1997		0.00		0.00		0.00		0.00		0.00
1998		0.00		0.29		0.14		0.00		0.29
1999		0.00		0.00		0.00		0.00		0.00
					Bluegill					
Pre-operational	7	0-2.06	8	0.42-62.46	8	0.62-103.05	8	0.45-62.80	8	0.75-50.71
Post-operational	7	0-2.00	7	0.36-5.71	7	0.21-3.21	7	0.14-28.38	8	0.07-39.36
1997		0.00		1.00		1.43		0.71		4.71
1998		7.57		6.00		7.00		16.14		12.71
1999		4.86		1.43		0.57		9.86		3.86
					Smallmouth bass					
Pre-operational	6	0-7.62	8	0-2.10	8	0-0.46	8	0-0.19	8	0-0.33
Post-operational	7	0-0.90	7	0.07-3.48	7	0-1.52	7	0-3.90	8	0-2.00
1997		1.14		1.14		0.57		0.43		0.00
1998		3.86		2.57		0.43		0.14		0.86
1999		3.57		1.29		2.29		2.14		1.14
					Largemouth bass					
Pre-operational	7	0-3.06	8	0.14-6.82	8	0-1.20	8	0-0.67	8	0-0.28
Post-operational	7	0.08-3.00	7	1.00-14.00	7	0.07-1.38	7	0-2.52	8	0.14-1.79
1997		10.29		3.14		1.00		0.71		0.00
1998		2.43		0.29		0.00		0.29		0.86
1999		12.14		1.29		3.43		1.71		1.00
					Spotfin shiner					
Pre-operational	7	11.50-85.43	8	2.11-79.92	8	19.17-100.95	8	26.53-124.10	8	27.42-134.74
Post-operational	7	27.62-79.92	7	9.64-60.21	7	17.58-105.71	7	20.91-213.29	8	22.31-284.43
1997		42.14		101.71		96.29		70.71		87.14
1998		28.86		44.14		214.14		176.86		262.57
1999		85.29		110.00		77.29		200.00		123.29
					Bluntnose minnow					
Pre-operational	7	0.35-1.30	8	0-8.15	8	0.08-47.00	8	0.20-11.40	8	0.43-6.55
Post-operational	7	0.30-6.33	7	0.86-7.43	7	0.23-8.79	7	0.09-20.48	8	0.71-62.50
1997		0.71		6.86		48.29		15.71		51.29
1998		13.86		1.43		84.00		36.86		31.57
1999		36.29		57.29		5.71		5.00		11.71
					Pumpkinseed					
Pre-operational	7	0-1.78	8	0.51-6.08	8	0.21-17.75	8	0.14-37.60	8	0-9.71
Post-operational	7	0-1.62	7	0.22-4.00	7	1.20-4.00	7	0.57-10.90	8	0-5.57
1997		0.71		1.43		1.86		1.14		1.57
1998		3.86		1.29		4.00		6.57		3.57
1999		1.57		1.86		2.00		4.29		2.71
					Spottail shiner					
Pre-operational	7	0.04-2.57	8	0-5.39	8	0-6.65	8	0-5.89	8	0-20.42
Post-operational	7	0.31-7.25	7	0.11-12.13	7	0-3.56	7	0-1.33	8	0-4.17
1997		9.71		27.00		5.71		3.57		1.57
1998		74.43		0.57		11.14		5.86		2.43
1999		0.14		5.00		0.00		0.29		2.43
					Tesselated darter					
Pre-operational	7	0-8.00	8	0-7.45	8	0-1.83	8	0-2.50	8	0-2.43
Post-operational	7	0.29-5.54	7	0.63-21.50	7	0.50-5.87	7	0.14-8.71	8	0.17-7.36
1997		31.14		54.00		5.29		2.00		1.29
1998		7.71		10.14		4.71		3.71		1.43
1999		59.29		8.86		2.29		0.86		0.43

* N= the number of years in the historical period (pre- or post-operational) that sampling occurred in a given month.

Table 3-21

Number and percent composition of fishes collected by trap net per month in Conowingo Pond, June-October 1999.

	June		July		August		September		October		Overall	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Gizzard shad	0	0.00	92	47.92	6	8.45	1	0.39	0	0.00	99	15.09
Common carp	4	10.53	4	2.08	3	4.23	22	8.66	14	13.86	47	7.16
Golden shiner	0	0.00	0	0.00	0	0.00	1	0.39	0	0.00	1	0.15
Spotfin shiner	0	0.00	1	0.52	0	0.00	0	0.00	0	0.00	1	0.15
Quillback	0	0.00	0	0.00	0	0.00	3	1.18	0	0.00	3	0.46
Shorthead redhorse	2	5.26	3	1.56	0	0.00	1	0.39	3	2.97	9	1.37
White catfish	2	5.26	0	0.00	0	0.00	0	0.00	0	0.00	2	0.30
Yellow bullhead	1	2.63	1	0.52	0	0.00	3	1.18	0	0.00	5	0.76
Brown bullhead	0	0.00	1	0.52	2	2.82	13	5.12	1	0.99	17	2.59
Channel catfish	7	18.42	17	8.85	24	33.80	54	21.26	9	8.91	111	16.92
White perch	0	0.00	0	0.00	1	1.41	7	2.76	0	0.00	8	1.22
Rock bass	0	0.00	0	0.00	2	2.82	5	1.97	17	16.83	24	3.66
Redbreast sunfish	0	0.00	0	0.00	0	0.00	0	0.00	1	0.99	1	0.15
Green sunfish	1	2.63	25	13.02	1	1.41	4	1.57	0	0.00	31	4.73
Pumpkinseed	4	10.53	5	2.60	4	5.63	1	0.39	2	1.98	16	2.44
Bluegill	13	34.21	27	14.06	14	19.72	36	14.17	15	14.85	105	16.01
Smallmouth bass	0	0.00	0	0.00	0	0.00	1	0.39	0	0.00	1	0.15
Largemouth bass	1	2.63	3	1.56	1	1.41	15	5.91	2	1.98	22	3.35
White crappie	3	7.89	13	6.77	13	18.31	85	33.46	34	33.66	148	22.56
Black crappie	0	0.00	0	0.00	0	0.00	0	0.00	1	0.99	1	0.15
Walleye	0	0.00	0	0.00	0	0.00	2	0.79	2	1.98	4	0.61
Overall	*38*	*100.00*	*192*	*100.00*	*71*	*100.00*	*254*	*100.00*	*101*	*100.00*	*656*	*100.00*
Number of species	*10*		*12*		*11*		*17*		*12*		*21*	

Table 3-22

Monthly catch per effort (number per 24 h) for fishes collected by trap net at stations in Conowingo Pond, June-October 1999.

	June	July	August	September	October	Mean
Gizzard shad	0.00	11.32	0.76	0.13	0.00	2.44
Common carp	0.48	0.45	0.37	2.78	1.69	1.15
Golden shiner	0.00	0.00	0.00	0.13	0.00	0.03
Spotfin shiner	0.00	0.13	0.00	0.00	0.00	0.03
Quillback	0.00	0.00	0.00	0.37	0.00	0.07
Shorthead redhorse	0.24	0.37	0.00	0.12	0.36	0.22
White catfish	0.25	0.00	0.00	0.00	0.00	0.05
Yellow bullhead	0.13	0.13	0.00	0.38	0.00	0.13
Brown bullhead	0.00	0.13	0.25	1.61	0.12	0.42
Channel catfish	0.89	2.07	3.01	6.79	1.11	2.77
White perch	0.00	0.00	0.12	0.90	0.00	0.20
Rock bass	0.00	0.00	0.25	0.64	2.15	0.61
Redbreast sunfish	0.00	0.00	0.00	0.00	0.13	0.03
Green sunfish	0.12	3.10	0.12	0.50	0.00	0.77
Pumpkinseed	0.51	0.58	0.49	0.12	0.25	0.39
Bluegill	1.57	3.14	1.77	4.50	1.86	2.57
Smallmouth bass	0.00	0.00	0.00	0.13	0.00	0.03
Largemouth bass	0.14	0.37	0.13	1.93	0.25	0.56
White crappie	0.37	1.59	1.62	10.53	4.14	3.65
Black crappie	0.00	0.00	0.00	0.00	0.11	0.02
Walleye	0.00	0.00	0.00	0.25	0.24	0.10
Overall	*4.70*	*23.38*	*8.89*	*31.81*	*12.41*	*16.24*
Number of species	*10*	*12*	*11*	*17*	*12*	*21*

Table 3-23

Catch per effort (number per 24 h) for fishes collected by trap net at stations in Conowingo Pond, June-October 1999.

	Station				
	104	107	108	110*	Mean
Gizzard shad	0.10	0.10	0.20	9.36	2.44
Common carp	0.10	0.49	0.61	3.42	1.15
Golden shiner	0.00	0.00	0.00	0.10	0.03
Spotfin shiner	0.00	0.00	0.00	0.10	0.03
Quillback	0.00	0.29	0.00	0.00	0.07
Shorthead redhorse	0.00	0.48	0.20	0.19	0.22
White catfish	0.20	0.00	0.00	0.00	0.05
Yellow bullhead	0.00	0.00	0.30	0.21	0.13
Brown bullhead	0.20	0.19	1.30	0.00	0.42
Channel catfish	0.67	0.57	0.80	9.07	2.77
White perch	0.00	0.09	0.00	0.72	0.20
Rock bass	2.02	0.00	0.00	0.41	0.61
Redbreast sunfish	0.10	0.00	0.00	0.00	0.03
Green sunfish	0.30	0.39	0.30	2.08	0.77
Pumpkinseed	0.68	0.20	0.19	0.49	0.39
Bluegill	2.63	1.63	2.17	3.83	2.57
Smallmouth bass	0.00	0.00	0.00	0.10	0.03
Largemouth bass	0.31	0.19	0.31	1.44	0.56
White crappie	3.12	3.93	6.31	1.23	3.65
Black crappie	0.00	0.00	0.00	0.09	0.02
Walleye	0.10	0.00	0.00	0.29	0.10
Overall	*10.53*	*8.55*	*12.69*	*33.13*	*16.24*
Number of species	*13*	*12*	*11*	*17*	*21*

* Located within influence of PBAPS thermal effluent.

Table 3-24

Comparison of the monthly catch per effort (number per 24 h) for the common and Environmental Protection Agency designated, representative, important species collected at trap net stations in Conowingo Pond in June-October. "-"-designates a period when no effort was expended. Underlined CPEs are greater than historical values and italicized are less than historical values.

	June		July		August		September		October	
	N*	Range	N*	Range	N*	Range	N*	Range	N*	Range
					White crappie					
Pre-operational	7	29.82-144.41	7	17.08-87.09	7	9.41-75.11	7	10.67-63.54	8	7.24-114.21
Post-operational	15	0.52-34.74	7	1.01-17.46	7	1.11-23.31	7	5.35-34.81	16	1.13-27.19
1997		0.65		1.38		3.37		*1.70*		3.64
1998		1.96		*1.00*		1.61		*0.86*		2.65
1999		*0.37*		1.59		1.62		10.53		4.14
					Channel catfish					
Pre-operational	7	2.37-12.66	7	1.67-65.55	7	1.53-13.38	7	1.37-14.71	8	0.92-19.93
Post-operational	15	0.00-135.67	7	2.61-21.71	7	4.70-21.77	7	2.60-16.24	16	0.11-62.98
1997		3.36		*0.75*		1.87		*0.75*		0.75
1998		0.78		*0.25*		*1.49*		*1.08*		1.62
1999		0.89		*2.07*		3.01		6.79		1.11
					Bluegill					
Pre-operational	7	0.55-8.16	7	2.49-10.54	7	1.10-9.98	7	2.75-5.72	8	0.50-7.80
Post-operational	15	0-6.00	7	1.02-3.36	7	1.34-11.65	7	1.51-7.00	16	0.31-13.06
1997		3.47		*0.92*		2.83		2.60		2.24
1998		0.52		4.76		4.56		5.99		2.24
1999		1.57		3.14		1.77		4.50		1.86
					Gizzard shad					
Pre-operational	1	0.08	2	0.06-0.14	2	0	2	0.04-0.13	2	0.02-0.04
Post-operational	15	0-0.52	7	0-1.68	7	0.06-0.57	7	0-0.64	16	0-102.66
1997		0.00		0.00		0.12		0.00		0.25
1998		0.00		0.00		0.00		0.13		0.25
1999		0.00		11.32		0.76		0.13		0.00
					Smallmouth bass					
Pre-operational	–	–	4	0-0.06	4	0-0.02	4	0	4	0-0.02
Post-operational	15	0	7	0-0.18	7	0-0.07	7	0	16	0
1997		0.00		0.00		0.00		0.00		0.00
1998		0.00		0.00		0.00		0.00		0.00
1999		0.00		0.00		0.00		0.13		0.00
					Largemouth bass					
Pre-operational	4	0-0.08	6	0-0.05	6	0-0.15	6	0-0.08	7	0-0.12
Post-operational	15	0-0.29	7	0-0.30	7	0-0.12	7	0-0.12	16	0-0.77
1997		0.25		0.12		0.12		0.00		0.00
1998		0.00		0.25		0.00		0.00		0.00
1999		0.14		0.37		0.13		1.93		0.25
					Walleye					
Pre-operational	6	0-0.29	6	0-0.18	6	0-0.04	6	0-0.04	7	0-0.08
Post-operational	15	0-0.52	7	0-0.07	7	0-0.05	7	0-0.24	16	0-0.39
1997		0.00		0.00		0.00		0.00		0.00
1998		0.00		0.00		0.00		0.00		0.13
1999		0.00		0.00		0.00		0.25		0.24
					Brown bullhead					
Pre-operational	7	0.88-5.38	7	0.65-3.98	7	0.58-2.21	7	0.15-3.02	8	0.33-2.63
Post-operational	15	0-12.16	7	0.27-0.55	7	0.46-1.78	7	0.34-2.00	16	0-4.99
1997		0.12		*0.00*		*0.00*		*0.00*		0.12
1998		0.40		*0.12*		*0.00*		*0.00*		0.13
1999		0.00		*0.13*		*0.25*		1.61		0.12
					Pumpkinseed					
Pre-operational	7	0.53-7.31	7	1.40-11.32	7	0.86-3.12	7	1.26-6.46	8	1.23-10.34
Post-operational	15	0-9.29	7	0.30-4.53	7	0.41-2.70	7	0.38-4.00	16	0-41.25
1997		0.89		*0.12*		0.74		*0.12*		1.09
1998		0.26		*0.13*		*0.26*		0.74		0.50
1999		0.51		0.58		0.49		*0.12*		0.25

* N= the number of years in the historical period (pre- or post-operational) that sampling occurred in a given month.

Table 3-25

Number and percent composition of fishes collected by a 16 ft semi-balloon trawl per month in trawl zone 405, Conowingo Pond, June-October 1999.

	June		July		August		September		October		Overall	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Gizzard shad	3	0.77	0	0.00	0	0.00	8	6.72	0	0.00	11	1.48
Common carp	4	1.02	3	2.78	2	5.00	8	6.72	5	6.02	22	2.97
Spottail shiner	0	0.00	1	0.93	0	0.00	0	0.00	0	0.00	1	0.13
Bluntnose minnow	0	0.00	1	0.93	0	0.00	0	0.00	0	0.00	1	0.13
Shorthead redhorse	1	0.26	1	0.93	0	0.00	0	0.00	0	0.00	2	0.27
White catfish	1	0.26	1	0.93	0	0.00	0	0.00	0	0.00	2	0.27
Yellow bullhead	0	0.00	0	0.00	0	0.00	1	0.84	0	0.00	1	0.13
Brown bullhead	1	0.26	1	0.93	0	0.00	1	0.84	0	0.00	3	0.40
Channel catfish	325	83.12	36	33.33	34	85.00	92	77.31	71	85.54	558	75.30
Rock bass	1	0.26	0	0.00	0	0.00	2	1.68	0	0.00	3	0.40
Bluegill	0	0.00	6	5.56	0	0.00	1	0.84	3	3.61	10	1.35
Largemouth bass	0	0.00	1	0.93	1	2.50	0	0.00	0	0.00	2	0.27
Tessellated darter	55	14.07	55	50.93	3	7.50	5	4.20	4	4.82	122	16.46
Yellow perch	0	0.00	1	0.93	0	0.00	0	0.00	0	0.00	1	0.13
Walleye	0	0.00	1	0.93	0	0.00	1	0.84	0	0.00	2	0.27
Overall	*391*	*100.00*	*108*	*100.00*	*40*	*100.00*	*119*	*100.00*	*83*	*100.00*	*741*	*100.00*
Number of species	*8*		*12*		*4*		*9*		*4*		*15*	

Table 3-26

Monthly catch per effort (number per 10 min haul) for fishes collected by a 16 ft semi-balloon trawl in trawl zone 405, Conowingo Pond, June-October 1999.

	June	July	August	September	October	Mean
Gizzard shad	0.57	0.00	0.00	1.33	0.00	0.38
Common carp	0.67	0.50	0.33	1.40	0.83	0.75
Spottail shiner	0.00	0.21	0.00	0.00	0.00	0.04
Bluntnose minnow	0.00	0.21	0.00	0.00	0.00	0.04
Shorthead redhorse	0.17	0.21	0.00	0.00	0.00	0.08
White catfish	0.17	0.21	0.00	0.00	0.00	0.08
Yellow bullhead	0.00	0.00	0.00	0.24	0.00	0.05
Brown bullhead	0.17	0.21	0.00	0.17	0.00	0.11
Channel catfish	54.88	6.67	5.67	15.33	11.83	18.88
Rock bass	0.17	0.00	0.00	0.33	0.00	0.10
Bluegill	0.00	1.17	0.00	0.24	0.50	0.38
Largemouth bass	0.00	0.21	0.24	0.00	0.00	0.09
Tessellated darter	10.45	10.04	0.50	0.83	0.67	4.50
Yellow perch	0.00	0.17	0.00	0.00	0.00	0.03
Walleye	0.00	0.21	0.00	0.24	0.00	0.09
Overall	*67.25*	*20.02*	*6.74*	*20.11*	*13.83*	*25.60*
Number of species	*8*	*12*	*4*	*9*	*4*	*15*

Table 3-27

Catch per effort (number per 10 min haul) for fishes collected by 16 ft semi-balloon trawl in trawl zone 405, Conowingo Pond, June-October 1999.

	Station						
	451*	452	453	454	455	456	Mean
Gizzard shad	0.00	0.80	0.40	0.80	0.00	0.29	0.38
Common carp	0.29	0.00	1.00	2.00	0.80	0.40	0.75
Spottail shiner	0.00	0.00	0.00	0.00	0.25	0.00	0.04
Bluntnose minnow	0.00	0.00	0.25	0.00	0.00	0.00	0.04
Shorthead redhorse	0.00	0.00	0.25	0.00	0.20	0.00	0.08
White catfish	0.00	0.00	0.00	0.00	0.45	0.00	0.08
Yellow bullhead	0.29	0.00	0.00	0.00	0.00	0.00	0.05
Brown bullhead	0.00	0.20	0.00	0.20	0.25	0.00	0.11
Channel catfish	1.40	40.60	16.70	11.80	35.10	7.66	18.88
Rock bass	0.00	0.00	0.00	0.00	0.20	0.40	0.10
Bluegill	0.29	0.00	1.20	0.80	0.00	0.00	0.38
Largemouth bass	0.29	0.00	0.00	0.00	0.25	0.00	0.09
Tessellated darter	0.00	1.20	3.30	7.60	3.95	10.94	4.50
Yellow perch	0.00	0.00	0.00	0.20	0.00	0.00	0.03
Walleye	0.29	0.00	0.25	0.00	0.00	0.00	0.09
Overall	*2.85*	*42.80*	*23.35*	*23.40*	*41.45*	*19.69*	*25.60*
Number of species	*6*	*4*	*8*	*7*	*9*	*5*	*15*

* Locates within influence of PBAPS thermal effluent.

Table 3-28

Comparison of the monthly catch per effort (number per 10 min haul) for the common and Environmental Protection Agency designated, representative, important species collected at trawl zone 405 in Conowingo Pond in June-October. "-"-designates a period when no effort was expended. Underlined CPEs are greater than historical values and italicized are less than historical values.

	June		July		August		September		October	
	N*	Range	N*	Range	N*	Range	N*	Range	N*	Range
					White crappie					
Pre-operational	7	0.04-41.00	8	0.00-63.33	8	0.58-84.25	7	0.21-145.88	7	0.31-418.40
Post-operational	6	0.00-0.09	15	0.00-0.70	15	0.00-4.23	15	0.00-1.90	16	0.00-2.59
1997		0.17		0.33		0.00		0.00		0.00
1998		0.00		0.00		0.21		0.33		0.17
1999		0.00		0.00		0.00		0.00		0.00
					Channel catfish					
Pre-operational	7	0.88-294.24	8	0.00-156.33	8	1.80-138.67	7	2.00-278.88	7	6.57-933.80
Post-operational	6	9.70-117.36	15	1.25-88.83	15	0.00-180.26	15	0.14-220.15	16	2.79-201.02
1997		244.94		163.17		183.33		63.00		31.33
1998		130.96		92.00		168.25		112.38		102.88
1999		54.88		6.67		5.67		15.33		11.83
					Bluegill					
Pre-operational	6	0.06-2.75	8	0.00-22.55	8	0.00-18.13	7	0.08-21.33	7	0.00-17.75
Post-operational	6	0	15	0.00-0.33	15	0.00-5.51	15	0.00-6.25	16	0.00-2.40
1997		0.00		13.00		1.90		2.00		1.50
1998		0.17		0.00		0.17		0.00		0.67
1999		0.00		1.17		0.00		0.24		0.50
					Gizzard shad					
Pre-operational	--	--	2	0	2	0.00-0.04	2	0.00-0.50	2	0
Post-operational	6	0.00-0.14	15	0.00-15.88	15	0.00-4.83	15	0.00-6.43	16	0.00-165.92
1997		0.00		3.17		0.24		0.00		0.40
1998		0.00		0.00		0.33		0.33		0.00
1999		0.57		0.00		0.00		1.33		0.00
					Smallmouth bass					
Pre-operational	2	0.13-0.33	3	0.00-0.50	3	0.00-0.38	2	0.04-0.13	2	0
Post-operational	6	0.00-0.20	15	0.00-0.09	15	0.00-0.17	15	0.00-0.15	16	0.00-0.20
1997		0.00		0.00		0.00		0.00		0.00
1998		0.00		0.00		0.00		0.00		0.00
1999		0.00		0.00		0.00		0.00		0.00
					Largemouth bass					
Pre-operational	5	0.00-0.13	3	0.00-0.11	3	0.00-0.13	2	0.00-0.63	2	0.00-0.04
Post-operational	6	0	15	0	15	0.00-0.05	15	0.00-0.17	16	0.00-0.17
1997		0.00		0.17		0.33		0.00		0.17
1998		0.00		0.00		0.00		0.00		0.00
1999		0.00		0.21		0.24		0.00		0.00
					Walleye					
Pre-operational	6	0.00-0.12	5	0.00-0.11	5	0.00-0.16	4	0.00-0.16	4	0.00-0.16
Post-operational	6	0.00-0.10	15	0.00-0.25	15	0.00-0.11	15	0.00-0.29	16	0.00-0.12
1997		0.00		0.00		0.00		0.00		0.00
1998		0.00		0.00		0.38		0.00		0.00
1999		0.00		0.21		0.00		0.24		0.00
					Pumpkinseed					
Pre-operational	6	0.24-2.33	8	0.00-7.92	8	0.00-9.94	7	0.04-14.33	7	0.14-6.95
Post-operational	6	0.00-0.33	14	0.00-1.80	14	0.00-1.75	14	0.00-5.95	16	0.00-3.65
1997		0.00		0.00		0.00		0.33		0.00
1998		0.00		0.00		0.00		0.00		0.00
1999		0.00		0.00		0.00		0.00		0.00
					Tesselated darter					
Pre-operational	7	0.00-1.25	8	0.00-7.42	8	0.04-6.00	7	0.00-5.54	7	0.00-4.43
Post-operational	6	0.67-4.00	14	0.67-30.60	14	0.25-16.29	14	0.13-7.70	16	0.50-15.17
1997		18.85		33.17		29.10		18.33		9.83
1998		8.50		10.33		8.68		9.33		2.00
1999		10.45		10.04		0.50		0.83		0.67
					Spottail shiner					
Pre-operational	7	0.00-2.29	8	0.00-3.00	8	0.00-3.25	7	0.00-5.33	7	0.00-19.00
Post-operational	6	0.00-0.67	14	0.00-6.27	14	0.00-4.50	14	0.00-2.57	16	0.00-3.83
1997		0.17		0.83		1.50		0.00		0.00
1998		0.33		7.67		11.74		1.04		0.00
1999		0.00		0.21		0.00		0.00		0.00

* N= the number of years in the historical period (pre- or post-operational) that sampling occurred in a given month.

Table 3-29

Number and percent composition of fishes collected by a 16 ft semi-balloon trawl per month in trawl zone 408, Conowingo Pond, June-October 1999.

	June		July		August		September		October		Overall	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Gizzard shad	401	59.14	5	7.81	1	2.33	2	13.33	0	0.00	409	48.69
Common carp	2	0.29	3	4.69	0	0.00	1	6.67	1	2.50	7	0.83
Spottail shiner	2	0.29	1	1.56	0	0.00	0	0.00	1	2.50	4	0.48
Bluntnose minnow	64	9.44	0	0.00	0	0.00	0	0.00	0	0.00	64	7.62
White catfish	0	0.00	0	0.00	0	0.00	0	0.00	1	2.50	1	0.12
Yellow bullhead	0	0.00	0	0.00	0	0.00	1	6.67	0	0.00	1	0.12
Brown bullhead	2	0.29	0	0.00	0	0.00	0	0.00	0	0.00	2	0.24
Channel catfish	61	9.00	24	37.50	30	69.77	3	20.00	1	2.50	119	14.17
Pumpkinseed	3	0.44	5	7.81	5	11.63	3	20.00	7	17.50	23	2.74
Bluegill	25	3.69	10	15.63	2	4.65	5	33.33	17	42.50	59	7.02
Smallmouth bass	9	1.33	1	1.56	2	4.65	0	0.00	0	0.00	12	1.43
Largemouth bass	10	1.47	9	14.06	1	2.33	0	0.00	4	10.00	24	2.86
Tessellated darter	99	14.60	6	9.38	2	4.65	0	0.00	7	17.50	114	13.57
Yellow perch	0	0.00	0	0.00	0	0.00	0	0.00	1	2.50	1	0.12
Overall	*678*	*100.00*	*64*	*100.00*	*43*	*100.00*	*15*	*100.00*	*40*	*100.00*	*840*	*100.00*
Number of species	*11*		*9*		*7*		*6*		*9*		*14*	

Table 3-30

Monthly catch per effort (number per 10 min haul) for fishes collected by a 16 ft semi-balloon trawl in trawl zone 408, Conowingo Pond, June-October 1999.

	June	July	August	September	October	Mean
Gizzard shad	67.40	0.88	0.17	0.33	0.00	13.76
Common carp	0.40	0.50	0.00	0.17	0.17	0.25
Spottail shiner	0.33	0.21	0.00	0.00	0.17	0.14
Bluntnose minnow	10.67	0.00	0.00	0.00	0.00	2.13
White catfish	0.00	0.00	0.00	0.00	0.17	0.03
Yellow bullhead	0.00	0.00	0.00	0.17	0.00	0.03
Brown bullhead	0.33	0.00	0.00	0.00	0.00	0.07
Channel catfish	10.24	4.00	5.00	0.50	0.17	3.98
Pumpkinseed	0.50	0.83	0.83	0.50	1.17	0.77
Bluegill	4.24	1.83	0.33	0.83	2.83	2.01
Smallmouth bass	1.50	0.17	0.33	0.00	0.00	0.40
Largemouth bass	1.67	1.50	0.17	0.00	0.67	0.80
White crappie	0.00	0.00	0.00	0.00	0.00	0.00
Tessellated darter	17.00	1.00	0.33	0.00	1.17	3.90
Yellow perch	0.00	0.00	0.00	0.00	0.17	0.03
Overall	*114.28*	*10.92*	*7.16*	*2.50*	*6.69*	*28.30*
Number of species	*11*	*9*	*7*	*6*	*9*	*14*

Table 3-31

Catch per effort (number per 10 min haul) for fishes collected by 16 ft semi-balloon trawl in trawl zone 408, Conowingo Pond, June-October 1999.

	Station						
	481	482	483	484	485	486	Mean
Gizzard shad	0.25	13.20	0.40	19.40	47.00	2.29	13.76
Common carp	0.00	0.40	0.20	0.20	0.00	0.69	0.25
Spottail shiner	0.45	0.00	0.40	0.00	0.00	0.00	0.14
Bluntnose minnow	0.00	0.00	0.60	0.60	11.60	0.00	2.13
White catfish	0.00	0.20	0.00	0.00	0.00	0.00	0.03
Yellow bullhead	0.00	0.20	0.00	0.00	0.00	0.00	0.03
Brown bullhead	0.00	0.20	0.00	0.20	0.00	0.00	0.07
Channel catfish	3.60	12.40	5.00	1.80	0.20	0.89	3.98
Pumpkinseed	0.20	2.20	1.80	0.20	0.20	0.00	0.77
Bluegill	1.20	4.40	2.00	2.20	1.80	0.49	2.01
Smallmouth bass	0.40	0.00	0.20	0.40	1.40	0.00	0.40
Largemouth bass	0.00	0.80	0.60	1.80	1.40	0.20	0.80
Tessellated darter	2.80	3.20	1.00	13.20	1.00	2.20	3.90
Yellow perch	0.00	0.20	0.00	0.00	0.00	0.00	0.03
Overall	*8.90*	*37.40*	*12.20*	*40.00*	*64.60*	*6.76*	*28.30*
Number of species	*7*	*11*	*10*	*10*	*8*	*6*	*14*

Table 3-32

Comparison of the monthly catch per effort (number per 10 min haul) for the common and Environmental Protection Agency designated, representative, important species collected at trawl zone 408 in Conowingo Pond in June-October. "-"-designates a period when no effort was expended. Underlined CPEs are greater than historical values and italicized are less than historical values.

	June		July		August		September		October	
	N*	Range	N*	Range	N*	Range	N*	Range	N*	Range
					White crappie					
Pre-operational	7	2.96-59.39	8	5.92-569.88	8	1.83-216.36	6	2.00-343.00	7	0.00-95.54
Post-operational	7	0.22-10.97	15	0.18-9.45	15	0.33-50.78	15	0.17-37.04	16	0.33-32.76
1997		*0.00*		*0.00*		*0.00*		*0.00*		*0.00*
1998		0.33		3.83		*0.00*		*0.00*		0.33
1999		*0.00*		*0.00*		*0.00*		*0.00*		0.00
					Channel catfish					
Pre-operational	7	5.67-113.88	8	3.60-144.25	8	0.00-226.17	6	0.00-139.25	7	2.31-13.44
Post-operational	7	3.22-26.17	15	0.67-55.25	15	0.42-49.81	15	1.45-41.96	16	0.17-95.57
1997		6.83		10.00		63.33		21.17		6.00
1998		7.00		2.50		2.83		1.67		0.17
1999		10.24		4.00		5.00		0.50		0.17
					Bluegill					
Pre-operational	6	0.04-7.25	8	0.04-42.50	8	0.83-243.41	6	0.00-22.16	7	0.29-22.54
Post-operational	7	0.00-0.49	15	0.00-38.09	15	1.25-32.00	15	1.17-35.37	16	0.09-19.33
1997		0.67		53.17		4.67		3.50		3.67
1998		3.83		103.83		7.17		3.33		5.83
1999		4.24		1.83		*0.33*		0.83		2.83
					Gizzard shad					
Pre-operational	–	–	2	0	2	0.33-12.46	2	0.58-10.58	2	0.03-0.08
Post-operational	7	0.00-32.33	15	0.10-673.00	15	0.14-22.17	15	0.08-66.97	16	0.00-173.73
1997		0.00		1.17		0.33		0.67		7.33
1998		75.17		0.00		0.17		4.00		0.00
1999		67.40		0.88		0.17		0.33		0.00
					Smallmouth bass					
Pre-operational	2	0.08-0.42	3	0.00-0.38	3	0.00-0.17	3	0.00-0.17	3	0.00-0.08
Post-operational	7	0.00-2.84	15	0.00-2.73	15	0.00-1.92	15	0.00-0.62	16	0.00-0.32
1997		1.17		1.00		0.33		0.17		0.17
1998		4.50		1.00		0.17		0.00		0.00
1999		1.50		0.17		0.33		0.00		0.00
					Largemouth bass					
Pre-operational	5	0.00-0.42	7	0.00-0.75	7	0.00-1.33	6	0.00-0.25	6	0.00-2.50
Post-operational	7	0.00-1.33	15	0.00-2.18	15	0.00-0.63	15	0.00-1.33	16	0.00-0.67
1997		0.17		10.00		1.67		1.00		0.17
1998		0.67		0.50		0.00		0.17		0.00
1999		1.67		1.50		0.17		0.00		0.67
					Walleye					
Pre-operational	3	0.00-0.08	6	0.00-0.08	6	0.00-0.08	5	0.00-0.08	5	0.00-0.08
Post-operational	7	0.00-0.24	15	0.00-0.09	15	0.00-0.13	15	0.00-0.09	16	0.00-0.45
1997		0.00		0.00		0.00		0.00		0.17
1998		0.00		0.00		0.00		0.00		0.00
1999		0.00		0.00		0.00		0.00		0.00
					Pumpkinseed					
Pre-operational	7	0.08-7.00	8	0.17-7.88	8	0.58-26.16	6	0.00-13.25	7	0.83-12.12
Post-operational	7	0.67-2.82	15	0.35-8.61	15	0.90-13.28	15	0.61-19.70	16	0.27-5.33
1997		1.50		0.50		2.50		2.33		3.00
1998		1.33		1.50		3.33		3.67		2.33
1999		0.50		0.83		0.83		0.50		1.17
					Tesselated darter					
Pre-operational	7	0.00-0.96	8	0.00-4.04	8	0.02-2.67	6	0.00-3.71	7	0.33-3.83
Post-operational	7	0.13-4.46	15	0.56-40.27	15	0.00-19.36	15	0.00-17.50	16	0.00-11.58
1997		36.50		221.17		6.17		3.83		3.33
1998		26.17		10.67		1.00		0.67		0.50
1999		17.00		1.00		0.33		0.00		1.17
					Spottail shiner					
Pre-operational	7	0.00-1.89	8	0.00-1.75	8	0.00-13.08	6	0.00-5.66	7	0.00-7.33
Post-operational	7	0.00-4.00	15	0.00-32.64	15	0.39-31.89	15	0.20-19.50	16	0.00-21.33
1997		1.17		0.17		0.00		0.00		0.33
1998		93.67		18.17		0.17		0.17		0.00
1999		0.33		0.21		0.00		0.00		0.17

* N= the number of years in the historical period (pre- or post-operational) that sampling occurred in a given month.

Table 3-33

Number and percent composition of fishes collected by 16 ft semi-balloon trawl per month at trawl transects in Conowingo Pond, June-October 1999.

	June		July		August		September		October		Overall	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
American shad	0	0.00	0	0.00	0	0.00	0	0.00	1	1.92	1	0.04
Gizzard shad	1,755	73.16	2	1.53	1	1.09	7	3.83	0	0.00	1,765	61.78
Common carp	10	0.42	3	2.29	1	1.09	4	2.19	1	1.92	19	0.67
Spottail shiner	11	0.46	0	0.00	0	0.00	3	1.64	1	1.92	15	0.53
Bluntnose minnow	7	0.29	0	0.00	0	0.00	0	0.00	0	0.00	7	0.25
Quillback	0	0.00	1	0.76	0	0.00	1	0.55	0	0.00	2	0.07
Shorthead redhorse	0	0.00	1	0.76	0	0.00	0	0.00	1	1.92	2	0.07
White catfish	0	0.00	1	0.76	0	0.00	0	0.00	0	0.00	1	0.04
Brown bullhead	1	0.04	0	0.00	4	4.35	1	0.55	0	0.00	6	0.21
Channel catfish	311	12.96	81	61.83	76	82.61	146	79.78	6	11.54	620	21.70
White perch	0	0.00	0	0.00	0	0.00	0	0.00	1	1.92	1	0.04
Pumpkinseed	2	0.08	0	0.00	2	2.17	1	0.55	2	3.85	7	0.25
Bluegill	10	0.42	29	22.14	1	1.09	3	1.64	20	38.46	63	2.21
Smallmouth bass	4	0.17	1	0.76	0	0.00	0	0.00	0	0.00	5	0.18
Largemouth bass	4	0.17	1	0.76	6	6.52	0	0.00	4	7.69	15	0.53
White crappie	2	0.08	0	0.00	0	0.00	0	0.00	0	0.00	2	0.07
Tessellated darter	280	11.67	11	8.40	0	0.00	16	8.74	12	23.08	319	11.17
Yellow perch	2	0.08	0	0.00	0	0.00	1	0.55	3	5.77	6	0.21
Walleye	0	0.00	0	0.00	1	1.09	0	0.00	0	0.00	1	0.04
Overall	*2,399*	*100.00*	*131*	*100.00*	*92*	*100.00*	*183*	*100.00*	*52*	*100.00*	*2,857*	*100.00*
Number of species	*13*		*10*		*8*		*10*		*11*		*19*	

Table 3-34

Monthly catch per effort (number per 10 min haul) for fishes collected by 16 ft semi-balloon trawl at trawl transects in Conowingo Pond, June-October 1999.

	June	July	August	September	October	Mean
American shad	0.00	0.00	0.00	0.00	0.11	0.02
Gizzard shad	195.00	0.22	0.12	0.78	0.00	39.22
Common carp	1.14	0.33	0.14	0.44	0.11	0.43
Spottail shiner	1.25	0.00	0.00	0.33	0.11	0.34
Bluntnose minnow	0.78	0.00	0.00	0.00	0.00	0.16
Quillback	0.00	0.11	0.00	0.11	0.00	0.04
Shorthead redhorse	0.00	0.11	0.00	0.00	0.11	0.04
White catfish	0.00	0.11	0.00	0.00	0.00	0.02
Brown bullhead	0.11	0.00	0.44	0.11	0.00	0.13
Channel catfish	35.03	9.00	9.14	16.22	0.67	14.01
White perch	0.00	0.00	0.00	0.00	0.11	0.02
Pumpkinseed	0.22	0.00	0.22	0.11	0.22	0.16
Bluegill	1.11	3.22	0.11	0.33	2.22	1.40
Smallmouth bass	0.44	0.11	0.00	0.00	0.00	0.11
Largemouth bass	0.44	0.11	0.71	0.00	0.44	0.34
White crappie	0.22	0.00	0.00	0.00	0.00	0.04
Tessellated darter	34.81	1.22	0.00	1.78	1.33	7.83
Yellow perch	0.25	0.00	0.00	0.11	0.33	0.14
Walleye	0.00	0.00	0.12	0.00	0.00	0.02
Overall	*270.80*	*14.54*	*11.00*	*20.32*	*5.76*	*64.47*
Number of species	*13*	*10*	*8*	*10*	*11*	*19*

Table 3-35

Catch per effort (number per 10 min haul) for fishes collected by 16 ft semi-balloon trawl at stations on trawl transects in Conowingo Pond, June-October 1999.

	Station									
	321	322	323	341	342	343	371	372	373	Mean
American shad	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.02
Gizzard shad	0.00	0.42	30.20	310.20	0.20	9.40	0.00	0.00	2.60	39.22
Common carp	0.45	0.25	0.60	0.60	0.40	1.00	0.00	0.60	0.00	0.43
Spottail shiner	0.20	0.25	1.40	0.00	0.00	0.40	0.00	0.20	0.60	0.34
Bluntnose minnow	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.40	0.16
Quillback	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.04
Shorthead redhorse	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.04
White catfish	0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.02
Brown bullhead	0.00	0.00	0.00	0.60	0.40	0.20	0.00	0.00	0.00	0.13
Channel catfish	8.45	20.45	6.40	23.00	17.00	1.20	4.60	34.00	11.00	14.01
White perch	0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.02
Pumpkinseed	0.00	0.00	0.40	0.20	0.00	0.20	0.00	0.00	0.60	0.16
Bluegill	0.60	0.60	0.60	3.60	0.20	5.40	0.40	0.20	1.00	1.40
Smallmouth bass	0.00	0.00	0.40	0.00	0.00	0.00	0.20	0.00	0.40	0.11
Largemouth bass	0.25	0.42	0.40	0.60	0.20	0.20	0.00	0.00	1.00	0.34
White crappie	0.00	0.00	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.04
Tessellated darter	6.20	34.05	6.40	5.80	1.00	14.60	0.20	0.40	1.80	7.83
Yellow perch	0.20	0.45	0.40	0.00	0.00	0.20	0.00	0.00	0.00	0.14
Walleye	0.00	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Overall	*16.55*	*57.31*	*47.20*	*345.00*	*19.40*	*33.20*	*5.40*	*35.60*	*20.80*	*64.47*
Number of species	*8*	*10*	*10*	*10*	*7*	*11*	*4*	*6*	*11*	*19*

Table 3-36

Comparison of the monthly catch per effort (number per 10 min haul) for the common and Environmental Protection Agency designated, representative, important species collected at trawl transects stations in Conowingo Pond in June-October. "-"-designates a period when no effort was expended. Underlined CPEs are greater than historical values and italicized are less than historical values.

	June		July		August		September		October	
	N*	Range	N*	Range	N*	Range	N*	Range	N*	Range
					White crappie					
Pre-operational	7	0.15-25.59	7	0.76-269.54	7	1.28-89.46	7	1.14-102.31	7	1.10-66.46
Post-operational	7	0-5.33	7	0.20-7.38	7	0.31-4.47	7	0-6.46	8	0.20-2.12
1997		0.11		2.78		0.67		0.22		0.22
1998		0.44		*0.00*		0.33		0.11		0.89
1999		0.22		*0.00*		*0.00*		0.00		*0.00*
					Channel catfish					
Pre-operational	7	4.85-120.38	7	11.75-134.27	7	9.0-141.14	7	4.68-495.08	7	9.48-48.70
Post-operational	7	3.43-59.35	7	6.44-84.50	7	0.80-166.29	7	7.25-185.54	8	2.80-133.28
1997		45.20		90.89		94.44		52.78		15.83
1998		36.78		77.58		61.87		23.33		7.11
1999		35.03		9.00		9.14		16.22		*0.67*
					Bluegill					
Pre-operational	6	0.05-1.77	7	0.02-17.19	7	0-65.07	7	0.54-18.77	7	0-35.54
Post-operational	7	0-0.09	7	0-3.31	7	0.30-11.08	7	0.25-13.92	8	0-9.63
1997		1.00		54.87		24.44		7.56		8.11
1998		0.78		11.14		2.25		3.44		2.00
1999		1.11		3.22		0.11		0.33		2.22
					Gizzard shad					
Pre-operational	--	--	2	0.00-0.19	2	0.07-1.00	2	0.00-0.38	2	0.00-0.12
Post-operational	7	0.00-8.09	7	0.08-12.58	7	0.18-2.70	7	0.00-6.25	8	0.00-2.27
1997		0.00		3.32		0.44		2.00		3.61
1998		46.33		0.14		4.65		0.22		0.56
1999		195.00		0.22		0.12		0.78		0.00
					Smallmouth bass					
Pre-operational	4	0.02-0.42	3	0.00-0.42	3	0.00-0.04	3	0.00-0.33	3	0
Post-operational	7	0	7	0.00-1.50	7	0.00-0.45	7	0.00-0.23	8	0.00-0.31
1997		0.44		0.94		0.11		0.33		0.11
1998		1.56		0.00		0.00		0.00		0.00
1999		0.44		0.11		0.00		0.00		0.00
					Largemouth bass					
Pre-operational	2	0.03	6	0.00-0.15	6	0.00-0.08	6	0.00-0.04	6	0.00-0.10
Post-operational	7	0.00-0.15	7	0.00-0.25	7	0.00-0.09	7	0.00-0.07	8	0.00-0.07
1997		0.12		0.38		0.44		0.67		0.00
1998		0.00		0.00		0.28		0.11		0.00
1999		0.44		0.11		0.71		0.00		0.44
					Walleye					
Pre-operational	5	0.02-0.14	6	0.00-0.12	6	0.00-0.04	6	0.00-0.17	6	0.00-0.04
Post-operational	7	0.00-0.36	7	0.00-0.04	7	0.00-0.18	7	0.00-0.06	8	0.00-0.19
1997		0.00		0.00		0.00		0.11		0.00
1998		0.11		0.00		0.00		0.00		0.00
1999		0.00		0.00		0.12		0.00		0.00
					Tesselated darter					
Pre-operational	6	0.00-0.69	7	0.00-0.64	7	0.04-1.78	7	0.12-8.67	7	0.23-3.78
Post-operational	7	0.00-15.50	7	0.50-58.33	7	0.00-12.25	7	0.00-11.50	8	0.45-4.80
1997		50.55		33.48		26.44		14.33		13.89
1998		22.78		12.75		5.89		5.56		0.89
1999		34.81		1.22		0.00		1.78		1.33
					Pumpkinseed					
Pre-operational	7	0.00-1.77	7	0.00-5.62	7	0.00-7.75	7	0.08-5.23	7	0.00-4.23
Post-operational	7	0.08-1.25	7	0.00-1.44	7	0.40-3.20	7	0.50-7.45	8	0.00-4.33
1997		0.47		2.38		0.56		0.33		1.19
1998		0.89		1.50		0.22		2.89		1.89
1999		0.22		0.00		0.22		0.11		0.22
					Spottail shiner					
Pre-operational	6	0.00-1.38	7	0.03-2.60	7	0.00-11.27	7	0.04-23.23	7	0.00-4.26
Post-operational	7	0.00-5.92	7	0.17-7.00	7	0.00-32.71	7	0.00-6.73	8	0.00-9.60
1997		1.23		0.56		0.00		0.11		0.25
1998		2.00		16.11		2.69		1.56		2.89
1999		1.25		*0.00*		0.00		0.33		0.11

* N= the number of years in the historical period (pre- or post-operational) that sampling occurred in a given month.

4.0 SUMMARY AND CONCLUSIONS

Monthly surveys were completed in June-October 1999, as prescribed in PECO's Study Plan and approved by the PADEP, to monitor the operation of zero cooling towers on fishes and thermal conditions in Conowingo Pond. The same sampling protocols utilized during PBAPS pre- and post-operational studies and in 1996 to 1998 were employed in 1999.

Compared to the historical record (1952-1998), river flows and inflow water temperatures in 1999 were lower. Specifically, river flows in summer 1999 were substantially lower than those observed in 1996, 1997, and 1998. During the long-term monitoring period of 1996 to 1999 a wide range of hydrological conditions were observed; for example, in 1996 hydrological conditions were deemed above normal characterized by higher river flows and lower temperatures, whereas the 1999 period was characterized by lower river flows and higher temperatures. Thus, the fish community in Conowingo Pond presumably were exposed to near-worst summer temperature conditions in 1999 compared to summers of 1996 to 1998.

PBAPS generally operated at the maximum power level achievable (<200%) in late summer, due to the end of cycle coast down (an annual occurrence in spring through summer) of Unit 3. Following the Unit 3 refueling outage, total power output was restored to near 200% (in early November).

Inlet temperatures at PBAPS mirrored the pattern of variation in inflow temperatures, but were consistently 1 to 4°F higher than corresponding values at Holtwood Dam during the summer. Inlet temperatures in summer 1999 were higher for a longer period than in 1997 and 1998.

Discharge ΔT's were mostly 19 to 20°F above the Holtwood inflow temperatures or ambient inlet temperatures. Both are less than the designed criterion of 20.8°F

Under the existing river flow and temperature conditions surveyed, the heated effluent quickly dissipated within 2 miles downstream of the PBAPS discharge. The heated discharge was primarily limited to the top 5 to 15 ft of the water column along the western shore at the Burkins Run transect and west to mid-pond areas at the Williams Tunnel and PA/MD State Line transects. The West location at Burkins Run, being nearest the discharge outlet, displayed the highest temperatures in the water column, with surface values 7.5 to 13.9°F higher than corresponding values at the PBAPS inlet. Although differences in profile ΔT values were noted among other locations and depths on transects downstream of the PBAPS discharge and at the transect upstream (Fishing Creek), the differences generally were <3°F. Similar variations were also observed between Holtwood Dam and the PBAPS inlet temperatures. Profile temperatures and patterns observed at downstream locations in summer 1999 (zero tower operation) were most similar to those observed under low flow conditions in 1995 when a minimum of three towers operated.

DO conditions in the vicinity of PBAPS in 1999 were similar to seasonal, spatial, and diurnal variations observed historically.

In determining whether or not zero tower operation affects the relative abundance, distribution, and species composition in Conowingo Pond, the following were evident in 1999: most of the monthly CPE's for the commonly collected species were within or above the historic range; CPE's among species and between stations were variable likely due to differences in year class strength; and no thermally stressed fish were observed. Overall, zero tower operation in 1999 had no discernible effect on the integrity of the balanced, indigenous fish community of Conowingo Pond. This conclusion also extends to some 1.2 million additional fish (as part of the ongoing American shad restoration program) that were introduced into Conowingo Pond via the East fish lift downstream of Conowingo Dam.

Findings of no obvious adverse effects of zero tower operation on fish relative abundance are not surprising and indeed are consistent with results reported in the literature (Bennett and Gibbons 1974; Coutant 1972, 1974; Raney *et al.* 1973; Romberg *et al.* 1943; PECO 1975; Stauffer *et al.* 1975; Thorpe and Gibbons 1977). A major contributing factor for this conclusion is the fish behavioral response (preference or avoidance) to thermal discharge which assures continued propagation of balanced, indigenous, community. Conowingo Pond fishes are no exception in that regard; they are not trapped and thus they freely exercise their preference/avoidance behavior relative to PBAPS discharge. Because the

configuration and size of the PBAPS thermal plume and its associated temperature profiles vary with the prevailing hydrological conditions fishes are not consistently exposed to a specific temperature rise for a long time. The temperature regime created as a result of zero tower operation was within the tolerance limits of fishes; no direct mortality or stress was observed. The observations made during the monitoring in 1995 to 1999 are consistent with the laboratory-predicted responses of Conowingo fishes.

Fishes can and will follow a temperature gradient. They normally follow this gradient to or toward their preferred temperature. The behavior of a given species often depends on the magnitude of change of temperature to which it may be exposed. It may be attracted to a higher or lower temperature, or it may avoid higher or lower temperature, or it may not react.

The preference and avoidance behavior of fishes is an important factor which govern their distribution in relationship to heated discharges. Lethal temperatures are avoided by motile aquatic organisms. Thus, fishes generally avoid the hotter part of plumes. Observations at power stations discharging relatively large volumes of heated water into rivers and lakes confirm the absence or rarity of thermal fish kills or serious biological damage. Upper temperature tolerance limits are not applicable unless fishes are trapped and have no escape routes; fishes at PBAPS are not trapped. Even in a trapped situation, fishes can withstand a sudden temperature change of 20°F, depending upon the acclimation temperature.

The fish community in Conowingo Pond shows great seasonal and annual fluctuations in abundance under natural conditions, adapted to living over a wide range of temperatures within its own balance. This is well corroborated from the observations that the relative abundance of common fishes in Conowingo was within the historical range both during the complete shutdown of PBAPS in 1987 to 1989 and with full operation without cooling towers in 1996 to 1999. Based on these observations, a fair conclusion can be made that the propagation of a balanced, indigenous fish community in Conowingo Pond can be expected without operation of cooling towers at PBAPS.

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APPENDIX A

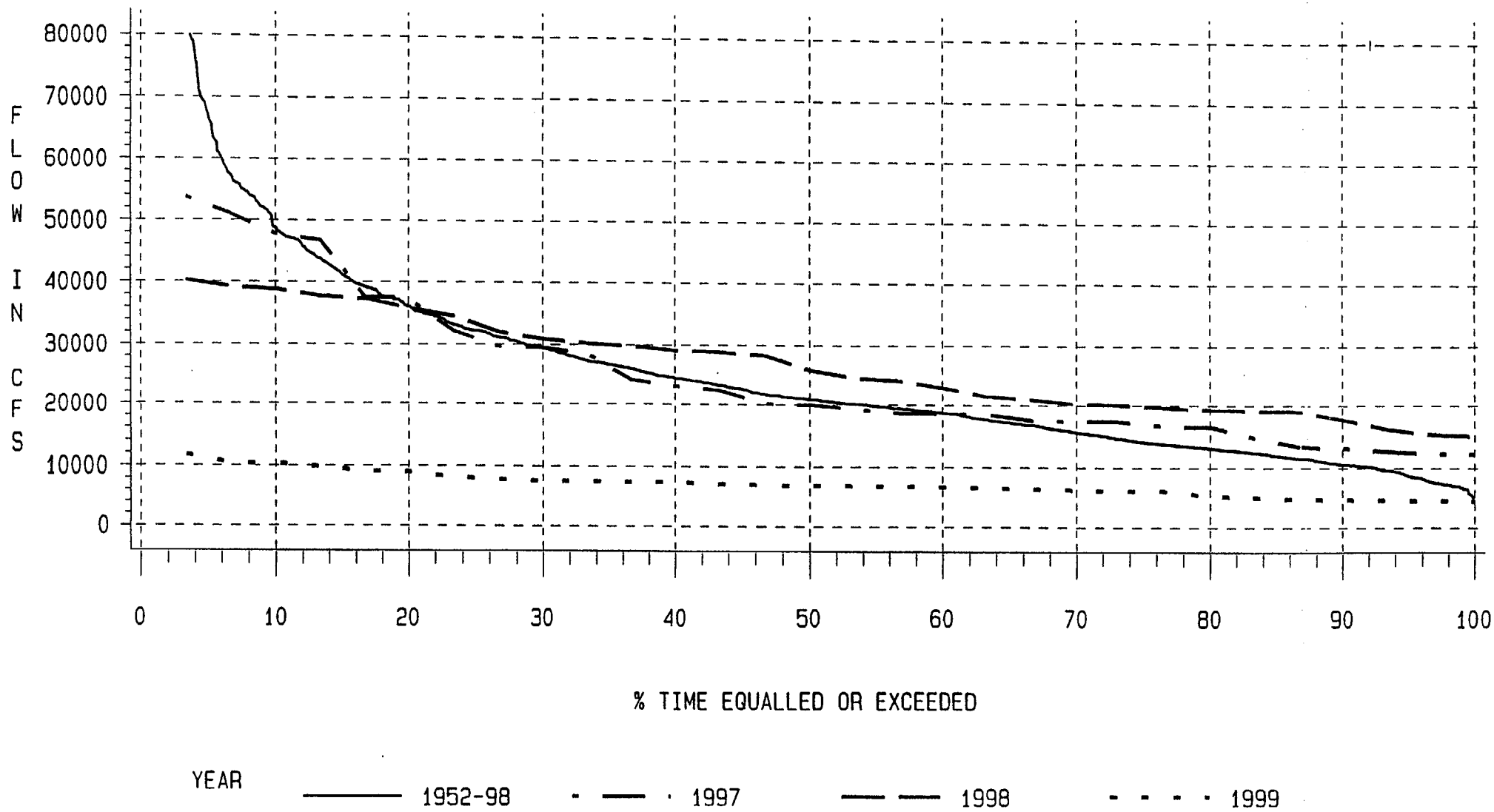
MONTHLY FLOW DURATION CURVES
JUNE-OCTOBER
HISTORICAL (1952-1998) VERSUS 1997, 1998, AND 1999

AND

JOINT OCCURRENCE OF DAILY WATER TEMPERATURE AND RIVER FLOW
JUNE-OCTOBER
HISTORICAL (1956-1998), 1997, 1998, AND 1999

Duration curve of average daily river flows at Holtwood Dam, 1952 to 1997 (historical), 1997, 1998 and 1999.

MONTH=JUNE



Duration curve of average daily river flows at Holtwood Dam, 1952 to 1997 (historical), 1997, 1998 and 1999.

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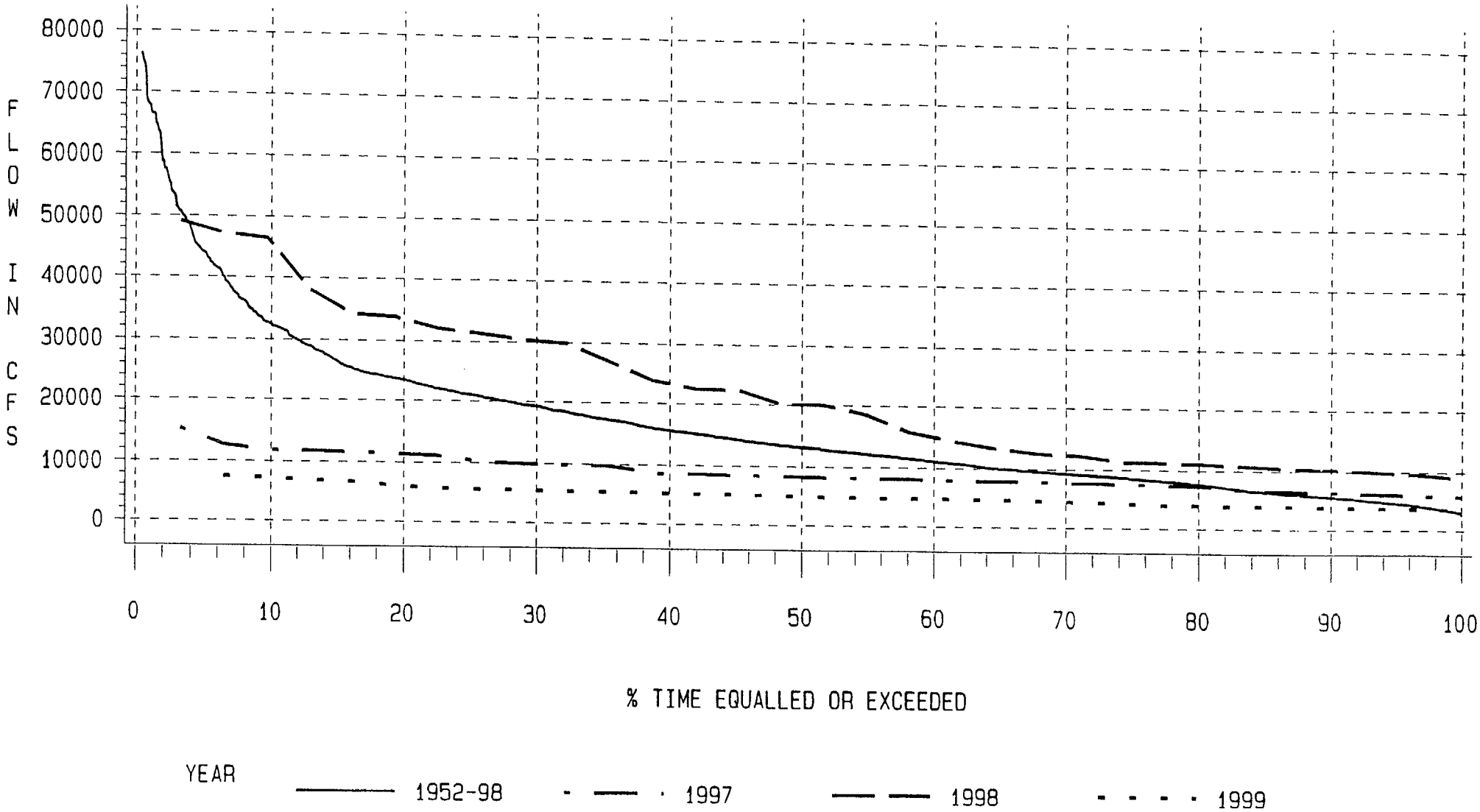
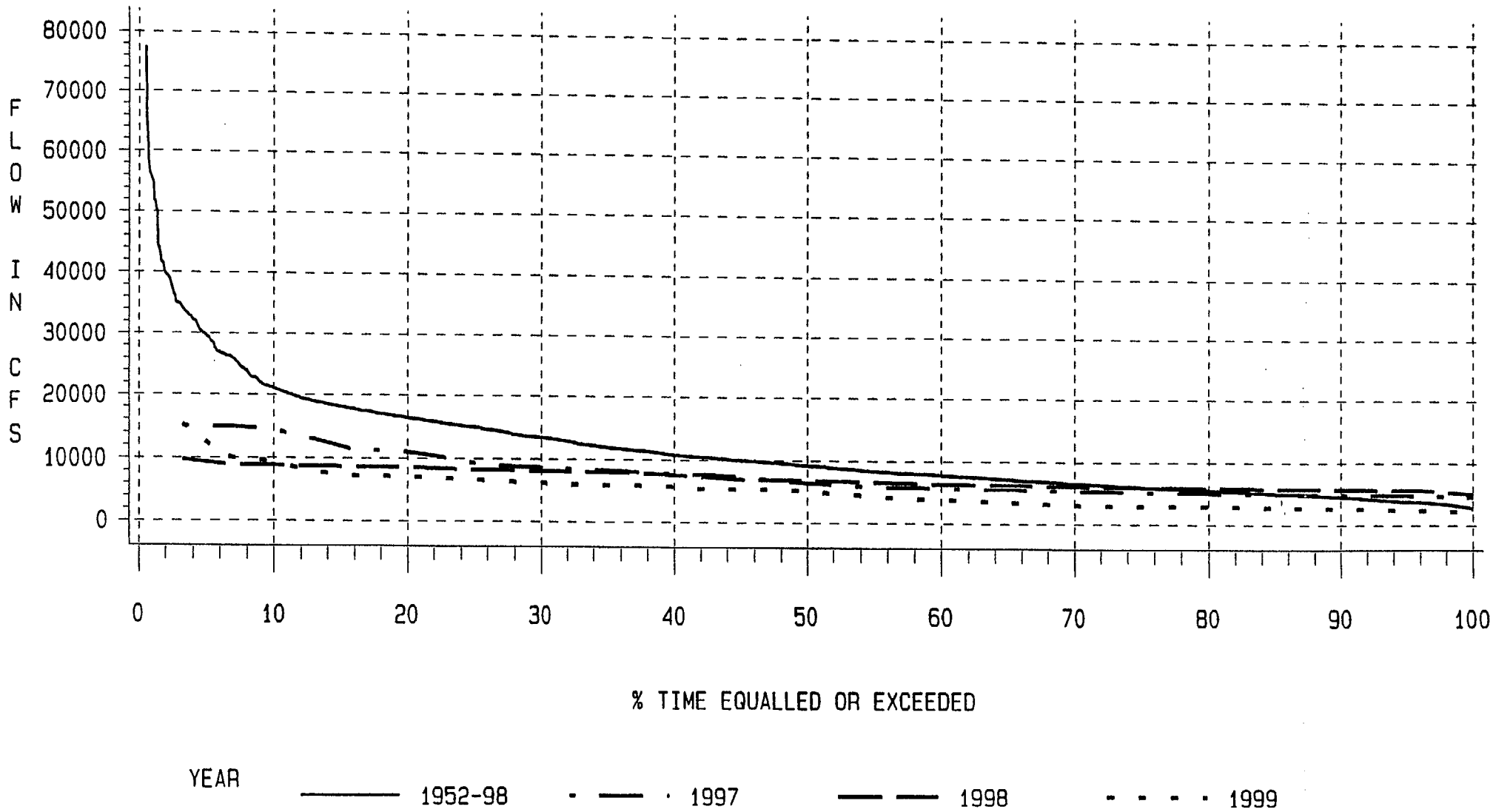


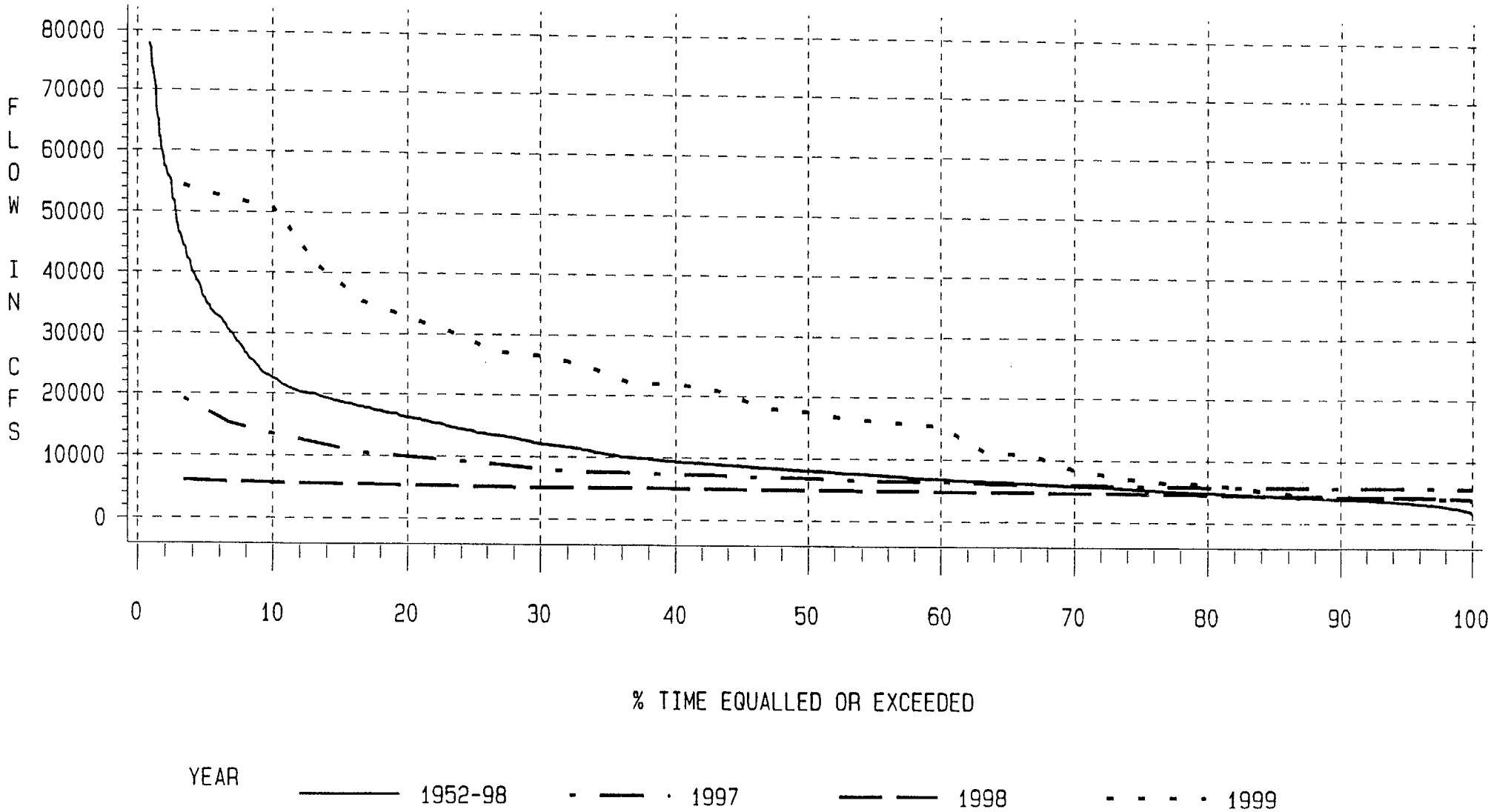
Duration curve of average daily river flows at Holtwood Dam, 1952 to 1997 (historical), 1997, 1998 and 1999.

MONTH=AUGUST



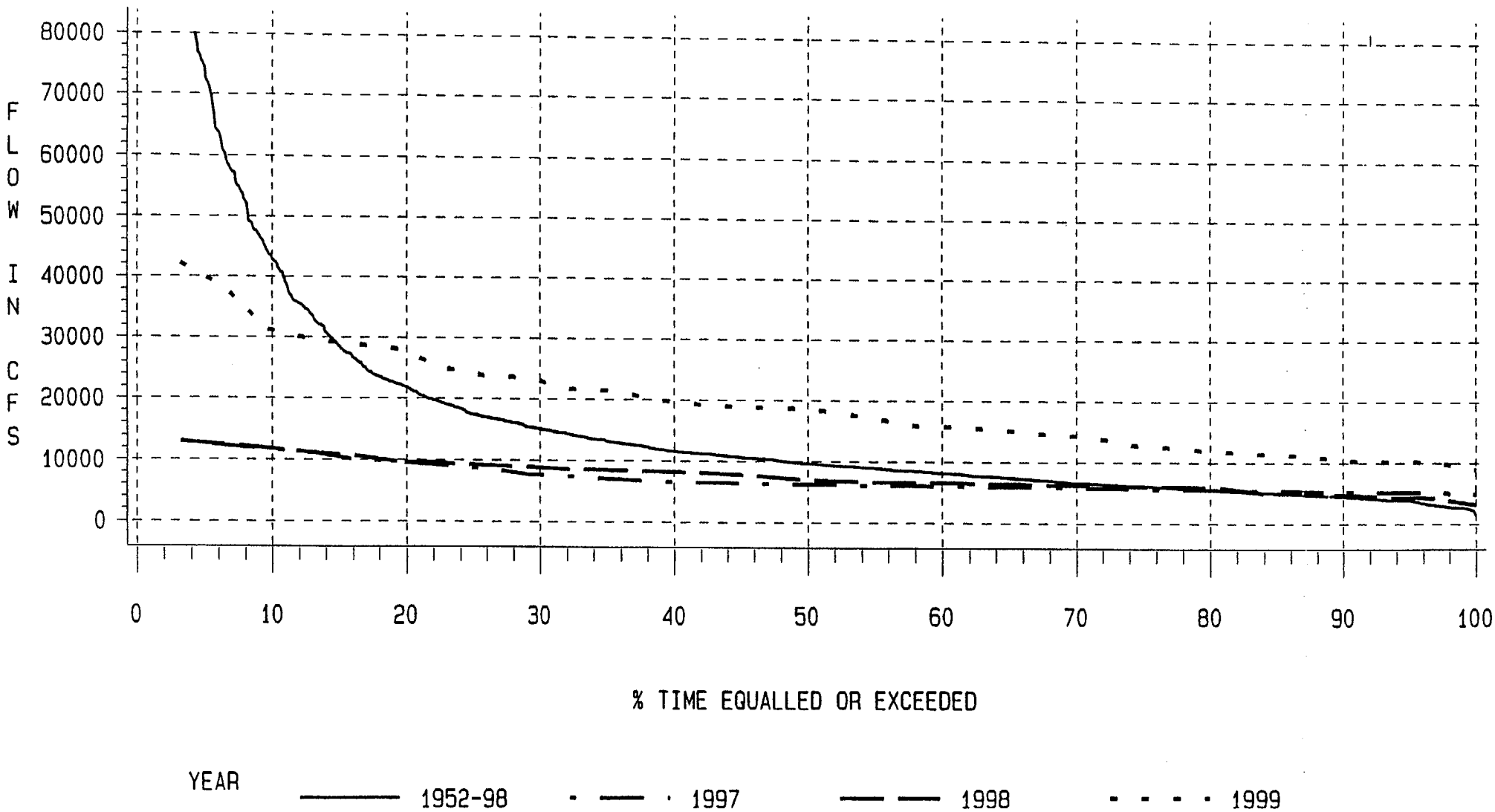
Duration curve of average daily river flows at Holtwood Dam, 1952 to 1997 (historical), 1997, 1998 and 1999.

MONTH=SEPTEMBER



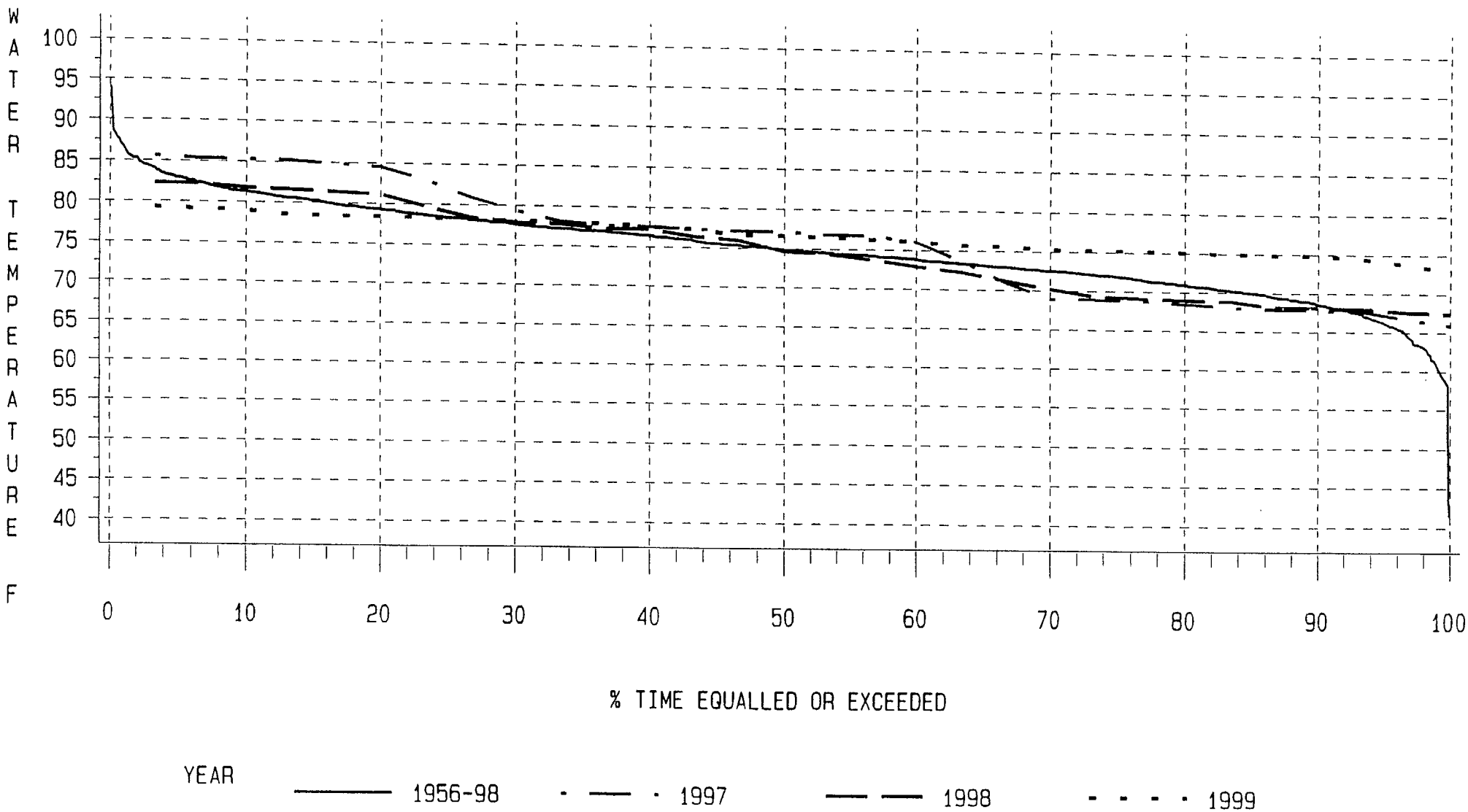
Duration curve of average daily river flows at Holtwood Dam, 1952 to 1997 (historical), 1997, 1998 and 1999.

MONTH=OCTOBER



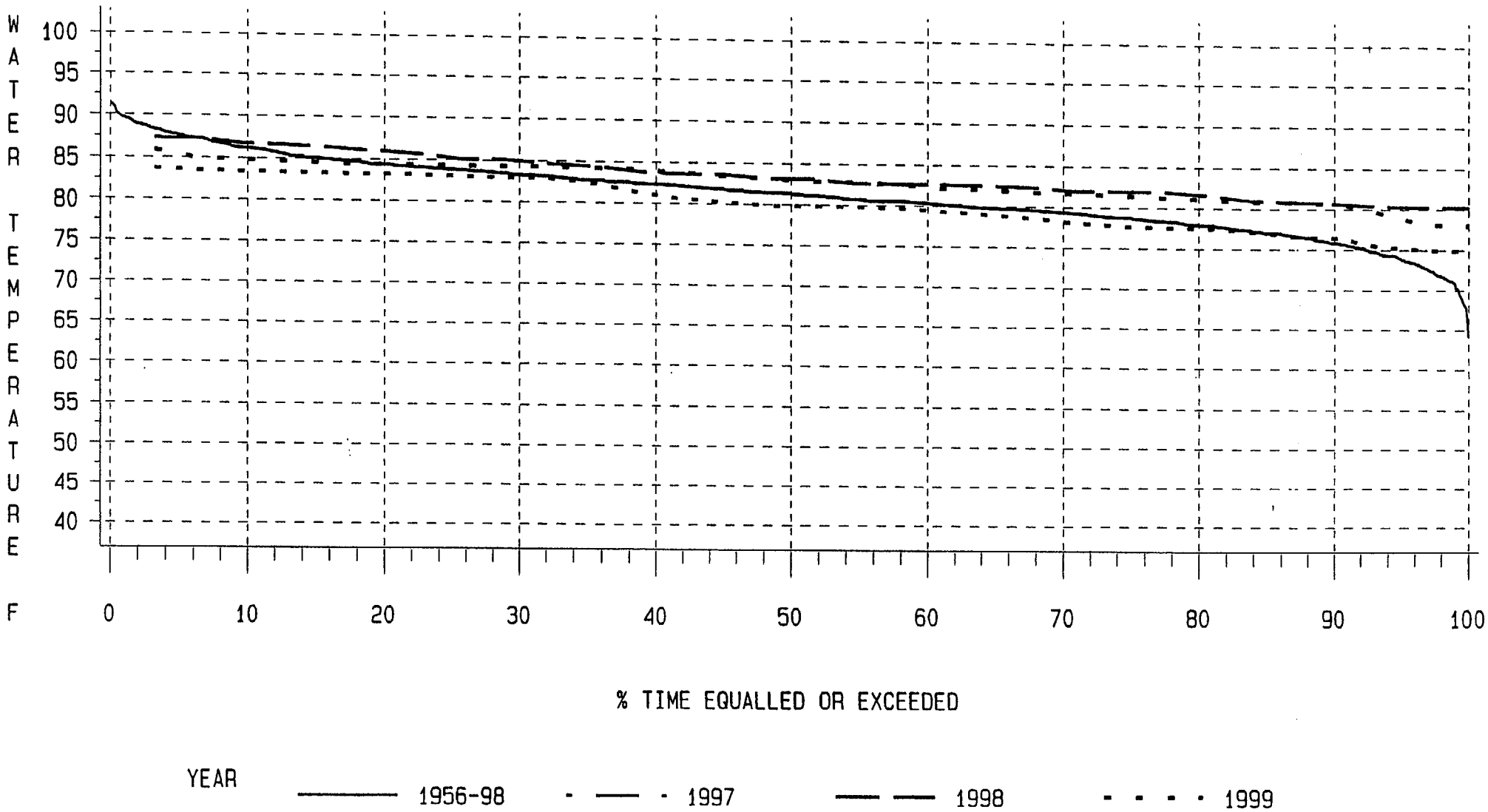
Duration curve of average daily river temperatures (°F) at Holtwood Dam, 1956 to 1997 (historical), 1997, 1998 and 1999.

MONTH=JUNE



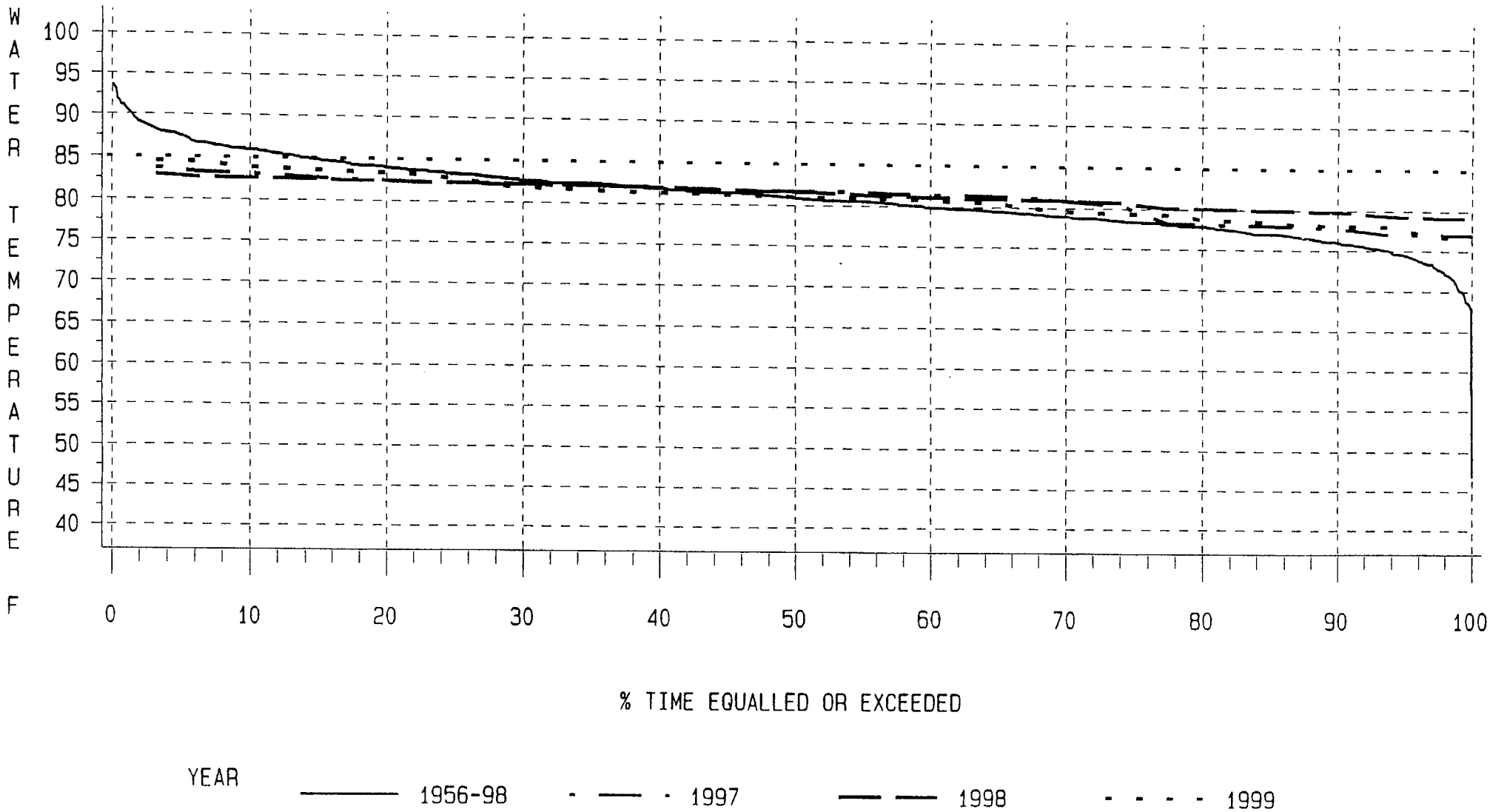
Duration curve of average daily river temperatures (°F) at Holtwood Dam, 1956 to 1997 (historical), 1997, 1998 and 1999.

MONTH=JULY



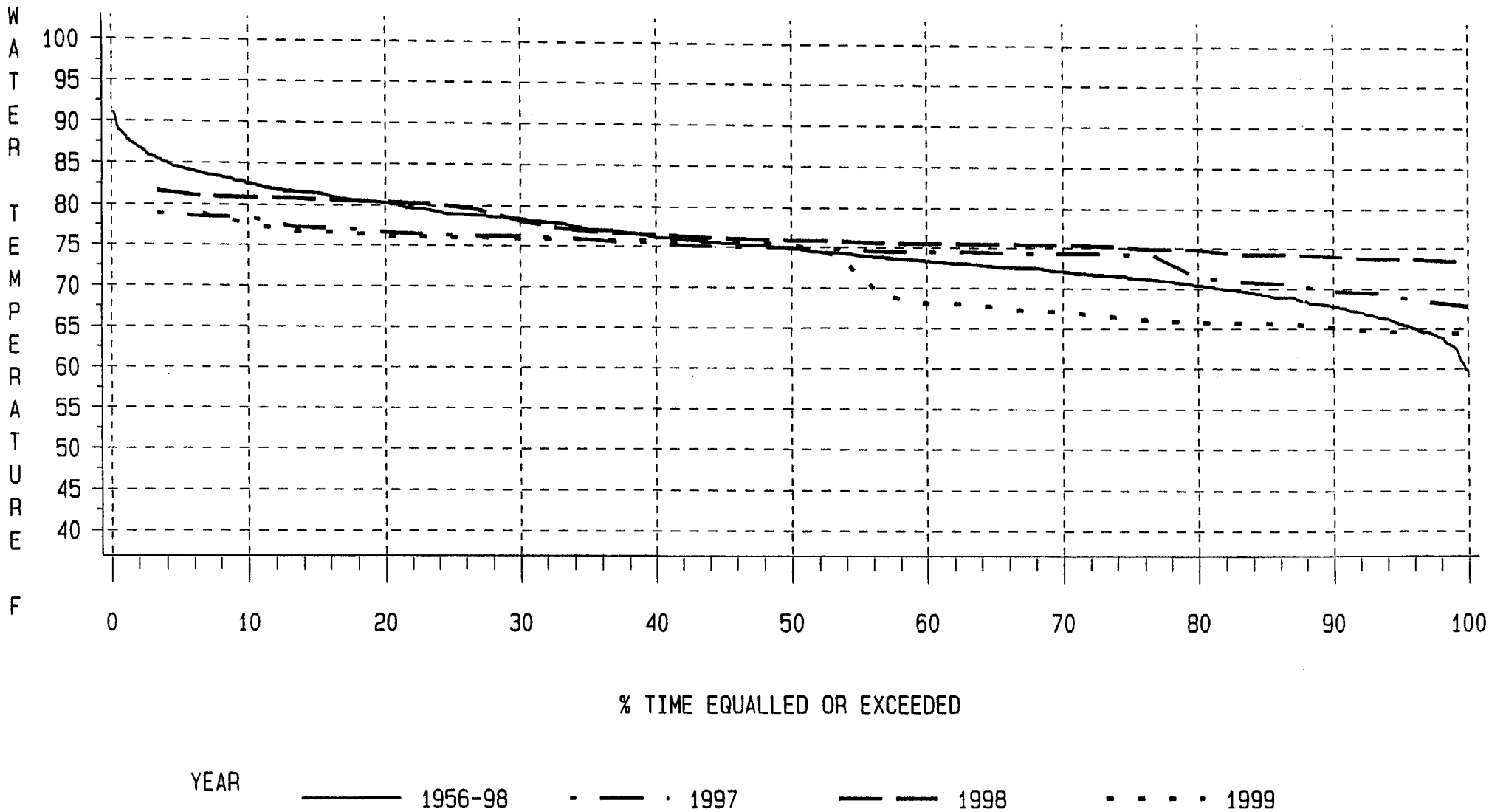
Duration curve of average daily river temperatures (°F) at Holtwood Dam, 1956 to 1997 (historical), 1997, 1998 and 1999.

MONTH=AUGUST



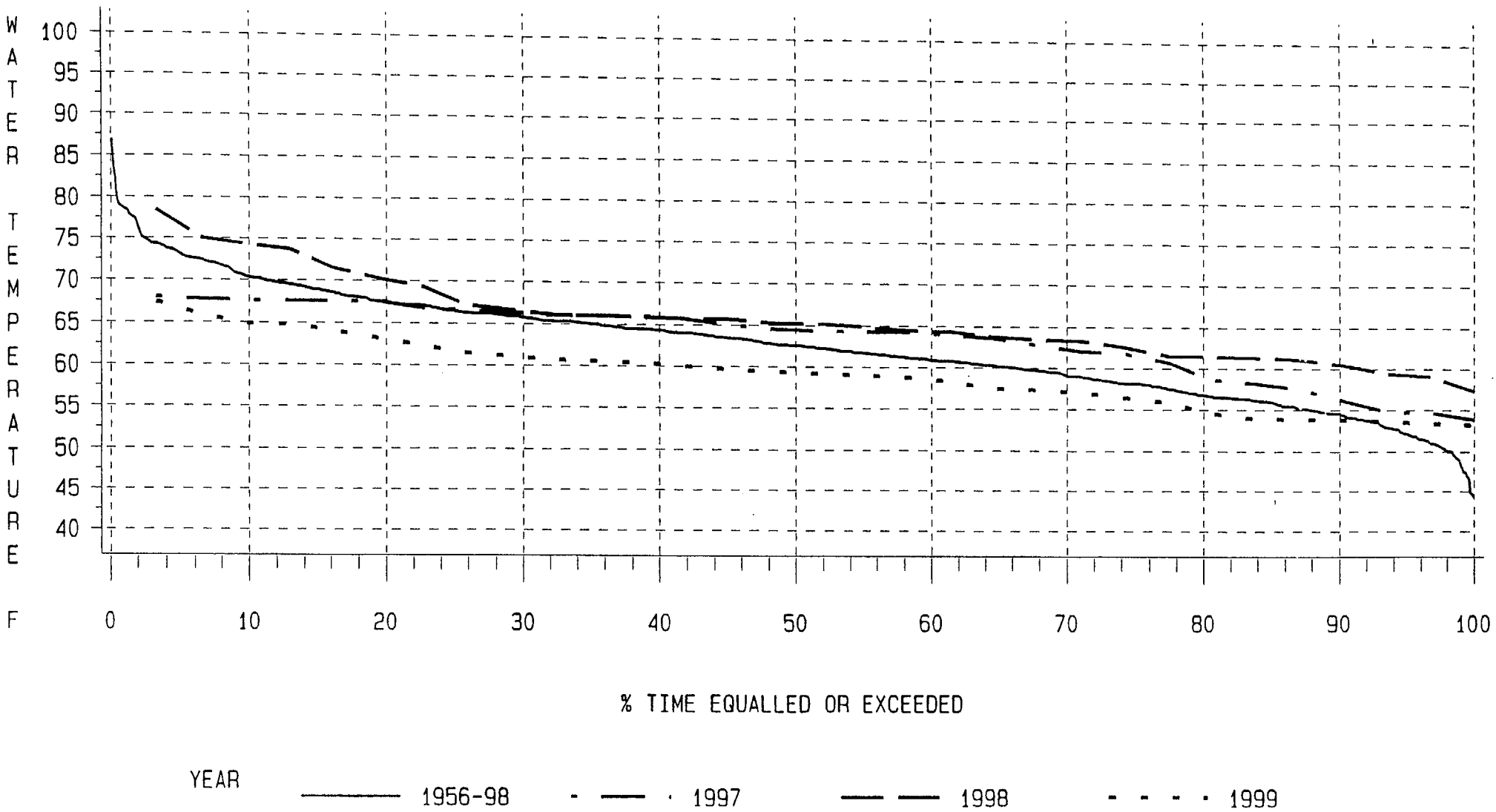
Duration curve of average daily river temperatures (°F) at Holtwood Dam, 1956 to 1997 (historical), 1997, 1998 and 1999.

MONTH=SEPTEMBER



Duration curve of average daily river temperatures (°F) at Holtwood Dam, 1956 to 1997 (historical), 1997, 1998 and 1999.

MONTH=OCTOBER



JOINT OCCURRENCE OF DAILY HOLTWOOD FLOWS AND TEMPERATURES, 1956 - 1998.

MONTH=JUNE

	HOLTWOOD DAILY AVG TEMPERATURE												TOTAL	
	40-49		50-59		60-69		70-79		80-85		86 AND GREATER			
	N	PCTN	N	PCTN	N	PCTN	N	PCTN	N	PCTN	N	PCTN	N	PCTN
HOLTWOOD DAILY AVG FLOW														
2,500-4,999	.	.	.	.	.	.	.	.	1	0.08	.	.	1	0.08
5,000-7,499	.	.	.	.	.	.	21	1.65	17	1.34	4	0.31	42	3.30
7,500-9,999	.	.	.	.	.	.	20	1.57	38	2.99	1	0.08	59	4.64
10,000-14,999	.	.	.	.	10	0.79	157	12.35	82	6.45	13	1.02	262	20.61
15,000-19,999	.	.	.	.	9	0.71	200	15.74	26	2.05	.	.	235	18.49
20,000-29,999	.	.	1	0.08	37	2.91	246	19.35	29	2.28	.	.	313	24.63
30,000-39,999	.	.	.	.	26	2.05	119	9.36	17	1.34	.	.	162	12.75
40,000-49,999	1	0.08	.	.	21	1.65	50	3.93	3	0.24	.	.	75	5.90
50,000 PLUS	1	0.08	6	0.47	58	4.56	55	4.33	2	0.16	.	.	122	9.60
TOTAL	2	0.16	7	0.55	161	12.67	868	68.29	215	16.92	18	1.42	1271	100.00

JOINT OCCURRENCE OF DAILY HOLTWOOD FLOWS AND TEMPERATURES, 1956 - 1998.

MONTH=JULY

	HOLTWOOD DAILY AVG TEMPERATURE								TOTAL	
	60-69		70-79		80-85		86 AND GREATER			
	N	PCTN	N	PCTN	N	PCTN	N	PCTN	N	PCTN
HOLTWOOD DAILY AVG FLOW										
2,500-4,999	.	.	.	.	54	4.18	45	3.48	99	7.66
5,000-7,499	.	.	10	0.77	92	7.12	56	4.33	158	12.22
7,500-9,999	.	.	20	1.55	128	9.90	39	3.02	187	14.46
10,000-14,999	.	.	57	4.41	218	16.86	16	1.24	291	22.51
15,000-19,999	.	.	65	5.03	117	9.05	4	0.31	186	14.39
20,000-29,999	.	.	117	9.05	86	6.65	1	0.08	204	15.78
30,000-39,999	.	.	58	4.49	18	1.39	.	.	76	5.88
40,000-49,999	.	.	37	2.86	7	0.54	.	.	44	3.40
50,000 PLUS	9	0.70	37	2.86	2	0.15	.	.	48	3.71
TOTAL	9	0.70	401	31.01	722	55.84	161	12.45	1293	100.00

JOINT OCCURRENCE OF DAILY HOLTWOOD FLOWS AND TEMPERATURES, 1956 - 1998.

MONTH=AUGUST

	HOLTWOOD DAILY AVG TEMPERATURE										TOTAL	
	40-49		60-69		70-79		80-85		86 AND GREATER			
	N	PCTN	N	PCTN	N	PCTN	N	PCTN	N	PCTN	N	PCTN
HOLTWOOD DAILY AVG FLOW												
2,500-4,999	.	.	.	.	12	0.91	125	9.43	54	4.08	191	14.42
5,000-7,499	.	.	.	.	53	4.00	171	12.91	67	5.06	291	21.96
7,500-9,999	.	.	1	0.08	44	3.32	146	11.02	24	1.81	215	16.23
10,000-14,999	.	.	.	.	113	8.53	156	11.77	9	0.68	278	20.98
15,000-19,999	.	.	.	.	112	8.45	77	5.81	2	0.15	191	14.42
20,000-29,999	1	0.08	.	.	75	5.66	16	1.21	.	.	92	6.94
30,000-39,999	.	.	.	.	33	2.49	7	0.53	.	.	40	3.02
40,000-49,999	.	.	.	.	7	0.53	1	0.08	.	.	8	0.60
50,000 PLUS	.	.	6	0.45	13	0.98	.	.	.	.	19	1.43
TOTAL	1	0.08	7	0.53	462	34.87	699	52.75	156	11.77	1325	100.00

JOINT OCCURRENCE OF DAILY HOLTWOOD FLOWS AND TEMPERATURES, 1956 - 1998.

MONTH=SEPTEMBER

	HOLTWOOD DAILY AVG TEMPERATURE								TOTAL	
	60-69		70-79		80-85		86 AND GREATER			
	N	PCTN	N	PCTN	N	PCTN	N	PCTN	N	PCTN
HOLTWOOD DAILY AVG FLOW										
0-2,500	.	.	6	0.48	10	0.80	9	0.72	25	2.00
2,500-4,999	6	0.48	153	12.25	93	7.45	8	0.64	260	20.82
5,000-7,499	28	2.24	176	14.09	53	4.24	11	0.88	268	21.46
7,500-9,999	12	0.96	155	12.41	49	3.92	7	0.56	223	17.85
10,000-14,999	14	1.12	134	10.73	23	1.84	3	0.24	174	13.93
15,000-19,999	49	3.92	73	5.84	8	0.64	1	0.08	131	10.49
20,000-29,999	37	2.96	36	2.88	7	0.56	.	.	80	6.41
30,000-39,999	22	1.76	12	0.96	.	.	.	.	34	2.72
40,000-49,999	6	0.48	8	0.64	2	0.16	.	.	16	1.28
50,000 PLUS	26	2.08	8	0.64	4	0.32	.	.	38	3.04
TOTAL	200	16.01	761	60.93	249	19.94	39	3.12	1249	100.00

JOINT OCCURRENCE OF DAILY HOLTWOOD FLOWS AND TEMPERATURES, 1956 - 1998.

MONTH=OCTOBER

	HOLTWOOD DAILY AVG TEMPERATURE												TOTAL	
	40-49		50-59		60-69		70-79		80-85		86 AND GREATER			
	N	PCTN	N	PCTN	N	PCTN	N	PCTN	N	PCTN	N	PCTN	N	PCTN
HOLTWOOD DAILY AVG FLOW														
0-2,500	.	.	.	.	8	0.63	5	0.39	.	.	.	.	13	1.03
2,500-4,999	.	.	22	1.74	96	7.58	54	4.27	4	0.32	1	0.08	177	13.98
5,000-7,499	.	.	59	4.66	142	11.22	23	1.82	1	0.08	.	.	225	17.77
7,500-9,999	.	.	35	2.76	138	10.90	28	2.21	.	.	.	.	201	15.88
10,000-14,999	.	.	67	5.29	150	11.85	20	1.58	.	.	.	.	237	18.72
15,000-19,999	.	.	49	3.87	58	4.58	11	0.87	.	.	.	.	118	9.32
20,000-29,999	.	.	41	3.24	50	3.95	9	0.71	.	.	.	.	100	7.90
30,000-39,999	.	.	19	1.50	23	1.82	5	0.39	.	.	.	.	47	3.71
40,000-49,999	1	0.08	27	2.13	7	0.55	1	0.08	.	.	.	.	36	2.84
50,000 PLUS	19	1.50	68	5.37	20	1.58	5	0.39	.	.	.	.	112	8.85
TOTAL	20	1.58	387	30.57	692	54.66	161	12.72	5	0.39	1	0.08	1266	100.00

JOINT OCCURRENCE OF DAILY HOLTWOOD FLOWS AND TEMPERATURES, JUNE - OCTOBER, 1997

MONTH=JUNE

	HOLTWOOD DAILY AVG TEMPERATURE								TOTAL	
	60-69		70-79		80-85		86 AND GREATER			
	N	PCTN	N	PCTN	N	PCTN	N	PCTN	N	PCTN
HOLTWOOD DAILY AVG FLOW										
10,000-14,999	.	.	.	.	5	16.67	1	3.33	6	20.00
15,000-19,999	.	.	8	26.67	2	6.67	.	.	10	33.33
20,000-29,999	3	10.00	4	13.33	.	.	.	.	7	23.33
30,000-39,999	3	10.00	.	.	.	.	.	.	3	10.00
40,000-49,999	2	6.67	.	.	.	.	.	.	2	6.67
50,000 PLUS	2	6.67	.	.	.	.	.	.	2	6.67
TOTAL	10	33.33	12	40.00	7	23.33	1	3.33	30	100.00

JOINT OCCURRENCE OF DAILY HOLTWOOD FLOWS AND TEMPERATURES, JUNE - OCTOBER, 1997

MONTH=JULY

	HOLTWOOD DAILY AVG TEMPERATURE				TOTAL	
	80-85		86 AND GREATER			
	N	PCTN	N	PCTN	N	PCTN
HOLTWOOD DAILY AVG FLOW						
5,000-7,499	3	9.68	5	16.13	8	25.81
7,500-9,999	13	41.94	2	6.45	15	48.39
10,000-14,999	7	22.58	.	.	7	22.58
15,000-19,999	1	3.23	.	.	1	3.23
TOTAL	24	77.42	7	22.58	31	100.00

JOINT OCCURRENCE OF DAILY HOLTWOOD FLOWS AND TEMPERATURES, JUNE - OCTOBER, 1997

MONTH=AUGUST

	HOLTWOOD DAILY AVG TEMPERATURE				TOTAL	
	70-79		80-85			
	N	PCTN	N	PCTN	N	PCTN
HOLTWOOD DAILY AVG FLOW						
2,500-4,999	.	.	6	19.35	6	19.35
5,000-7,499	.	.	12	38.71	12	38.71
7,500-9,999	5	16.13	1	3.23	6	19.35
10,000-14,999	3	9.68	4	12.90	7	22.58
TOTAL	8	25.81	23	74.19	31	100.00

JOINT OCCURRENCE OF DAILY HOLTWOOD FLOWS AND TEMPERATURES, JUNE - OCTOBER, 1997

MONTH=SEPTEMBER

	HOLTWOOD DAILY AVG TEMPERATURE				TOTAL	
	60-69		70-79			
	N	PCTN	N	PCTN	N	PCTN
HOLTWOOD DAILY AVG FLOW						
5,000-7,499	3	10.00	16	53.33	19	63.33
7,500-9,999	.	.	6	20.00	6	20.00
10,000-14,999	.	.	3	10.00	3	10.00
15,000-19,999	.	.	2	6.67	2	6.67
TOTAL	3	10.00	27	90.00	30	100.00

JOINT OCCURRENCE OF DAILY HOLTWOOD FLOWS AND TEMPERATURES, JUNE - OCTOBER, 1997

MONTH=OCTOBER

	HOLTWOOD DAILY AVG TEMPERATURE				TOTAL	
	50-59		60-69			
	N	PCTN	N	PCTN	N	PCTN
HOLTWOOD DAILY AVG FLOW						
2,500-4,999	.	.	1	3.23	1	3.23
5,000-7,499	7	22.58	14	45.16	21	67.74
7,500-9,999	.	.	4	12.90	4	12.90
10,000-14,999	.	.	5	16.13	5	16.13
TOTAL	7	22.58	24	77.42	31	100.00

JOINT OCCURRENCE OF DAILY HOLTWOOD FLOWS AND TEMPERATURES, JUNE - OCTOBER, 1998

MONTH=JUNE

	HOLTWOOD DAILY AVG TEMPERATURE						TOTAL	
	60-69		70-79		80-85			
	N	PCTN	N	PCTN	N	PCTN	N	PCTN
HOLTWOOD DAILY AVG FLOW								
15,000-19,999	5	16.67	3	10.00	.	.	8	26.67
20,000-29,999	2	6.67	5	16.67	5	16.67	12	40.00
30,000-39,999	2	6.67	5	16.67	2	6.67	9	30.00
40,000-49,999	.	.	1	3.33	.	.	1	3.33
TOTAL	9	30.00	14	46.67	7	23.33	30	100.00

JOINT OCCURRENCE OF DAILY HOLTWOOD FLOWS AND TEMPERATURES, JUNE - OCTOBER, 1998

MONTH=JULY

	HOLTWOOD DAILY AVG TEMPERATURE				TOTAL	
	70-79		80-85			
	N	PCTN	N	PCTN	N	PCTN
HOLTWOOD DAILY AVG FLOW						
7,500-9,999	.	.	3	9.68	3	9.68
10,000-14,999	.	.	10	32.26	10	32.26
15,000-19,999	1	3.23	1	3.23	2	6.45
20,000-29,999	6	19.35	1	3.23	7	22.58
30,000-39,999	5	16.13	1	3.23	6	19.35
40,000-49,999	1	3.23	2	6.45	3	9.68
TOTAL	13	41.94	18	58.06	31	100.00

JOINT OCCURRENCE OF DAILY HOLTWOOD FLOWS AND TEMPERATURES, JUNE - OCTOBER, 1998

MONTH=AUGUST

	HOLTWOOD DAILY AVG TEMPERATURE						TOTAL	
	70-79		80-85		86 AND GREATER			
	N	PCTN	N	PCTN	N	PCTN	N	PCTN
HOLTWOOD DAILY AVG FLOW								
5,000-7,499	1	3.23	16	51.61	2	6.45	19	61.29
7,500-9,999	2	6.45	10	32.26	.	.	12	38.71
TOTAL	3	9.68	26	83.87	2	6.45	31	100.00

JOINT OCCURRENCE OF DAILY HOLTWOOD FLOWS AND TEMPERATURES, JUNE - OCTOBER, 1998

MONTH=SEPTEMBER

	HOLTWOOD DAILY AVG TEMPERATURE				TOTAL	
	70-79		80-85			
	N	PCTN	N	PCTN	N	PCTN
HOLTWOOD DAILY AVG FLOW						
2,500-4,999	16	53.33	2	6.67	18	60.00
5,000-7,499	6	20.00	6	20.00	12	40.00
TOTAL	22	73.33	8	26.67	30	100.00

JOINT OCCURRENCE OF DAILY HOLTWOOD FLOWS AND TEMPERATURES, JUNE - OCTOBER, 1998

MONTH=OCTOBER

	HOLTWOOD DAILY AVG TEMPERATURE						TOTAL	
	50-59		60-69		70-79			
	N	PCTN	N	PCTN	N	PCTN	N	PCTN
HOLTWOOD DAILY AVG FLOW								
2,500-4,999	.	.	.	.	6	19.35	6	19.35
5,000-7,499	3	9.68	8	25.81	.	.	11	35.48
7,500-9,999	.	.	9	29.03	.	.	9	29.03
10,000-14,999	.	.	5	16.13	.	.	5	16.13
TOTAL	3	9.68	22	70.97	6	19.35	31	100.00

JOINT OCCURRENCE OF DAILY HOLTWOOD FLOWS AND TEMPERATURES, JUNE - OCTOBER, 1999

---------- MONTH=JUNE ----------

	HOLTWOOD DAILY AVG TEMPERATURE			
	70-79		TOTAL	
	N	PCTN	N	PCTN
HOLTWOOD DAILY AVG FLOW				
2,500-4,999	5	16.67	5	16.67
5,000-7,499	16	53.33	16	53.33
7,500-9,999	6	20.00	6	20.00
10,000-14,999	3	10.00	3	10.00
TOTAL	30	100.00	30	100.00

JOINT OCCURRENCE OF DAILY HOLTWOOD FLOWS AND TEMPERATURES, JUNE - OCTOBER, 1999

---------- MONTH=JULY ----------

	HOLTWOOD DAILY AVG TEMPERATURE						TOTAL	
	70-79		80-85		86 AND GREATER			
	N	PCTN	N	PCTN	N	PCTN	N	PCTN
HOLTWOOD DAILY AVG FLOW								
2,500-4,999	1	3.23	15	48.39	.	.	16	51.61
5,000-7,499	1	3.23	11	35.48	1	3.23	13	41.94
7,500-9,999	1	3.23	1	3.23	.	.	2	6.45
TOTAL	3	9.68	27	87.10	1	3.23	31	100.00

JOINT OCCURRENCE OF DAILY HOLTWOOD FLOWS AND TEMPERATURES, JUNE - OCTOBER, 1999

---------- MONTH=AUGUST ----------

	HOLTWOOD DAILY AVG TEMPERATURE				TOTAL	
	70-79		80-85			
	N	PCTN	N	PCTN	N	PCTN
HOLTWOOD DAILY AVG FLOW						
0-2,500	.	.	3	9.68	3	9.68
2,500-4,999	.	.	13	41.94	13	41.94
5,000-7,499	7	22.58	4	12.90	11	35.48
7,500-9,999	1	3.23	1	3.23	2	6.45
10,000-14,999	1	3.23	.	.	1	3.23
15,000-19,999	1	3.23	.	.	1	3.23
TOTAL	10	32.26	21	67.74	31	100.00

JOINT OCCURRENCE OF DAILY HOLTWOOD FLOWS AND TEMPERATURES, JUNE - OCTOBER, 1999

---------- MONTH=SEPTEMBER ----------

	HOLTWOOD DAILY AVG TEMPERATURE				TOTAL	
	60-69		70-79			
	N	PCTN	N	PCTN	N	PCTN
HOLTWOOD DAILY AVG FLOW						
2,500-4,999	.	.	6	20.00	6	20.00
5,000-7,499	.	.	3	10.00	3	10.00
7,500-9,999	.	.	1	3.33	1	3.33
10,000-14,999	.	.	2	6.67	2	6.67
15,000-19,999	4	13.33	1	3.33	5	16.67
20,000-29,999	5	16.67	1	3.33	6	20.00
30,000-39,999	2	6.67	1	3.33	3	10.00
40,000-49,999	1	3.33	.	.	1	3.33
50,000 PLUS	2	6.67	1	3.33	3	10.00
TOTAL	14	46.67	16	53.33	30	100.00

JOINT OCCURRENCE OF DAILY HOLTWOOD FLOWS AND TEMPERATURES, JUNE - OCTOBER, 1999

---------- MONTH=OCTOBER ----------

	HOLTWOOD DAILY AVG TEMPERATURE				TOTAL	
	50-59		60-69			
	N	PCTN	N	PCTN	N	PCTN
HOLTWOOD DAILY AVG FLOW						
7,500-9,999	1	3.23	.	.	1	3.23
10,000-14,999	10	32.26	.	.	10	32.26
15,000-19,999	5	16.13	4	12.90	9	29.03
20,000-29,999	1	3.23	7	22.58	8	25.81
30,000-39,999	.	.	2	6.45	2	6.45
40,000-49,999	.	.	1	3.23	1	3.23
TOTAL	17	54.84	14	45.16	31	100.00

ASSESSMENT OF COOLING TOWER OPERATION AT PEACH BOTTOM ATOMIC POWER STATION ON POTENTIAL FISH HABITAT

PREPARED FOR:
PECO Energy Company
2301 Market Street
Philadelphia, Pennsylvania 19101

PREPARED BY:
Normandeau Associates, Inc.
1921 River Road
Drumore, Pennsylvania 17518

JUNE 2000

NORMANDEAU ASSOCIATES
ENVIRONMENTAL CONSULTANTS

ASSESSMENT OF COOLING TOWER OPERATION AT PEACH BOTTOM ATOMIC POWER STATION ON POTENTIAL FISH HABITAT

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JUNE 2000

TABLE OF CONTENTS

1.0 INTRODUCTION AND BACKGROUND 1
2.0 ESTIMATION OF POTENTIAL FISH HABITAT EXCLUSION 1
2.1 Example Calculations of Habitat Exclusion Area for Spotfin Shiner 2
2.2 Perspective on Potential Habitat Exclusion Based on Fish Avoidance Temperature 3
3.0 RESULTS 4
4.0 CONCLUSIONS 4
5.0 LITERATURE CITED 5
TABLES
FIGURES
APPENDIX A

LIST OF TABLES

Table 2-1 Comparison of Eaton *et al.* (1995) fish temperature tolerance, the highest temperature at which each species was collected in Conowingo Pond, predicted avoidance temperature, and percent time predicted avoidance temperature was equaled or exceeded at Station 201.

Table 2-2 Various species collected at water temperatures ≥30.5°C in Conowingo Pond, June through October 1997-1999.

Table 2-3 The percent time, area, and percent of total pond area potentially avoided by spotfin shiner at zero tower operation in June.

Table 2-4 Estimated ambient temperature which results in spotfin shiner avoidance at location/depth downstream of the PBAPS discharge canal outfall at 0, 1, 2, and 3 tower operation, May-October.

Table 2-5 The percent time exceedance that results in spotfin shiner avoidance at affected locations/depths downstream of the PBAPS discharge canal outfall at zero tower operation, May-October.

Table 2-6 Exclusion area calculation data and information (based on zero tower operations 1996 through 1999).

Table 3-1 The percent time, area, and percent of total pond area potentially avoided by RIS species by month at 0, 1, 2, and 3 tower operations at Peach Bottom Atomic Power Station.

LIST OF FIGURES

Figure 2-1 Thermal profiling locations in the vicinity of PBAPS.

Figure 2-2 Monthly intake temperature duration curves (1956-1999), May.

Figure 2-3 Monthly intake temperature duration curves (1956-1999), June.

Figure 2-4 Monthly intake temperature duration curves (1956-1999), July.

Figure 2-5 Monthly intake temperature duration curves (1956-1999), August.

Figure 2-6 Monthly intake temperature duration curves (1956-1999), September.

Figure 2-7 Monthly intake temperature duration curves (1956-1999), October.

Figure 2-8 Relationship of Station 201 versus avoidance temperature at zero tower operation.

Figure 3-1 Map of Conowingo Pond showing distribution of seine stations.

APPENDIX A

Table A-1 RIS avoidance temperature at known acclimation/ambient intake temperature.

Table A-2 Estimate ambient temperature which results in RIS species avoidance at location/depth downstream of the PBAPS discharge canal outfall at 0, 1, 2, and 3 tower operations, May-October.

Table A-3 Exclusion area calculation data and information (based on zero tower operations 1996 through 1999).

Table A-4 Estimated temperatures at end of berm and at depth at Station 201 versus 0, 1, 2, and 3 tower operations and known ambient temperature.

Table A-5 Estimated temperatures at end of berm and at depth at Station 301 versus 0, 1, 2, and 3 tower operations and known ambient temperature.

Table A-6 Estimated temperatures at end of berm and at depth at Station 302 versus 0, 1, 2, and 3 tower operations and known ambient temperature.

Table A-7 Estimated temperatures at end of berm and at depth at Station 303 versus 0, 1, 2, and 3 tower operations and known ambient temperature.

Table A-8 Estimated temperatures at end of berm and at depth at Station 402 versus 0, 1, 2, and 3 tower operations and known ambient temperature.

Table A-9 The percent time exceedance at 0 tower operation that results in RIS avoidance at a given location/depth downstream of the PBAPS discharge canal outfall in May-October.

Table A-10 The percent time exceedance at 1 tower operation that results in RIS avoidance at a given location/depth downstream of the PBAPS discharge canal outfall in May-October.

Table A-11 The percent time exceedance at 2 tower operation that results in RIS avoidance at a given location/depth downstream of the PBAPS discharge canal outfall in May-October.

Table A-12 The percent time exceedance at 3 tower operation that results in RIS avoidance at a given location/depth downstream of the PBAPS discharge canal outfall in May-October.

Figure A-1 Relationship between the PBAPS discharge (berm) temperature and profiled locations at the surface, 5 ft, 10 ft, and bottom depths, at 0 tower operation in May-October 1996-1999.

Figure A-2 Relationship between the PBAPS intake temperature and profiled locations at the surface, 5 ft, 10 ft, and bottom depths, at 0 tower operation in May-October 1996-1999.

Figure A-3 Relationship of Station 201 temperature versus fish avoidance temperature (°C) at 0 to 3 tower operations.

Figure A-4 Relationship of Station 301 temperature versus fish avoidance temperature (°C) at 0 to 3 tower operations.

Figure A-5 Relationship of Station 302 temperature versus fish avoidance temperature (°C) at 0 to 3 tower operations.

Figure A-6 Relationship of Station 303 temperature versus fish avoidance temperature (°C) at 0 to 3 tower operations.

Figure A-7 Relationship of Station 402 temperature versus fish avoidance temperature (°C) at 0 to 3 tower operations.

1.0 INTRODUCTION AND BACKGROUND

This report is prepared in response to a request from the Pennsylvania Fish and Boat Commission (PFBC) to assess the effects of the operation of variable number of cooling towers at Peach Bottom Atomic Power Station (PBAPS) on potential fish habitat. The initial study plan, developed and implemented in consultation with the participating resource agencies, required monitoring fish populations in Conowingo Pond using the gears (e.g., seine, trap net, trawl, and electrofishing) employed historically at selected stations so that the resulting data would be consistent with the historical data. The reports (Normandeau Associates 1997a,b, 1998, 1999, 2000; PECO 1975; Robbins and Mathur 1975) emanating from these efforts had focused on evaluating the potential effects on the operation of variable number of cooling towers at the existing fish population and fish community levels. These reports had concluded that a thriving, balanced fish community, based on long-term data, can exist in Conowingo Pond with PBAPS thermal discharge. Much of the published literature on fish responses to thermal discharges suggests strong resiliency of fish populations to thermal perturbations (Coutant 1972, 1974, 1977; Bennett and Gibbons 1974; Romberg *et al.* 1974; Dickson *et al.* 1976; Thorpe and Gibbons 1977). The historical staged operation of variable number of cooling towers was based on the integration of laboratory derived behavioral responses (e.g., fish preference and avoidance) and tolerances (e.g., sudden heat or cold shock assuming different acclimation (ambient temperatures)) with the predicted plant operational characteristics, and manufacturer specifications for cooling tower performance. It was assumed that fishes would be trapped and thus be exposed to the maximum prevailing temperatures and changes in temperatures; the operating criterion was based on the tolerance of temperature-sensitive species (white crappie).

Prior to initiating efforts for this report, an approach to quantify fish habitat exclusion at variable cooling tower operations was developed and submitted to PFBC for comments and concurrence. Feedback from the agency suggested examining the approach used by Eaton *et al.* (1995) relative to potential temperature effects on fish. The approach developed by Eaton *et al.* (1995) was examined and its brief review is provided in Section 2.2.

2.0 ESTIMATION OF POTENTIAL FISH HABITAT EXCLUSION

The analytical steps taken to estimate the potential fish habitat exclusion (expressed in acre-feet) area incorporate historical inflow temperature (measured at Holtwood), PBAPS intake water temperature (1995-1999), water temperature at sampled sites in Conowingo Pond (Figure 2-1), and fish avoidance temperature are described below. For comparisons, these calculations were made for 0, 1, 2, and 3 tower operation. Only summarized data for all species are presented in the main body of the report; the results of supporting analyses either in graphical or tabular form are provided in Appendix A. However, for ease in understanding the steps involved in calculating the amount of excluded area given in Section 3.0, the calculations for spotfin shiner are provided for illustrative purposes in Section 2.1.

First, the historical daily inflow temperatures (Holtwood) were converted to and expressed as PBAPS intake water temperatures via a predictive relationship (R^2=0.97) between the average daily Holtwood temperature and corresponding temperature at the PBAPS intake for the period 1995-1999. Because average daily temperatures at Holtwood are usually higher than the corresponding values at the intake (thus, may falsely inflate temperature conditions than actual), it was deemed more realistic and accurate to describe thermal conditions in the plume area based on the intake temperature. Figures 2-2 through 2-7 show the monthly PBAPS intake water temperature exceedance probabilities for May through October.

The avoidance temperature, over the range of ambient (intake) temperatures that have occurred in May through October, for each species were predicted from statistical equations given in Mathur *et al.* (1983; Table 1); the laboratory based experiments related fish avoidance temperatures and acclimation temperature. These temperature values highlighted for spotfin shiner in Appendix A, Table A-1, were compared with results of ambient temperature versus known temperatures at locations/depth (from profile data collected in areas downstream of the discharge (Figure 2-1) at zero tower in 1996-1999) relationships, to see when (and percent time) each of the Resident Important Species (RIS) would be excluded from (or avoid) the discharge area (the area of highest temperature) and at sampled locations as the heat is dissipated downstream.

Statistical relationships were developed between the temperature measured at the point of discharge (end of berm) and profiled depths at each location sampled in the plume area during thermal surveys conducted at zero tower operation in 1996-1999 (Appendix A, Figure A-1). Also, statistical relationships between intake temperature and the temperatures at downstream locations were developed (Appendix A, Figure A-2). These relationships provide a better predictive ability since the historical record for Holtwood inflow temperatures is much longer (43 years) than that currently available for discharge temperatures at zero tower operations (three years).

Using the above statistical relationships, the temperature at each downstream location/depth was estimated and plotted along with the avoidance temperatures of each species (Appendix A, Figures A-3 to A-7). From these plots, the temperature (ambient/intake) that results in the occurrence, if any, of an avoidance temperature at a given location/depth for each affected fish species was determined (Appendix A, Table A-2). Once the "ambient/avoidance" temperatures were known, then the percent of time that each is equaled or exceeded for a given location/depth/species in each month was determined (Appendix A, Tables A-9 through A-12).

Using the percent time the temperature is exceeded and the area exceeded for each species, a habitat exclusion area (*i.e.*, acre-feet) was calculated and expressed in terms of percent excluded versus the area of the entire Pond (322,000 acre-feet), as well as the percent time that such will occur, for zero tower operation. Appendix A (Table A-3) provides information used in calculating the amount of affected area (acre-feet).

To quantify habitat exclusion by area and time durations for 1, 2, and 3 tower operations a similar analysis was conducted by adjusting the end of berm/avoidance relationships to reflect the cooling effect (reduction in berm temperature at zero tower) of each tower scenario based on an average of 1.5°F (0.83°C) cooling per tower. Appendix A (Tables A-4 to A-8) provides information relative to these calculations.

2.1 Example Calculations of Habitat Exclusion Area for Spotfin Shiner

The habitat exclusion area for each RIS and tower operation are summarized in Section 3.0 (Table 3-1) herein. An example habitat exclusion area determination is provided below for spotfin shiner in June at zero tower operation for ease in understanding the process used. The summary data for spotfin shiner (extracted from Table 3-1) are shown in Table 2-3.

Percent time (%T) in Table 2-3 refers to the percentage of time that an avoidance temperature for spotfin shiner was equaled or exceeded at one or more locations/depths downstream of the PBAPS discharge structure in June.

The avoidance temperatures by location and depth for spotfin shiner were estimated based on acclimation temperature (see highlighted areas in Appendix A, Table A-1) and the relationship between the PBAPS intake temperature and measured temperature at each location/depth (see Appendix A, Figure A-2) during zero tower operation. The results of these calculations at Station 201 are plotted in Figure 2-8. Appendix A, Figures A-3 through A-7 show similar plots for all affected locations and depths for each RIS. The temperature (X-axis) at which the spotfin shiner plotted line intersects each depth at Station 201 (surface, 5 ft, 10 ft, and bottom) is the intake temperature which results in an avoidance temperature (Figure 2-8). An intake temperature of ≥24.5°C (76.1°F) results in an avoidance temperature at 201 Surface (201-S), an intake temperature of ≥26°C (78.8°F) results in an avoidance temperature at 201 5-ft depth (201-5), while an intake temperature of ≥28°C (82.4°F) results in avoidance at the 10-ft and bottom depths.

The PBAPS intake temperatures that result in an avoidance temperature for spotfin shiner at affected locations/depths for each tower operation is shown in Table 2-4 (and for all RIS in Appendix A, Table A-2).

The percent of time that these intake temperatures occurred on a monthly basis (May through October) was determined from the intake temperature duration curves (Figures 2-2 through 2-7). A summary of these data for spotfin shiner at zero tower are included in Table 2-5 (and for all RIS in Appendix A, Tables A-9 through A-12).

As shown in Table 2-5, at an intake temperature of ≥24.5°C (76.1°F) the temperature at Station 201-S would equal or exceed the spotfin shiner avoidance temperature 38% of the time in June, 18% of the time at ≥26°C (78.8°F) at the 5 ft depth, while 5% of the time at ≥28°C (82.4°F) the entire water column at Station 201 would exceed avoidance temperatures.

With the surface temperature at Station 201 potentially avoided by spotfin shiner 38% of the time in June at zero tower operation, the habitat exclusion area (acres) affected is assumed to encompass that area from the end of the berm to halfway between Stations 201 and 301, or 59 acres (Table 2-6). Since the surface (S) is defined as 0 to 3 ft depth, the corresponding acre-feet excluded is 177 (59 acres x 3 ft). Eighteen percent of the time the exclusion area includes that for 201-S and 201-5 depths, or 472 acre-feet (59 acres x 8 ft), while 10% of the time the excluded area includes 201-S and 201-5 to Station 301 surface (301-S), or 895 acre-feet (472 acre-feet for 201-S to 5 ft plus 423 acre-feet for 301-S). Five percent of the time the excluded area includes all depths at 201 and 301-S, or 1,190 acre-feet (767 acre-feet for 201 plus 423 acre-feet for 301-S). One percent of the time the potential exclusion area also includes Station 301-5 and Station 302-S, or 2,159 acre-feet (767 acre-feet for all depths at 201 plus1,128 acre-feet for 301-S to 301-5 plus 264 acre-feet for 302-S.

The results of the above calculations for spotfin shiner along with the other RIS, affected location/depth, and tower operation scenario (0, 1, 2, and 3) are summarized in Table 3-1.

2.2 Perspective on Potential Habitat Exclusion Based on Fish Avoidance Temperature

A brief examination of Eaton *et al.* (1995) revealed the following:

- the impetus of the paper was the potential effects of "global warming" on overall rise in lake temperature on fish;
- the paper focused on developing fish temperature tolerances based on presence of a species (not collected near shore or lake shore) collected at the highest temperature;
- the data used came from over a wide geographical range throughout the United States;
- fish presence/absence data were matched with prevailing temperature;
- fish tolerances were determined from weekly mean temperatures; and
- does not appear that fish data collected in thermal plumes throughout the United States were included in the analysis.

Eaton *et al.* (1995) reported temperature tolerances of 30 species among which the following are of potential interest in Conowingo Pond: black crappie, white crappie, bluegill, smallmouth bass, largemouth bass, channel catfish, gizzard shad, walleye, and yellow perch. Although not explicitly used in the analysis by Eaton *et al.* (1995) it should be noted that fish temperature tolerances increase with gradual increase in temperature; it is unknown from their analysis whether fishes would have tolerated higher temperature in the studied water bodies if available. In contrast, Dickson *et al.* (1976) recommended using fish preference, avoidance, and site-specific field data in making a reasonable and realistic assessment of potential effects of thermal discharges. However, to be consistent with the PFBC request, a habitat based approach is relied upon for assessing potential effects of cooling tower operation; it should be noted that fish behavioral responses are an integral component of habitat calculations. Secondarily, a brief comparison is made between the data on temperature tolerances of species given by Eaton *et al.* (1995), highest temperature at which species was collected in Conowingo Pond in 1997-1999, and predicted avoidance temperatures (used in the habitat calculations herein).

Relative to the Eaton *et al.* (1995) approach, based on temperature tolerances determined from highest temperature at which a species is collected, potential habitat exclusion calculations based on fish avoidance temperature are quite conservative. Table 2-1 shows that the site-specific field fish temperature tolerances (*i.e.*, highest temperature at which a species was collected in Conowingo Pond) for all species except walleye are much higher than predicted fish avoidance temperatures. For walleye the predicted avoidance temperature (31.1°C or 88°F) is virtually identical to the highest temperature (30.9°C or 87.6°F) at which walleye were collected in Conowingo Pond. Temperature tolerances of species reported by Eaton *et al.* (1995) are several degrees lower than those temperatures at which these fishes were captured in Conowingo

Pond. In 1997-1999, some 22 species were collected at water temperatures of 33°C (91.4°F) or higher (Table 2-2). Additionally, field observations indicated that actual temperature tolerances for many Conowingo Pond fishes are higher yet because many were observed actively swimming in cooling ponds (trapped condition), discharge canal, and at the outfall. Water temperatures at the latter locations are higher than at fish sampling sites (downstream of discharge structure) in Conowingo Pond. Many of these species have been routinely acclimated to temperatures exceeding 33°C (91.4°F) in laboratory thermal preference and avoidance experiments (Cherry *et al.* 1995, 1977).

3.0 RESULTS

Table 3-1 presents the calculated duration and magnitude of potential habitat exclusion as a function of variable number of cooling towers (0 to 3) in May through October. Except for near the berm area which was assumed to be avoided 100% of the time, little or no habitat exclusion is projected for any species in May and October; the near berm area constitutes 0.05% of the total pond area. Peak spawning activity of most species in Conowingo Pond occurs in May to early June (PECO 1975, 1976). In other months even though the amount of potential acreage excluded increases at zero tower, particularly for spotfin shiner, white crappie, and walleye, the incremental amount excluded is mostly less than 1% of the total Pond area and for less than 20% of the time. This potential habitat exclusion occurs at a time (July-September) when peak spawning activity of fishes is completed. For the other species, changes in potential habitat exclusion between the variable number of cooling towers are relatively small and of lesser duration (Table 3-1).

In reality, however, little area appears to be completely excluded for important fish activity (spawning). Seine catches at Station 214 (Figure 3-1) which were most affected by the thermal plume, showed the presence of young-of-the-year bluegill, smallmouth bass, largemouth bass, spotfin shiner, and bluntnose minnow indicating successful spawning activity. The 10 by 4 ft seine used in sampling shoreline fishes tends to capture young-of-the-year fish of larger sized species (e.g., largemouth bass, smallmouth bass, etc.) and juvenile and adults of smaller sized species (e.g., spotfin shiner, bluntnose minnow, etc.). Thus, it appears that the most important aspect of fish recruitment process does not appear to be affected. This conclusion is corroborated by a similarity in relative abundance of fishes between the pre-operational and zero tower operation periods reported in Normandeau Associates (2000). Additionally, during various fish and water quality surveys, schools of young fishes were observed in the cooling ponds, discharge canal, and near the berm.

4.0 CONCLUSIONS

Examination of multiple sources of data and observations over a long period of time and widely varying hydrological conditions suggest that zero tower operation is compatible with the existence of a balanced, thriving, indigenous Conowingo Pond fish community. PBAPS thermal plume is relatively small compared to the size of Conowingo Pond and fishes are free to move about and avoid the areas with temperatures not in their preferred range. Little or no habitat activity exclusion occurs in May and early June, a peak spawning period for most fishes in Conowingo Pond. The calculated potential habitat exclusion area occurs mostly in July through September when either the species naturally move out of the area or the important spawning activity does not occur. Also, it should be noted that much of the habitat projected to be potentially excluded is consistent with the intent of the discharge structure design features at the end of the berm. That is, the discharge structure was designed to have a jet velocity of 5 to 8 ft/s which in combination with high temperature was intended to discourage fish entry in that area. Thus, some habitat exclusion was expected even with all the cooling towers operating. These conclusions are consistent with observations at many steam electric and nuclear power plants.

A conservative approach, based on laboratory derived fish avoidance temperatures, was utilized to assess the effects of variable number of cooling tower operation on potential fish habitat exclusion. Relative to one to three tower operation, the effects of zero tower operation on potential excluded area were minimal; for 8 of the 9 species the percentage of area excluded was less 1% of the total pond. Only for walleye did the excluded area exceed 1% of the total, but it was less than 3.5% of the time and only in July and August. Walleye are not common in the area at that time of the year regardless of the number of cooling towers in operation. If the Eaton *et al.* (1995) approach of fish temperature tolerance (that utilized the highest

temperature at which a species was collected) is used the potential excluded area and its frequency of occurrence herein are overestimates, because most species were collected (tolerated) and observed at temperatures higher than the laboratory predicted avoidance temperatures.

Natural occurring hydrological events such as Hurricane Agnes in 1972 and Hurricane Eloise in 1975 and biological events (*i.e.*, introduction of gizzard shad) have had much longer lasting effects on potential fish habitat and fish populations than PBAPS thermal discharge (RMC 1994).

The shutdown of the station between March 1987 to July 1989 provided an opportunity to examine the potential effects of cessation of heated discharge. No substantial changes in Conowingo Pond fish populations were observed before and after this shutdown. Thus, it is difficult to relate thermal discharge as causative mechanism for fluctuations in fish community which occur naturally in Conowingo Pond.

The four years of monitoring at the zero tower operation over a wide range of hydrological conditions did not reveal obvious changes in the Conowingo Pond fish community. Specifically, in 1999 the fish community was exposed to near-worst summer temperature conditions and appears to have thrived well. No thermally-stressed fish mortality was observed.

In summary, the combined use of long-term site-specific field data, habitat analysis, laboratory thermal responses of Conowingo Pond fishes leads to the conclusion that a thriving, balanced, indigenous fish community can exist without cooling tower usage.

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TABLES

Table 2-1

Comparison of Eaton *et al.* (1995) fish temperature tolerance, the highest temperature at which each species was collected in Conowingo Pond, predicted fish avoidance temperature, and percent time predicted avoidance temperature was equaled or exceeded at Station 201.

Species	Eaton *et al.* (1995)	Fish Captured in Conowingo Pond[1]	Estimated Avoidance Temperature[2]	Percent Exceedance[3]
Gizzard shad	31.5°C	37.3°C	31.5°C	17.8
Spotfin shiner	-	37.3°C	30.3°C	27.5
Bluntnose minnow	-	35.0°C	34.9°C	2.1
Channel catfish	31.6°C	37.3°C	32.8°C	9.3
Bluegill	29.5°C	37.3°C	33.3°C	6.1
Smallmouth bass	29.5°C	36.5°C	32.9°C	8.7
Largemouth bass	31.7°C	35.0°C	33.2°C	6.6
White crappie	31.3°C	32.6°C	30.7°C	25.4
Walleye	29.0°C	30.9°C	31.1°C	21.3

1 Actively swimming fishes in cooling ponds, discharge canal, and the outfall; observed at higher temperatures; fishermen activity common in the plume.
2 Estimates based on fishes acclimated at 25°C (77°F).
3 Station 201 most frequently recorded highest water temperature and with most area of predicted avoidance.

Table 2-2

Various species collected at water temperatures ≥30.5°C (86.9°F) in Conowingo Pond, June through October 1997-1999.

Species	30.5°C	30.9°C	31.0°C	31.2°C	32.0°C	32.5°C	33.0°C	33.5°C	33.9°C	34.0°C	35.0°C	36.5°C	37.1°C	37.3°C
Gizzard shad														x
Central stoneroller							x							
Common carp													x	
Golden shiner										x				
Comely shiner										x				
Common shiner											x			
Spottail shiner							x							
Spotfin shiner														x
Mimic shiner							x							
Bluntnose minnow											x			
Quillback										x				
Shorthead redhorse										x				
White catfish	x													
Yellow bullhead				x										x
Brown bullhead														
Channel catfish														x
Rock bass									x					
Redbreast sunfish								x						
Green sunfish														x
Pumpkinseed														x
Bluegill														x
Smallmouth bass												x		
Largemouth bass											x			
White crappie						x								
Tessellated darter							x							
Banded darter	x													
Yellow perch			x											
Logperch					x									
Walleye		x												

Table 2-3

The percent of time (%T), area (acre-feet), and percent of total pond area (%P) potentially avoided by spotfin shiner at 0 tower operation in June.

0 Tower	June		
RIS	% T	Acre-ft	% P
Spotfin shiner	100	169	0.05
	38	177	0.05
	18	472	0.15
	10	895	0.28
	5	1190	0.37
	1	2159	0.67

Data extracted from Table 3-1

Table 2-4

Estimated ambient (intake) temperature which results in spotfin shiner avoidance at location/depth downstream of the PBAPS discharge canal outfall at 0, 1, 2, and 3 tower operation, May-October.

		Depth	Tower Operation			
RIS	Location	(ft)	0	1	2	3
Spotfin shiner	201	Surface	24.5	26.5	28.5	30.5
		5	26.0	28.0	30.0	32.0
		10	28.0	30.0	32.0	33.5
		Bottom	28.0	30.0	32.0	33.5
	301	Surface	27.0	29.0	31.0	33.0
		5	29.5	31.0	33.0	*
		10	32.0	33.0	*	*
		Bottom	*	*	*	*
	302	Surface	29.5	31.0	33.0	*
		5	30.5	32.5	*	*
		10	33.5	*	*	*
		Bottom	*	*	*	*
	303	Surface	31.0	33.0		*
		5	31.5	33.0	*	*
		10	33.0	*	*	*
		Bottom	*	*	*	*
	402	Surface	33.5	*	*	*
		5	*	*	*	*
		10	*	*	*	*
		Bottom	*	*	*	*

* No avoidance; intake temperatures resulting in an avoidance temp at location/depth, did not occur historically.
Data extracted from Appendix A, Table A-2.

Table 2-5

The percent time exceedance (1956-99 intake °C) that results in spotfin shiner avoidance at affected locations/depths downstream of the PBAPS discharge canal outfall at 0 tower operation, May-October.

0 Tower RIS	Station Location	Depth (ft)	Intake (°C) **	% of Time Intake Temperature was Equaled or Exceeded					
				May	June	July	August	September	October
Spotfin	201	Surface	24.5	2	38	87	87	37	2
		5-ft	26.0	*	18	70	66	23	*
		10-ft	28.0	*	5	33	27	9	*
		Bottom (13)	28.0	*	5	33	27	9	*
	301	Surface	27.0	*	10	51	47	15	*
		5-ft	29.5	*	1	11	9	3	*
		10-ft	32.0	*	*	*	1	*	*
		Bottom (23)	*	*	*	*	*	*	*
	302	Surface	29.5	*	1	11	9	3	*
		5-ft	30.5	*	*	4	4	1	*
		10ft-Bottom	33.5	*	*	*	*	*	*
	303	Surface	31.0	*	*	3	2	*	*
		5-ft	31.5	*	*	*	1	*	*
		10ft-Bottom	33.0	*	*	*	*	*	*
	402	Surface-Bottom	33.5	*	*	*	*	*	*

* No avoidance; intake temps resulting in an avoidance temp at location/depth did not occur historically or occurred <1% of the time.
** The intake temperature which results in an avoidance temperature at location/depth downstream of the canal outfall.
Data extracted from Appendix A, Table A-9

Table 2-6

Exclusion area calculation data and information (based on 0 tower operations 1996 through 1999).

Avoidance Area (Acres) Determination for Affected Locations

Includes the acreage from the Berm to the location where an avoidance temp occurred plus ~one-half the area (where appropriate) between the avoided location and the next sampled stations (immediately east and downstream) where avoidance temperatures were not readily apparent.

Affected acreage (given below) was estimated using a grid map of the study area in Conowingo Pond (Figure 3-1 in the report).

	Surface Acres	
	At Location	Running total
If **No** avoidance at Station 201, the exclusion area = the Berm =	13	13
If avoidance temperature occurred at **201**, the exclusion area =	59 *	59 *
If avoidance temperature occurred at **301**, the exclusion area =	141	200
If avoidance temperature occurred at **302**, the exclusion area =	88	288
If avoidance temperature occurred at **303**, the exclusion area =	115	403
If avoidance temperature occurred at **402**, the exclusion area =	518	921

* includes the Berm area

Avoidance Acre-feet Determination for Affected Locations

Location depths for subsequent calculations were as follows:

Surface (S) includes depths of 0 to 3 ft
5-ft (5) includes depths 0 to 8 ft
10-ft (10) includes depths 0-12 ft if ≤15 ft; otherwise 0 to 13 ft
Bottom (B) uses the mean depth at location

Estimated acre-feet by depth and affected location :

Acre-feet (By location alone)

Depth (ft)	Berm	At 201 *	At 301	At 302	At 303	At 402
Surface	39	177	423	264	345	1554
5-ft	104	472	1128	704	920	4144
10-ft	156	708	1833	1056	1495	6734
Bottom	169	767	2820	1320	1840	10878
	* Includes Berm acre-ft					
Ave Depth	13 ft	13 ft	20 ft	15 ft	16 ft	21 ft

Example: If avoidance temperatures for a given RIS are exceeded at all depths at 201; surface, 5 and 10 ft at 301; and surface at 302, the exclusion area would = 2864 acre-ft as shown below:

Acre-ft = (767 acre-ft for 201-S to B) + (1833 acre-ft for 301-S to 10-ft) + (264 acre-ft for 302-S) = 2864

Estimated % ot the total Pond acre-feet by depth and affected location:

% Pond Acre-ft (Pond = 322,000 acre-ft) *

Depth (ft)	Berm	At 201	At 301	At 302	At 303	At 402
Surface	0.01	0.05	0.13	0.08	0.11	0.48
5-ft	0.03	0.15	0.35	0.22	0.29	1.29
10-ft	0.05	0.22	0.57	0.33	0.46	2.09
Bottom	0.05	0.24	0.88	0.41	0.57	3.38

* from Moyer and Raney,1969 (ASCE Meeting Preprint #834)

Table 3-1

The percent time (%T), area (acre-ft), and percent of total pond area (%P) potentially avoided by RIS species by month (May-October) at 0, 1, 2, and 3 tower operations at Peach Bottom Atomic Power Station.

MAY	0			1			2			3		
RIS	% T	Ac-ft	% P	% T	Ac-ft	% P	% T	Ac-ft	% P	% T	Ac-ft	% P
Gizz shad	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05
Spotfin	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05
	2	177	0.05									
Bluntnose	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05
Ch Catfish	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05
Bluegill	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05
Smallmouth	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05
Largemouth	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05
Wh. Crappie	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05
Walleye	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05

JUNE	0			1			2			3		
RIS	% T	Ac-ft	% P	% T	Ac-ft	% P	% T	Ac-ft	% P	% T	Ac-ft	% P
Gizz shad	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05
	5	177	0.05									
Spotfin	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05
	38	177	0.05	14	177	0.05	3	177	0.05			
	18	472	0.15	5	472	0.15	2	427	0.15			
	10	895	0.28	2	895	0.28						
	5	1190	0.37									
	1	2159	0.67									
Bluntnose	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05
Ch Catfish	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05
Bluegill	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05
	1	177	0.05									
Smallmouth	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05
	1	177	0.05									
Largemouth	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05
Wh. Crappie	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05
	18	177	0.05	5	177	0.05	1	177	0.05			
	10	472	0.15	2	472	0.15						
	5	895	0.28									
	2	1190	0.37									
Walleye	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05
	18	177	0.05	7	177	0.05	2	177	0.05			
	10	472	0.15	3	472	0.15	1	472	0.15			
	7	895	0.28	2	895	0.28						
	3	1190	0.37									
	1	2159	0.67									

(continued)

Table 3-1

Continued.

JULY RIS	0			1			2			3		
	% T	Ac-ft	% P	% T	Ac-ft	% P	% T	Ac-ft	% P	% T	Ac-ft	% P
Gizz shad	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05
	33	177	0.05									
	4	472	0.15									
Spotfin	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05
	87	177	0.05	61	177	0.05	23	177	0.05	4	177	0.05
	70	472	0.15	33	472	0.15	7	472	0.15			
	51	895	0.28	16	895	0.28	3	895	0.28			
	33	1190	0.37	7	1190	0.37						
	11	2159	0.67	3	2159	0.67						
	4	2599	0.81									
	3	2944	0.91									
Bluntnose	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05
Ch Catfish	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05
Bluegill	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05
	11	177	0.05	4	177	0.05						
	7	472	0.15	1	600	0.19						
	3	895	0.28									
Smallmouth	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05
	11	177	0.05	3	177	0.05						
	3	472	0.15									
Largemouth	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05
Wh. Crappie	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05
	70	177	0.05	33	177	0.05	11	177	0.05			
	51	472	0.15	16	472	0.15	3	472	0.15			
	33	895	0.28	4	895	0.28						
	16	1190	0.37	3	1190	0.37						
	7	1454	0.45									
	4	1895	0.59									
Walleye	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05
	70	177	0.05	42	177	0.05	16	177	0.05	7	177	0.05
	51	472	0.15	23	472	0.15	11	472	0.15	3	472	0.15
	42	895	0.28	16	895	0.28	4	895	0.28			
	23	1190	0.37	7	1190	0.37						
	11	2159	0.67	4	2159	0.67						
	4	2944	0.91									
	3	4224	1.31									
	1	6705	2.08									

(continued)

Table 3-1

Continued.

AUGUST RIS	0			1			2			3		
	% T	Ac-ft	% P	% T	Ac-ft	% P	% T	Ac-ft	% P	% T	Ac-ft	% P
Gizz shad	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05
	14	177	0.05	2	177	0.05						
	4	472	0.15									
Spotfin	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05
	87	177	0.05	57	177	0.05	19	177	0.05	4	177	0.05
	66	472	0.15	27	472	0.15	5	472	0.15	1	472	0.15
	47	895	0.28	14	895	0.28	2	895	0.28			
	27	1190	0.37	5	1190	0.37	1	1190	0.37			
	9	2159	0.67	2	2159	0.67						
	4	2599	0.81									
	2	2944	0.91									
	1	4224	1.31									
Bluntnose	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05
Ch Catfish	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05
	1	177	0.05									
Bluegill	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05
	9	177	0.05	4	177	0.05	1	177	0.05			
	5	472	0.15	1	895	0.28						
	2	1190	0.37									
	1	2159	0.67									
Smallmouth	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05
	9	177	0.05	2	177	0.05						
	2	472	0.15	1	472	0.15						
	1	1190	0.37									
Largemouth	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05
Wh. Crappie	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05
	66	177	0.05	27	177	0.05	9	177	0.05	1	177	0.05
	47	472	0.15	14	472	0.15	2	472	0.15			
	27	895	0.28	4	895	0.28	1	895	0.28			
	14	1190	0.37	2	1190	0.37						
	5	1454	0.45	1	2159	0.67						
	4	1895	0.59									
	1	2944	0.91									
Walleye	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05
	66	177	0.05	36	177	0.05	14	177	0.05	4	177	0.05
	47	472	0.15	19	472	0.15	9	472	0.15	2	472	0.15
	36	895	0.28	14	895	0.28	4	895	0.28	1	895	0.28
	19	1190	0.37	5	1190	0.37	1	2159	0.67			
	9	2159	0.67	4	2159	0.67						
	4	2944	0.91	1	3519	1.09						
	2	4224	1.31									
	1	6705	2.08									

(continued)

Table 3-1

Continued.

SEPTEMBER RIS	0			1			2			3		
	% T	Ac-ft	% P	% T	Ac-ft	% P	% T	Ac-ft	% P	% T	Ac-ft	% P
Gizz shad	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05
	9	177	0.05									
	1	472	0.15									
Spotfin	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05
	37	177	0.05	19	177	0.05	6	177	0.05	1	177	0.05
	23	472	0.15	9	472	0.15	2	472	0.15			
	15	895	0.28	4	895	0.28						
	9	1190	0.37	2	1190	0.37						
	3	2159	0.67									
	1	2599	0.81									
Bluntnose	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05
Ch Catfish	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05
Bluegill	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05
	3	177	0.05	1	177	0.05						
	2	472	0.15									
Smallmouth	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05
	3	177	0.05									
Largemouth	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05
Wh. Crappie	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05
	23	177	0.05	9	177	0.05	3	177	0.05			
	15	472	0.15	4	472	0.15						
	9	895	0.28	1	895	0.28						
	4	1190	0.37									
	2	1454	0.45									
	1	1895	0.59									
Walleye	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05
	23	177	0.05	11	177	0.05	4	177	0.05	2	177	0.05
	15	472	0.15	6	472	0.15	3	472	0.15			
	11	895	0.28	4	895	0.28	1	895	0.28			
	6	1190	0.37	2	1190	0.37						
	3	2159	0.67	1	2159	0.67						
	1	2944	0.91									

OCTOBER RIS	0			1			2			3		
	% T	Ac-ft	% P	% T	Ac-ft	% P	% T	Ac-ft	% P	% T	Ac-ft	% P
Gizz shad	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05
Spotfin	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05
	2	177	0.05									
Bluntnose	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05
Ch Catfish	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05
Bluegill	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05
Smallmouth	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05
Largemouth	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05
Wh. Crappie	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05
Walleye	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05	100 *	169	0.05

* Assumes that all RIS will avoid the Berm discharge area 100 % of the time, even though this is not always the case.
%T=percent of time (≥1%) that the corresponding area (acre-ft) may be avoided by an RIS species
%P=percent of the total acre-ft (322,000) in Conowingo Pond

FIGURES

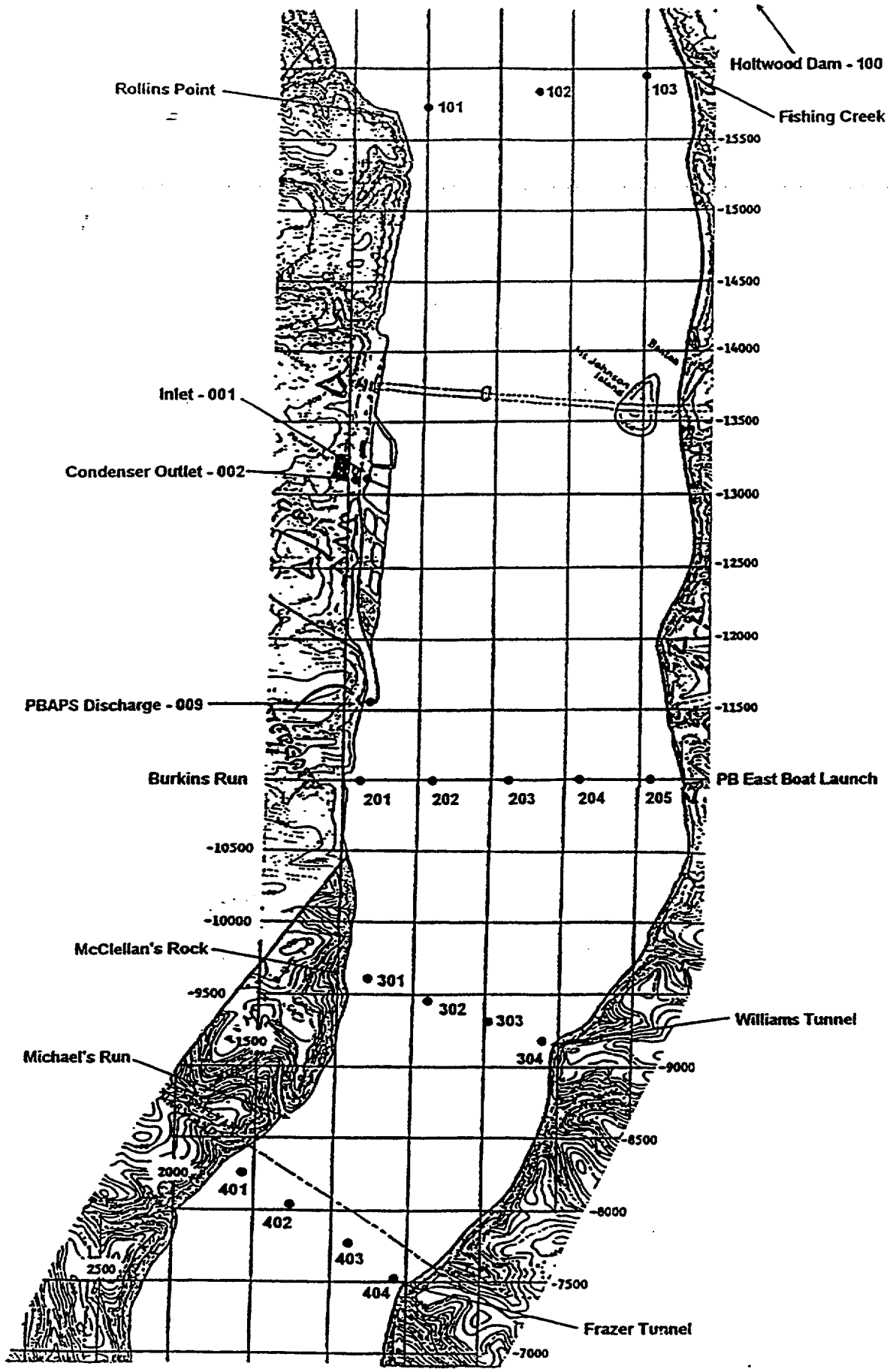


Figure 2-1

Thermal profiling locations in the vicinity of PBAPS.

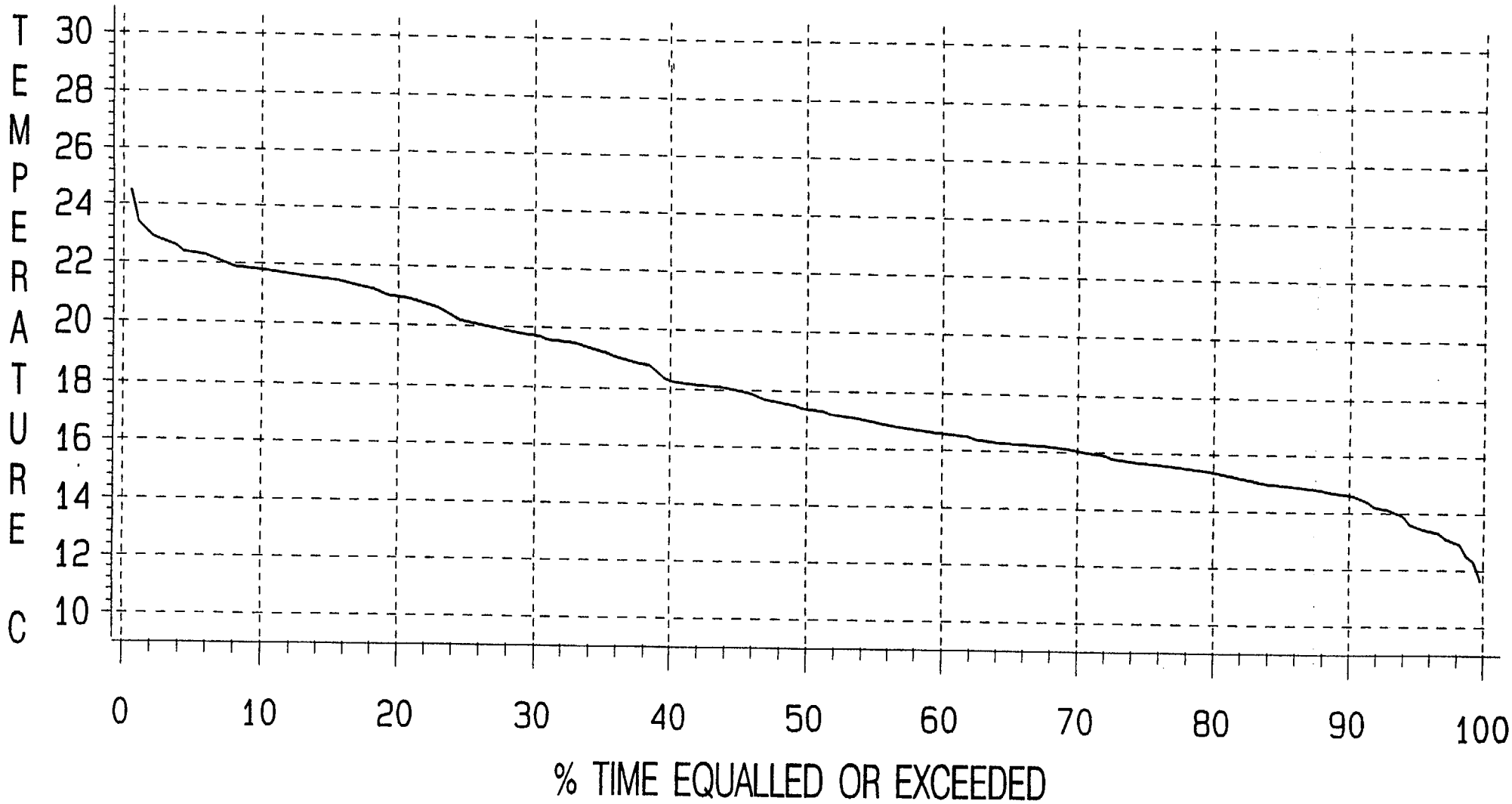


Figure 2–2.
Duration of daily average intake temperatures (°C) at PBAPS, May 1956 to 1999.

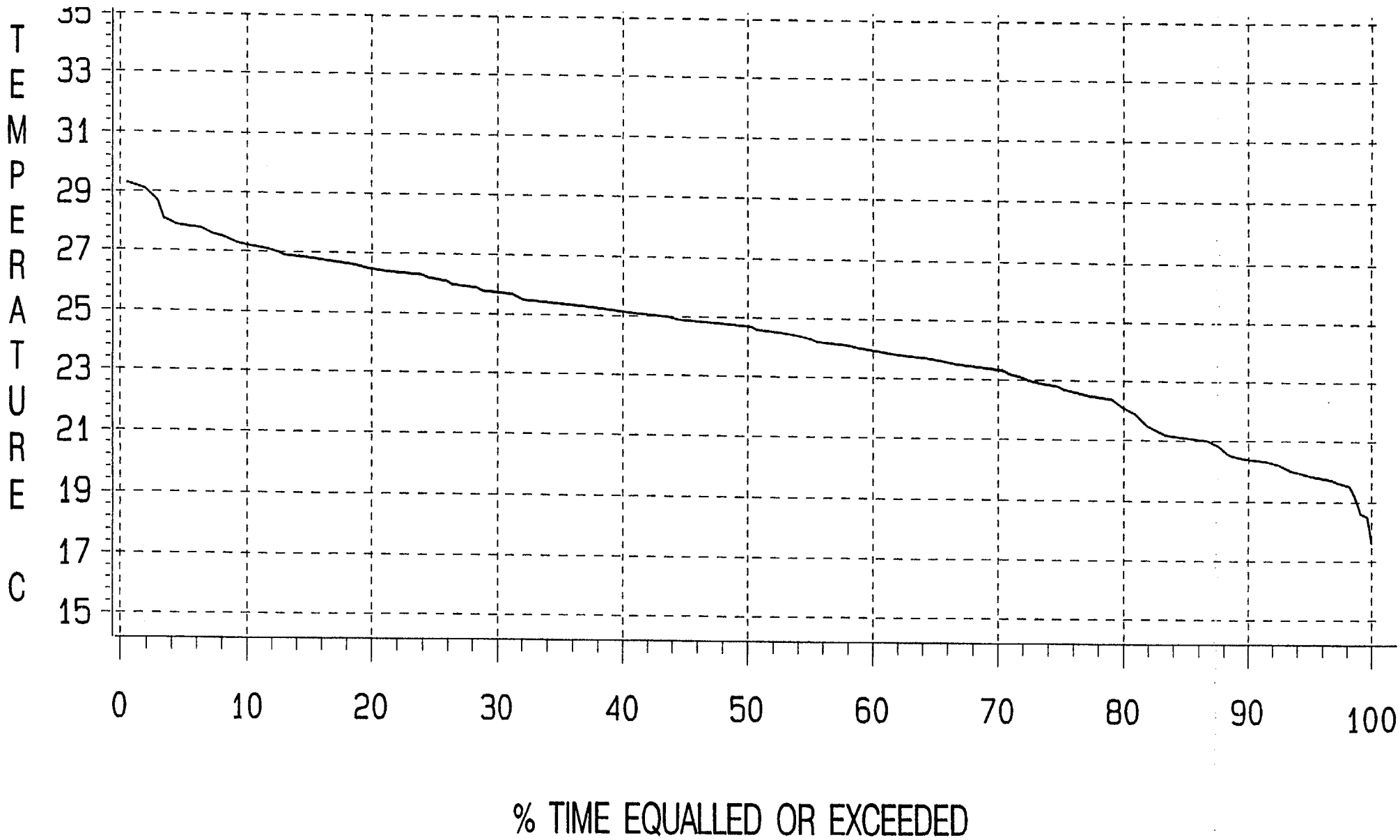


Figure 2–3.
Duration of daily average intake temperatures (°C) at PBAPS, June 1956 to 1999.

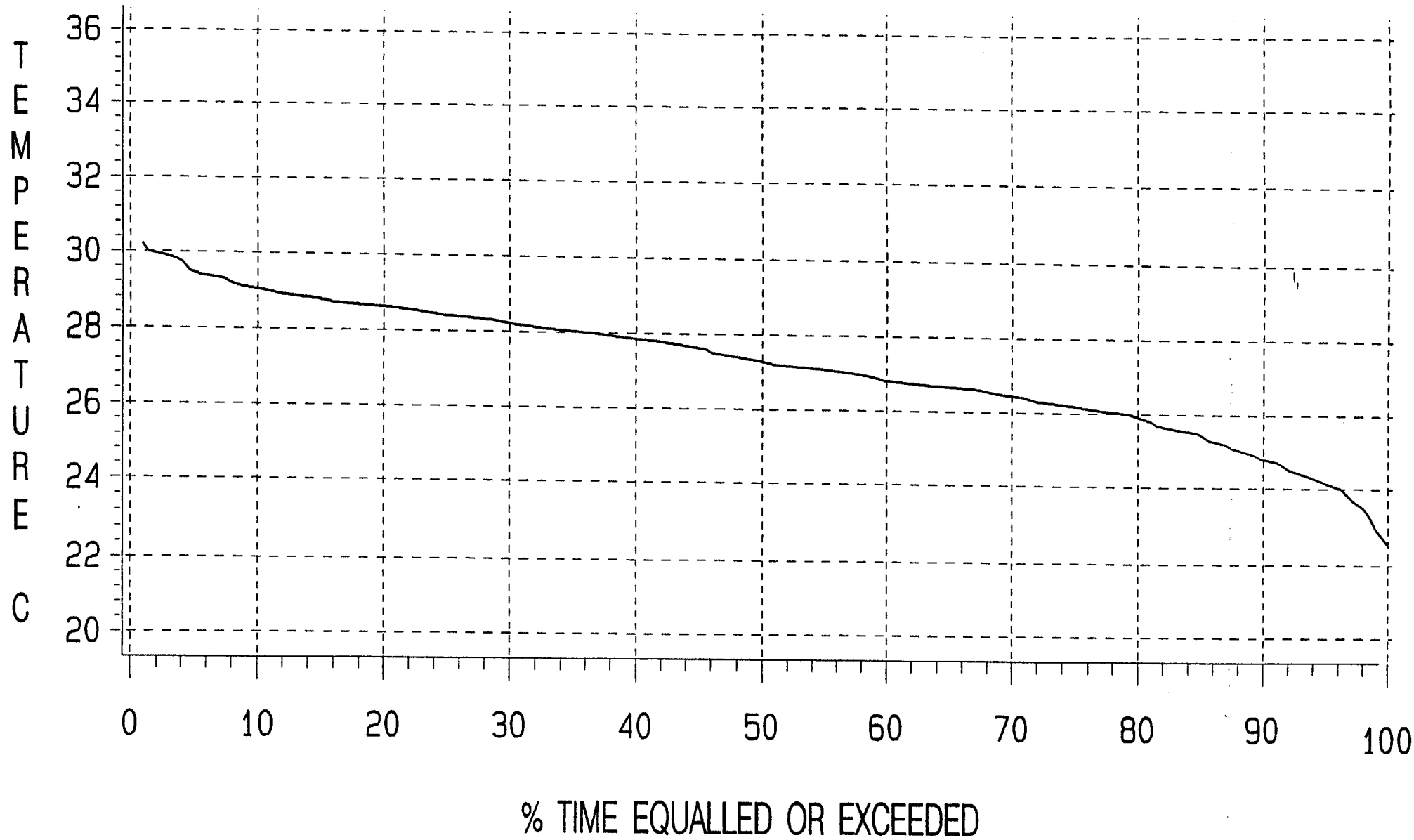


Figure 2–4.

Duration of daily average intake temperatures (°C) at PBAPS, July 1956 to 1999.

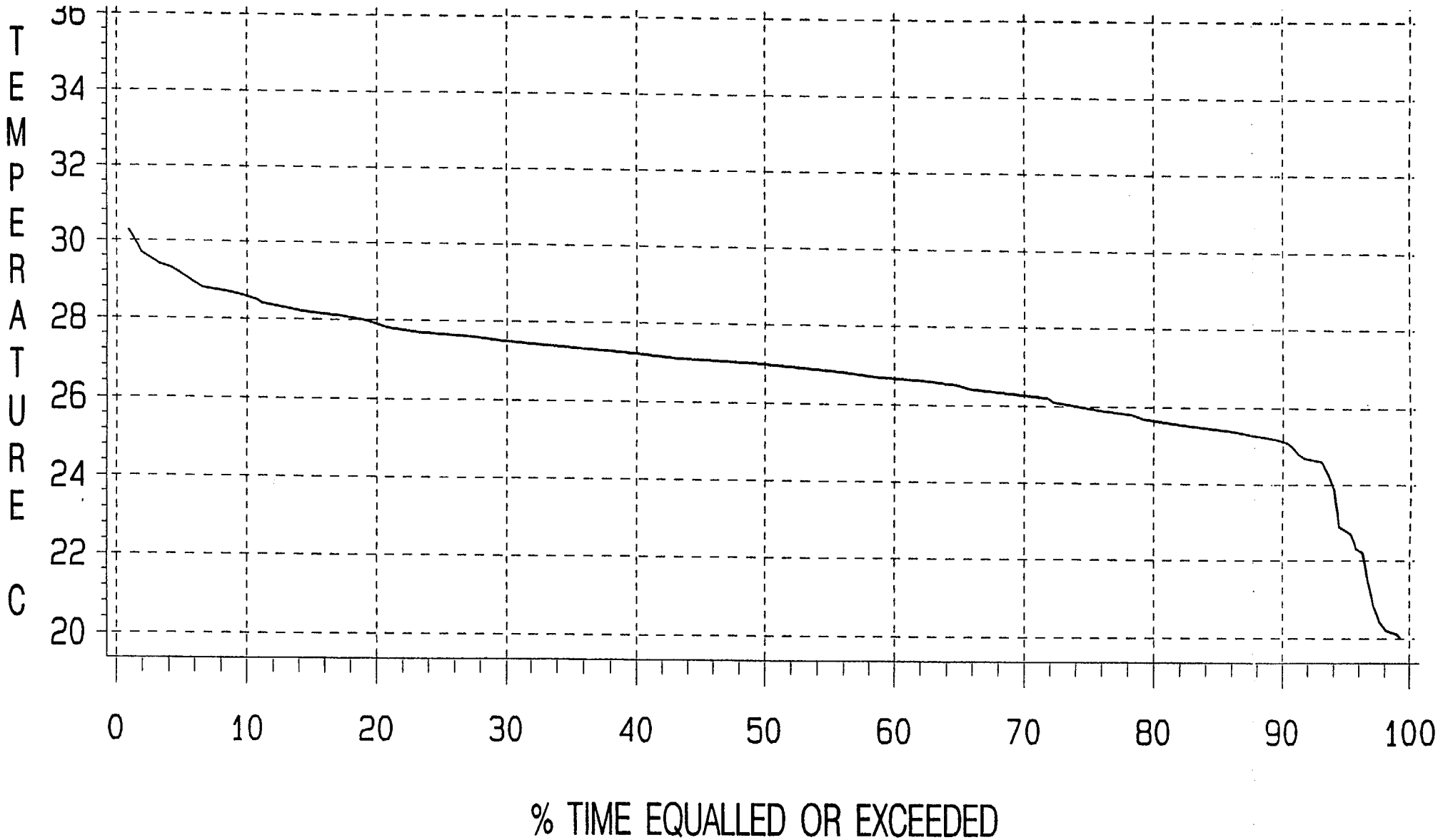


Figure 2–5.
Duration of daily average intake temperatures (°C) at PBAPS, August 1956 to 1999.

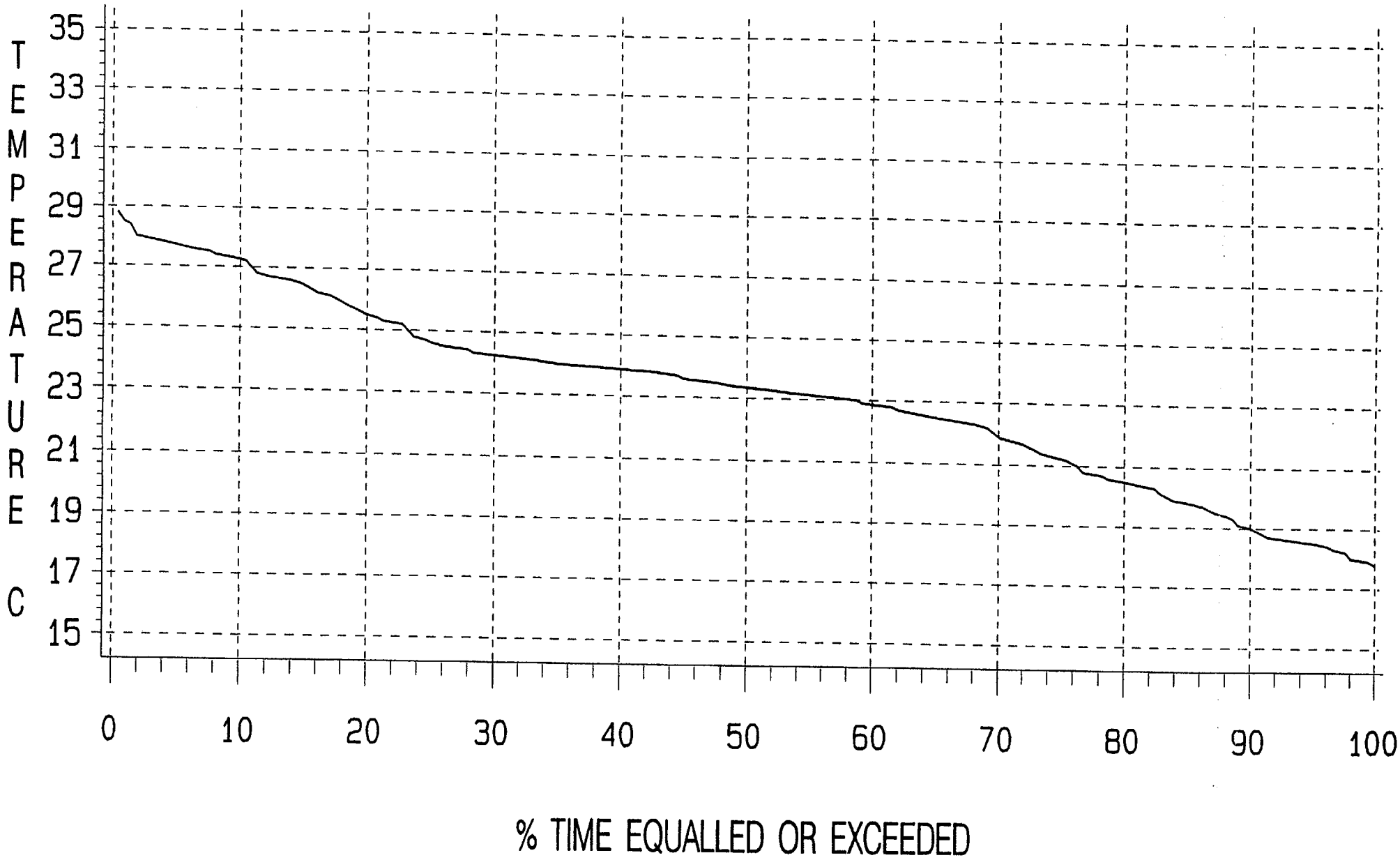


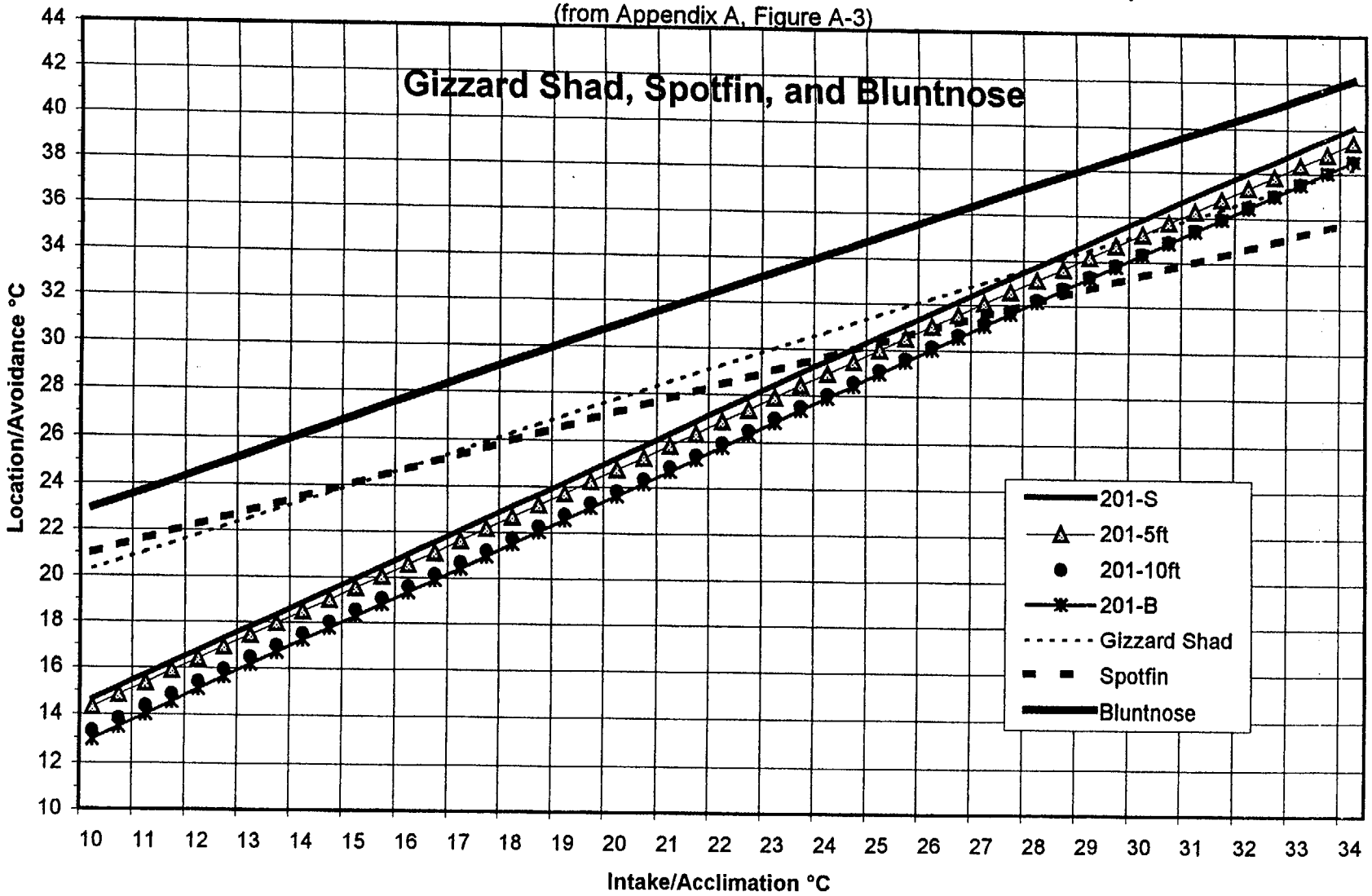
Figure 2-6.

Duration of daily average intake temperatures (oC) at PBAPS. September 1956 to 1999.

Figure 2–7.

Duration of daily average intake temperatures (°C) at PBAPS, October 1956 to 1999.

Figure 2-8
Relationship of Station 201 versus Avoidance Temperature °C at 0 Tower Operation
(from Appendix A, Figure A-3)



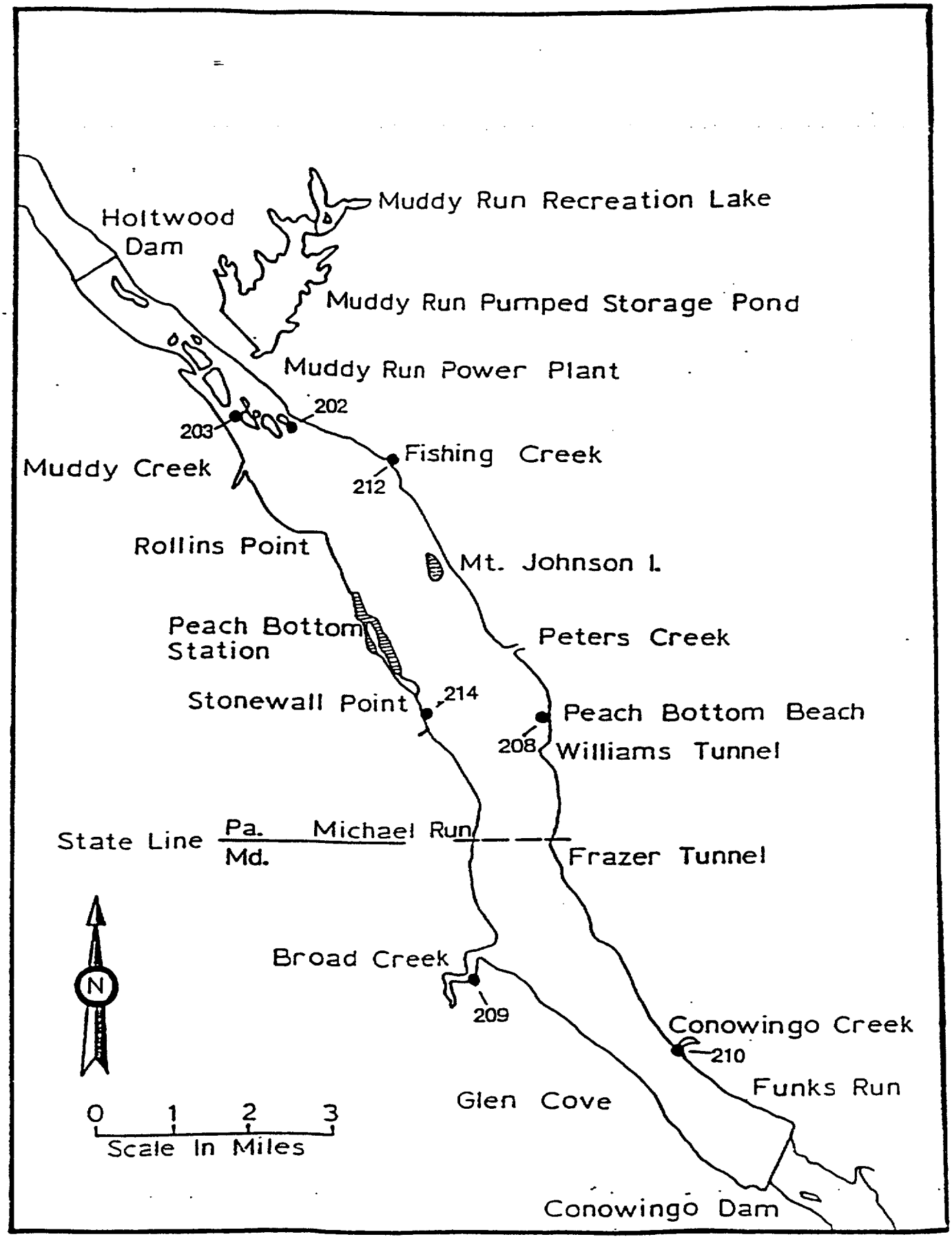


Figure 3-1

Map of Conowingo Pond showing distribution of seine stations.

APPENDIX A

Table A-1

RIS Avoidance Temperature (°C) at known Acclimation / Ambient Intake Temperature (°C) *
Highlighted column for spotfin shiner discussed as example calculation in Section 2.1.

Acclimation/ Ambient°C	Gizzard shad	Spotfin shiner	Bluntnose minnow	Channel catfish	Bluegill	Smallmouth bass	Largemouth bass	White crappie	Walleye
10.0	20.3	21.0	22.9	21.7	27.6	25.2	23.9	21.4	24.8
10.5	20.7	21.3	23.3	22.1	27.8	25.5	24.2	21.7	25.0
11.0	21.0	21.6	23.7	22.5	27.9	25.8	24.5	22.1	25.2
11.5	21.4	21.9	24.1	22.8	28.1	26.0	24.8	22.4	25.4
12.0	21.8	22.2	24.5	23.2	28.3	26.3	25.1	22.7	25.6
12.5	22.2	22.5	24.9	23.6	28.5	26.5	25.4	23.0	25.8
13.0	22.5	22.8	25.3	23.9	28.7	26.8	25.8	23.3	26.0
13.5	22.9	23.2	25.7	24.3	28.9	27.0	26.1	23.6	26.3
14.0	23.3	23.5	26.1	24.7	29.1	27.3	26.4	23.9	26.5
14.5	23.7	23.8	26.5	25.0	29.3	27.5	26.7	24.2	26.7
15.0	24.0	24.1	26.9	25.4	29.5	27.8	27.0	24.5	26.9
15.5	24.4	24.4	27.3	25.8	29.7	28.0	27.3	24.8	27.1
16.0	24.8	24.7	27.7	26.2	29.8	28.3	27.6	25.2	27.3
16.5	25.1	25.0	28.1	26.5	30.0	28.6	27.9	25.5	27.5
17.0	25.5	25.3	28.5	26.9	30.2	28.8	28.2	25.8	27.7
17.5	25.9	25.6	28.9	27.3	30.4	29.1	28.5	26.1	27.9
18.0	26.3	25.9	29.3	27.6	30.6	29.3	28.9	26.4	28.1
18.5	26.6	26.3	29.7	28.0	30.8	29.6	29.2	26.7	28.4
19.0	27.0	26.6	30.1	28.4	31.0	29.8	29.5	27.0	28.6
19.5	27.4	26.9	30.5	28.7	31.2	30.1	29.8	27.3	28.8
20.0	27.8	27.2	30.9	29.1	31.4	30.3	30.1	27.6	29.0
20.5	28.1	27.5	31.3	29.5	31.6	30.6	30.4	27.9	29.2
21.0	28.5	27.8	31.7	29.9	31.7	30.9	30.7	28.3	29.4
21.5	28.9	28.1	32.1	30.2	31.9	31.1	31.0	28.6	29.6
22.0	29.3	28.4	32.5	30.6	32.1	31.4	31.3	28.9	29.8
22.5	29.6	28.7	32.9	31.0	32.3	31.6	31.6	29.2	30.0
23.0	30.0	29.0	33.3	31.3	32.5	31.9	32.0	29.5	30.2
23.5	30.4	29.4	33.7	31.7	32.7	32.1	32.3	29.8	30.5
24.0	30.7	29.7	34.1	32.1	32.9	32.4	32.6	30.1	30.7
24.5	31.1	30.0	34.5	32.4	33.1	32.6	32.9	30.4	30.9
25.0	31.5	30.3	34.9	32.8	33.3	32.9	33.2	30.7	31.1
25.5	31.9	30.6	35.3	33.2	33.5	33.1	33.5	31.0	31.3
26.0	32.2	30.9	35.7	33.6	33.6	33.4	33.8	31.4	31.5
26.5	32.6	31.2	36.1	33.9	33.8	33.7	34.1	31.7	31.7
27.0	33.0	31.5	36.5	34.3	34.0	33.9	34.4	32.0	31.9
27.5	33.4	31.8	*36.9*	34.7	34.2	34.2	34.7	32.3	32.1
28.0	33.7	32.1	*37.3*	35.0	34.4	34.4	35.1	32.6	32.3
28.5	34.1	32.5	*37.7*	35.4	34.6	34.7	35.4	32.9	*32.6*
29.0	34.5	32.8	*38.1*	35.8	34.8	34.9	35.7	33.2	*32.8*
29.5	34.9	33.1	*38.5*	36.1	35.0	35.2	36.0	*33.5*	*33.0*
30.0	35.2	33.4	*38.9*	36.5	35.2	35.4	36.3	*33.8*	*33.2*
30.5	35.6	33.7	*39.3*	36.9	35.4	35.7	36.6	*34.1*	*33.4*
31.0	36.0	34.0	*39.7*	37.3	35.5	36.0	36.9	*34.5*	*33.6*
31.5	36.4	34.3	*40.1*	37.6	35.7	36.2	37.2	*34.8*	*33.8*
32.0	36.7	34.6	*40.5*	38.0	35.9	36.5	37.5	*35.1*	*34.0*
32.5	37.1	34.9	*40.9*	*38.4*	*36.1*	*36.7*	*37.8*	*35.4*	*34.2*
33.0	37.5	35.2	*41.3*	*38.7*	*36.3*	*37.0*	*38.2*	*35.7*	*34.4*
33.5	37.8	35.6	*41.7*	*39.1*	*36.5*	*37.2*	*38.5*	*36.0*	*34.7*
34.0	38.2	35.9	*42.1*	*39.5*	*36.7*	*37.5*	*38.8*	*36.3*	*34.9*

* Based on avoidance regression statistics from Mathur et. al. 1983. (Canadian Journal of Fisheries & Aquatic Sciences, Vol. 40, No.12, p.2144-2152).

Avoidance temps in italics are estimated beyond actual acclimation temps tested.

Table A-2

Estimated Ambient (Intake) Temperature Which Results in RIS Species Avoidance at Location/Depth Downstream of the PBAPS Discharge Canal Outfall at 0, 1, 2, and 3 Tower Operations, May-October. Highlighted column for spotfin shiner discussed as example calculation in Section 2.1.

RIS species		Gizzard shad				Spotfin shiner				Bluntnose minnow	Channel catfish		Bluegill				Smallmouth bass				Largemouth bass			White crappie				Walleye			
Loc	ft	0	1	2	3	0	1	2	3	0-3	0	1-3	0	1	2	3	0	1	2	3	0	1	2-3	0	1	2	3	0	1	2	3
201	Surf	28.0	31.0	33.5	*	24.5	26.5	28.5	30.5	*	32.0	*	29.5	30.5	32.0	33.0	29.5	31.0	32.5	*	31.0	33.0	*	26.0	28.0	29.5	31.5	26.0	27.5	29.0	30.0
	5	30.5	33.0	*	*	26.0	28.0	30.0	32.0	*	34.0	*	30.0	31.5	32.5	*	31.0	32.0	33.5	*	32.5	*	*	27.0	29.0	31.0	33.0	27.0	28.5	29.5	31.0
	10	33.0	*	*	*	28.0	30.0	32.0	33.5	*	*	*	31.5	33.0	*	*	32.0	33.5	*	*	*	*	*	29.0	31.0	33.0	*	28.5	30.0	31.5	32.5
	Bot	33.0	*	*	*	28.0	30.0	32.0	33.5	*	*	*	31.5	33.0	*	*	32.0	33.5	*	*	*	*	*	29.0	31.0	33.0	*	28.5	30.0	31.5	32.5
301	Surf	32.0	*	*	*	27.0	29.0	31.0	33.0	*	*	*	31.0	32.0	33.5	*	31.5	33.0	*	*	33.5	*	*	28.0	30.5	32.0	33.5	27.5	29.0	30.5	32.0
	5	33.5	*	*	*	28.5	31.0	33.0	*	*	*	*	32.0	33.0	*	*	33.0	*	*	*	*	*	*	30.5	32.0	33.5	*	29.5	30.5	32.0	33.5
	10	*	*	*	*	32.0	33.0	*	*	*	*	*	33.5	*	*	*	*	*	*	*	*	*	*	32.5	*	*	*	31.0	32.5	33.5	*
	Bot	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
302	Surf	*	*	*	*	29.5	31.0	33.0	*	*	*	*	32.0	33.5	*	*	33.0	*	*	*	*	*	*	30.0	32.0	33.5	*	29.5	30.5	32.0	33.0
	5	*	*	*	*	30.5	32.5	*	*	*	*	*	33.0	*	*	*	33.5	*	*	*	*	*	*	31.5	33.0	*	*	30.5	31.5	33.0	*
	10	*	*	*	*	33.5	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	32.0	33.5	*	*
	Bot	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	33.5	*	*	*
303	Surf	*	*	*	*	31.0	33.0		*	*	*	*	33.0	*	*	*	*	*	*	*	*	*	*	32.0	*	*	*	30.5	32.0	33.5	*
	5	*	*	*	*	31.5	33.0	*	*	*	*	*	33.5	*	*	*	*	*	*	*	*	*	*	32.5	*	*	*	31.0	32.0	33.5	*
	10	*	*	*	*	33.0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	32.0	33.0	*	*
	Bot	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
402	Surf	*	*	*	*	33.5	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	32.0	33.0	*	*
	5	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	32.5	*	*	*
	10	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	32.5	*	*	*
	Bot	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*

* = No avoidance possible; intake temps, which would have resulted in an avoidance temp at location/depth, did not occur historically.

Table A-3

EXCLUSION AREA CALCULATION DATA AND INFORMATION

(Based on Zero Tower Operations 1996 through 1999)

Avoidance Area (Acres) Determination for Affected Locations

Includes the acreage from the Berm to the location where an avoidance temp occurred plus ~one-half the area (where appropriate) between the avoided location and the next sampled stations (immediately east and downstream) where avoidance temperatures were not readily apparent.

Affected acreage (given below) was estimated using a grid map of the study area in Conowingo Pond (Figure 3-1 in the report).

	Surface Acres	
	At Location	Running total
If No avoidance at Station 201, the exclusion area = the Berm =	13	13
If avoidance temperature occurred at **201**, the exclusion area =	59 *	59 *
If avoidance temperature occurred at **301**, the exclusion area =	141	200
If avoidance temperature occurred at **302**, the exclusion area =	88	288
If avoidance temperature occurred at **303**, the exclusion area =	115	403
If avoidance temperature occurred at **402**, the exclusion area =	518	921

* includes the Berm area

Avoidance Acre-feet Determination for Affected Locations

Location depths for subsequent calculations were as follows:

Surface (S) includes depths of 0 to 3 ft
5-ft (5) includes depths 0 to 8 ft
10-ft (10) includes depths 0-12 ft if ≤15 ft; otherwise 0 to 13 ft
Bottom (B) uses the mean depth at location

Estimated acre-feet by depth and affected location :

Acre-feet (By location alone)

Depth (ft)	Berm	At 201 *	At 301	At 302	At 303	At 402
Surface	39	177	423	264	345	1554
5-ft	104	472	1128	704	920	4144
10-ft	156	708	1833	1056	1495	6734
Bottom	169	767	2820	1320	1840	10878
	* Includes Berm acre-ft					
Ave Depth	13 ft	13 ft	20 ft	15 ft	16 ft	21 ft

Example: If avoidance temperatures for a given RIS are exceeded at all depths at 201; surface, 5 and 10 ft at 301; and surface at 302, the exclusion area would = 2864 acre-ft as shown below:

Acre-ft = (767 acre-ft for 201-S to B) + (1833 acre-ft for 301-S to 10-ft) + (264 acre-ft for 302-S) = 2864

Estimated % of the total Pond acre-feet by depth and affected location:

% Pond Acre-ft (Pond = 322,000 acre-ft) *

Depth (ft)	Berm	At 201	At 301	At 302	At 303	At 402
Surface	0.01	0.05	0.13	0.08	0.11	0.48
5-ft	0.03	0.15	0.35	0.22	0.29	1.29
10-ft	0.05	0.22	0.57	0.33	0.46	2.09
Bottom	0.05	0.24	0.88	0.41	0.57	3.38

* from Moyer and Raney, 1969 (ASCE Meeting Preprint #834)

Table A-4

Estimated Temperatures (°C) at End of Berm and at Depth (ft) at Station 201 versus 0, 1, 2, and 3 Tower Operations and known Ambient (Intake) Temperature

0 Tower Intake C	0 Tower Berm °C	1 Tower Berm °C	2 Tower Berm °C	3 Tower Berm °C	4 Tower Berm °C	0 Tower 201-S	0 Tower 201-5ft	0 Tower 201-10ft	0 Tower 201-B	1 Tower 201-S	1 Tower 201-5ft	1 Tower 201-10ft	1 Tower 201-B	2 Tower 201-S	2 Tower 201-5ft	2 Tower 201-10ft	2 Tower 201-B	3 Tower 201-S	3 Tower 201-5ft	3 Tower 201-10ft	3 Tower 201-B
10	19.9	19.1	18.2	17.4	16.6	14.6	14.3	13.3	12.9	13.8	13.5	12.4	12.1	12.9	12.6	11.6	11.2	12.0	11.8	10.7	10.3
10.5	20.4	19.6	18.7	17.9	17.1	15.2	14.8	13.8	13.5	14.3	14.0	13.0	12.6	13.4	13.1	12.1	11.7	12.6	12.3	11.2	10.9
11	20.9	20.1	19.3	18.4	17.6	15.7	15.3	14.3	14.0	14.8	14.5	13.5	13.1	14.0	13.6	12.6	12.3	13.1	12.8	11.8	11.4
11.5	21.4	20.6	19.8	18.9	18.1	16.2	15.9	14.9	14.5	15.4	15.0	14.0	13.7	14.5	14.2	13.2	12.8	13.6	13.3	12.3	11.9
12	21.9	21.1	20.3	19.4	18.6	16.7	16.4	15.4	15.1	15.9	15.5	14.5	14.2	15.0	14.7	13.7	13.3	14.2	13.8	12.8	12.5
12.5	22.5	21.6	20.8	20.0	19.1	17.3	16.9	15.9	15.6	16.4	16.1	15.1	14.7	15.6	15.2	14.2	13.9	14.7	14.4	13.4	13.0
13	23.0	22.1	21.3	20.5	19.6	17.8	17.4	16.4	16.1	16.9	16.6	15.6	15.3	16.1	15.7	14.7	14.4	15.2	14.9	13.9	13.5
13.5	23.5	22.6	21.8	21.0	20.1	18.3	18.0	17.0	16.7	17.5	17.1	16.1	15.8	16.6	16.3	15.3	14.9	15.7	15.4	14.4	14.1
14	24.0	23.2	22.3	21.5	20.7	18.9	18.5	17.5	17.2	18.0	17.6	16.6	16.3	17.1	16.8	15.8	15.5	16.3	15.9	14.9	14.6
14.5	24.5	23.7	22.8	22.0	21.2	19.4	19.0	18.0	17.7	18.5	18.2	17.2	16.9	17.7	17.3	16.3	16.0	16.8	16.5	15.5	15.1
15	25.0	24.2	23.3	22.5	21.7	19.9	19.5	18.6	18.3	19.1	18.7	17.7	17.4	18.2	17.8	16.8	16.5	17.3	17.0	16.0	15.7
15.5	25.5	24.7	23.9	23.0	22.2	20.5	20.1	19.1	18.8	19.6	19.2	18.2	17.9	18.7	18.4	17.4	17.1	17.9	17.5	16.5	16.2
16	26.0	25.2	24.4	23.5	22.7	21.0	20.6	19.6	19.4	20.1	19.7	18.8	18.5	19.3	18.9	17.9	17.6	18.4	18.0	17.0	16.7
16.5	26.5	25.7	24.9	24.1	23.2	21.5	21.1	20.1	19.9	20.7	20.2	19.3	19.0	19.8	19.4	18.4	18.1	18.9	18.5	17.6	17.3
17	27.1	26.2	25.4	24.6	23.7	22.1	21.6	20.7	20.4	21.2	20.8	19.8	19.6	20.3	19.9	18.9	18.7	19.5	19.1	18.1	17.8
17.5	27.6	26.7	25.9	25.1	24.2	22.6	22.1	21.2	21.0	21.7	21.3	20.3	20.1	20.9	20.4	19.5	19.2	20.0	19.6	18.6	18.3
18	28.1	27.3	26.4	25.6	24.8	23.1	22.7	21.7	21.5	22.3	21.8	20.9	20.6	21.4	21.0	20.0	19.8	20.5	20.1	19.1	18.9
18.5	28.6	27.8	26.9	26.1	25.3	23.6	23.2	22.2	22.0	22.8	22.3	21.4	21.2	21.9	21.5	20.5	20.3	21.1	20.6	19.7	19.4
19	29.1	28.3	27.4	26.6	25.8	24.2	23.7	22.8	22.6	23.3	22.9	21.9	21.7	22.4	22.0	21.1	20.8	21.6	21.2	20.2	20.0
19.5	29.6	28.8	28.0	27.1	26.3	24.7	24.2	23.3	23.1	23.8	23.4	22.4	22.2	23.0	22.5	21.6	21.4	22.1	21.7	20.7	20.5
20	30.1	29.3	28.5	27.6	26.8	25.2	24.8	23.8	23.6	24.4	23.9	23.0	22.8	23.5	23.1	22.1	21.9	22.6	22.2	21.3	21.0
20.5	30.6	29.8	29.0	28.1	27.3	25.8	25.3	24.3	24.2	24.9	24.4	23.5	23.3	24.0	23.6	22.6	22.4	23.2	22.7	21.8	21.6
21	31.2	30.3	29.5	28.7	27.8	26.3	25.8	24.9	24.7	25.4	25.0	24.0	23.8	24.6	24.1	23.2	23.0	23.7	23.3	22.3	22.1
21.5	31.7	30.8	30.0	29.2	28.3	26.8	26.3	25.4	25.2	26.0	25.5	24.5	24.4	25.1	24.6	23.7	23.5	24.2	23.8	22.8	22.6
22	32.2	31.3	30.5	29.7	28.8	27.4	26.8	25.9	25.8	26.5	26.0	25.1	24.9	25.6	25.1	24.2	24.0	24.8	24.3	23.4	23.2
22.5	32.7	31.9	31.0	30.2	29.4	27.9	27.4	26.5	26.3	27.0	26.5	25.6	25.4	26.2	25.7	24.7	24.6	25.3	24.8	23.9	23.7
23	33.2	32.4	31.5	30.7	29.9	28.4	27.9	27.0	26.8	27.6	27.0	26.1	26.0	26.7	26.2	25.3	25.1	25.8	25.3	24.4	24.2
23.5	33.7	32.9	32.0	31.2	30.4	29.0	28.4	27.5	27.4	28.1	27.6	26.7	26.5	27.2	26.7	25.8	25.6	26.4	25.9	24.9	24.8
24	34.2	33.4	32.6	31.7	30.9	29.5	28.9	28.0	27.9	28.6	28.1	27.2	27.0	27.8	27.2	26.3	26.2	26.9	26.4	25.5	25.3
24.5	34.7	33.9	33.1	32.2	31.4	30.0	29.5	28.6	28.4	29.1	28.6	27.7	27.6	28.3	27.8	26.8	26.7	27.4	26.9	26.0	25.8
25	35.2	34.4	33.6	32.8	31.9	30.5	30.0	29.1	29.0	29.7	29.1	28.2	28.1	28.8	28.3	27.4	27.2	28.0	27.4	26.5	26.4
25.5	35.8	34.9	34.1	33.3	32.4	31.1	30.5	29.6	29.5	30.2	29.7	28.8	28.6	29.3	28.8	27.9	27.8	28.5	28.0	27.0	26.9
26	36.3	35.4	34.6	33.8	32.9	31.6	31.0	30.1	30.0	30.7	30.2	29.3	29.2	29.9	29.3	28.4	28.3	29.0	28.5	27.6	27.4
26.5	36.8	36.0	35.1	34.3	33.5	32.1	31.6	30.7	30.6	31.3	30.7	29.8	29.7	30.4	29.9	29.0	28.8	29.5	29.0	28.1	28.0
27	37.3	36.5	35.6	34.8	34.0	32.7	32.1	31.2	31.1	31.8	31.2	30.3	30.2	30.9	30.4	29.5	29.4	30.1	29.5	28.6	28.5
27.5	37.8	37.0	36.1	35.3	34.5	33.2	32.6	31.7	31.6	32.3	31.7	30.9	30.8	31.5	30.9	30.0	29.9	30.6	30.0	29.2	29.0
28	38.3	37.5	36.7	35.8	35.0	33.7	33.1	32.2	32.2	32.9	32.3	31.4	31.3	32.0	31.4	30.5	30.4	31.1	30.6	29.7	29.6
28.5	38.8	38.0	37.2	36.3	35.5	34.3	33.6	32.8	32.7	33.4	32.8	31.9	31.8	32.5	31.9	31.1	31.0	31.7	31.1	30.2	30.1
29	39.3	38.5	37.7	36.8	36.0	34.8	34.2	33.3	33.2	33.9	33.3	32.4	32.4	33.1	32.5	31.6	31.5	32.2	31.6	30.7	30.6
29.5	39.9	39.0	38.2	37.4	36.5	35.3	34.7	33.8	33.8	34.5	33.8	33.0	32.9	33.6	33.0	32.1	32.0	32.7	32.1	31.3	31.2
30	40.4	39.5	38.7	37.9	37.0	35.8	35.2	34.4	34.3	35.0	34.4	33.5	33.4	34.1	33.5	32.6	32.6	33.3	32.7	31.8	31.7
30.5	40.9	40.0	39.2	38.4	37.5	36.4	35.7	34.9	34.8	35.5	34.9	34.0	34.0	34.7	34.0	33.2	33.1	33.8	33.2	32.3	32.2
31	41.4	40.6	39.7	38.9	38.1	36.9	36.3	35.4	35.4	36.0	35.4	34.5	34.5	35.2	34.6	33.7	33.6	34.3	33.7	32.8	32.8
31.5	41.9	41.1	40.2	39.4	38.6	37.4	36.8	35.9	35.9	36.6	35.9	35.1	35.0	35.7	35.1	34.2	34.2	34.9	34.2	33.4	33.3
32	42.4	41.6	40.7	39.9	39.1	38.0	37.3	36.5	36.4	37.1	36.5	35.6	35.6	36.2	35.6	34.7	34.7	35.4	34.8	33.9	33.8
32.5	42.9	42.1	41.3	40.4	39.6	38.5	37.8	37.0	37.0	37.6	37.0	36.1	36.1	36.8	36.1	35.3	35.2	35.9	35.3	34.4	34.4
33	43.4	42.6	41.8	40.9	40.1	39.0	38.3	37.5	37.5	38.2	37.5	36.7	36.6	37.3	36.6	35.8	35.8	36.4	35.8	34.9	34.9
33.5	43.9	43.1	42.3	41.5	40.6	39.6	38.9	38.0	38.0	38.7	38.0	37.2	37.2	37.8	37.2	36.3	36.3	37.0	36.3	35.5	35.4
34	44.5	43.6	42.8	42.0	41.1	40.1	39.4	38.6	38.6	39.2	38.5	37.7	37.7	38.4	37.7	36.9	36.8	37.5	36.8	36.0	36.0

Table A-5

Estimated Temperatures (°C) at End of Berm and at Depth (ft) at Station 301 versus 0, 1, 2, and 3 Tower Operations and known Ambient (Intake) Temperature

0 Tower Intake C	0 Tower Berm °C	1 Tower Berm °C	2 Tower Berm °C	3 Tower Berm °C	0 Tower 301-S	0 Tower 301-5ft	0 Tower 301-10ft	0 Tower 301-B	1 Tower 301-S	1 Tower 301-5ft	1 Tower 301-10ft	1 Tower 301-B	2 Tower 301-S	2 Tower 301-5ft	2 Tower 301-10ft	2 Tower 301-B	3 Tower 301-S	3 Tower 301-5ft	3 Tower 301-10ft	3 Tower 301-B
10	19.9	19.1	18.2	17.4	13.8	11.4	11.2	11.3	13.0	10.5	10.3	10.5	12.1	9.6	9.5	9.8	11.3	8.7	8.6	9.0
10.5	20.4	19.6	18.7	17.9	14.4	11.9	11.7	11.8	13.5	11.0	10.9	11.0	12.7	10.1	10.0	10.2	11.8	9.2	9.1	9.5
11	20.9	20.1	19.3	18.4	14.9	12.5	12.3	12.3	14.0	11.6	11.4	11.5	13.2	10.7	10.5	10.7	12.3	9.8	9.7	9.9
11.5	21.4	20.6	19.8	18.9	15.4	13.1	12.8	12.7	14.5	12.1	11.9	12.0	13.7	11.2	11.1	11.2	12.9	10.3	10.2	10.4
12	21.9	21.1	20.3	19.4	15.9	13.6	13.3	13.2	15.1	12.7	12.5	12.4	14.2	11.8	11.6	11.7	13.4	10.9	10.7	10.9
12.5	22.5	21.6	20.8	20.0	16.4	14.2	13.9	13.7	15.6	13.3	13.0	12.9	14.7	12.4	12.1	12.1	13.9	11.4	11.3	11.4
13	23.0	22.1	21.3	20.5	17.0	14.7	14.4	14.2	16.1	13.8	13.5	13.4	15.3	12.9	12.7	12.6	14.4	12.0	11.8	11.8
13.5	23.5	22.6	21.8	21.0	17.5	15.3	14.9	14.6	16.6	14.4	14.1	13.9	15.8	13.5	13.2	13.1	14.9	12.6	12.3	12.3
14	24.0	23.2	22.3	21.5	18.0	15.9	15.5	15.1	17.2	14.9	14.6	14.3	16.3	14.0	13.7	13.6	15.5	13.1	12.9	12.8
14.5	24.5	23.7	22.8	22.0	18.5	16.4	16.0	15.6	17.7	15.5	15.1	14.8	16.8	14.6	14.3	14.0	16.0	13.7	13.4	13.3
15	25.0	24.2	23.3	22.5	19.0	17.0	16.5	16.1	18.2	16.1	15.7	15.3	17.4	15.2	14.8	14.5	16.5	14.2	13.9	13.7
15.5	25.5	24.7	23.9	23.0	19.6	17.5	17.1	16.5	18.7	16.6	16.2	15.8	17.9	15.7	15.3	15.0	17.0	14.8	14.5	14.2
16	26.0	25.2	24.4	23.5	20.1	18.1	17.6	17.0	19.2	17.2	16.7	16.2	18.4	16.3	15.9	15.5	17.5	15.4	15.0	14.7
16.5	26.5	25.7	24.9	24.1	20.6	18.7	18.1	17.5	19.8	17.7	17.3	16.7	18.9	16.8	16.4	16.0	18.1	15.9	15.5	15.2
17	27.1	26.2	25.4	24.6	21.1	19.2	18.7	18.0	20.3	18.3	17.8	17.2	19.4	17.4	16.9	16.4	18.6	16.5	16.1	15.7
17.5	27.6	26.7	25.9	25.1	21.7	19.8	19.2	18.5	20.8	18.9	18.3	17.7	20.0	18.0	17.5	16.9	19.1	17.0	16.6	16.1
18	28.1	27.3	26.4	25.6	22.2	20.3	19.7	18.9	21.3	19.4	18.9	18.2	20.5	18.5	18.0	17.4	19.6	17.6	17.1	16.6
18.5	28.6	27.8	26.9	26.1	22.7	20.9	20.3	19.4	21.8	20.0	19.4	18.6	21.0	19.1	18.5	17.9	20.2	18.2	17.7	17.1
19	29.1	28.3	27.4	26.6	23.2	21.5	20.8	19.9	22.4	20.5	19.9	19.1	21.5	19.6	19.1	18.3	20.7	18.7	18.2	17.6
19.5	29.6	28.8	28.0	27.1	23.7	22.0	21.3	20.4	22.9	21.1	20.5	19.6	22.0	20.2	19.6	18.8	21.2	19.3	18.7	18.0
20	30.1	29.3	28.5	27.6	24.3	22.6	21.9	20.8	23.4	21.7	21.0	20.1	22.6	20.8	20.1	19.3	21.7	19.8	19.3	18.5
20.5	30.6	29.8	29.0	28.1	24.8	23.1	22.4	21.3	23.9	22.2	21.5	20.5	23.1	21.3	20.7	19.8	22.2	20.4	19.8	19.0
21	31.2	30.3	29.5	28.7	25.3	23.7	23.0	21.8	24.5	22.8	22.1	21.0	23.6	21.9	21.2	20.2	22.8	21.0	20.3	19.5
21.5	31.7	30.8	30.0	29.2	25.8	24.3	23.5	22.3	25.0	23.3	22.6	21.5	24.1	22.4	21.7	20.7	23.3	21.5	20.9	19.9
22	32.2	31.3	30.5	29.7	26.3	24.8	24.0	22.7	25.5	23.9	23.2	22.0	24.7	23.0	22.3	21.2	23.8	22.1	21.4	20.4
22.5	32.7	31.9	31.0	30.2	26.9	25.4	24.6	23.2	26.0	24.5	23.7	22.4	25.2	23.6	22.8	21.7	24.3	22.6	21.9	20.9
23	33.2	32.4	31.5	30.7	27.4	25.9	25.1	23.7	26.5	25.0	24.2	22.9	25.7	24.1	23.4	22.1	24.8	23.2	22.5	21.4
23.5	33.7	32.9	32.0	31.2	27.9	26.5	25.6	24.2	27.1	25.6	24.8	23.4	26.2	24.7	23.9	22.6	25.4	23.8	23.0	21.8
24	34.2	33.4	32.6	31.7	28.4	27.0	26.2	24.6	27.6	26.1	25.3	23.9	26.7	25.2	24.4	23.1	25.9	24.3	23.6	22.3
24.5	34.7	33.9	33.1	32.2	29.0	27.6	26.7	25.1	28.1	26.7	25.8	24.3	27.3	25.8	25.0	23.6	26.4	24.9	24.1	22.8
25	35.2	34.4	33.6	32.8	29.5	28.2	27.2	25.6	28.6	27.3	26.4	24.8	27.8	26.3	25.5	24.0	26.9	25.4	24.6	23.3
25.5	35.8	34.9	34.1	33.3	30.0	28.7	27.8	26.1	29.2	27.8	26.9	25.3	28.3	26.9	26.0	24.5	27.5	26.0	25.2	23.7
26	36.3	35.4	34.6	33.8	30.5	29.3	28.3	26.5	29.7	28.4	27.4	25.8	28.8	27.5	26.6	25.0	28.0	26.6	25.7	24.2
26.5	36.8	36.0	35.1	34.3	31.0	29.8	28.8	27.0	30.2	28.9	28.0	26.3	29.3	28.0	27.1	25.5	28.5	27.1	26.2	24.7
27	37.3	36.5	35.6	34.8	31.6	30.4	29.4	27.5	30.7	29.5	28.5	26.7	29.9	28.6	27.6	26.0	29.0	27.7	26.8	25.2
27.5	37.8	37.0	36.1	35.3	32.1	31.0	29.9	28.0	31.2	30.1	29.0	27.2	30.4	29.1	28.2	26.4	29.5	28.2	27.3	25.7
28	38.3	37.5	36.7	35.8	32.6	31.5	30.4	28.5	31.8	30.6	29.6	27.7	30.9	29.7	28.7	26.9	30.1	28.8	27.8	26.1
28.5	38.8	38.0	37.2	36.3	33.1	32.1	31.0	28.9	32.3	31.2	30.1	28.2	31.4	30.3	29.2	27.4	30.6	29.4	28.4	26.6
29	39.3	38.5	37.7	36.8	33.6	32.6	31.5	29.4	32.8	31.7	30.6	28.6	32.0	30.8	29.8	27.9	31.1	29.9	28.9	27.1
29.5	39.9	39.0	38.2	37.4	34.2	33.2	32.0	29.9	33.3	32.3	31.2	29.1	32.5	31.4	30.3	28.3	31.6	30.5	29.4	27.6
30	40.4	39.5	38.7	37.9	34.7	33.8	32.6	30.4	33.8	32.9	31.7	29.6	33.0	31.9	30.8	28.8	32.1	31.0	30.0	28.0
30.5	40.9	40.0	39.2	38.4	35.2	34.3	33.1	30.8	34.4	33.4	32.2	30.1	33.5	32.5	31.4	29.3	32.7	31.6	30.5	28.5
31	41.4	40.6	39.7	38.9	35.7	34.9	33.6	31.3	34.9	34.0	32.8	30.5	34.0	33.1	31.9	29.8	33.2	32.2	31.0	29.0
31.5	41.9	41.1	40.2	39.4	36.3	35.4	34.2	31.8	35.4	34.5	33.3	31.0	34.6	33.6	32.4	30.2	33.7	32.7	31.6	29.5
32	42.4	41.6	40.7	39.9	36.8	36.0	34.7	32.3	35.9	35.1	33.8	31.5	35.1	34.2	33.0	30.7	34.2	33.3	32.1	29.9
32.5	42.9	42.1	41.3	40.4	37.4	36.6	35.4	33.0	36.6	35.7	34.6	32.2	35.7	34.8	33.7	31.4	34.9	33.9	32.8	30.7
33	43.4	42.6	41.8	40.9	37.9	37.2	36.0	33.5	37.1	36.3	35.1	32.7	36.2	35.4	34.2	31.9	35.4	34.5	33.4	31.1
33.5	43.9	43.1	42.3	41.5	38.5	37.7	36.5	34.0	37.6	36.8	35.7	33.2	36.8	35.9	34.8	32.4	35.9	35.0	33.9	31.6
34	44.5	43.6	42.8	42.0	39.0	38.3	37.1	34.5	38.1	37.4	36.2	33.7	37.3	36.5	35.3	32.9	36.4	35.6	34.4	32.1

Table A-6

Estimated Temperatures (°C) at End of Berm and at Depth (ft) at Station 302 versus 0, 1, 2, and 3 Tower Operations and known Ambient (Intake) Temperature

0 Tower Intake C	0 Tower Berm °C	1 Tower Berm °C	2 Tower Berm °C	3 Tower Berm °C	0 Tower 302-S	0 Tower 302-5ft	0 Tower 302-10ft	0 Tower 302-B	1 Tower 302-S	1 Tower 302-5ft	1 Tower 302-10ft	1 Tower 302-B	2 Tower 302-S	2 Tower 302-5ft	2 Tower 302-10ft	2 Tower 302-B	3 Tower 302-S	3 Tower 302-5ft	3 Tower 302-10ft	3 Tower 302-B
10	19.9	19.1	18.2	17.4	12.1	10.6	11.3	11.1	11.2	9.7	10.4	10.3	10.3	8.8	9.6	9.5	9.4	7.8	8.7	8.6
10.5	20.4	19.6	18.7	17.9	12.6	11.2	11.8	11.6	11.8	10.2	10.9	10.8	10.9	9.3	10.1	10.0	10.0	8.4	9.3	9.1
11	20.9	20.1	19.3	18.4	13.2	11.7	12.3	12.1	12.3	10.8	11.5	11.3	11.4	9.9	10.6	10.5	10.5	9.0	9.8	9.6
11.5	21.4	20.6	19.8	18.9	13.7	12.3	12.8	12.6	12.8	11.4	12.0	11.8	12.0	10.4	11.1	11.0	11.1	9.5	10.3	10.1
12	21.9	21.1	20.3	19.4	14.3	12.8	13.3	13.1	13.4	11.9	12.5	12.3	12.5	11.0	11.7	11.5	11.6	10.1	10.8	10.7
12.5	22.5	21.6	20.8	20.0	14.8	13.4	13.9	13.6	13.9	12.5	13.0	12.8	13.0	11.6	12.2	12.0	12.2	10.7	11.3	11.2
13	23.0	22.1	21.3	20.5	15.4	14.0	14.4	14.1	14.5	13.1	13.5	13.3	13.6	12.1	12.7	12.5	12.7	11.2	11.9	11.7
13.5	23.5	22.6	21.8	21.0	15.9	14.5	14.9	14.6	15.0	13.6	14.1	13.8	14.1	12.7	13.2	13.0	13.2	11.8	12.4	12.2
14	24.0	23.2	22.3	21.5	16.4	15.1	15.4	15.1	15.6	14.2	14.6	14.3	14.7	13.3	13.7	13.5	13.8	12.4	12.9	12.7
14.5	24.5	23.7	22.8	22.0	17.0	15.7	15.9	15.7	16.1	14.7	15.1	14.8	15.2	13.8	14.3	14.0	14.3	12.9	13.4	13.2
15	25.0	24.2	23.3	22.5	17.5	16.2	16.5	16.2	16.6	15.3	15.6	15.3	15.8	14.4	14.8	14.5	14.9	13.5	13.9	13.7
15.5	25.5	24.7	23.9	23.0	18.1	16.8	17.0	16.7	17.2	15.9	16.1	15.8	16.3	15.0	15.3	15.0	15.4	14.0	14.4	14.2
16	26.0	25.2	24.4	23.5	18.6	17.4	17.5	17.2	17.7	16.4	16.6	16.3	16.8	15.5	15.8	15.5	16.0	14.6	15.0	14.7
16.5	26.5	25.7	24.9	24.1	19.2	17.9	18.0	17.7	18.3	17.0	17.2	16.9	17.4	16.1	16.3	16.0	16.5	15.2	15.5	15.2
17	27.1	26.2	25.4	24.6	19.7	18.5	18.5	18.2	18.8	17.6	17.7	17.4	17.9	16.7	16.8	16.5	17.1	15.7	16.0	15.7
17.5	27.6	26.7	25.9	25.1	20.2	19.1	19.0	18.7	19.4	18.1	18.2	17.9	18.5	17.2	17.4	17.0	17.6	16.3	16.5	16.2
18	28.1	27.3	26.4	25.6	20.8	19.6	19.6	19.2	19.9	18.7	18.7	18.4	19.0	17.8	17.9	17.6	18.1	16.9	17.0	16.7
18.5	28.6	27.8	26.9	26.1	21.3	20.2	20.1	19.7	20.5	19.3	19.2	18.9	19.6	18.3	18.4	18.1	18.7	17.4	17.6	17.2
19	29.1	28.3	27.4	26.6	21.9	20.7	20.6	20.2	21.0	19.8	19.8	19.4	20.1	18.9	18.9	18.6	19.2	18.0	18.1	17.7
19.5	29.6	28.8	28.0	27.1	22.4	21.3	21.1	20.7	21.5	20.4	20.3	19.9	20.7	19.5	19.4	19.1	19.8	18.6	18.6	18.2
20	30.1	29.3	28.5	27.6	23.0	21.9	21.6	21.2	22.1	21.0	20.8	20.4	21.2	20.0	20.0	19.6	20.3	19.1	19.1	18.8
20.5	30.6	29.8	29.0	28.1	23.5	22.4	22.2	21.7	22.6	21.5	21.3	20.9	21.7	20.6	20.5	20.1	20.9	19.7	19.6	19.3
21	31.2	30.3	29.5	28.7	24.1	23.0	22.7	22.2	23.2	22.1	21.8	21.4	22.3	21.2	21.0	20.6	21.4	20.2	20.1	19.8
21.5	31.7	30.8	30.0	29.2	24.6	23.6	23.2	22.7	23.7	22.6	22.3	21.9	22.8	21.7	21.5	21.1	21.9	20.8	20.7	20.3
22	32.2	31.3	30.5	29.7	25.1	24.1	23.7	23.2	24.3	23.2	22.9	22.4	23.4	22.3	22.0	21.6	22.5	21.4	21.2	20.8
22.5	32.7	31.9	31.0	30.2	25.7	24.7	24.2	23.8	24.8	23.8	23.4	22.9	23.9	22.9	22.5	22.1	23.0	21.9	21.7	21.3
23	33.2	32.4	31.5	30.7	26.2	25.3	24.7	24.3	25.3	24.3	23.9	23.4	24.5	23.4	23.1	22.6	23.6	22.5	22.2	21.8
23.5	33.7	32.9	32.0	31.2	26.8	25.8	25.3	24.8	25.9	24.9	24.4	23.9	25.0	24.0	23.6	23.1	24.1	23.1	22.7	22.3
24	34.2	33.4	32.6	31.7	27.3	26.4	25.8	25.3	26.4	25.5	24.9	24.4	25.5	24.5	24.1	23.6	24.7	23.6	23.3	22.8
24.5	34.7	33.9	33.1	32.2	27.9	26.9	26.3	25.8	27.0	26.0	25.5	25.0	26.1	25.1	24.6	24.1	25.2	24.2	23.8	23.3
25	35.2	34.4	33.6	32.8	28.4	27.5	26.8	26.3	27.5	26.6	26.0	25.5	26.6	25.7	25.1	24.6	25.8	24.8	24.3	23.8
25.5	35.8	34.9	34.1	33.3	28.9	28.1	27.3	26.8	28.1	27.2	26.5	26.0	27.2	26.2	25.7	25.1	26.3	25.3	24.8	24.3
26	36.3	35.4	34.6	33.8	29.5	28.6	27.9	27.3	28.6	27.7	27.0	26.5	27.7	26.8	26.2	25.7	26.8	25.9	25.3	24.8
26.5	36.8	36.0	35.1	34.3	30.0	29.2	28.4	27.8	29.1	28.3	27.5	27.0	28.3	27.4	26.7	26.2	27.4	26.5	25.8	25.3
27	37.3	36.5	35.6	34.8	30.6	29.8	28.9	28.3	29.7	28.8	28.0	27.5	28.8	27.9	27.2	26.7	27.9	27.0	26.4	25.8
27.5	37.8	37.0	36.1	35.3	31.1	30.3	29.4	28.8	30.2	29.4	28.6	28.0	29.4	28.5	27.7	27.2	28.5	27.6	26.9	26.3
28	38.3	37.5	36.7	35.8	31.7	30.9	29.9	29.3	30.8	30.0	29.1	28.5	29.9	29.1	28.2	27.7	29.0	28.1	27.4	26.9
28.5	38.8	38.0	37.2	36.3	32.2	31.5	30.4	29.8	31.3	30.5	29.6	29.0	30.4	29.6	28.8	28.2	29.6	28.7	27.9	27.4
29	39.3	38.5	37.7	36.8	32.8	32.0	31.0	30.3	31.9	31.1	30.1	29.5	31.0	30.2	29.3	28.7	30.1	29.3	28.4	27.9
29.5	39.9	39.0	38.2	37.4	33.3	32.6	31.5	30.8	32.4	31.7	30.6	30.0	31.5	30.8	29.8	29.2	30.6	29.8	29.0	28.4
30	40.4	39.5	38.7	37.9	33.8	33.1	32.0	31.3	33.0	32.2	31.2	30.5	32.1	31.3	30.3	29.7	31.2	30.4	29.5	28.9
30.5	40.9	40.0	39.2	38.4	34.4	33.7	32.5	31.9	33.5	32.8	31.7	31.0	32.6	31.9	30.8	30.2	31.7	31.0	30.0	29.4
31	41.4	40.6	39.7	38.9	34.9	34.3	33.0	32.4	34.0	33.4	32.2	31.5	33.2	32.4	31.4	30.7	32.3	31.5	30.5	29.9
31.5	41.9	41.1	40.2	39.4	35.5	34.8	33.6	32.9	34.6	33.9	32.7	32.0	33.7	33.0	31.9	31.2	32.8	32.1	31.0	30.4
32	42.4	41.6	40.7	39.9	36.0	35.4	34.1	33.4	35.1	34.5	33.2	32.5	34.2	33.6	32.4	31.7	33.4	32.7	31.5	30.9
32.5	42.9	42.1	41.3	40.4	36.6	36.0	34.6	33.9	35.7	35.1	33.7	33.1	34.8	34.1	32.9	32.2	33.9	33.2	32.1	31.4
33	43.4	42.6	41.8	40.9	37.1	36.5	35.1	34.4	36.2	35.6	34.3	33.6	35.3	34.7	33.4	32.7	34.4	33.8	32.6	31.9
33.5	43.9	43.1	42.3	41.5	37.6	37.1	35.6	34.9	36.8	36.2	34.8	34.1	35.9	35.3	33.9	33.2	35.0	34.3	33.1	32.4
34	44.5	43.6	42.8	42.0	38.2	37.7	36.1	35.4	37.3	36.7	35.3	34.6	36.4	35.8	34.5	33.8	35.5	34.9	33.6	32.9

Table A-7

Estimated Temperatures (°C) at End of Berm and at Depth (ft) at Station 303 versus 0, 1, 2, and 3 Tower Operations and known Ambient (Intake) Temperature

0 Tower Intake C	0 Tower Berm °C	1 Tower Berm °C	2 Tower Berm °C	3 Tower Berm °C	0 Tower 303-S	0 Tower 303-5ft	0 Tower 303-10ft	0 Tower 303-B	1 Tower 303-S	1 Tower 303-5ft	1 Tower 303-10ft	1 Tower 303-B	2 Tower 303-S	2 Tower 303-5ft	2 Tower 303-10ft	2 Tower 303-B	3 Tower 303-S	3 Tower 303-5ft	3 Tower 303-10ft	3 Tower 303-B
10	19.9	19.1	18.2	17.4	11.0	10.6	10.5	10.9	10.1	9.7	9.7	10.1	9.2	8.8	8.8	9.3	8.3	7.9	7.9	8.5
10.5	20.4	19.6	18.7	17.9	11.5	11.2	11.1	11.4	10.6	10.3	10.2	10.6	9.7	9.4	9.3	9.8	8.8	8.5	8.4	9.0
11	20.9	20.1	19.3	18.4	12.1	11.8	11.6	11.9	11.2	10.9	10.7	11.1	10.3	10.0	9.9	10.3	9.4	9.0	9.0	9.5
11.5	21.4	20.6	19.8	18.9	12.6	12.3	12.2	12.4	11.7	11.4	11.3	11.6	10.8	10.5	10.4	10.8	9.9	9.6	9.5	10.0
12	21.9	21.1	20.3	19.4	13.2	12.9	12.7	12.9	12.3	12.0	11.8	12.1	11.4	11.1	10.9	11.3	10.5	10.2	10.1	10.5
12.5	22.5	21.6	20.8	20.0	13.7	13.4	13.2	13.4	12.8	12.5	12.4	12.6	11.9	11.6	11.5	11.8	11.1	10.7	10.6	11.0
13	23.0	22.1	21.3	20.5	14.3	14.0	13.8	13.9	13.4	13.1	12.9	13.1	12.5	12.2	12.0	12.3	11.6	11.3	11.1	11.5
13.5	23.5	22.6	21.8	21.0	14.8	14.5	14.3	14.4	13.9	13.6	13.4	13.6	13.0	12.7	12.6	12.8	12.2	11.8	11.7	12.0
14	24.0	23.2	22.3	21.5	15.4	15.1	14.9	14.9	14.5	14.2	14.0	14.1	13.6	13.3	13.1	13.3	12.7	12.4	12.2	12.5
14.5	24.5	23.7	22.8	22.0	15.9	15.6	15.4	15.4	15.0	14.7	14.5	14.6	14.2	13.8	13.6	13.8	13.3	12.9	12.8	13.0
15	25.0	24.2	23.3	22.5	16.5	16.2	15.9	15.9	15.6	15.3	15.1	15.1	14.7	14.4	14.2	14.3	13.8	13.5	13.3	13.5
15.5	25.5	24.7	23.9	23.0	17.0	16.7	16.5	16.4	16.2	15.8	15.6	15.6	15.3	14.9	14.7	14.8	14.4	14.0	13.8	14.0
16	26.0	25.2	24.4	23.5	17.6	17.3	17.0	16.9	16.7	16.4	16.1	16.1	15.8	15.5	15.3	15.3	14.9	14.6	14.4	14.5
16.5	26.5	25.7	24.9	24.1	18.1	17.8	17.5	17.4	17.3	16.9	16.7	16.6	16.4	16.0	15.8	15.8	15.5	15.1	14.9	15.0
17	27.1	26.2	25.4	24.6	18.7	18.4	18.1	17.9	17.8	17.5	17.2	17.1	16.9	16.6	16.3	16.3	16.0	15.7	15.5	15.5
17.5	27.6	26.7	25.9	25.1	19.3	19.0	18.6	18.4	18.4	18.1	17.8	17.6	17.5	17.2	16.9	16.8	16.6	16.3	16.0	16.0
18	28.1	27.3	26.4	25.6	19.8	19.5	19.2	18.9	18.9	18.6	18.3	18.1	18.0	17.7	17.4	17.3	17.1	16.8	16.5	16.5
18.5	28.6	27.8	26.9	26.1	20.4	20.1	19.7	19.4	19.5	19.2	18.8	18.6	18.6	18.3	18.0	17.8	17.7	17.4	17.1	16.9
19	29.1	28.3	27.4	26.6	20.9	20.6	20.2	19.9	20.0	19.7	19.4	19.1	19.1	18.8	18.5	18.2	18.2	17.9	17.6	17.4
19.5	29.6	28.8	28.0	27.1	21.5	21.2	20.8	20.4	20.6	20.3	19.9	19.6	19.7	19.4	19.0	18.7	18.8	18.5	18.2	17.9
20	30.1	29.3	28.5	27.6	22.0	21.7	21.3	20.9	21.1	20.8	20.4	20.0	20.2	19.9	19.6	19.2	19.3	19.0	18.7	18.4
20.5	30.6	29.8	29.0	28.1	22.6	22.3	21.9	21.3	21.7	21.4	21.0	20.5	20.8	20.5	20.1	19.7	19.9	19.6	19.2	18.9
21	31.2	30.3	29.5	28.7	23.1	22.8	22.4	21.8	22.2	21.9	21.5	21.0	21.3	21.0	20.6	20.2	20.4	20.1	19.8	19.4
21.5	31.7	30.8	30.0	29.2	23.7	23.4	22.9	22.3	22.8	22.5	22.1	21.5	21.9	21.6	21.2	20.7	21.0	20.7	20.3	19.9
22	32.2	31.3	30.5	29.7	24.2	23.9	23.5	22.8	23.3	23.0	22.6	22.0	22.4	22.1	21.7	21.2	21.5	21.2	20.9	20.4
22.5	32.7	31.9	31.0	30.2	24.8	24.5	24.0	23.3	23.9	23.6	23.1	22.5	23.0	22.7	22.3	21.7	22.1	21.8	21.4	20.9
23	33.2	32.4	31.5	30.7	25.3	25.0	24.6	23.8	24.4	24.1	23.7	23.0	23.5	23.2	22.8	22.2	22.6	22.3	21.9	21.4
23.5	33.7	32.9	32.0	31.2	25.9	25.6	25.1	24.3	25.0	24.7	24.2	23.5	24.1	23.8	23.3	22.7	23.2	22.9	22.5	21.9
24	34.2	33.4	32.6	31.7	26.4	26.2	25.6	24.8	25.5	25.3	24.8	24.0	24.6	24.4	23.9	23.2	23.7	23.5	23.0	22.4
24.5	34.7	33.9	33.1	32.2	27.0	26.7	26.2	25.3	26.1	25.8	25.3	24.5	25.2	24.9	24.4	23.7	24.3	24.0	23.5	22.9
25	35.2	34.4	33.6	32.8	27.5	27.3	26.7	25.8	26.6	26.4	25.8	25.0	25.7	25.5	25.0	24.2	24.8	24.6	24.1	23.4
25.5	35.8	34.9	34.1	33.3	28.1	27.8	27.3	26.3	27.2	26.9	26.4	25.5	26.3	26.0	25.5	24.7	25.4	25.1	24.6	23.9
26	36.3	35.4	34.6	33.8	28.6	28.4	27.8	26.8	27.7	27.5	26.9	26.0	26.8	26.6	26.0	25.2	25.9	25.7	25.2	24.4
26.5	36.8	36.0	35.1	34.3	29.2	28.9	28.3	27.3	28.3	28.0	27.5	26.5	27.4	27.1	26.6	25.7	26.5	26.2	25.7	24.9
27	37.3	36.5	35.6	34.8	29.7	29.5	28.9	27.8	28.8	28.6	28.0	27.0	27.9	27.7	27.1	26.2	27.0	26.8	26.2	25.4
27.5	37.8	37.0	36.1	35.3	30.3	30.0	29.4	28.3	29.4	29.1	28.5	27.5	28.5	28.2	27.7	26.7	27.6	27.3	26.8	25.9
28	38.3	37.5	36.7	35.8	30.8	30.6	30.0	28.8	29.9	29.7	29.1	28.0	29.0	28.8	28.2	27.2	28.1	27.9	27.3	26.4
28.5	38.8	38.0	37.2	36.3	31.4	31.1	30.5	29.3	30.5	30.2	29.6	28.5	29.6	29.3	28.7	27.7	28.7	28.4	27.9	26.9
29	39.3	38.5	37.7	36.8	31.9	31.7	31.0	29.8	31.0	30.8	30.2	29.0	30.1	29.9	29.3	28.2	29.2	29.0	28.4	27.4
29.5	39.9	39.0	38.2	37.4	32.5	32.3	31.6	30.3	31.6	31.4	30.7	29.5	30.7	30.5	29.8	28.7	29.8	29.6	28.9	27.9
30	40.4	39.5	38.7	37.9	33.0	32.8	32.1	30.8	32.1	31.9	31.2	30.0	31.2	31.0	30.4	29.2	30.3	30.1	29.5	28.4
30.5	40.9	40.0	39.2	38.4	33.6	33.4	32.6	31.3	32.7	32.5	31.8	30.5	31.8	31.6	30.9	29.7	30.9	30.7	30.0	28.8
31	41.4	40.6	39.7	38.9	34.1	33.9	33.2	31.8	33.2	33.0	32.3	31.0	32.3	32.1	31.4	30.1	31.4	31.2	30.6	29.3
31.5	41.9	41.1	40.2	39.4	34.7	34.5	33.7	32.3	33.8	33.6	32.8	31.5	32.9	32.7	32.0	30.6	32.0	31.8	31.1	29.8
32	42.4	41.6	40.7	39.9	35.2	35.0	34.3	32.8	34.3	34.1	33.4	31.9	33.4	33.2	32.5	31.1	32.5	32.3	31.6	30.3
32.5	42.9	42.1	41.3	40.4	35.8	35.6	34.8	33.2	34.9	34.7	33.9	32.4	34.0	33.8	33.1	31.6	33.1	32.9	32.2	30.8
33	43.4	42.6	41.8	40.9	36.3	36.1	35.3	33.7	35.4	35.2	34.5	32.9	34.5	34.3	33.6	32.1	33.7	33.4	32.7	31.3
33.5	43.9	43.1	42.3	41.5	36.9	36.7	35.9	34.2	36.0	35.8	35.0	33.4	35.1	34.9	34.1	32.6	34.2	34.0	33.3	31.8
34	44.5	43.6	42.8	42.0	37.4	37.2	36.4	34.7	36.5	36.3	35.5	33.9	35.6	35.4	34.7	33.1	34.8	34.5	33.8	32.3

Table A-8

Estimated Temperatures (°C) at End of Berm and at Depth (ft) at Station 402 versus 0, 1, 2, and 3 Tower Operations and known Ambient (Intake) Temperature

0 Tower Intake C	0 Tower Berm °C	1 Tower Berm °C	2 Tower Berm °C	3 Tower Berm °C	0 Tower 402-S	0 Tower 402-5ft	0 Tower 402-10ft	0 Tower 402-B	1 Tower 402-S	1 Tower 402-5ft	1 Tower 402-10ft	1 Tower 402-B	2 Tower 402-S	2 Tower 402-5ft	2 Tower 402-10ft	2 Tower 402-B	3 Tower 402-S	3 Tower 402-5ft	3 Tower 402-10ft	3 Tower 402-B
10	19.9	19.1	18.2	17.4	12.5	12.0	11.8	11.6	11.7	11.2	11.0	10.9	10.9	10.4	10.2	10.1	10.1	9.6	9.4	9.3
10.5	20.4	19.6	18.7	17.9	13.0	12.5	12.3	12.1	12.2	11.7	11.5	11.3	11.4	10.9	10.7	10.6	10.6	10.1	9.8	9.8
11	20.9	20.1	19.3	18.4	13.5	13.0	12.8	12.6	12.7	12.2	12.0	11.8	11.9	11.4	11.2	11.0	11.0	10.6	10.3	10.3
11.5	21.4	20.6	19.8	18.9	14.0	13.5	13.3	13.0	13.2	12.7	12.5	12.3	12.3	11.9	11.6	11.5	11.5	11.1	10.8	10.7
12	21.9	21.1	20.3	19.4	14.4	14.0	13.8	13.5	13.6	13.2	12.9	12.7	12.8	12.4	12.1	12.0	12.0	11.6	11.3	11.2
12.5	22.5	21.6	20.8	20.0	14.9	14.5	14.2	14.0	14.1	13.7	13.4	13.2	13.3	12.9	12.6	12.4	12.5	12.1	11.8	11.7
13	23.0	22.1	21.3	20.5	15.4	15.0	14.7	14.4	14.6	14.2	13.9	13.7	13.8	13.4	13.1	12.9	13.0	12.6	12.3	12.2
13.5	23.5	22.6	21.8	21.0	15.9	15.5	15.2	14.9	15.1	14.7	14.4	14.2	14.3	13.9	13.6	13.4	13.5	13.1	12.8	12.6
14	24.0	23.2	22.3	21.5	16.4	16.0	15.7	15.4	15.6	15.2	14.9	14.6	14.8	14.4	14.1	13.9	14.0	13.6	13.3	13.1
14.5	24.5	23.7	22.8	22.0	16.9	16.5	16.2	15.9	16.1	15.7	15.4	15.1	15.3	14.9	14.6	14.3	14.5	14.1	13.8	13.6
15	25.0	24.2	23.3	22.5	17.4	17.0	16.7	16.3	16.6	16.2	15.9	15.6	15.8	15.4	15.1	14.8	15.0	14.6	14.3	14.0
15.5	25.5	24.7	23.9	23.0	17.9	17.5	17.2	16.8	17.1	16.7	16.4	16.0	16.3	15.9	15.6	15.3	15.5	15.1	14.8	14.5
16	26.0	25.2	24.4	23.5	18.4	18.0	17.7	17.3	17.6	17.2	16.9	16.5	16.8	16.4	16.1	15.7	16.0	15.6	15.3	15.0
16.5	26.5	25.7	24.9	24.1	18.9	18.5	18.2	17.7	18.1	17.7	17.4	17.0	17.3	16.9	16.6	16.2	16.5	16.1	15.8	15.4
17	27.1	26.2	25.4	24.6	19.4	19.0	18.7	18.2	18.6	18.2	17.9	17.5	17.8	17.4	17.1	16.7	17.0	16.5	16.3	15.9
17.5	27.6	26.7	25.9	25.1	19.9	19.5	19.2	18.7	19.1	18.6	18.4	17.9	18.3	17.8	17.6	17.2	17.5	17.0	16.8	16.4
18	28.1	27.3	26.4	25.6	20.4	19.9	19.7	19.2	19.6	19.1	18.9	18.4	18.8	18.3	18.1	17.6	18.0	17.5	17.3	16.9
18.5	28.6	27.8	26.9	26.1	20.9	20.4	20.2	19.6	20.1	19.6	19.4	18.9	19.3	18.8	18.6	18.1	18.5	18.0	17.8	17.3
19	29.1	28.3	27.4	26.6	21.4	20.9	20.7	20.1	20.6	20.1	19.9	19.3	19.8	19.3	19.1	18.6	19.0	18.5	18.3	17.8
19.5	29.6	28.8	28.0	27.1	21.9	21.4	21.2	20.6	21.1	20.6	20.4	19.8	20.3	19.8	19.6	19.0	19.5	19.0	18.8	18.3
20	30.1	29.3	28.5	27.6	22.4	21.9	21.7	21.0	21.6	21.1	20.9	20.3	20.7	20.3	20.1	19.5	19.9	19.5	19.3	18.7
20.5	30.6	29.8	29.0	28.1	22.8	22.4	22.2	21.5	22.0	21.6	21.4	20.7	21.2	20.8	20.6	20.0	20.4	20.0	19.8	19.2
21	31.2	30.3	29.5	28.7	23.3	22.9	22.7	22.0	22.5	22.1	21.9	21.2	21.7	21.3	21.1	20.5	20.9	20.5	20.3	19.7
21.5	31.7	30.8	30.0	29.2	23.8	23.4	23.2	22.5	23.0	22.6	22.4	21.7	22.2	21.8	21.6	20.9	21.4	21.0	20.8	20.2
22	32.2	31.3	30.5	29.7	24.3	23.9	23.7	22.9	23.5	23.1	22.9	22.2	22.7	22.3	22.1	21.4	21.9	21.5	21.3	20.6
22.5	32.7	31.9	31.0	30.2	24.8	24.4	24.2	23.4	24.0	23.6	23.4	22.6	23.2	22.8	22.6	21.9	22.4	22.0	21.7	21.1
23	33.2	32.4	31.5	30.7	25.3	24.9	24.7	23.9	24.5	24.1	23.9	23.1	23.7	23.3	23.0	22.3	22.9	22.5	22.2	21.6
23.5	33.7	32.9	32.0	31.2	25.8	25.4	25.2	24.3	25.0	24.6	24.3	23.6	24.2	23.8	23.5	22.8	23.4	23.0	22.7	22.0
24	34.2	33.4	32.6	31.7	26.3	25.9	25.7	24.8	25.5	25.1	24.8	24.0	24.7	24.3	24.0	23.3	23.9	23.5	23.2	22.5
24.5	34.7	33.9	33.1	32.2	26.8	26.4	26.1	25.3	26.0	25.6	25.3	24.5	25.2	24.8	24.5	23.8	24.4	24.0	23.7	23.0
25	35.2	34.4	33.6	32.8	27.3	26.9	26.6	25.8	26.5	26.1	25.8	25.0	25.7	25.3	25.0	24.2	24.9	24.5	24.2	23.5
25.5	35.8	34.9	34.1	33.3	27.8	27.4	27.1	26.2	27.0	26.6	26.3	25.5	26.2	25.7	25.5	24.7	25.4	24.9	24.7	23.9
26	36.3	35.4	34.6	33.8	28.3	27.8	27.6	26.7	27.5	27.0	26.8	25.9	26.7	26.2	26.0	25.2	25.9	25.4	25.2	24.4
26.5	36.8	36.0	35.1	34.3	28.8	28.3	28.1	27.2	28.0	27.5	27.3	26.4	27.2	26.7	26.5	25.6	26.4	25.9	25.7	24.9
27	37.3	36.5	35.6	34.8	29.3	28.8	28.6	27.6	28.5	28.0	27.8	26.9	27.7	27.2	27.0	26.1	26.9	26.4	26.2	25.3
27.5	37.8	37.0	36.1	35.3	29.8	29.3	29.1	28.1	29.0	28.5	28.3	27.3	28.2	27.7	27.5	26.6	27.4	26.9	26.7	25.8
28	38.3	37.5	36.7	35.8	30.3	29.8	29.6	28.6	29.5	29.0	28.8	27.8	28.7	28.2	28.0	27.0	27.9	27.4	27.2	26.3
28.5	38.8	38.0	37.2	36.3	30.8	30.3	30.1	29.1	30.0	29.5	29.3	28.3	29.1	28.7	28.5	27.5	28.3	27.9	27.7	26.8
29	39.3	38.5	37.7	36.8	31.3	30.8	30.6	29.5	30.4	30.0	29.8	28.8	29.6	29.2	29.0	28.0	28.8	28.4	28.2	27.2
29.5	39.9	39.0	38.2	37.4	31.7	31.3	31.1	30.0	30.9	30.5	30.3	29.2	30.1	29.7	29.5	28.5	29.3	28.9	28.7	27.7
30	40.4	39.5	38.7	37.9	32.2	31.8	31.6	30.5	31.4	31.0	30.8	29.7	30.6	30.2	30.0	28.9	29.8	29.4	29.2	28.2
30.5	40.9	40.0	39.2	38.4	32.7	32.3	32.1	30.9	31.9	31.5	31.3	30.2	31.1	30.7	30.5	29.4	30.3	29.9	29.7	28.6
31	41.4	40.6	39.7	38.9	33.2	32.8	32.6	31.4	32.4	32.0	31.8	30.6	31.6	31.2	31.0	29.9	30.8	30.4	30.2	29.1
31.5	41.9	41.1	40.2	39.4	33.7	33.3	33.1	31.9	32.9	32.5	32.3	31.1	32.1	31.7	31.5	30.3	31.3	30.9	30.7	29.6
32	42.4	41.6	40.7	39.9	34.2	33.8	33.6	32.3	33.4	33.0	32.8	31.6	32.6	32.2	32.0	30.8	31.8	31.4	31.2	30.1
32.5	42.9	42.1	41.3	40.4	34.7	34.3	34.1	32.8	33.9	33.5	33.3	32.1	33.1	32.7	32.5	31.3	32.3	31.9	31.7	30.5
33	43.4	42.6	41.8	40.9	35.2	34.8	34.6	33.3	34.4	34.0	33.8	32.5	33.6	33.2	33.0	31.8	32.8	32.4	32.2	31.0
33.5	43.9	43.1	42.3	41.5	35.7	35.3	35.1	33.8	34.9	34.5	34.3	33.0	34.1	33.6	33.5	32.2	33.3	32.8	32.7	31.5
34	44.5	43.6	42.8	42.0	36.2	35.7	35.6	34.2	35.4	34.9	34.8	33.5	34.6	34.1	34.0	32.7	33.8	33.3	33.1	31.9

Table A-9

The % Time Exceedance (1956-99 Intake °C) at 0 tower operation that results in RIS avoidance at a given location/depth downstream of the PBAPS discharge canal outfall in May-October. Highlighted area for spotfin shiner discussed as example calculation in Section 2.1.

0 Tower RIS	Station Location	Depth (ft)	Intake (°C) **	% of Time Intake Temperature was Equaled or Exceeded					
				May	June	July	August	September	October
Gizz Shad	201	Surf	28	*	5	33	14	9	*
		5	30.5	*	*	4	4	1	*
		10ft-Bot	33	*	*	*	*	*	*
	301-402	all	*	*	*	*	*	*	*
Spotfin	201	Surf	24.5	2	38	87	87	37	2
		5-ft	26.0	*	18	70	66	23	*
		10-ft	28.0	*	5	33	27	9	*
		Bot (13)	28.0	*	5	33	27	9	*
	301	Surf	27.0	*	10	51	47	15	*
		5-ft	29.5	*	1	11	9	3	*
		10-ft	32.0	*	*	*	1	*	*
		Bot (23)	*	*	*	*	*	*	*
	302	Surf	29.5	*	1	11	9	3	*
		5-ft	30.5	*	*	4	4	1	*
		10ft-Bot	33.5	*	*	*	*	*	*
	303	Surf	31.0	*	*	3	2	*	*
		5-ft	31.5	*	*	*	1	*	*
		10ft-Bot	33.0	*	*	*	*	*	*
	402	all	33.5	*	*	*	*	*	*
Bluntnose	all	all	*	*	*	*	*	*	*
Ch. Catfish	201	Surf	32.0	*	*	*	1	*	*
	all	5ft-Bot	*	*	*	*	*	*	*
	301-402	all	*	*	*	*	*	*	*
Bluegill	201	Surf	29.5	*	1	11	9	3	*
		5-ft	30.0	*	*	7	5	2	*
		10-ft	31.5	*	*	*	1	*	*
		Bot (13)	31.5	*	*	*	1	*	*
	301	Surf	31.0	*	*	3	2	*	*
		5-ft	32.0	*	*	*	1	*	*
		10-ft	33.5	*	*	*	*	*	*
		Bot (23)	*	*	*	*	*	*	*
	302	Surf	32.0	*	*	*	1	*	*
		5ft-Bot	33.0	*	*	*	*	*	*
	303-402	all	*	*	*	*	*	*	*
Smallmouth	201	Surf	29.5	*	1	11	9	3	*
		5	31.0	*	*	3	2	*	*
		10	32.0	*	*	*	1	*	*
		Bot(13)	32.0	*	*	*	1	*	*
	301	Surf	31.5	*	*	*	1	*	*
		5ft-Bot	33.0	*	*	*	*	*	*
	302-402	all	*	*	*	*	*	*	*

continued

Table A-9 (continued)

0 Tower RIS	Station Location	Depth (ft)	Intake (°C) **	% of Time Intake Temperature was Equaled or Exceeded					
				May	June	July	August	September	October
Largemouth	all	all	31.0	*	*	*	*	*	*
Wh. Crappie	201	Surf	26.0	*	18	70	66	23	*
		5-ft	27.0	*	10	51	47	15	*
		10-ft	29.0	*	2	16	14	4	*
		Bot (13)	29.0	*	2	16	14	4	*
	301	Surf	28.0	*	5	33	27	9	*
		5-ft	30.5	*	*	4	4	1	*
		10ft-Bot	32.5	*	*	*	*	*	*
	302	Surf	30.0	*	*	7	5	2	*
		5	31.5	*	*	*	1	*	*
		10-Bot	*	*	*	*	*	*	*
	303	Surf	32.0	*	*	*	1	*	*
		5ft-Bot	32.5	*	*	*	*	*	*
	402	all	*	*	*	*	*	*	*
Walleye	201	Surf	26.0	*	18	70	66	23	*
		5-ft	27.0	*	10	51	47	15	*
		10-ft	28.5	*	3	23	19	6	*
		Bot (13)	28.5	*	3	23	19	6	*
	301	Surf	27.5	*	7	42	36	11	*
		5-ft	29.5	*	1	11	9	3	*
		10-ft	31.0	*	*	3	2	*	*
		Bot	*	*	*	*	*	*	*
	302	Surf	29.5	*	1	11	9	3	*
		5-ft	30.5	*	*	4	4	1	*
		10-ft	32.0	*	*	*	1	*	*
		Bot	33.5	*	*	*	*	*	*
	303	Surf	30.5	*	*	4	4	1	*
		5-ft	31.0	*	*	3	2	*	*
		10-ft	32.0	*	*	*	1	*	*
		Bot	*	*	*	*	*	*	*
	402	Surf	32.0	*	*	1	1	*	*
		5ft-Bot	32.5	*	*	*	*	*	*

* = No avoidance; intake temps resulting in an avoidance temp at location/depth did not occur historically or occurred <1% of the time..

** = The intake temperature which results in an avoidance temperature at location/depth downstream of the canal outfall

Table A-10

The % Time Exceedance (1956-99 Intake °C) at 1 tower operation that results in RIS avoidance at a given location/depth downstream of the PBAPS discharge canal outfall in May-October.

1 Tower RIS	Station Location	Depth (ft)	Intake (°C) **	% of Time Intake Temperature was Equaled or Exceeded					
				May	June	July	August	September	October
Gizz Shad	201	Surf	31.0	*	*	2.5	2.4	*	*
		5ft-Bot	33.0	*	*	*	*	*	*
	301-402	all	*	*	*	*	*	*	*
Spotfin	201	Surf	26.5	*	14	61	57	19	*
		5-ft	28.0	*	5	33	27	9	*
		10-ft	30.0	*	*	7	5	2	*
		Bot (13)	30.0	*	*	7	5	2	*
	301	Surf	29.0	*	2	16	14	4	*
		5-ft	31.0	*	*	3	2	*	*
		10ft-Bot	33.0	*	*	*	*	*	*
	302	Surf	31.0	*	*	3	2	*	*
		5ft-Bot	32.5	*	*	*	*	*	*
	303-402	all	*	*	*	*	*	*	*
Bluntnose	all	all	*	*	*	*	*	*	*
Ch. Catfish	all	all	*	*	*	*	*	*	*
Bluegill	201	Surf	30.5	*	*	4	4	1	*
		5-ft	31.5	*	*	*	1	*	*
		10ft-Bot	33.0	*	*	*	*	*	*
	301	Surf	32.0	*	*	1	1	*	*
		5ft-Bot	33.0	*	*	*	*	*	*
	302-402	all	*	*	*	*	*	*	*
Smallmouth	201	Surf	31.0	*	*	3	2	*	*
		5-ft	32.0	*	*	*	1	*	*
		10ft-Bot	33.5	*	*	*	*	*	*
	301-402	all	*	*	*	*	*	*	*
Largemouth	all	all	33.0	*	*	*	*	*	*
Wh. Crappie	201	Surf	28.0	*	5	33	27	9	*
		5-ft	29.0	*	2	16	14	4	*
		10-ft	31.0	*	*	3	2	*	*
		Bot (13)	31.0	*	*	3	2	*	*
	301	Surf	30.5	*	*	4	4	1	*
		5-ft	32.0	*	*	*	1	*	*
		10-Bot	*	*	*	*	*	*	*
	302	Surf	32.0	*	*	*	1	*	*
		5ft-Bot	33.0	*	*	*	*	*	*
	303-402	all	*	*	*	*	*	*	*

continued

Table A-10 (continued)

1 Tower RIS	Station Location	Depth (ft)	Intake (°C) **	% of Time Intake Temperature was Equaled or Exceeded					
				May	June	July	August	September	October
Walleye	201	Surf	27.5	*	7	42	36	11	*
		5-ft	28.5	*	3	23	19	6	*
		10-ft	30.0	*	*	7	5	2	*
		Bot (13)	30.0	*	*	7	5	2	*
	301	Surf	29.0	*	2	16	14	4	*
		5-ft	30.5	*	*	4	4	1	*
		10ft-Bot	32.5	*	*	*	*	*	*
	302	Surf	30.5	*	*	4	4	1	*
		5-ft	31.5	*	*	*	1	*	*
		10ft-Bot	33.5	*	*	*	*	*	*
	303	all	32.0	*	*	*	1	*	*
		5-ft	32.0	*	*	*	1	*	*
		10ft-Bot	33.0	*	*	*	*	*	*
	402	all	33.0	*	*	*	*	*	*

* = No avoidance; intake temps resulting in an avoidance temp at location/depth did not occur historically or occurred <1% of the time..

** = The intake temperature which results in an avoidance temperature at location/depth downstream of the canal outfall

Table A-11

The % Time Exceedance (1956-99 Intake °C) at 2 tower operation that results in RIS avoidance at a given location/depth downstream of the PBAPS discharge canal outfall in May-October.

2 Tower RIS	Station Location	Depth (ft)	Intake (°C) **	% of Time Intake Temperature was Equaled or Exceeded					
				May	June	July	August	September	October
Gizz Shad	all	all	33.5	*	*	*	*	*	*
Spotfin	201	Surf	28.5	*	3	23	19	6	*
		5-ft	30.0	*	2	7	5	2	*
		10-ft	32.0	*	*	*	1	*	*
		Bot (13)	32.0	*	*	*	1	*	*
	301	Surf	31.0	*	*	3	2	*	*
		5-ft-Bot	33.0	*	*	*	*	*	*
	302-402	all	*	*	*	*	*	*	*
Bluntnose	all	all	*	*	*	*	*	*	*
Ch. Catfish	all	all	*	*	*	*	*	*	*
Bluegill	201	Surf	32.0	*	*	*	1	*	*
		5-ft-Bot	32.5	*	*	*	*	*	*
	301-402	all	*	*	*	*	*	*	*
Smallmouth	all	all	32.5	*	*	*	*	*	*
Largemouth	all	all	*	*	*	*	*	*	*
Wh. Crappie	201	Surf	29.5	*	1	11	9	3	*
		5-ft	31.0	*	*	3	2	*	*
		10-ft Bot	33.0	*	*	*	*	*	*
	301	Surf	32.0	*	*	*	1	*	*
		5-ft-Bot	33.5	*	*	*	*	*	*
	302	all	33.5	*	*	*	*	*	*
	301-402	all	*	*	*	*	*	*	*
Walleye	201	Surf	29.0	*	2	16	14	4	*
		5-ft	29.5	*	1	11	9	3	*
		10-ft	31.5	*	*	*	1	*	*
		Bot (13)	31.5	*	*	*	1	*	*
	301	Surf	30.5	*	*	4	4	1	*
		5-ft	32.0	*	*	*	1	*	*
		10-ft Bot	33.5	*	*	*	*	*	*
	302	Surf	32.0	*	*	*	1	*	*
		5-ft-Bot	33.0	*	*	*	*	*	*
	303	all	33.5	*	*	*	*	*	*
	402	all	*	*	*	*	*	*	*

* = No avoidance; intake temps resulting in an avoidance temp at location/depth did not occur historically or occurred <1% of the time..

** = The intake temperature which results in an avoidance temperature at location/depth downstream of the canal outfall

Table A-12

The % Time Exceedance (1956-99 Intake °C) at 3 tower operation that results in RIS avoidance at a given location/depth downstream of the PBAPS discharge canal outfall in May-October.

3 Tower RIS	Station Location	Depth (ft)	Intake (°C) **	% of Time Intake Temperature was Equaled or Exceeded					
				May	June	July	August	September	October
Gizz Shad	all	all	*	*	*	*	*	*	*
Spotfin	201	Surf	30.5	*	*	4	4	1	*
		5-ft	32.0	*	*	*	1	*	*
		10-ft Bot	33.5	*	*	*	*	*	*
	301	all	33.0	*	*	*	*	*	*
	302-402	all	*	*	*	*	*	*	*
Bluntnose	all	all	*	*	*	*	*	*	*
Ch. Catfish	all	all	*	*	*	*	*	*	*
Bluegill	201	all	33.0	*	*	*	*	*	*
	301-402	all	*	*	*	*	*	*	*
Smallmouth	all	all	*	*	*	*	*	*	*
Largemouth	all	all	*	*	*	*	*	*	*
Wh. Crappie	201	Surf	31.5	*	*	*	1	*	*
		5-ft	33.0	*	*	*	*	*	*
		10-ft Bot	*	*	*	*	*	*	*
	301	all	33.5	*	*	*	*	*	*
	302-402	all	*	*	*	*	*	*	*
Walleye	201	Surf	30.0	*	*	7	4	2	*
		5-ft	31.0	*	*	3	2	*	*
		10-ft Bot	32.5	*	*	*	*	*	*
	301	Surf	32.0	*	*	*	1	*	*
		5ft-Bot	33.5	*	*	*	*	*	*
	302	all	33.0	*	*	*	*	*	*
	303-402	all	*	*	*	*	*	*	*

* = No avoidance; intake temps resulting in an avoidance temp at location/depth did not occur historically or occurred <1% of the time..

** = The intake temperature which results in an avoidance temperature at location/depth downstream of the canal outfall

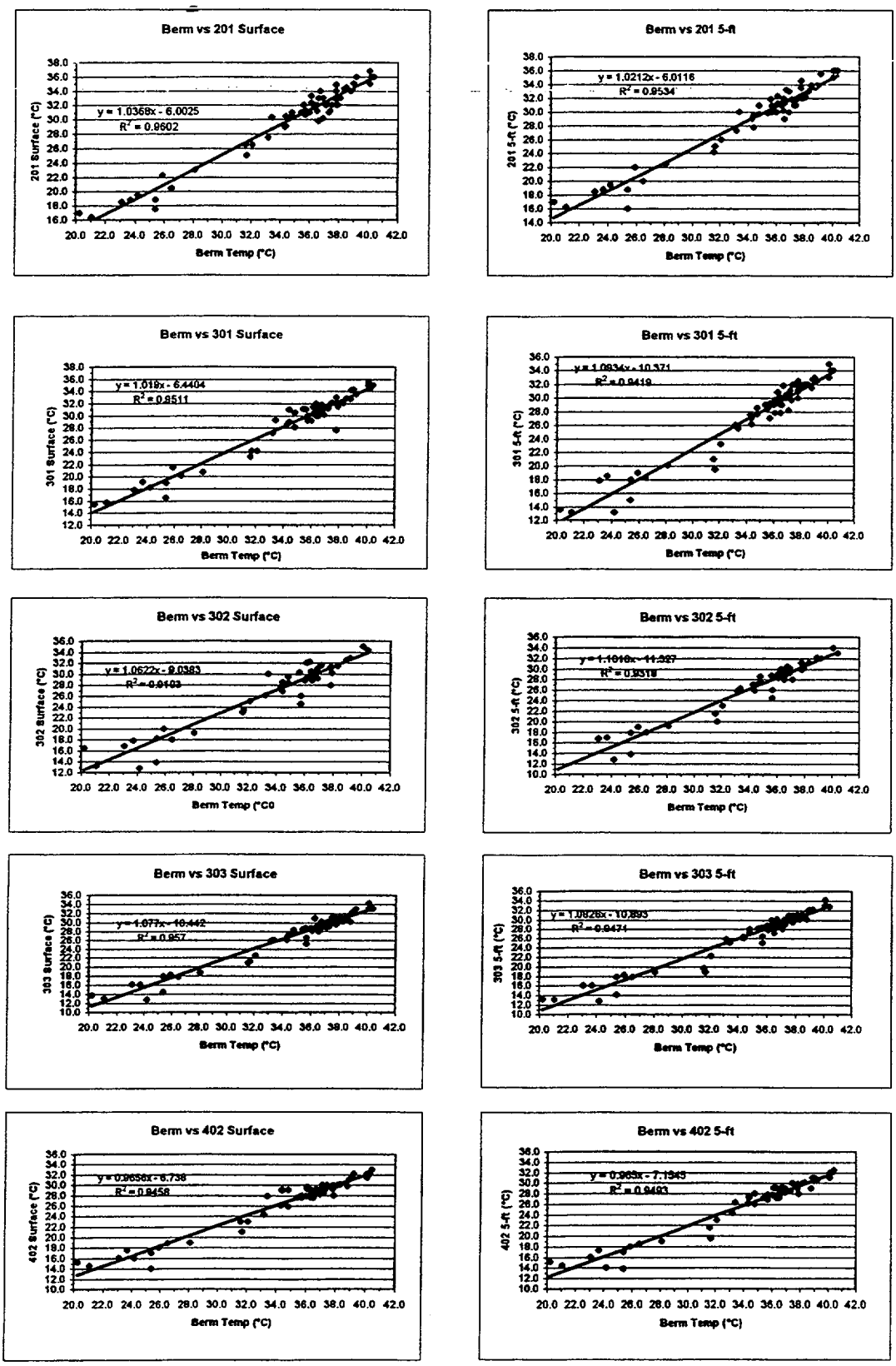
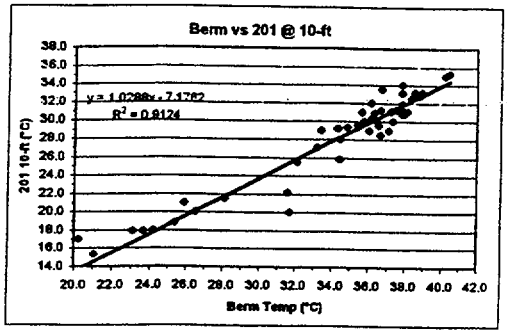
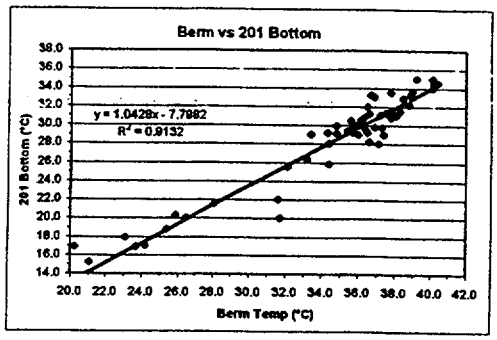
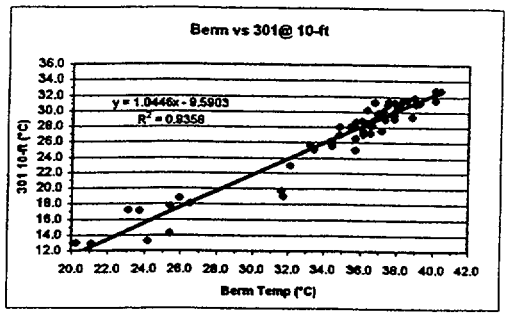


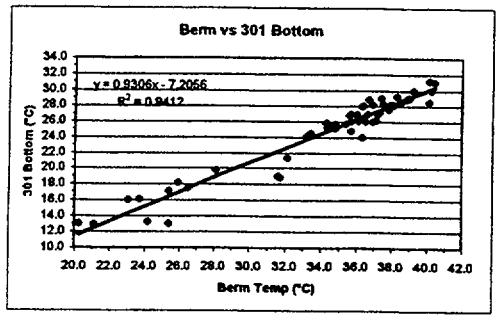
Figure A-1

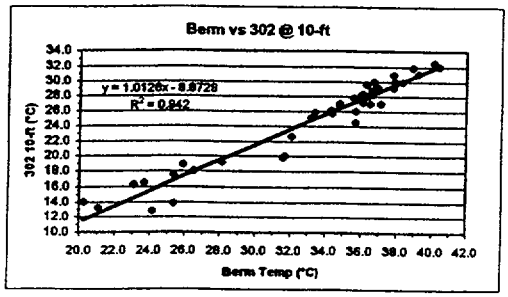
Relationship between the PBAPS discharge (Berm) temperature and profiled locations (201, 301, 302, 303, and 402) at the surface, 5-ft, 10-ft, and bottom depths, at 0 tower operation in May-October, 1996-1999.

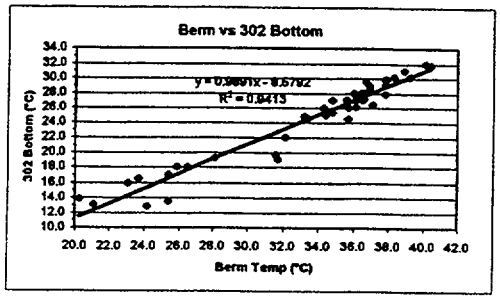


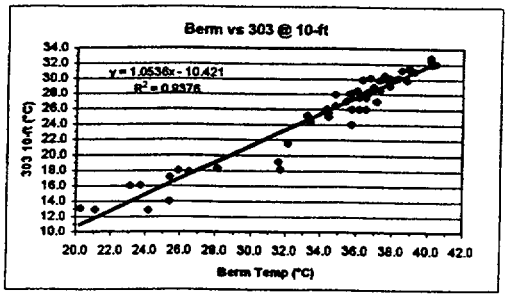


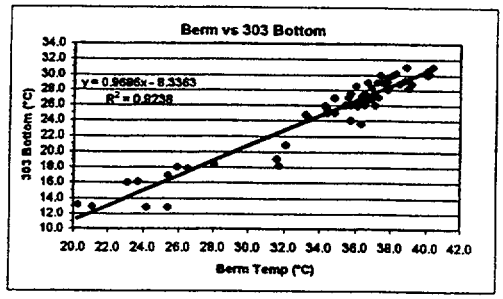


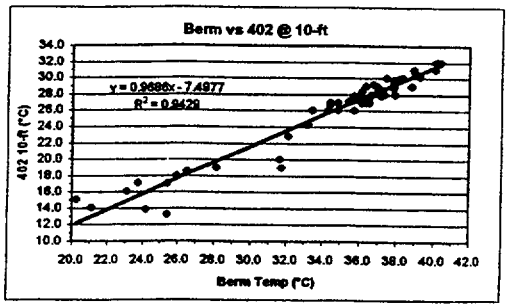












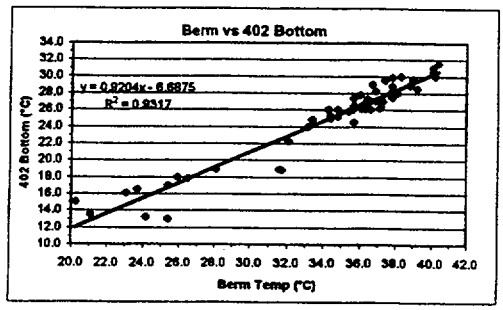
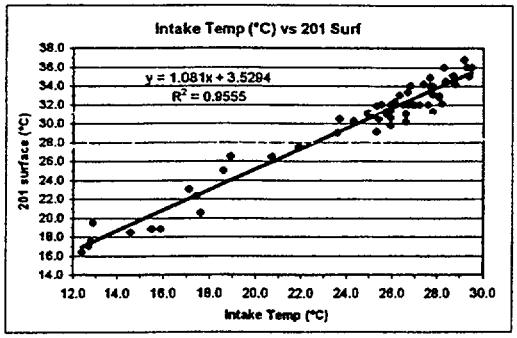
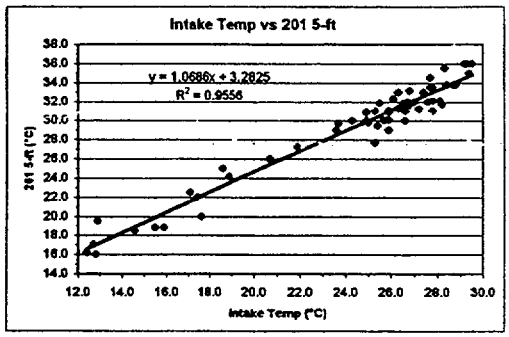
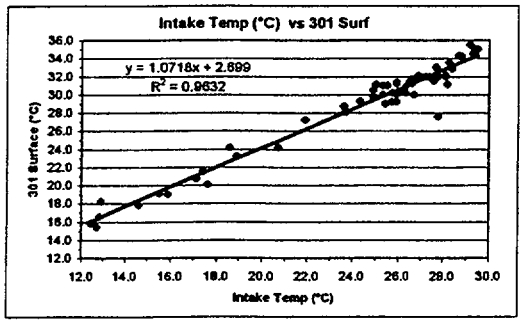


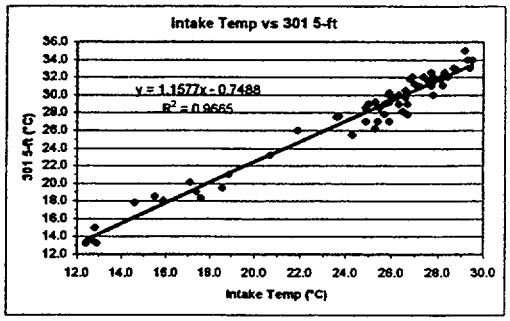
Figure A-1 (continued)

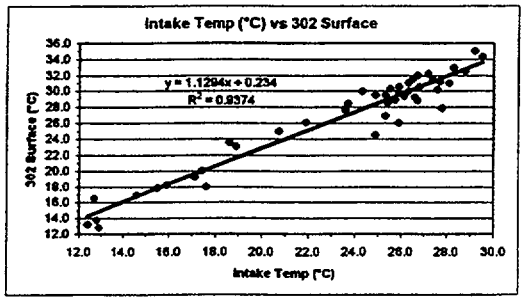
Relationship between the PBAPS discharge (Berm) temperature and profiled locations (201, 301, 302, 303, and 402) at the surface, 5-ft, 10-ft, and bottom depths, at 0 tower operation in May-October, 1996-1999.

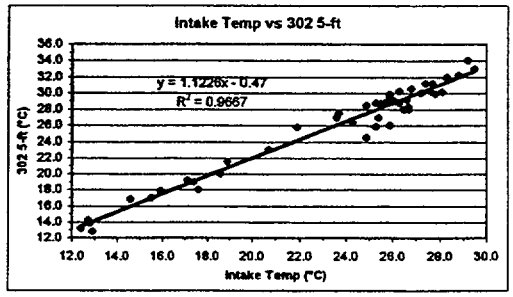


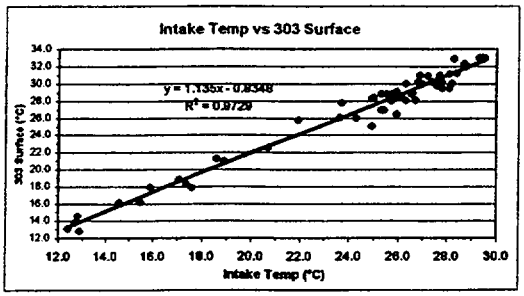


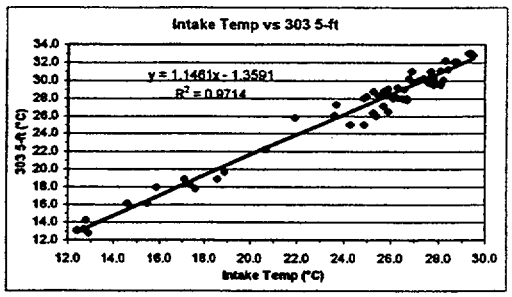


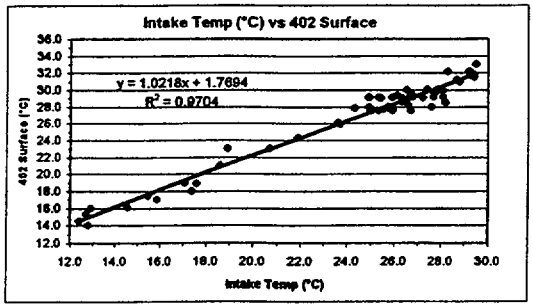












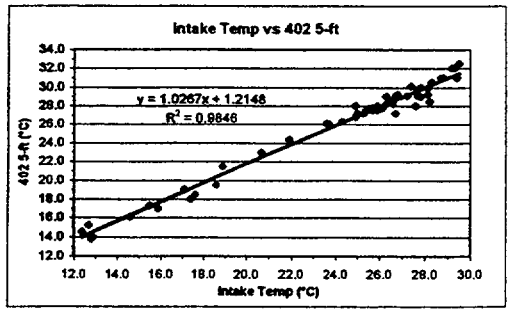
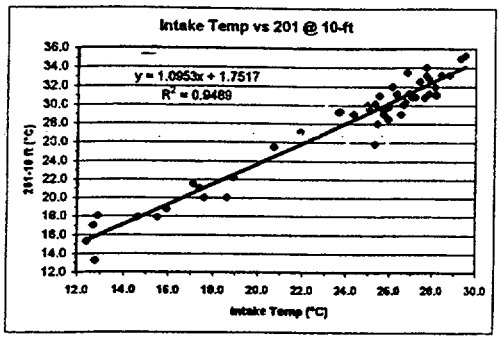
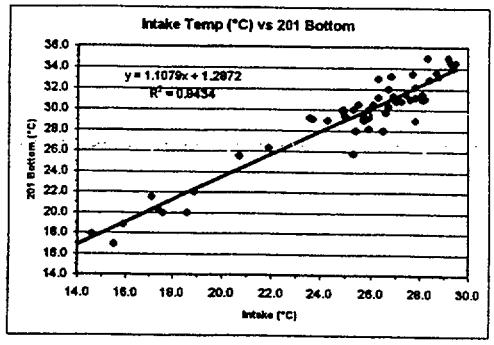
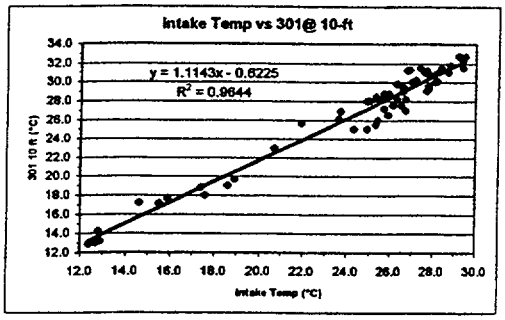


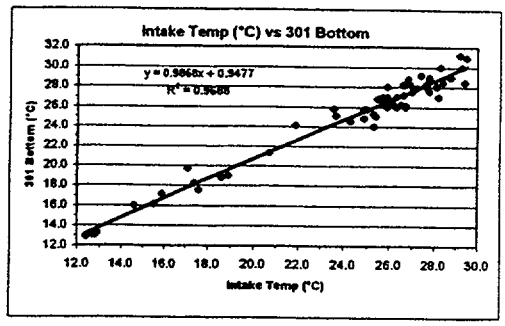
Figure A-2

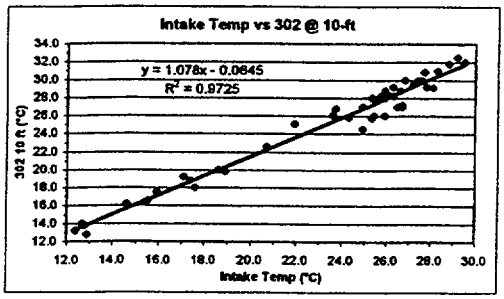
Relationship between the PBAPS intake temperature and profiled locations (201, 301, 302, 303, and 402) at the surface, 5-ft, 10-ft, and bottom depths, at 0 tower operation in May-October, 1996-1999.

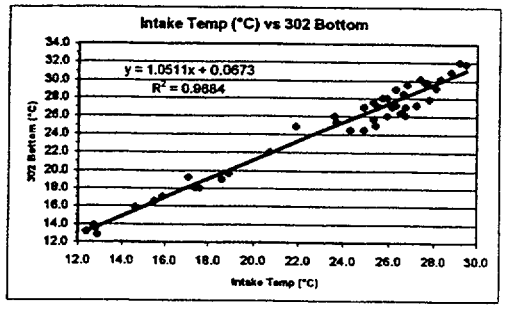


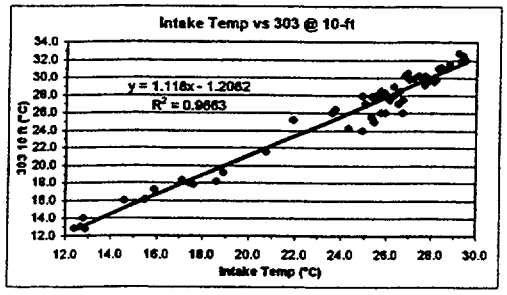


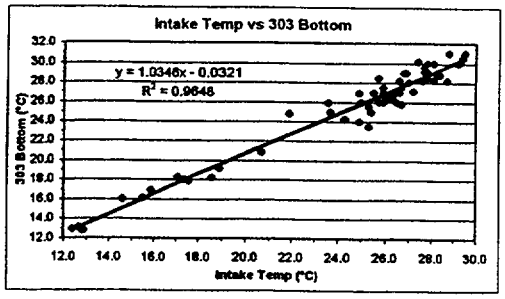


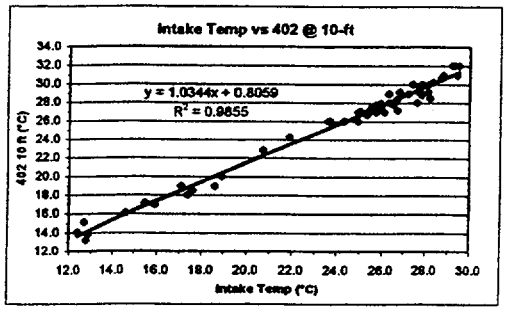












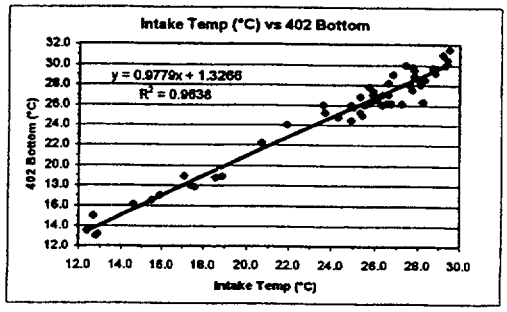


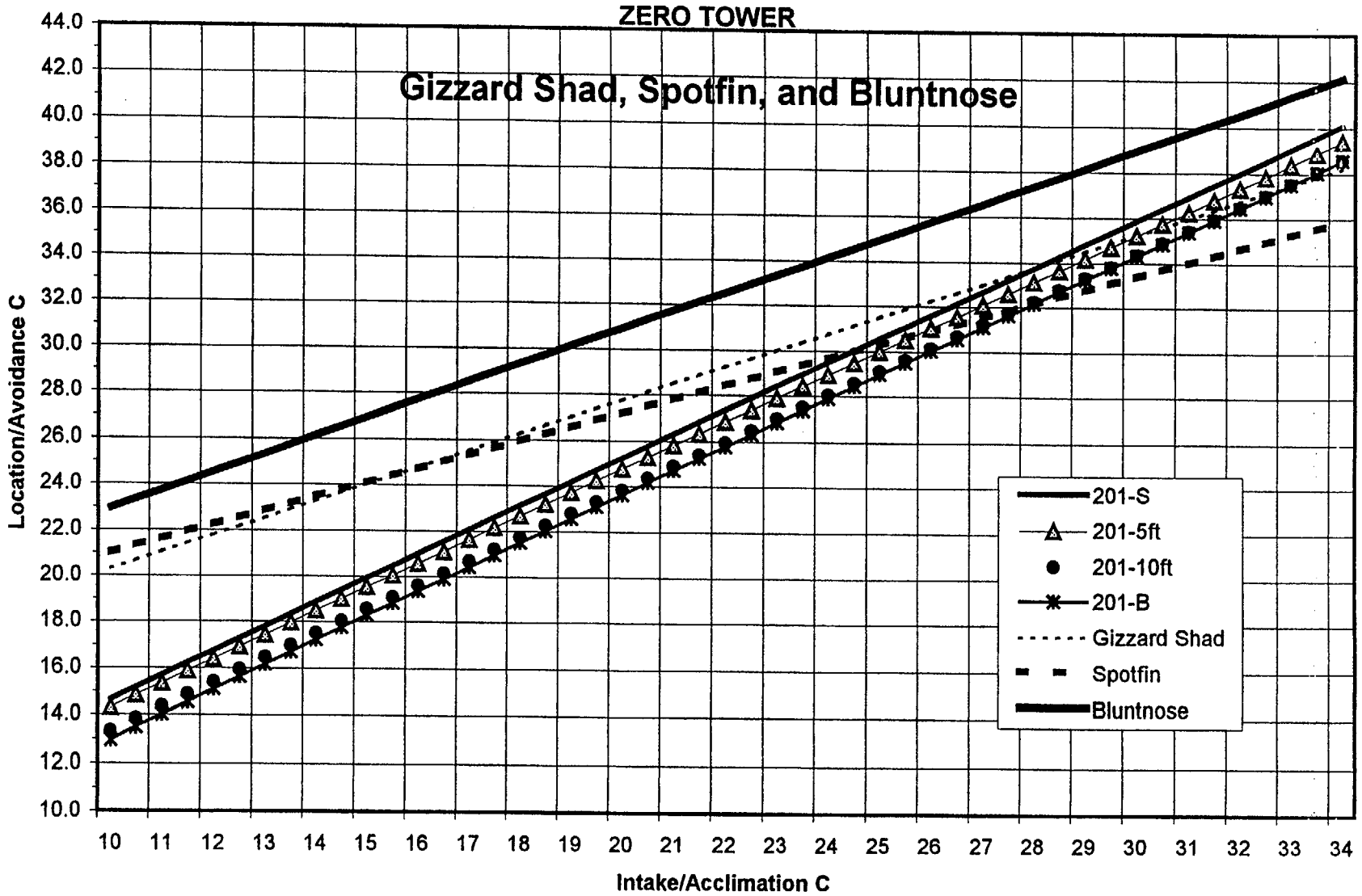
Figure A-2 (continued)

Relationship between the PBAPS intake temperature and profiled locations (201, 301, 302, 303, and 402) at the surface, 5-ft, 10-ft, and bottom depths, at 0 tower operation in May-October, 1996-1998.

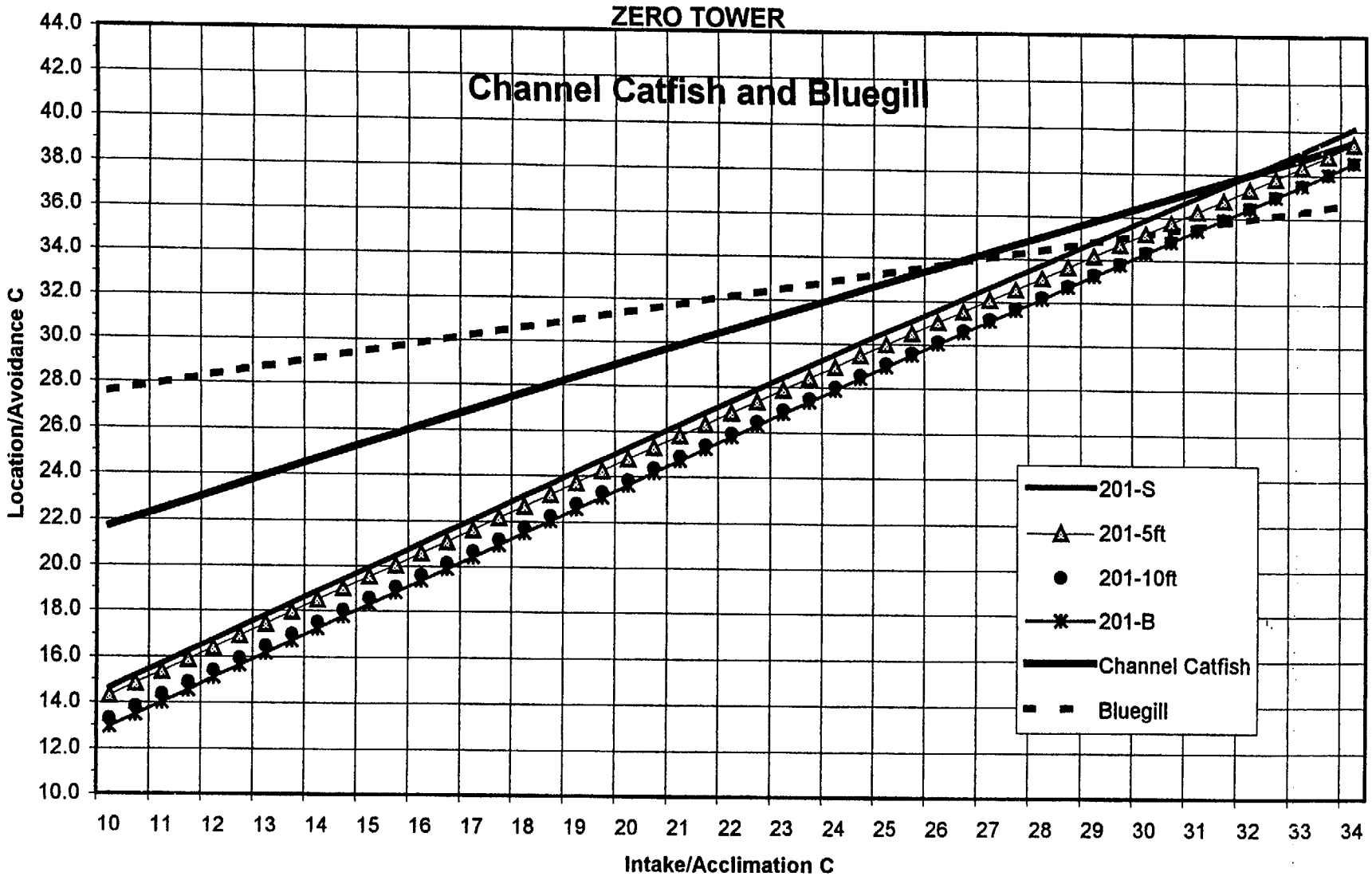
Figure A-3

Relationship of Station 201 Temperature versus Fish Avoidance Temperature (°C) at 0 to 3 Tower Operations

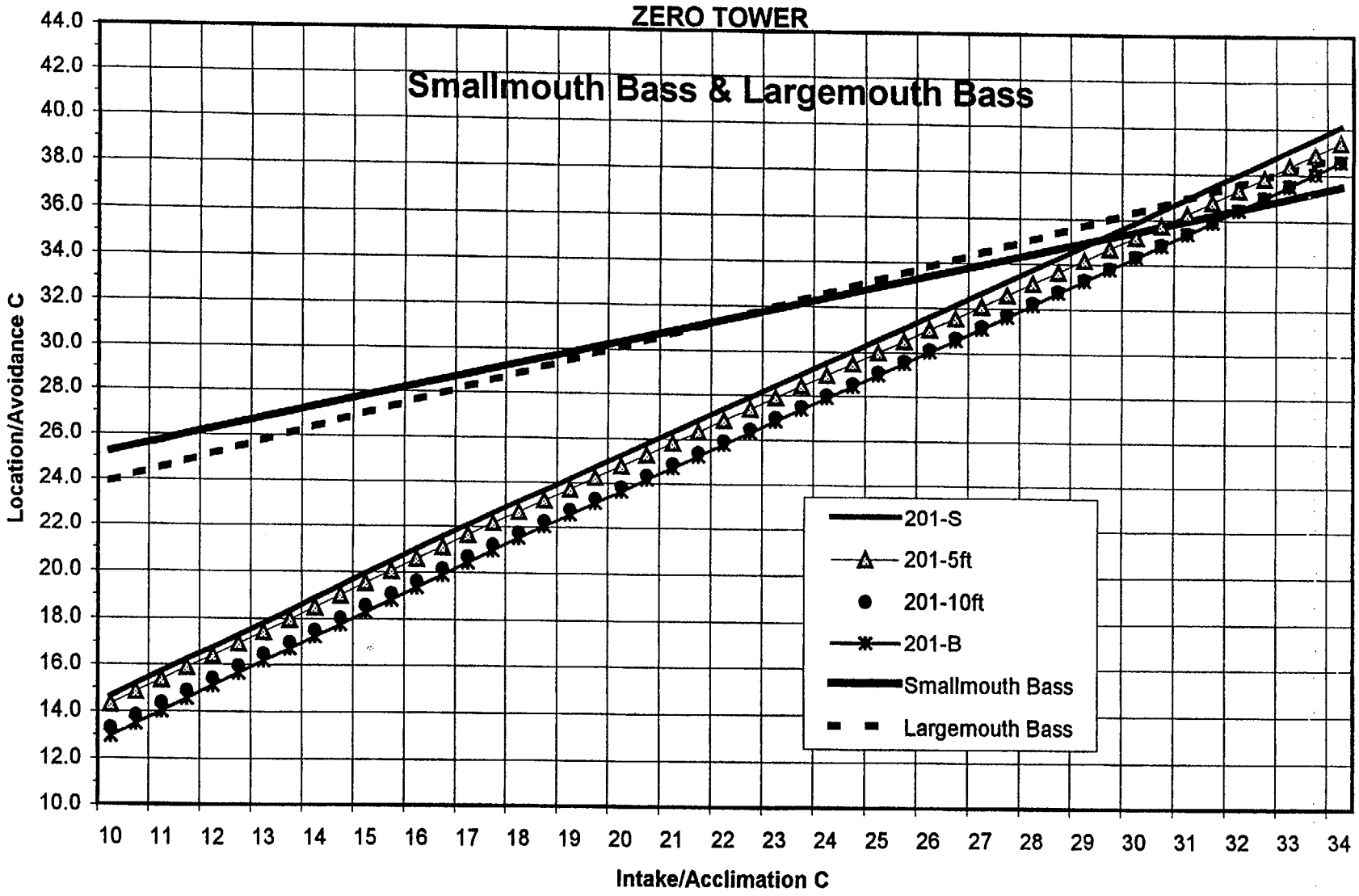
201 vs Avoidance C at 0 to 3 Tower Operations



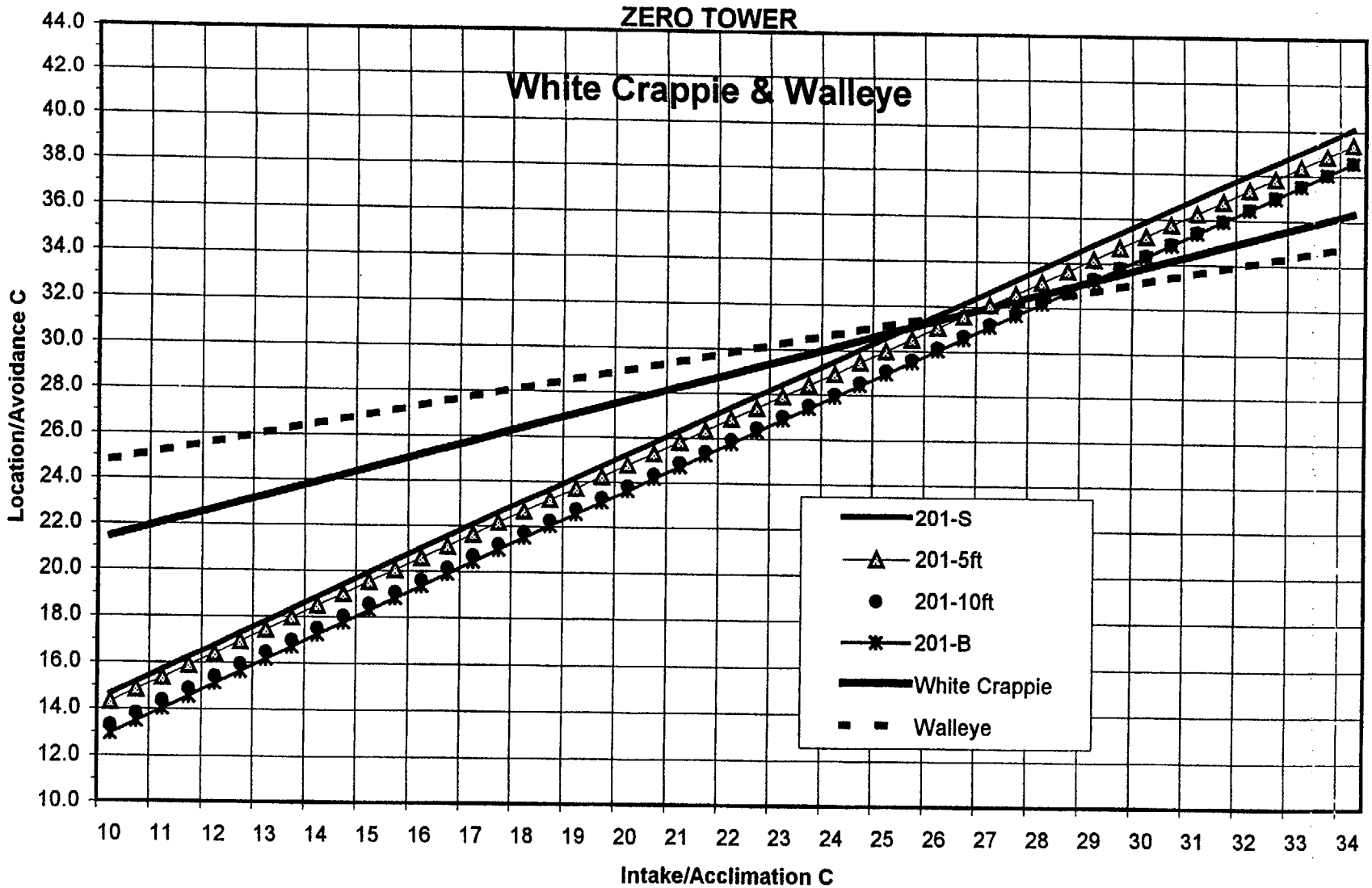
201 vs Avoidance C at 0 to 3 Tower Operations

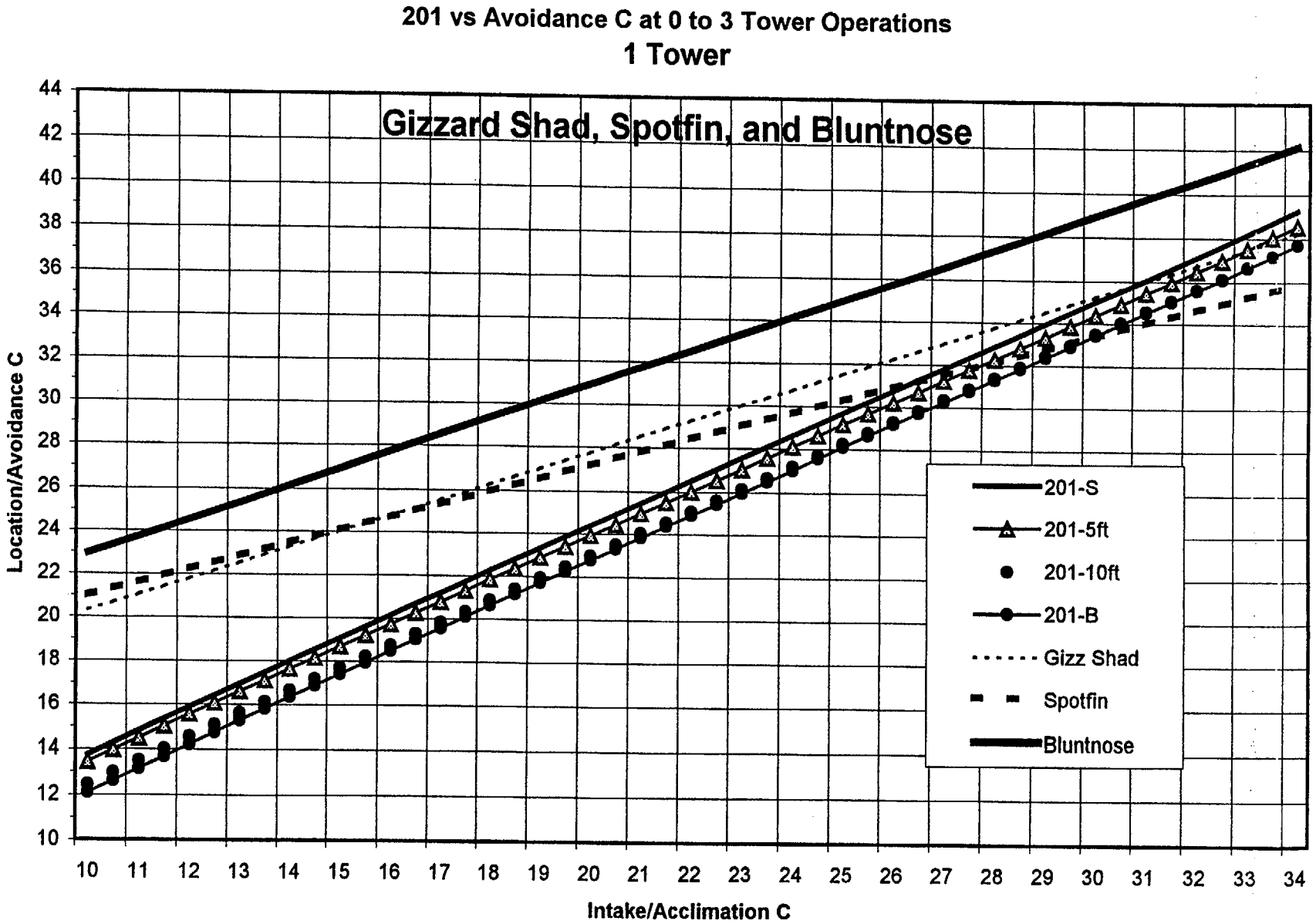


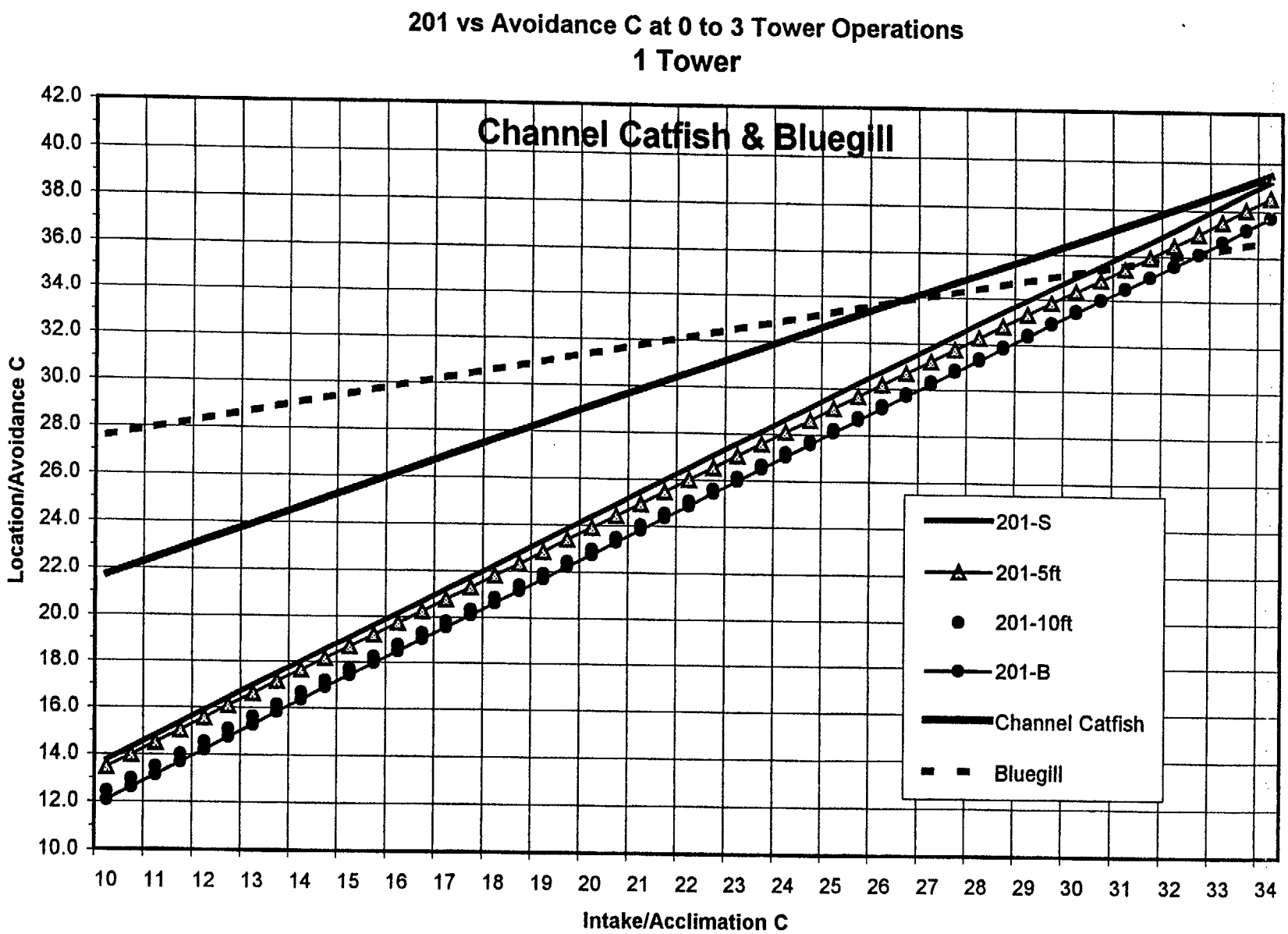
201 vs Avoidance C at 0 to 3 Tower Operations

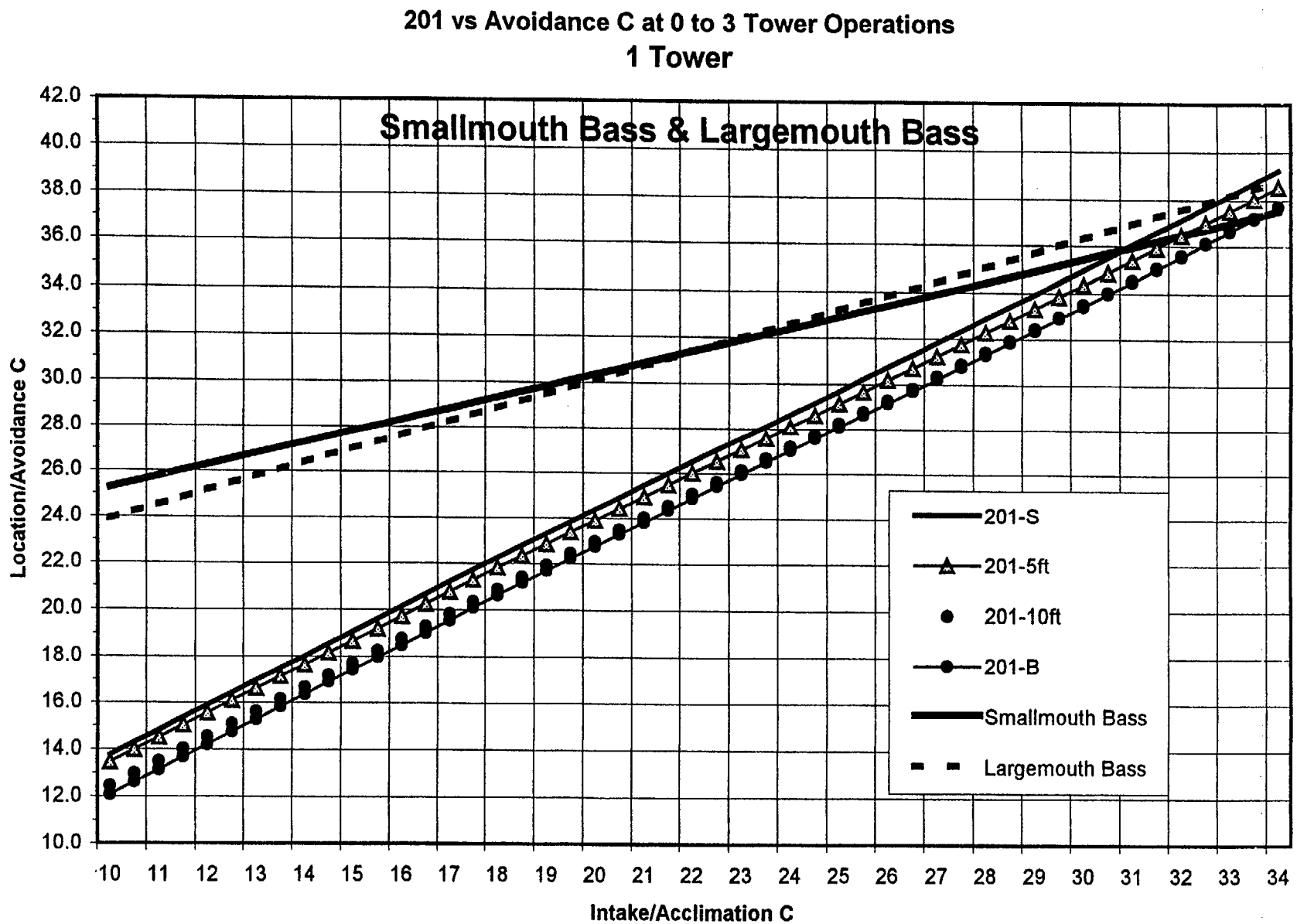


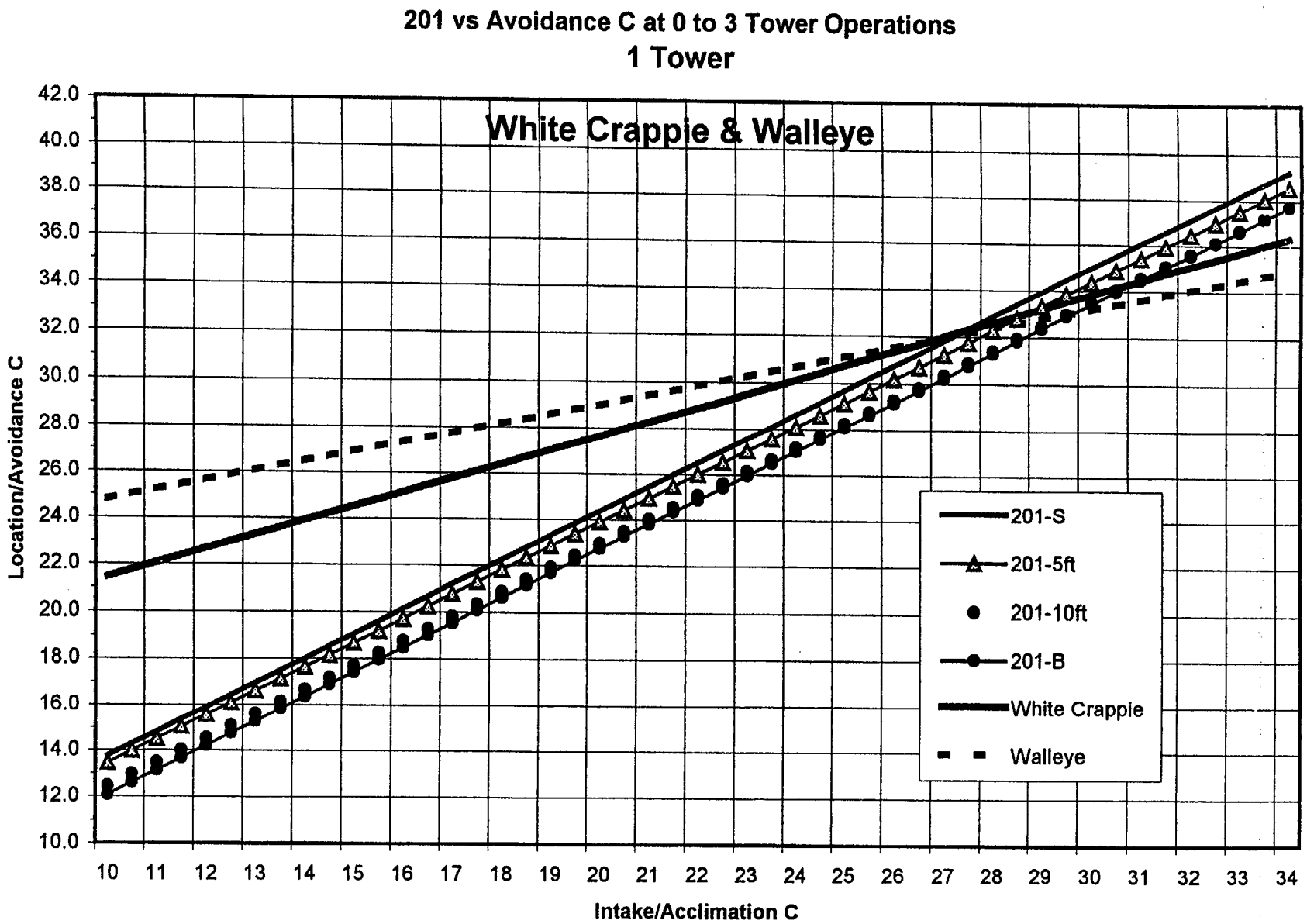
201 vs Avoidance C at 0 to 3 Tower Operations




201 vs Avoidance C at 0 to 3 Tower Operations
1 Tower
Gizzard Shad, Spotfin, and Bluntnose
Location/Avoidance C
Intake/Acclimation C
44
42
40
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34
201-S
201-5ft
201-10ft
201-B
Gizz Shad
Spotfin
Bluntnose

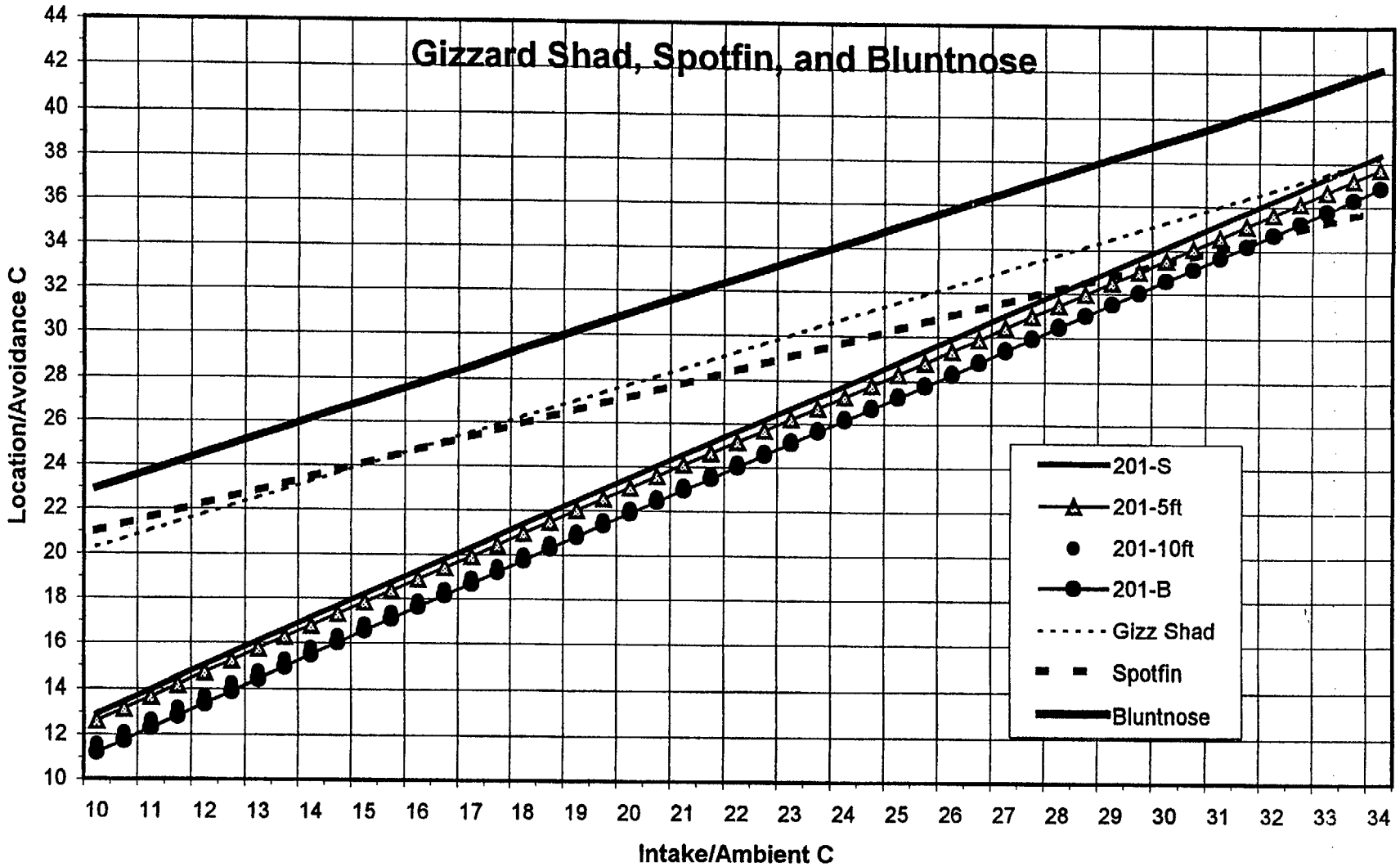

201 vs Avoidance C at 0 to 3 Tower Operations
1 Tower
Channel Catfish & Bluegill
Location/Avoidance C
Intake/Acclimation C
42.0
40.0
38.0
36.0
34.0
32.0
30.0
28.0
26.0
24.0
22.0
20.0
18.0
16.0
14.0
12.0
10.0
10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34
201-S
201-5ft
201-10ft
201-B
Channel Catfish
Bluegill


201 vs Avoidance C at 0 to 3 Tower Operations
1 Tower
Smallmouth Bass & Largemouth Bass
Location/Avoidance C
Intake/Acclimation C
42.0
40.0
38.0
36.0
34.0
32.0
30.0
28.0
26.0
24.0
22.0
20.0
18.0
16.0
14.0
12.0
10.0
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
201-S
201-5ft
201-10ft
201-B
Smallmouth Bass
Largemouth Bass


201 vs Avoidance C at 0 to 3 Tower Operations
1 Tower
White Crappie & Walleye
Location/Avoidance C
Intake/Acclimation C
42.0
40.0
38.0
36.0
34.0
32.0
30.0
28.0
26.0
24.0
22.0
20.0
18.0
16.0
14.0
12.0
10.0
10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34
201-S
201-5ft
201-10ft
201-B
White Crappie
Walleye

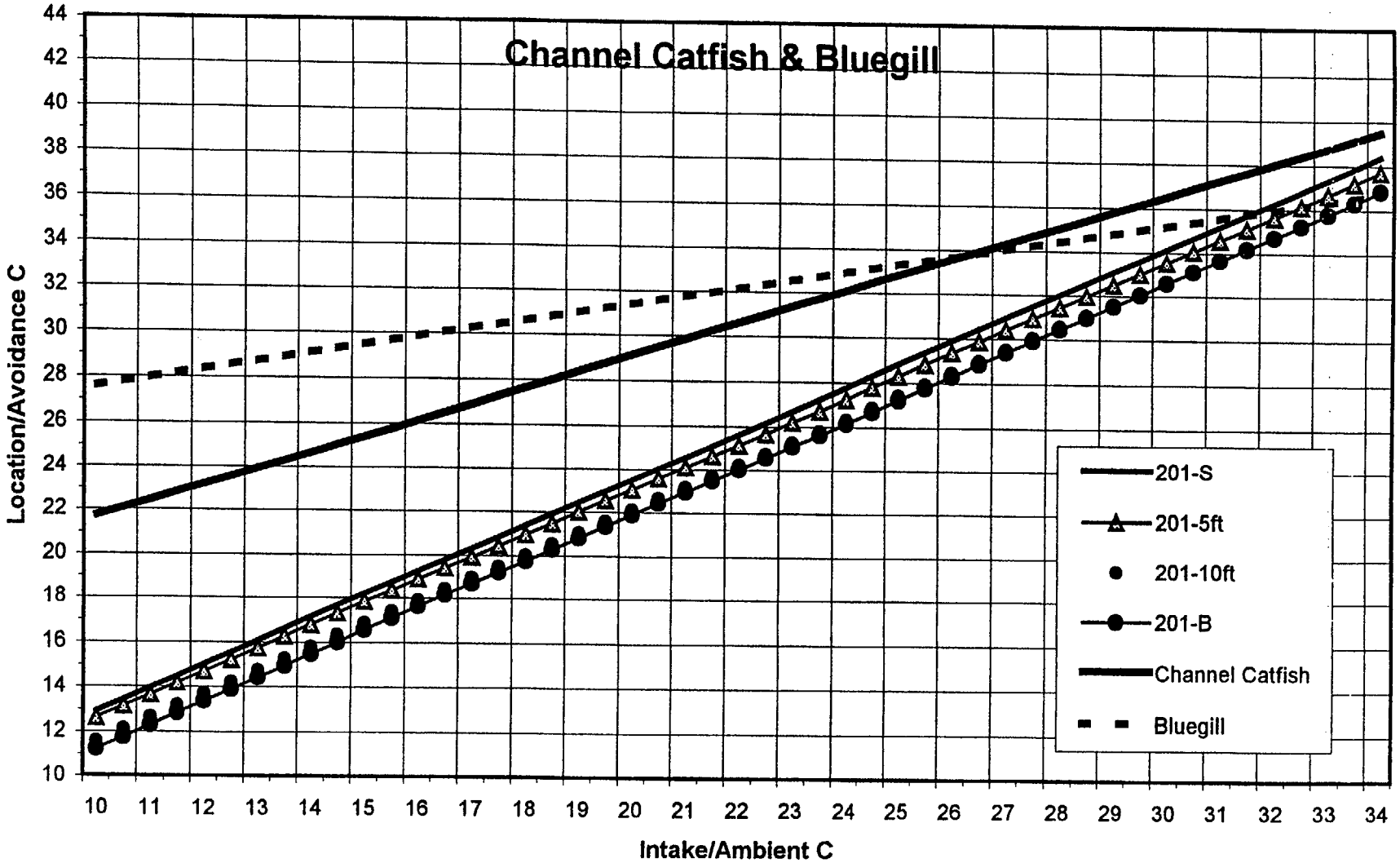
201 vs Avoidance C at 0 to 3 Tower Operations

2 Towers



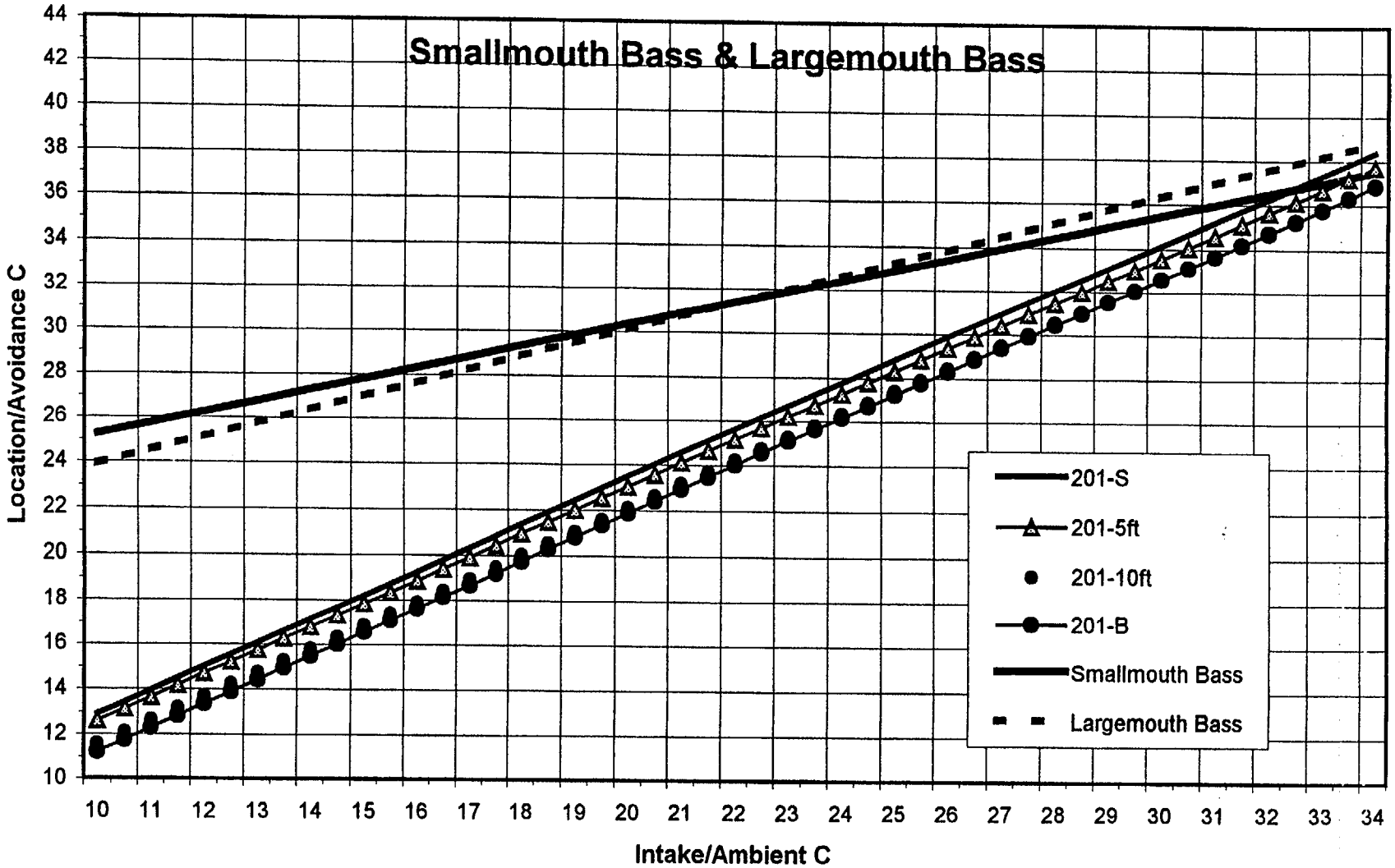
201 vs Avoidance C at 0 to 3 Tower Operations

2 Towers



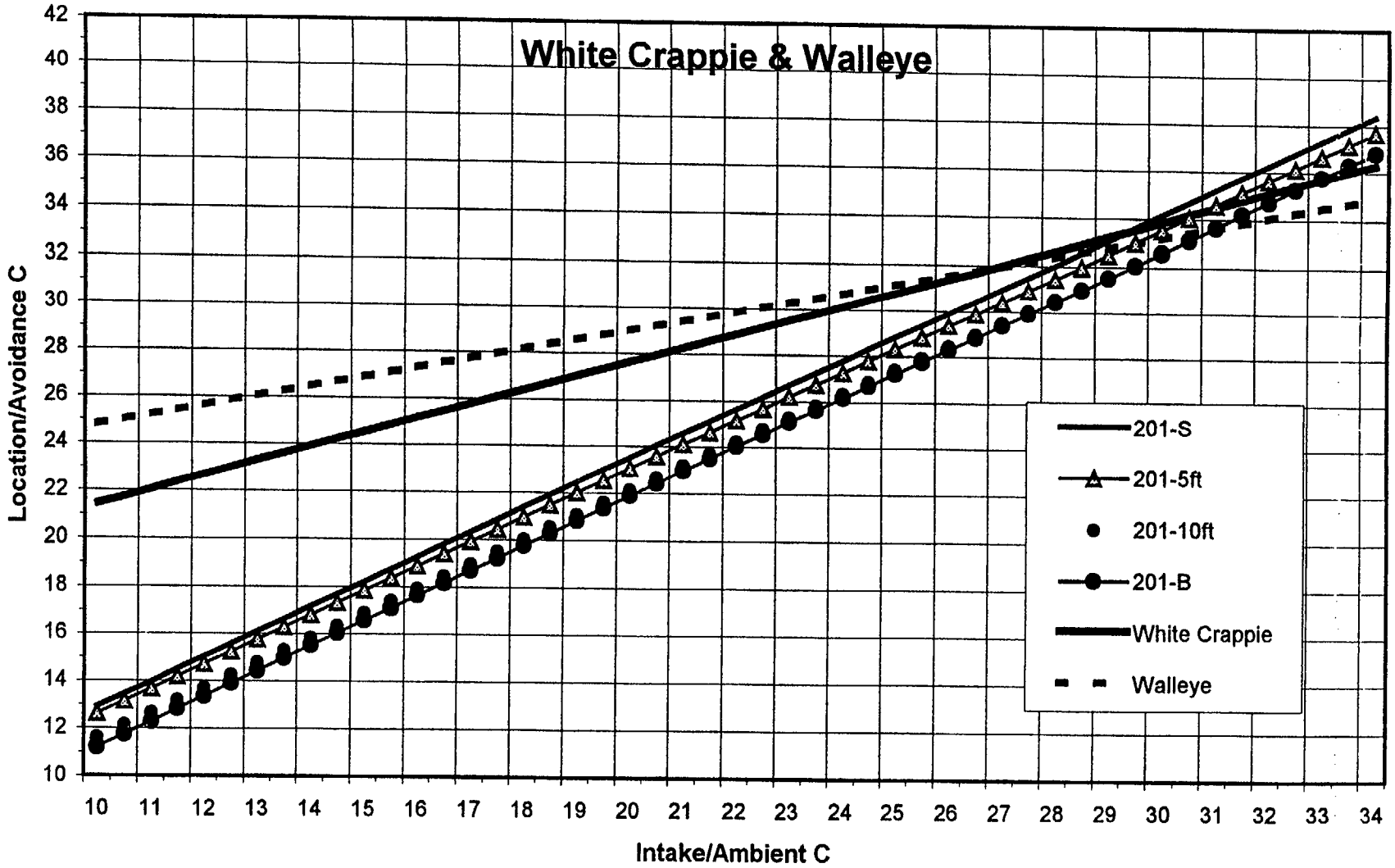
201 vs Avoidance C at 0 to 3 Tower Operations

2 Towers

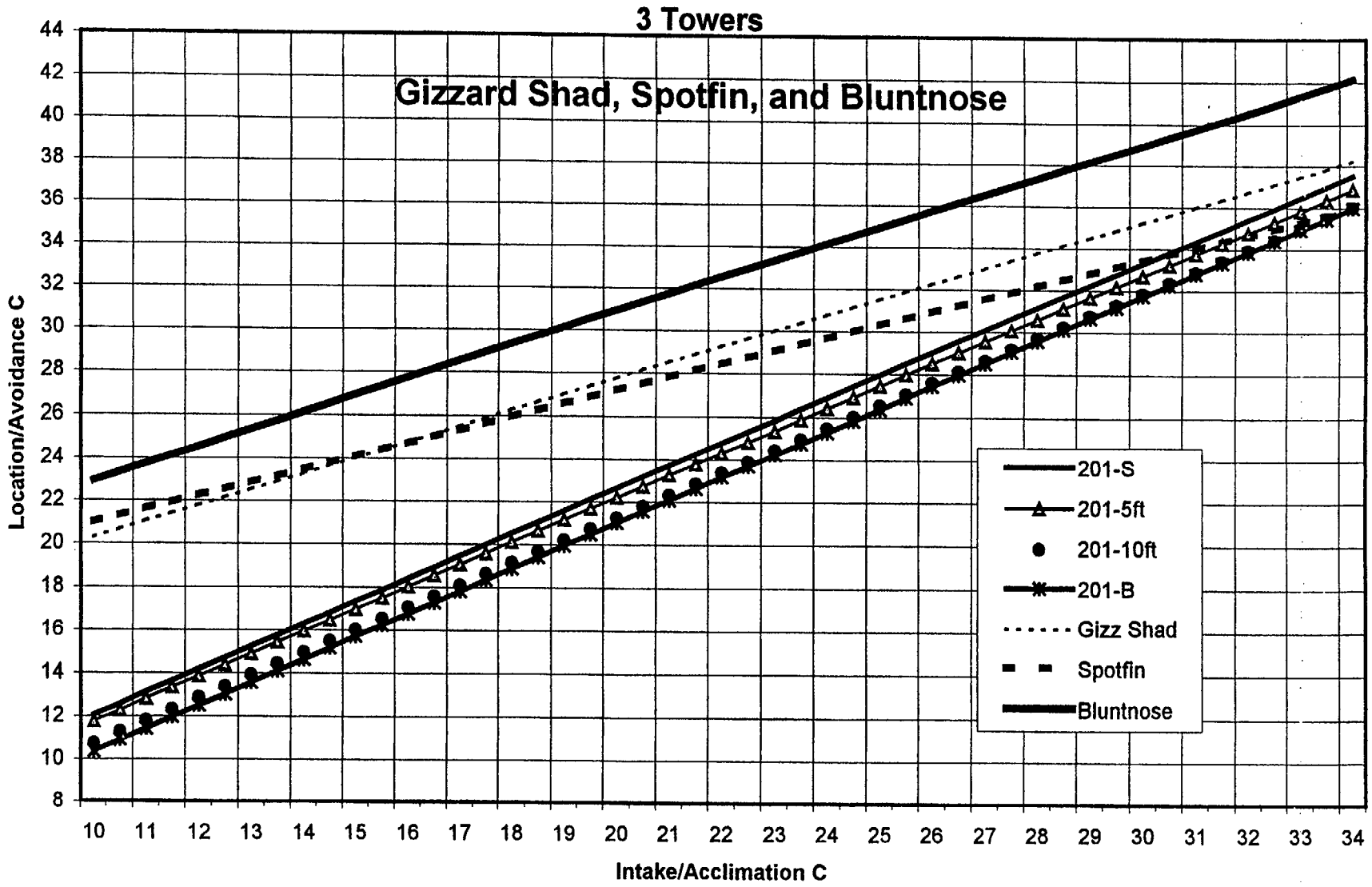


201 vs Avoidance C at 0 to 3 Tower Operations

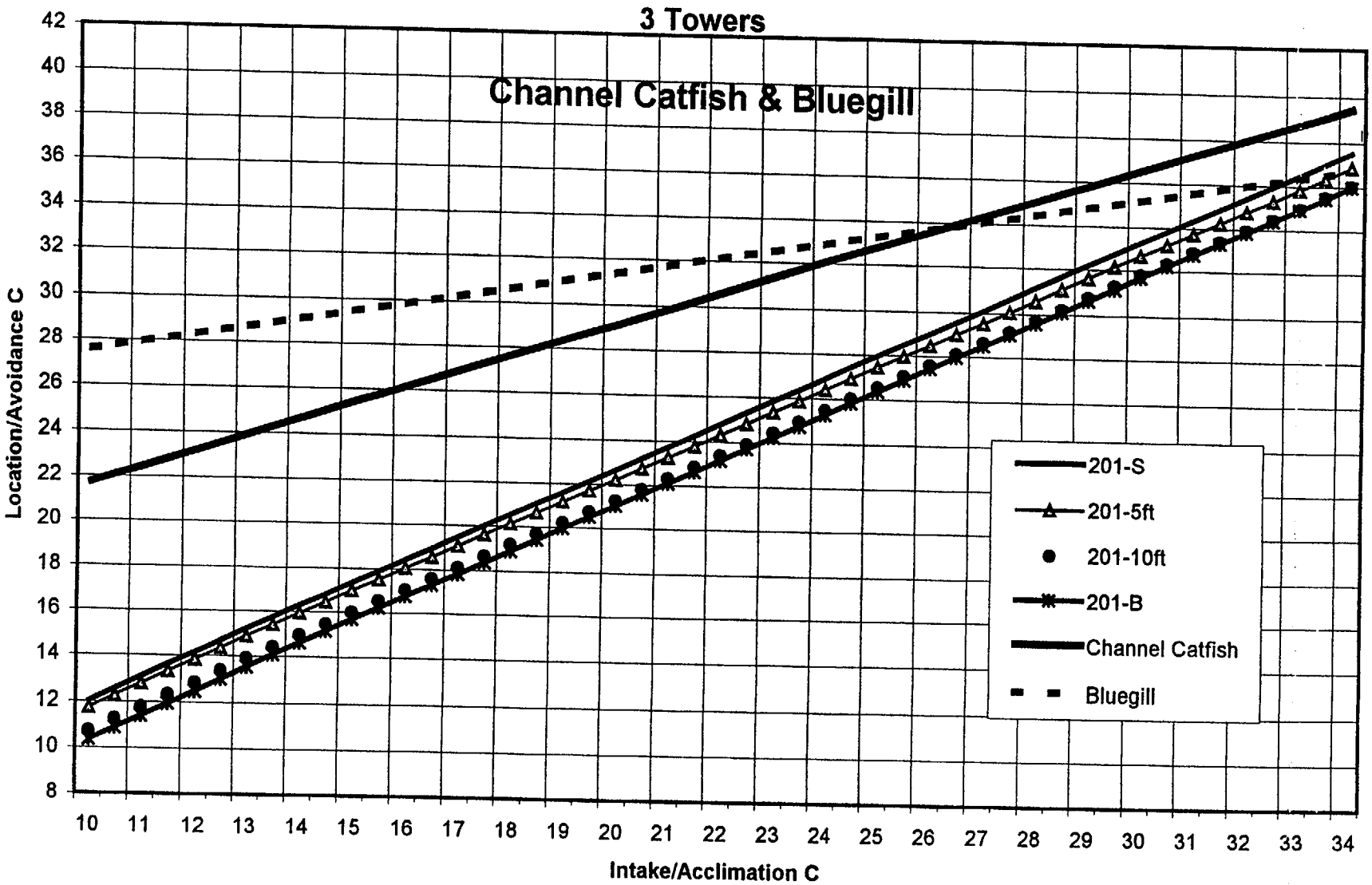
2 Towers



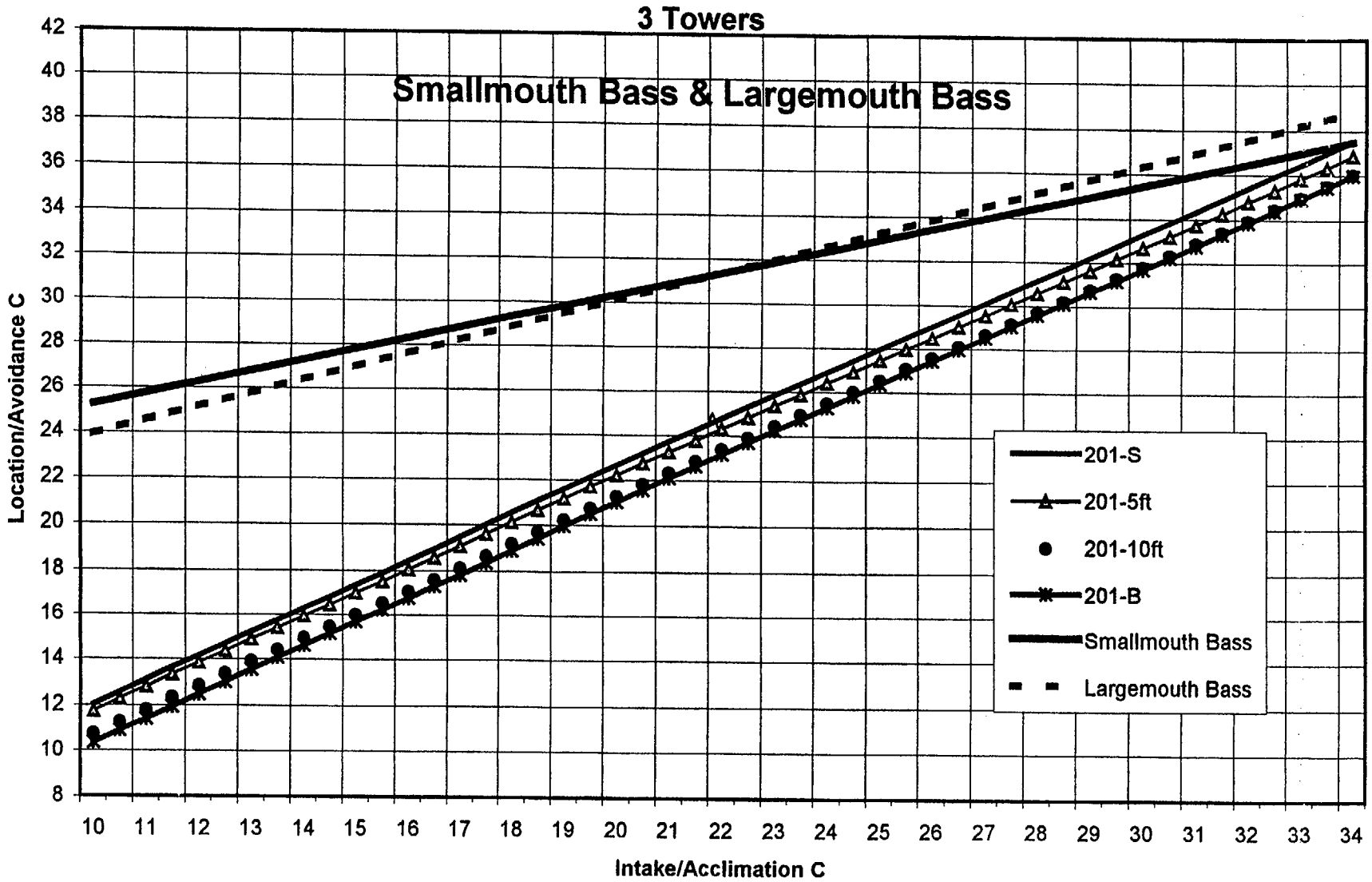
201 vs Avoidance C at 0 to 3 Tower Operations



201 vs Avoidance C at 0 to 3 Tower Operations



201 vs Avoidance C at 0 to 3 Tower Operations



201 vs Avoidance C at 0 to 3 Tower Operations

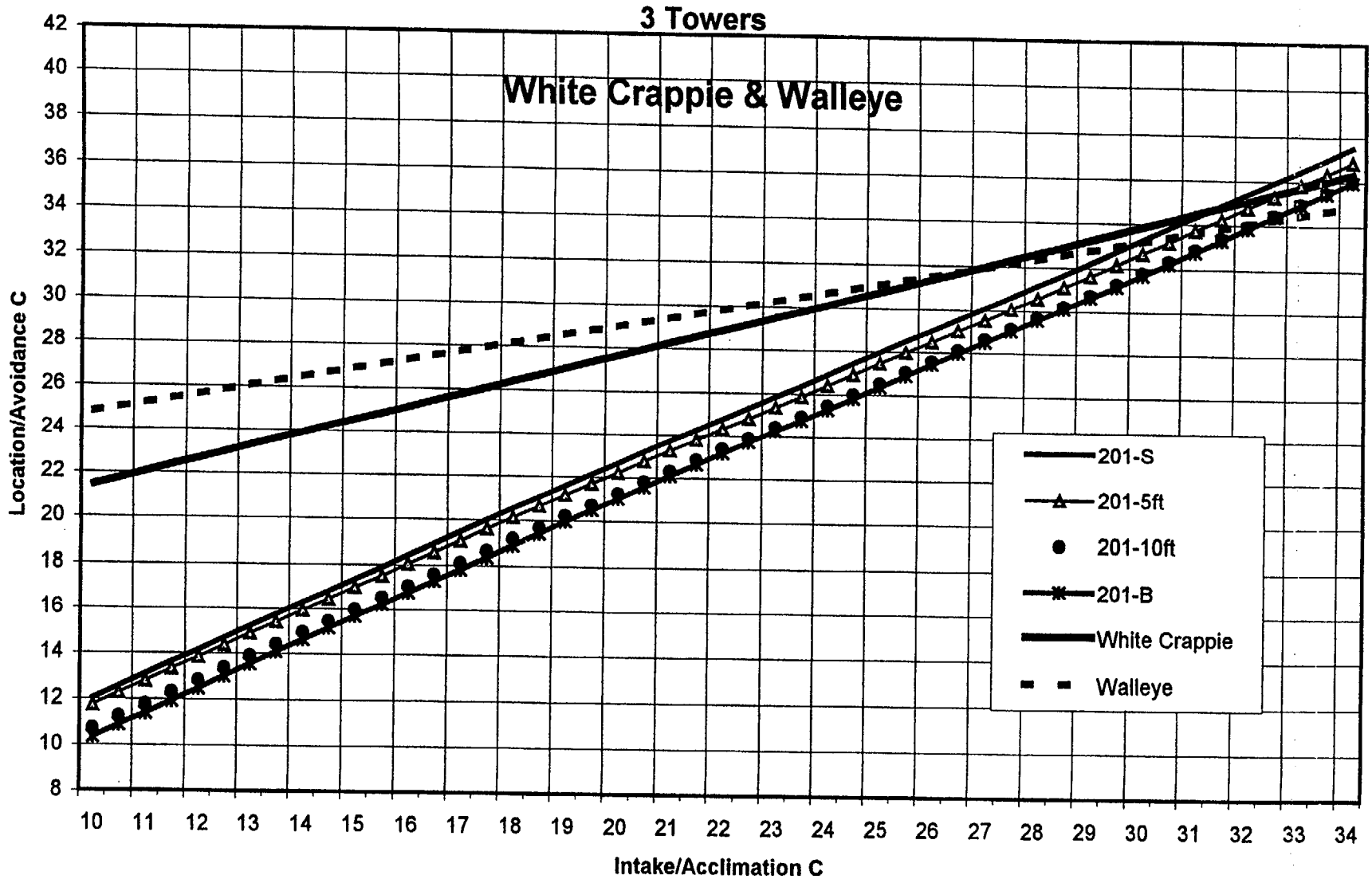
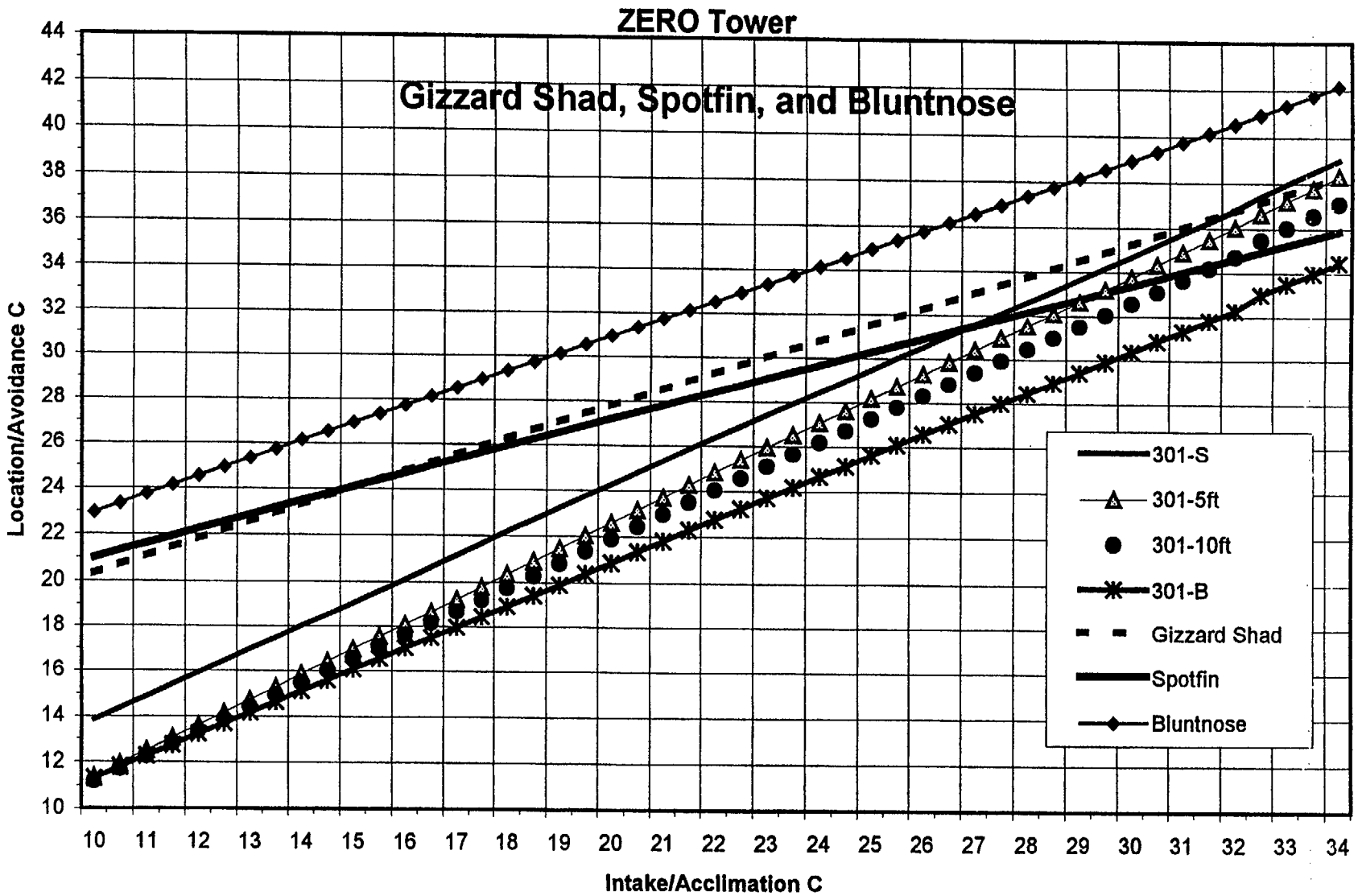


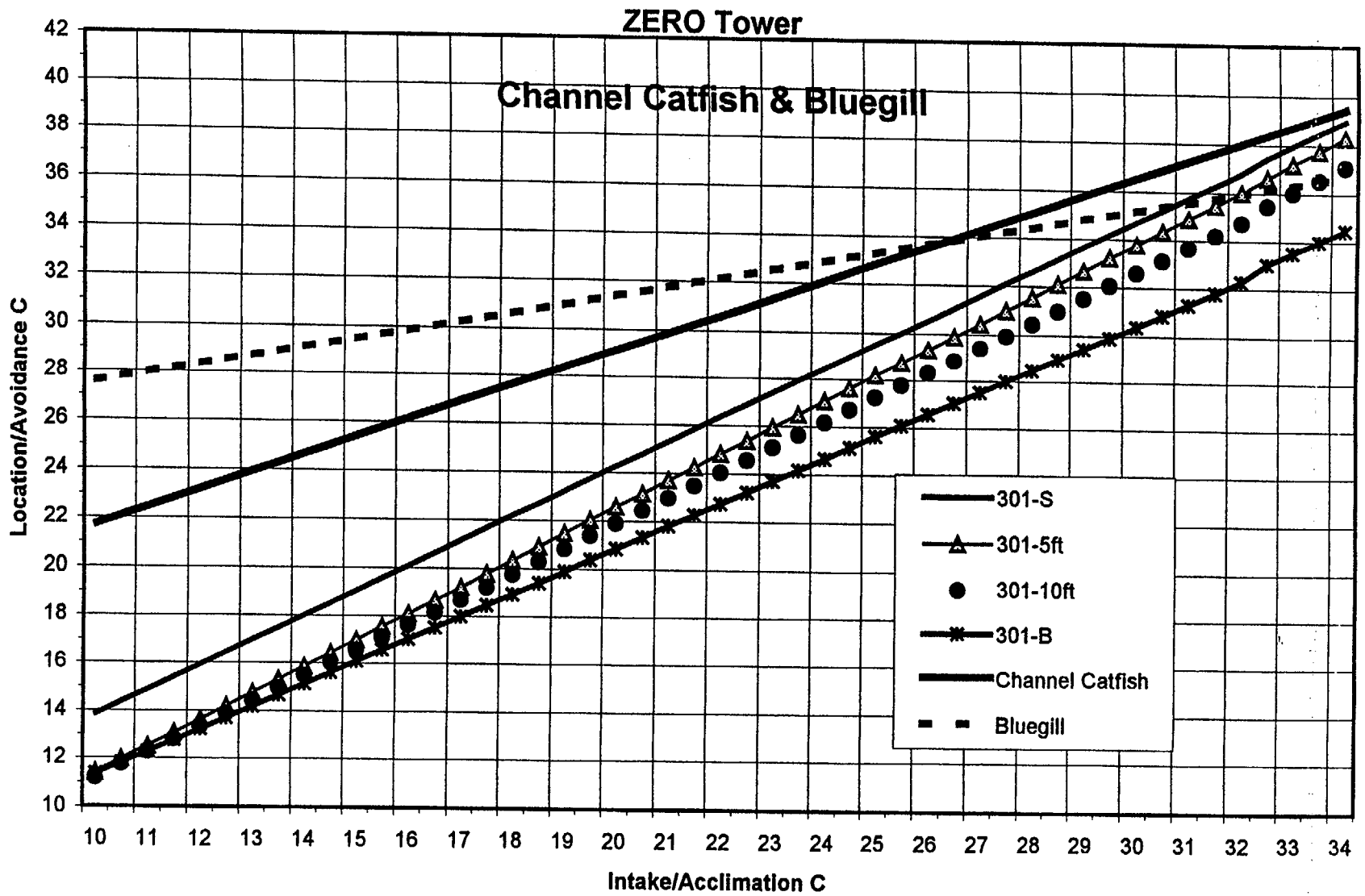
Figure A-4

Relationship of Station 301 Temperature versus Fish Avoidance Temperature (°C) at 0 to 3 Tower Operations

301 vs Avoidance C at 0 to 3 Tower Operations

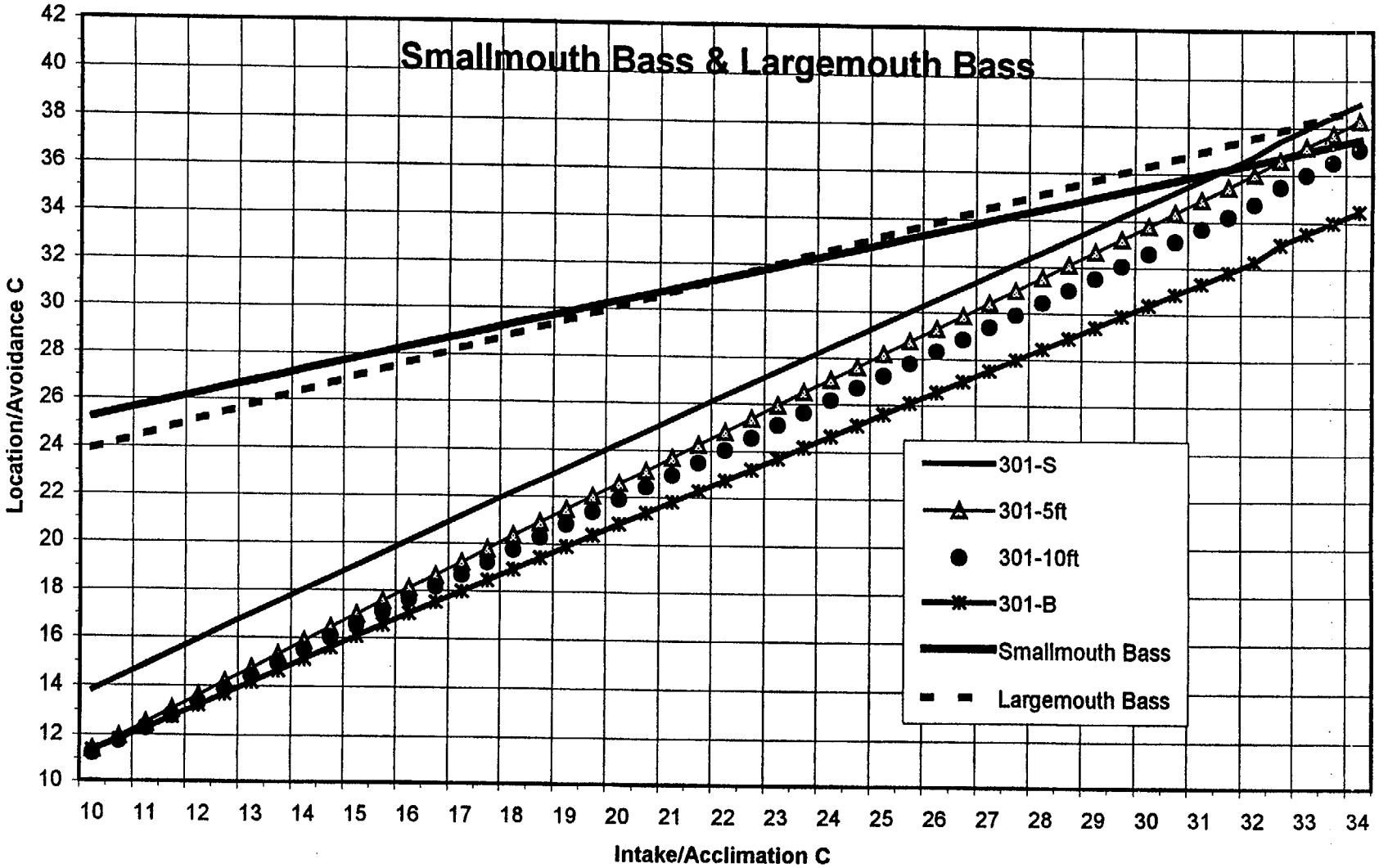


301 vs Avoidance C at 0 to 3 Tower Operations



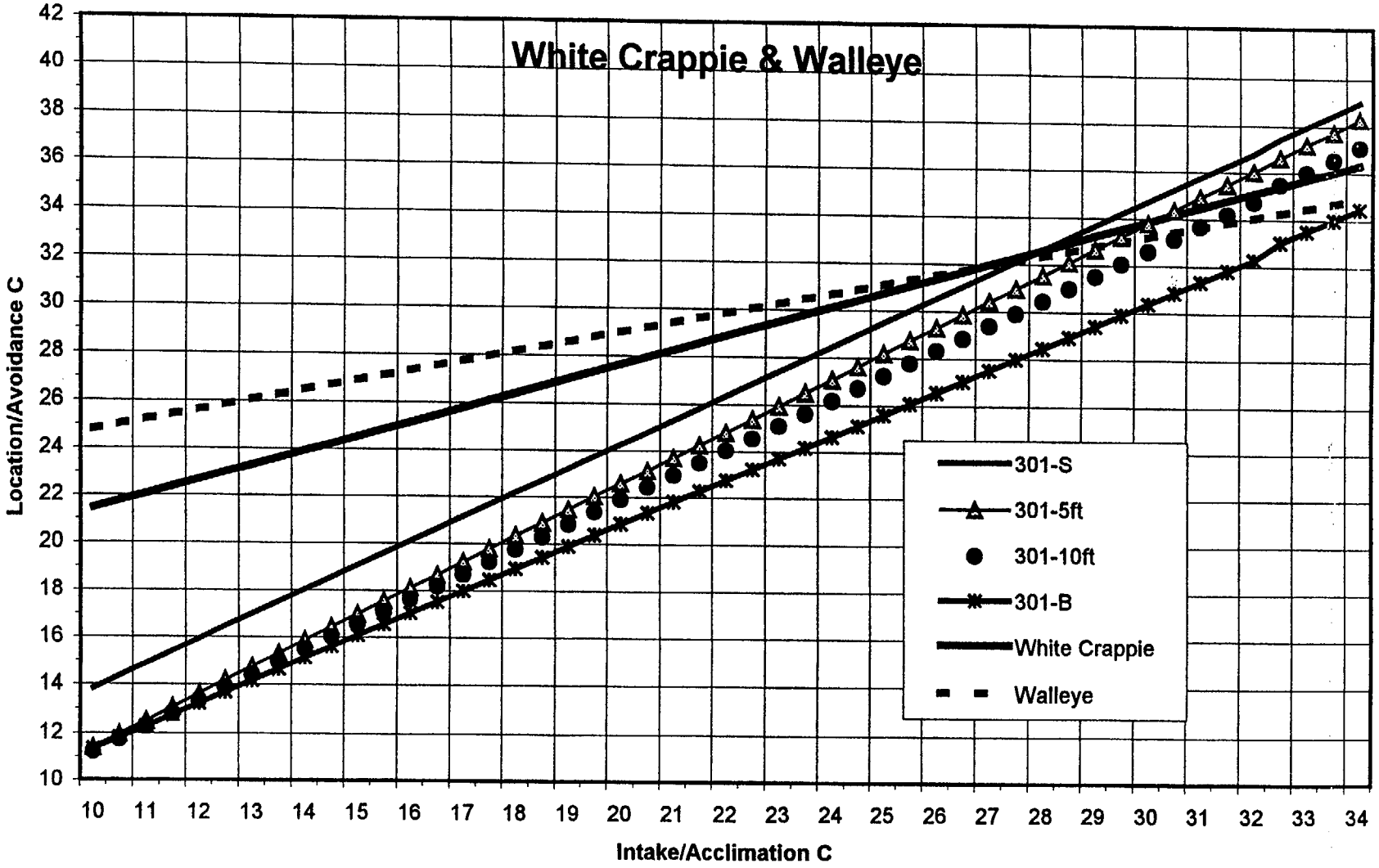
301 vs Avoidance C at 0 to 3 Tower Operations

ZERO Tower

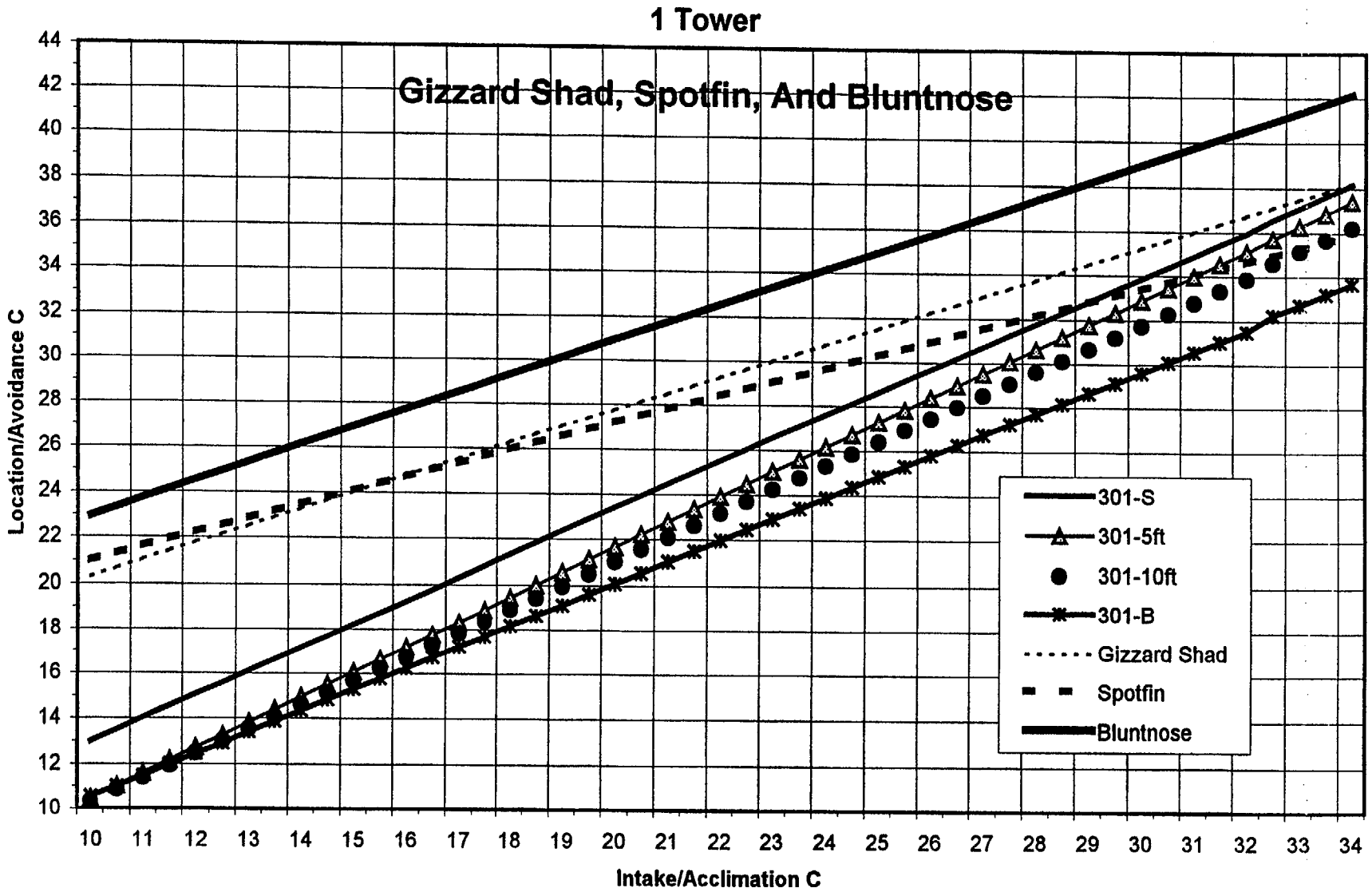


301 vs Avoidance C at 0 to 3 Tower Operations

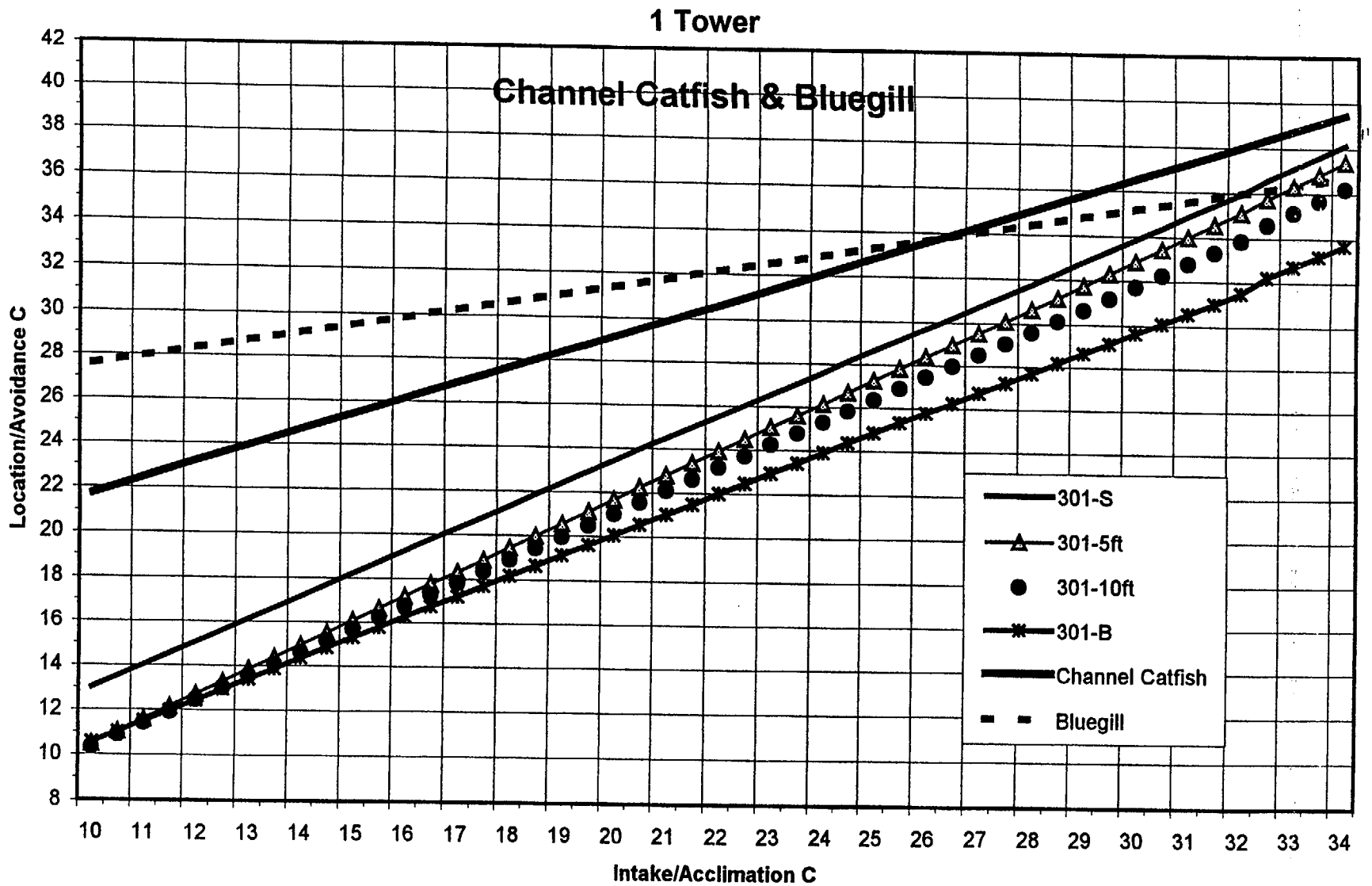
ZERO Tower



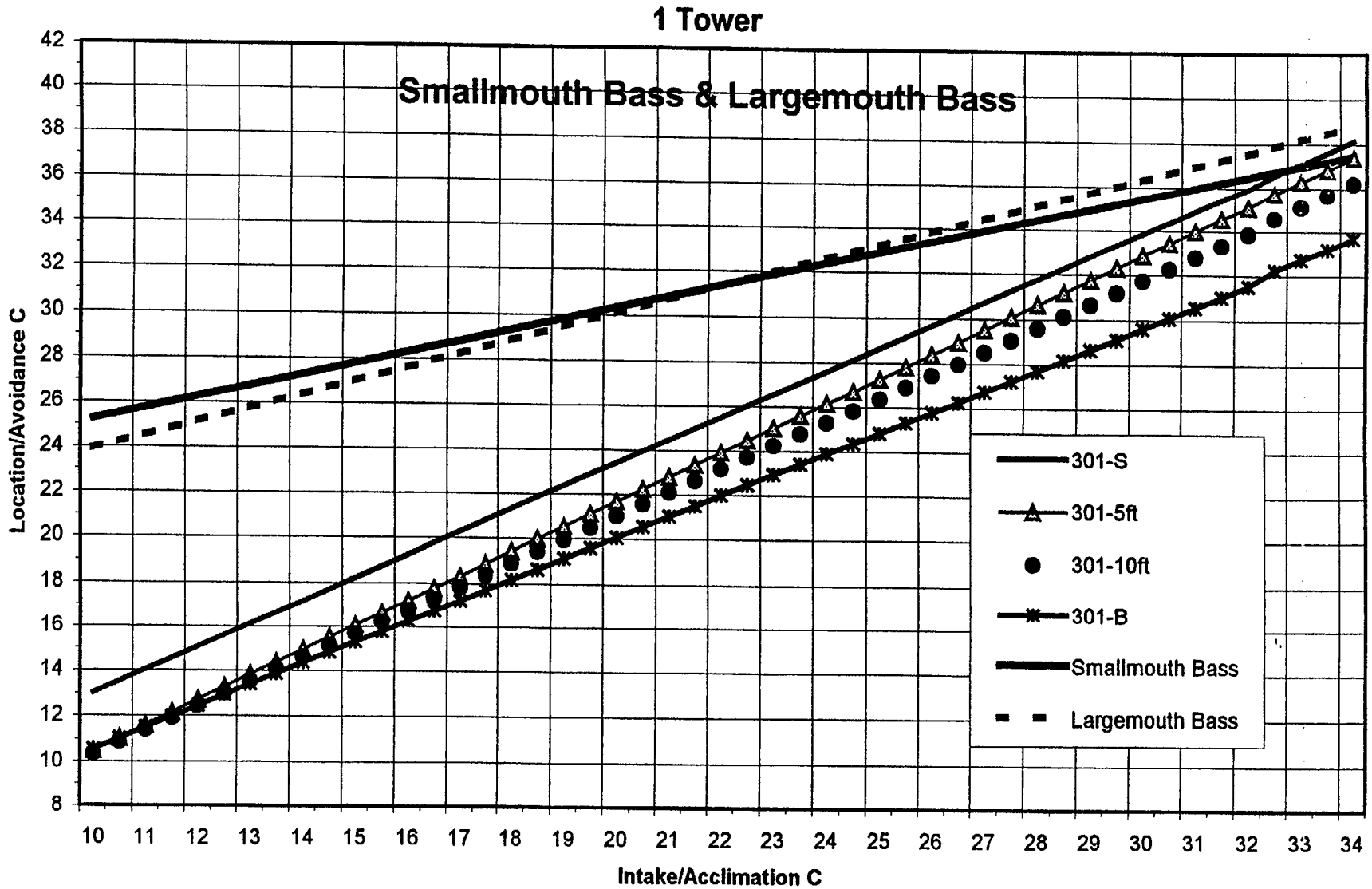
301 vs Avoidance C at 0 to 3 Tower Operations



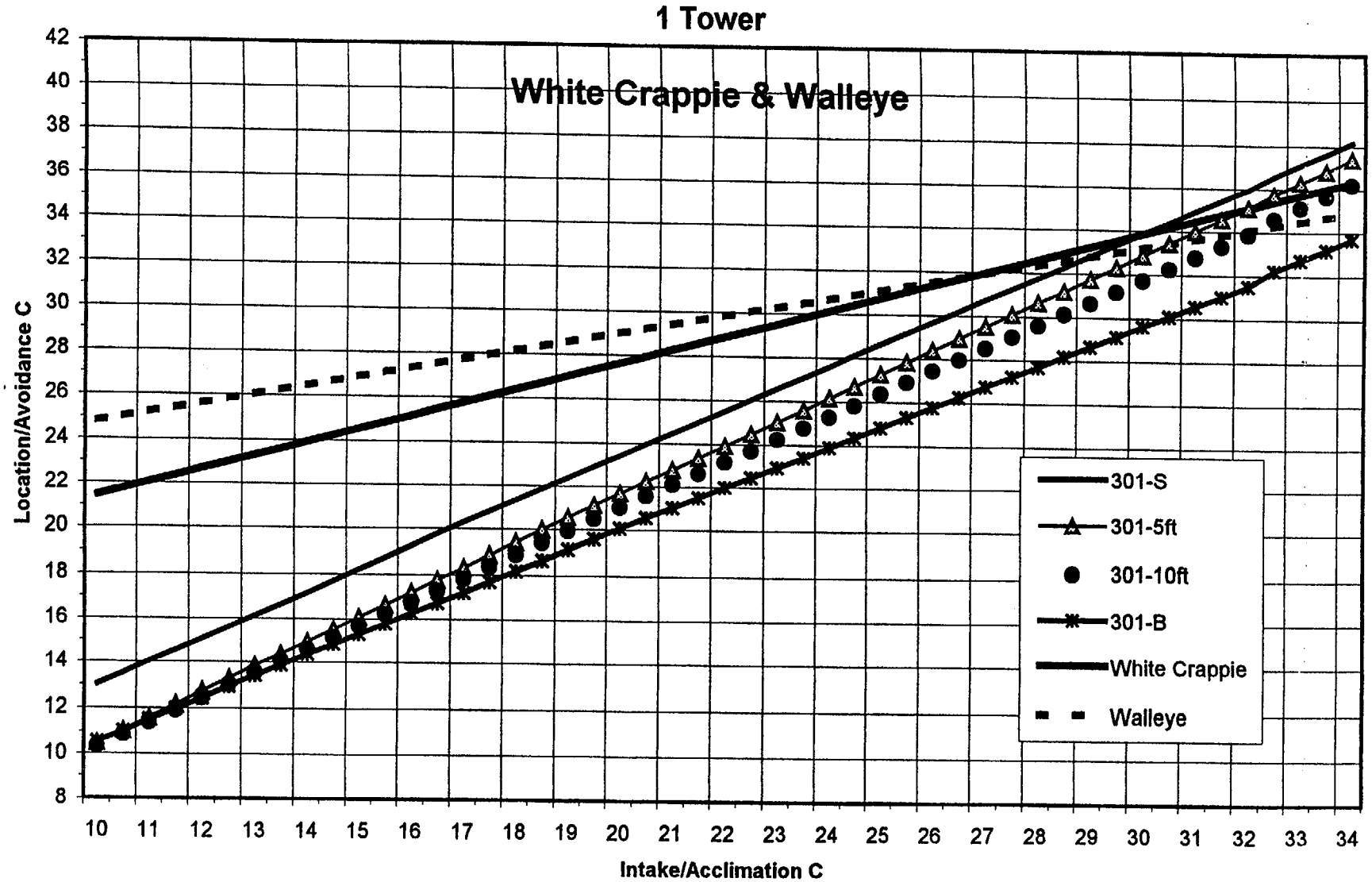
301 vs Avoidance C at 0 to 3 Tower Operations



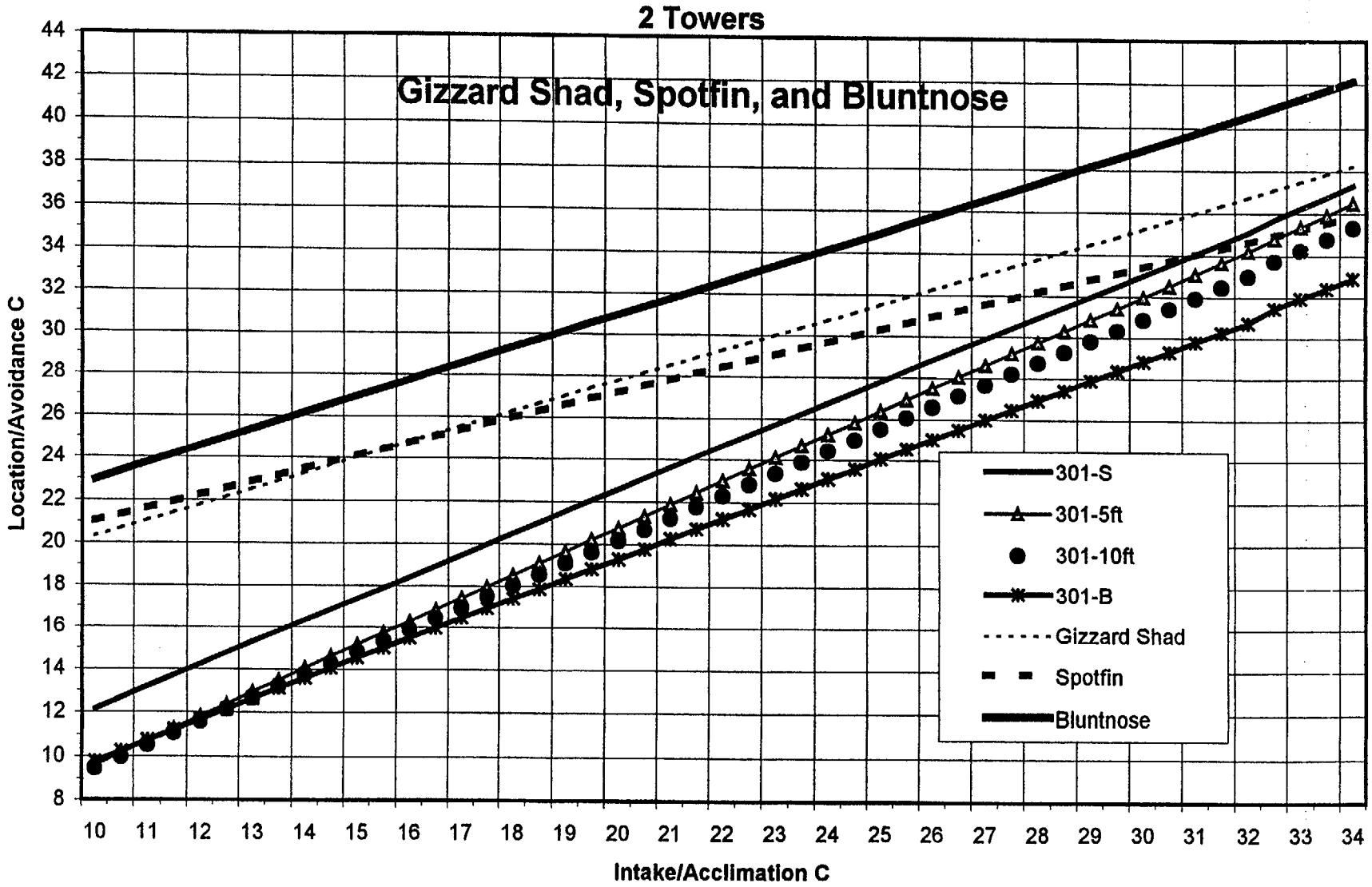
301 vs Avoidance C at 0 to 3 Tower Operations

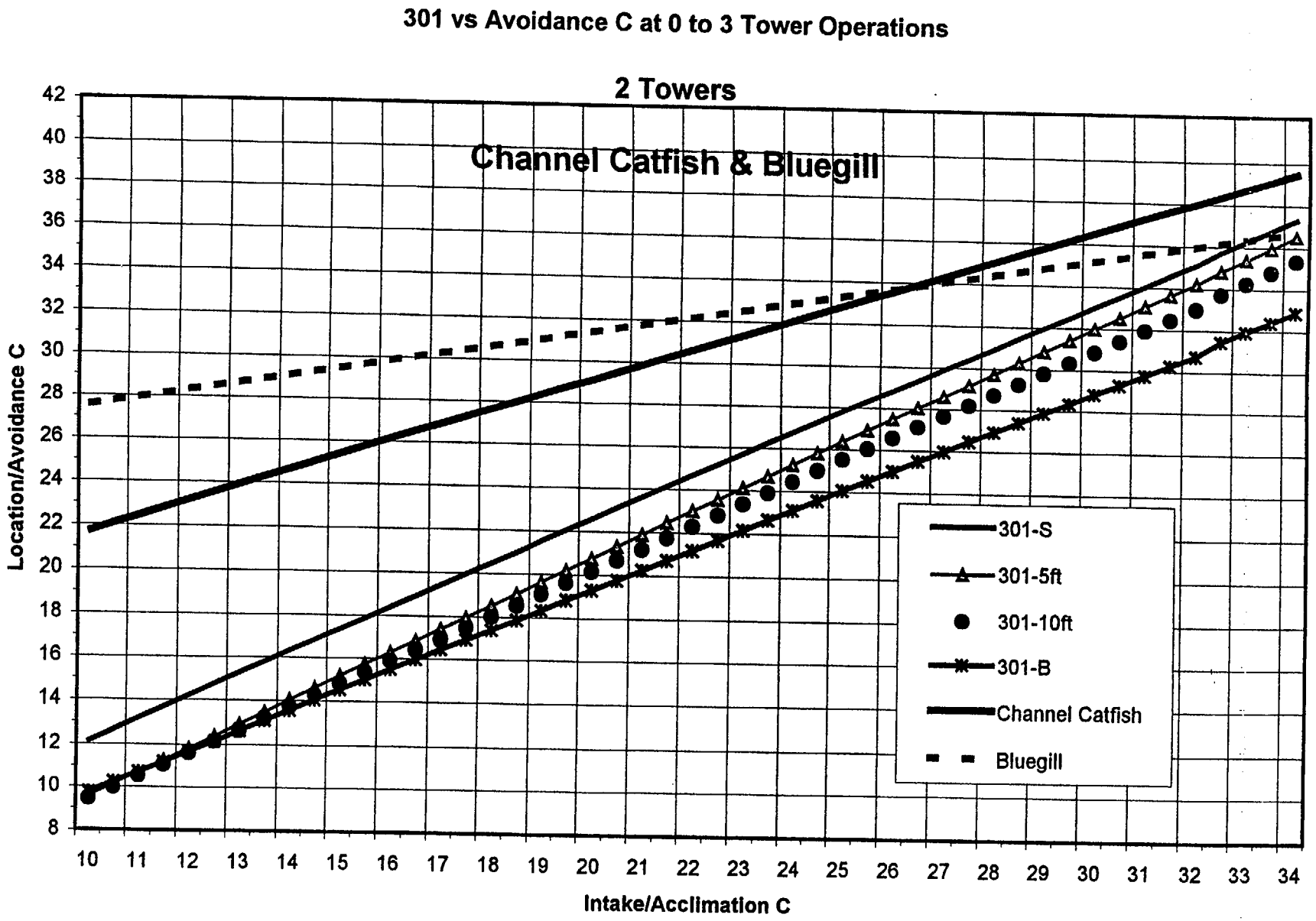


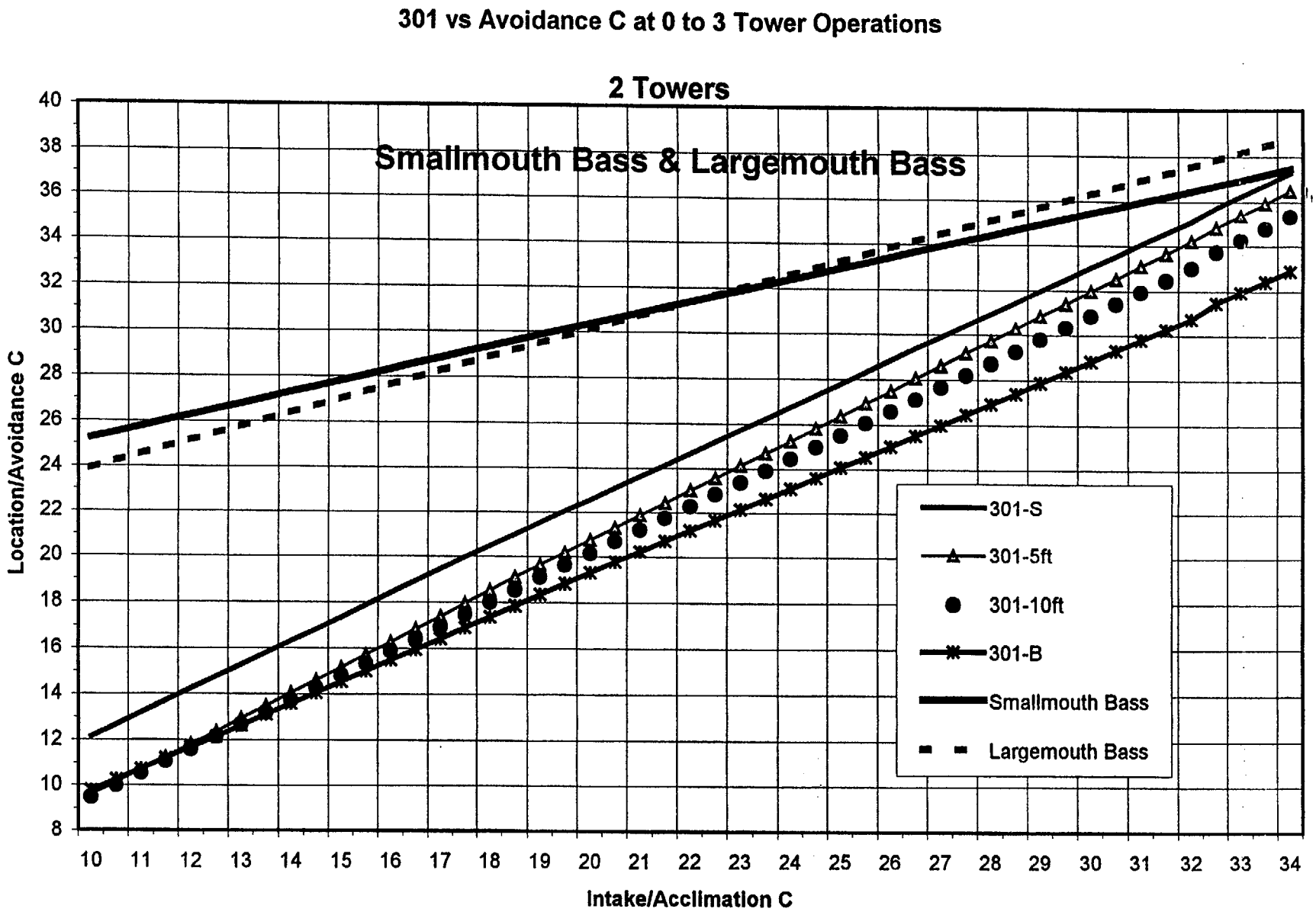
301 vs Avoidance C at 0 to 3 Tower Operations

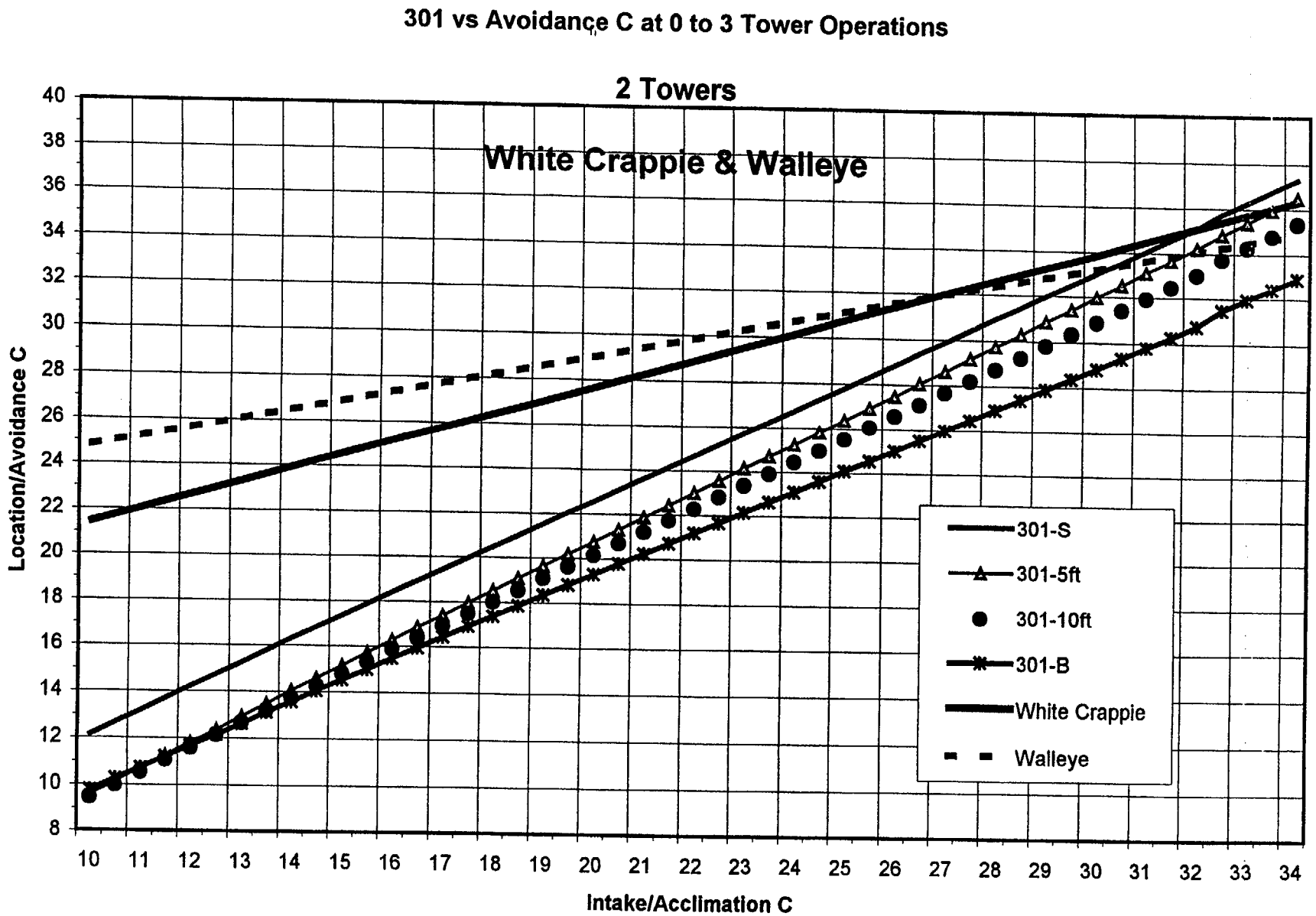


301 vs Avoidance C at 0 to 3 Tower Operations




301 vs Avoidance C at 0 to 3 Tower Operations
2 Towers
Channel Catfish & Bluegill
Location/Avoidance C
Intake/Acclimation C
42
40
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34
301-S
301-5ft
301-10ft
301-B
Channel Catfish
Bluegill


301 vs Avoidance C at 0 to 3 Tower Operations
2 Towers
Smallmouth Bass & Largemouth Bass
Location/Avoidance C
Intake/Acclimation C
40
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
301-S
301-5ft
301-10ft
301-B
Smallmouth Bass
Largemouth Bass


301 vs Avoidance C at 0 to 3 Tower Operations
2 Towers
White Crappie & Walleye
Location/Avoidance C
Intake/Acclimation C
40
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
10
11
12
13
14
15
16
17
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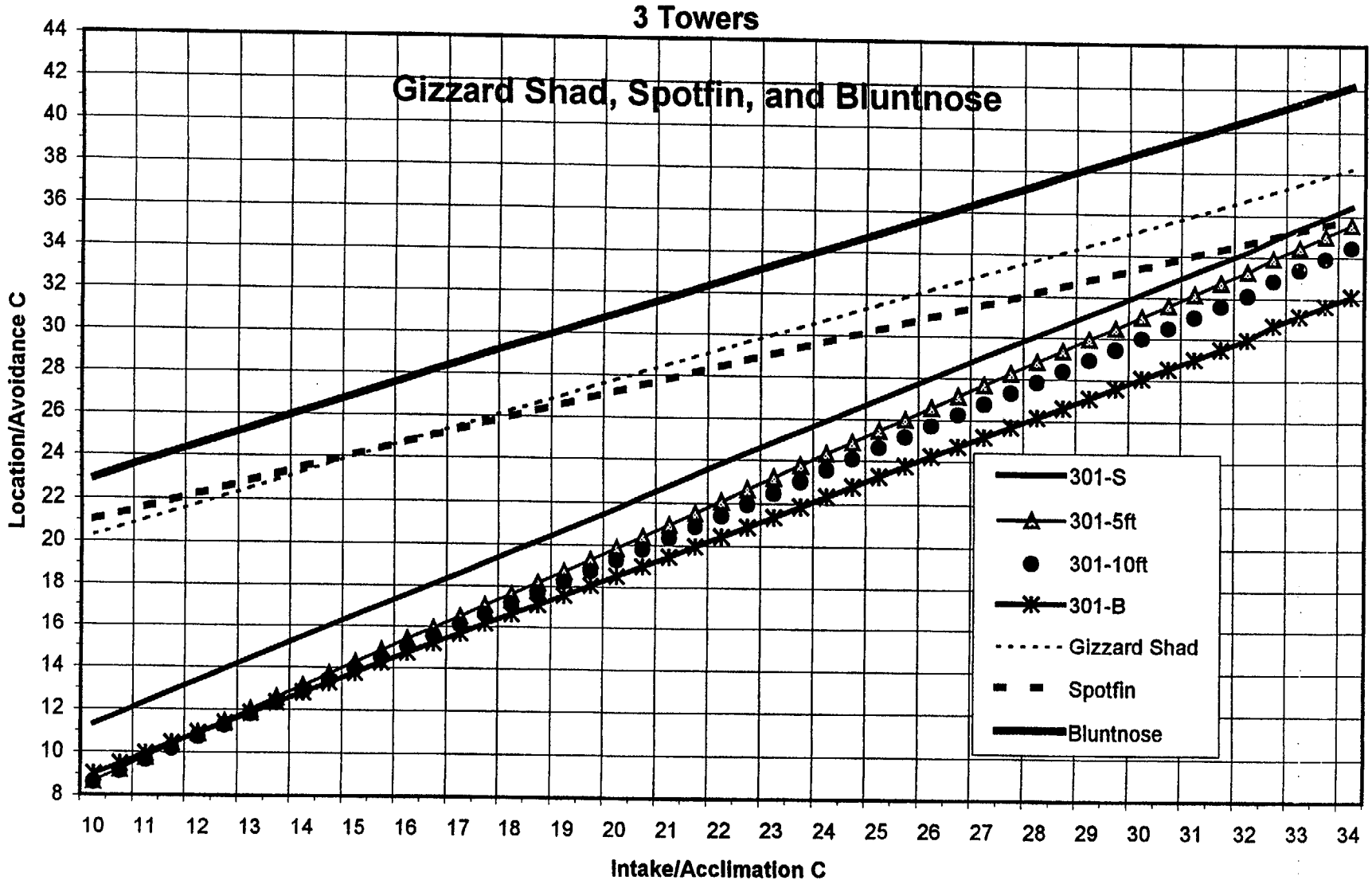
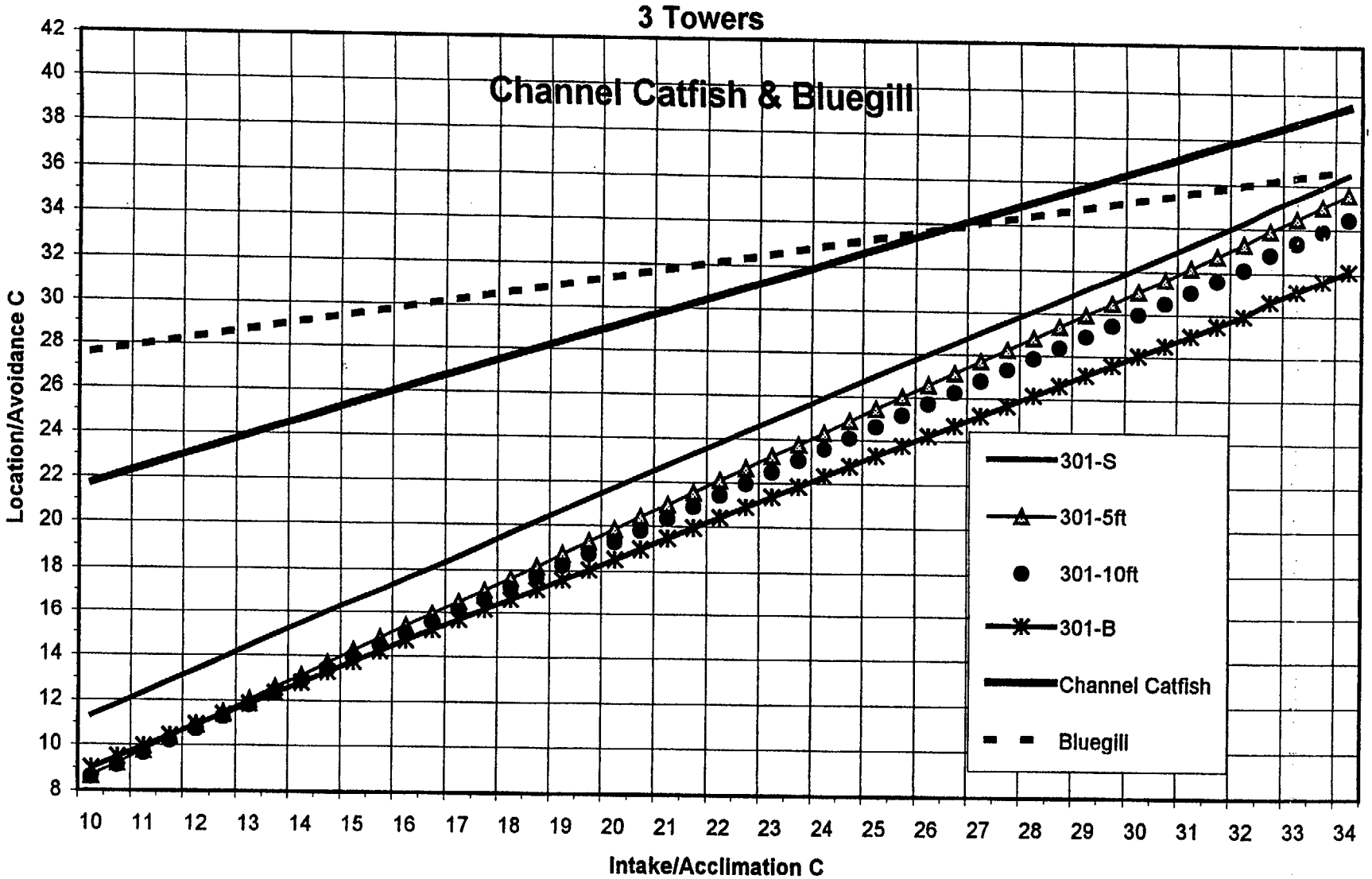
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
301-S
301-5ft
301-10ft
301-B
White Crappie
Walleye

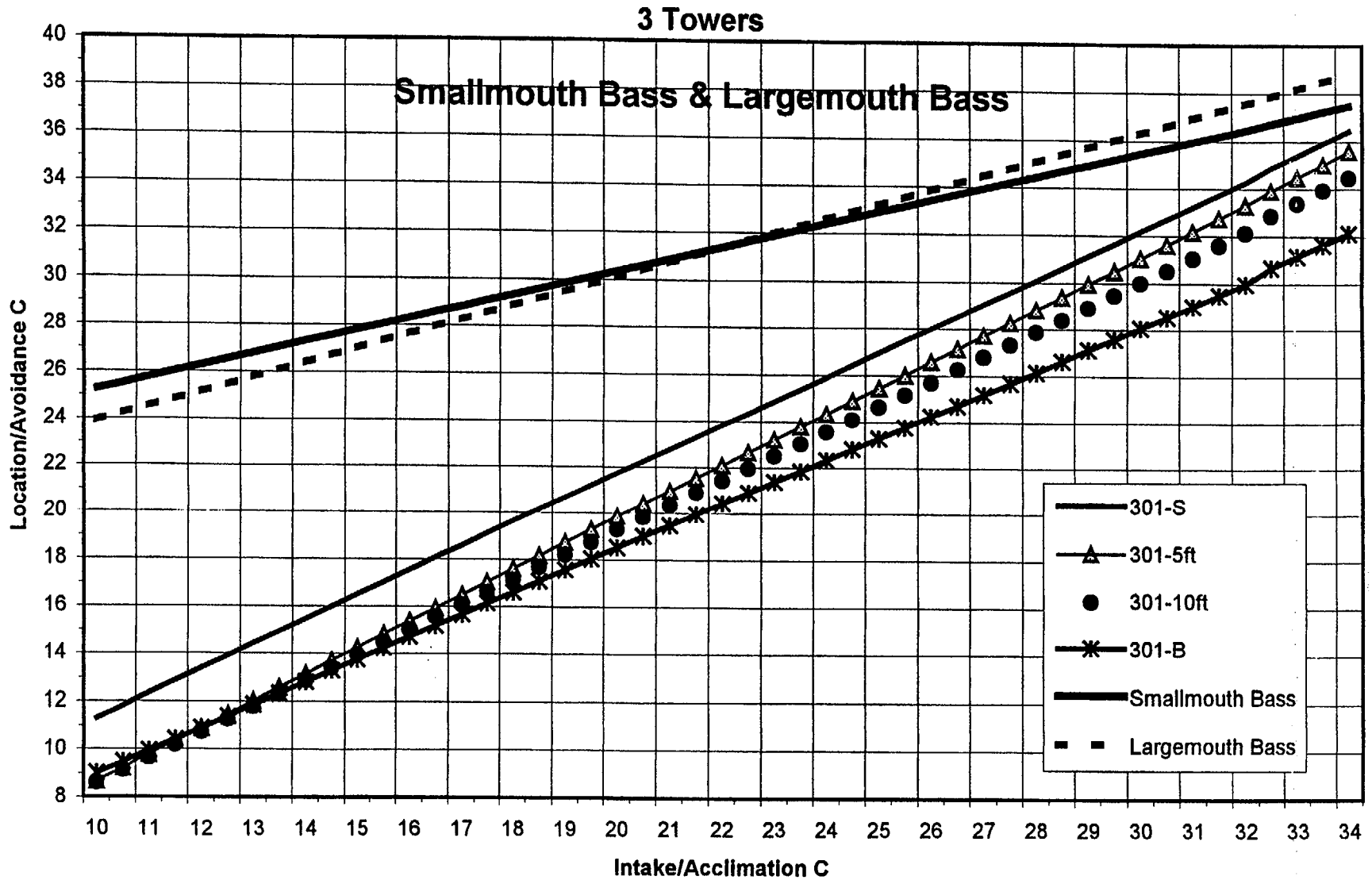
301 vs Avoidance C at 0 to 3 Tower Operations



301 vs Avoidance C at 0 to 3 Tower Operations



301 vs Avoidance C at 0 to 3 Tower Operations



301 vs Avoidance C at 0 to 3 Tower Operations

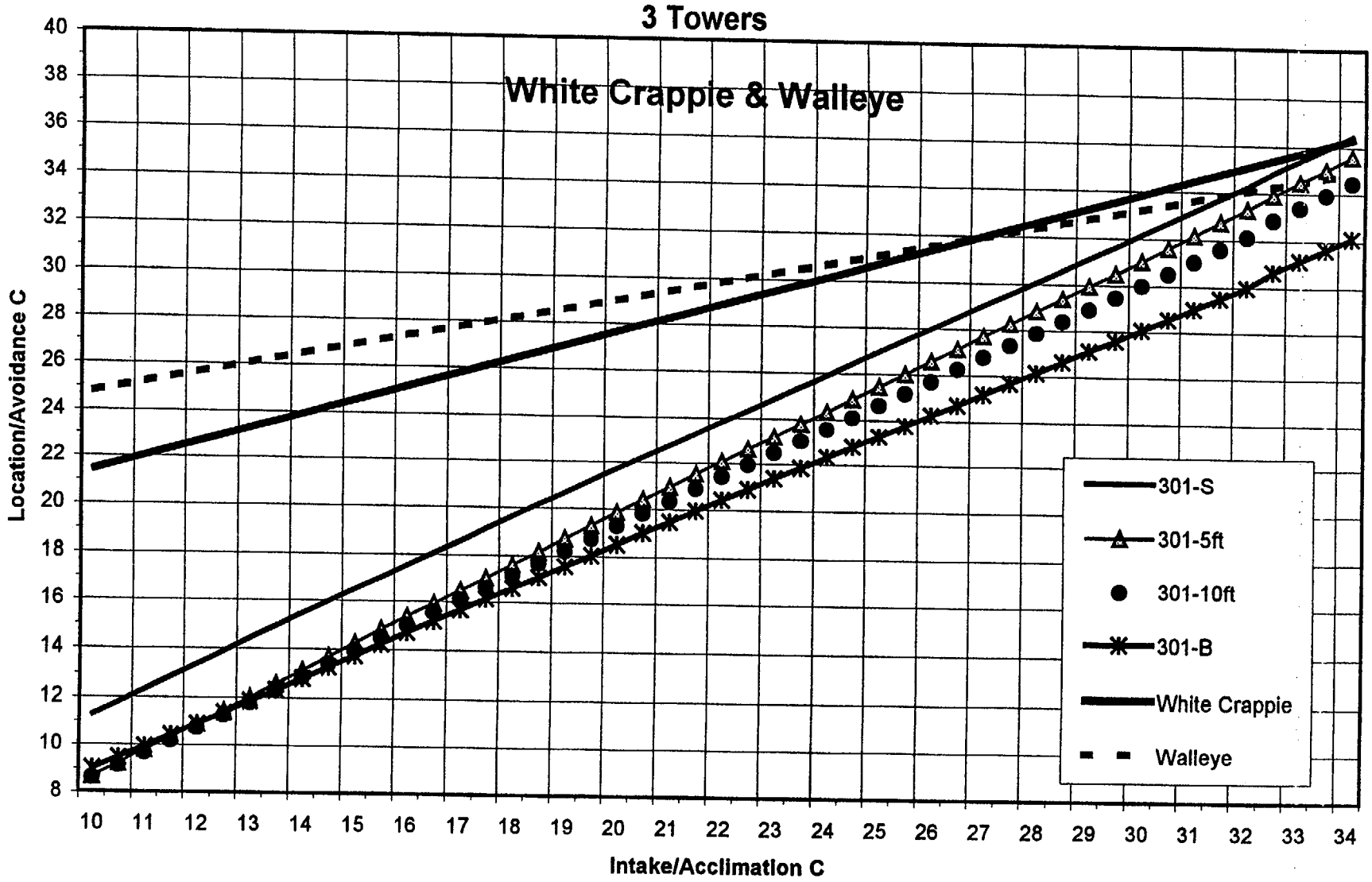
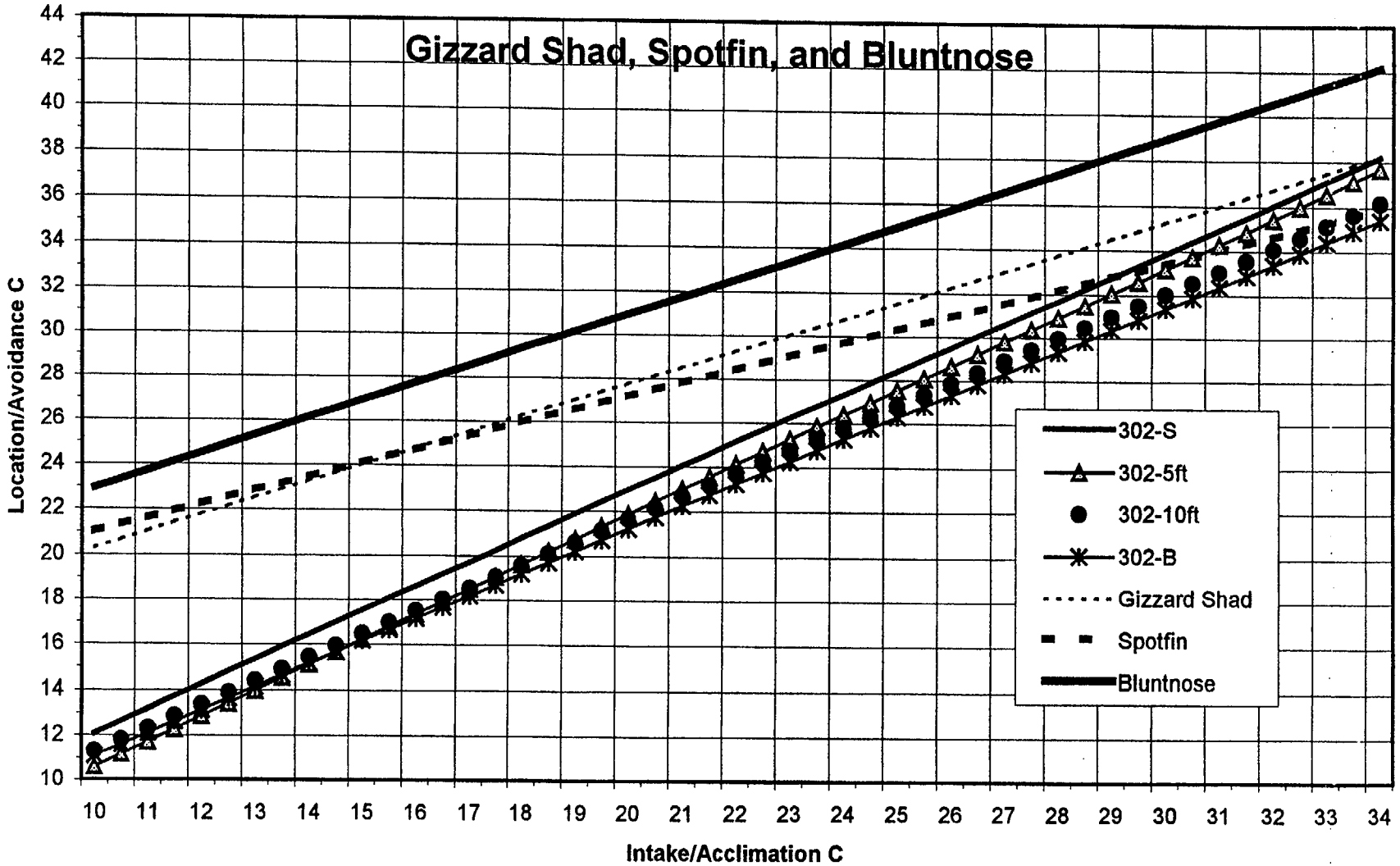


Figure A-5

Relationship of Station 302 Temperature versus Fish Avoidance Temperature (°C) at 0 to 3 Tower Operations

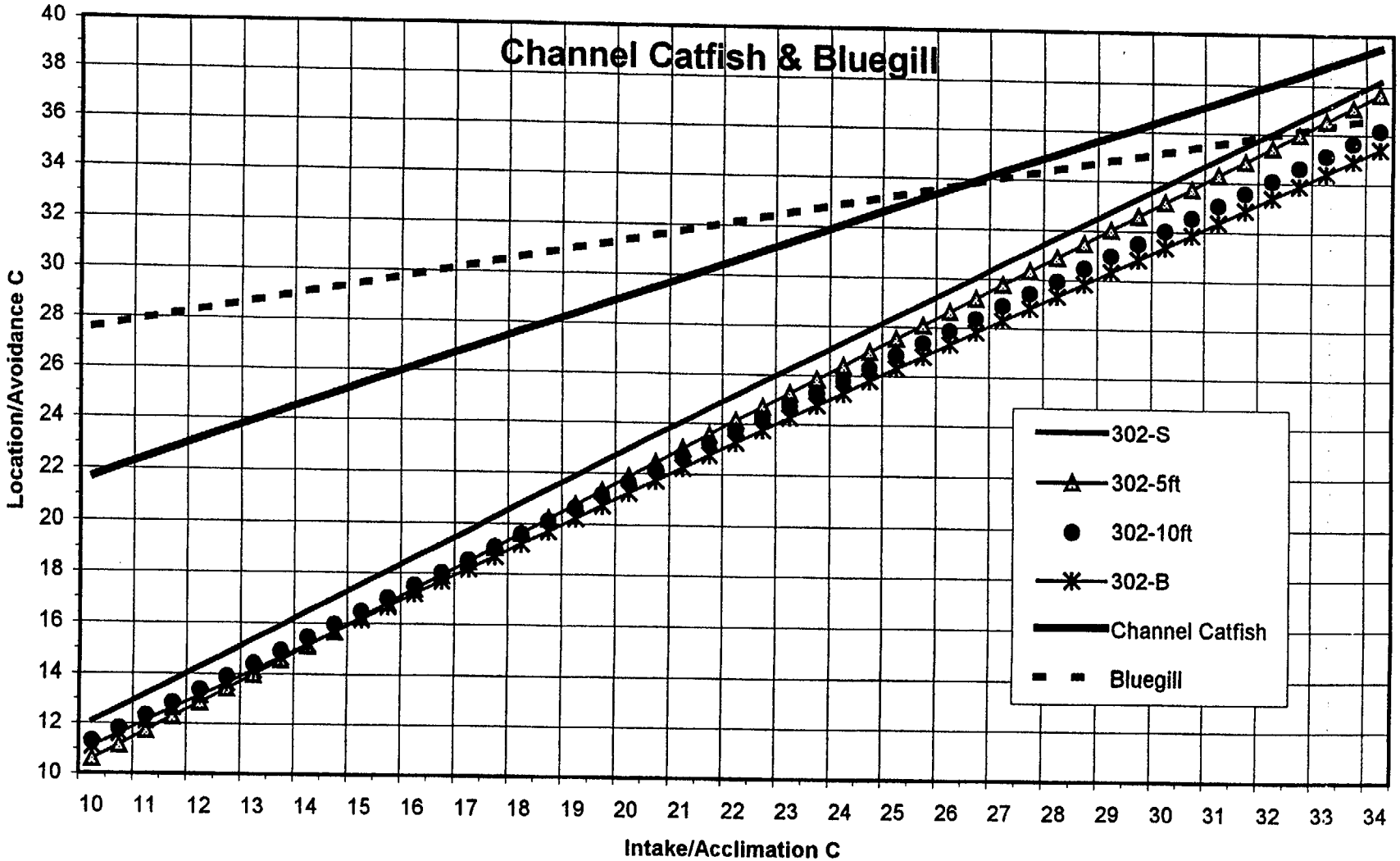
302 vs Avoidance C at 0 to 3 Tower Operations

ZERO Tower



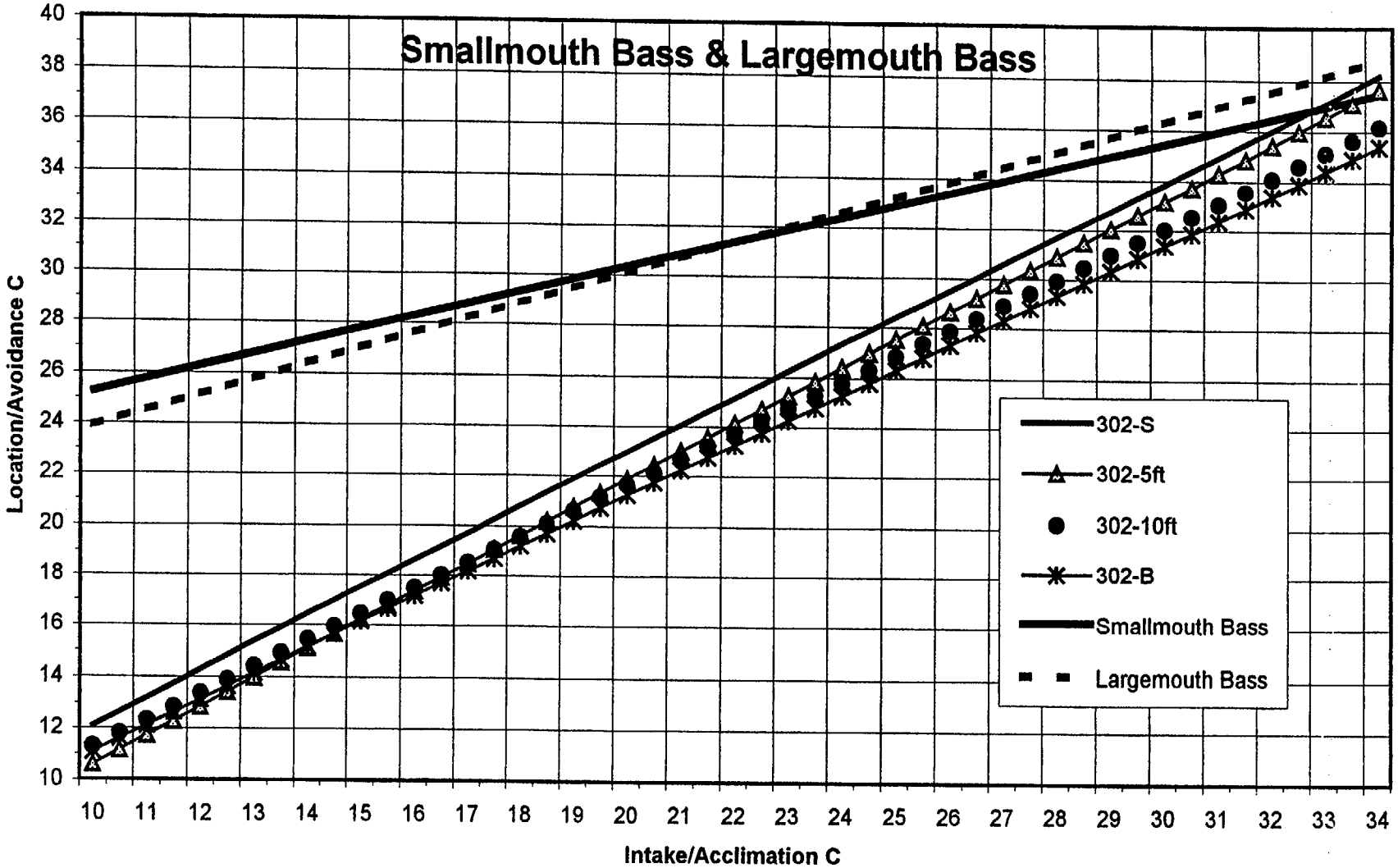
302 vs Avoidance C at 0 to 3 Tower Operations

ZERO Tower



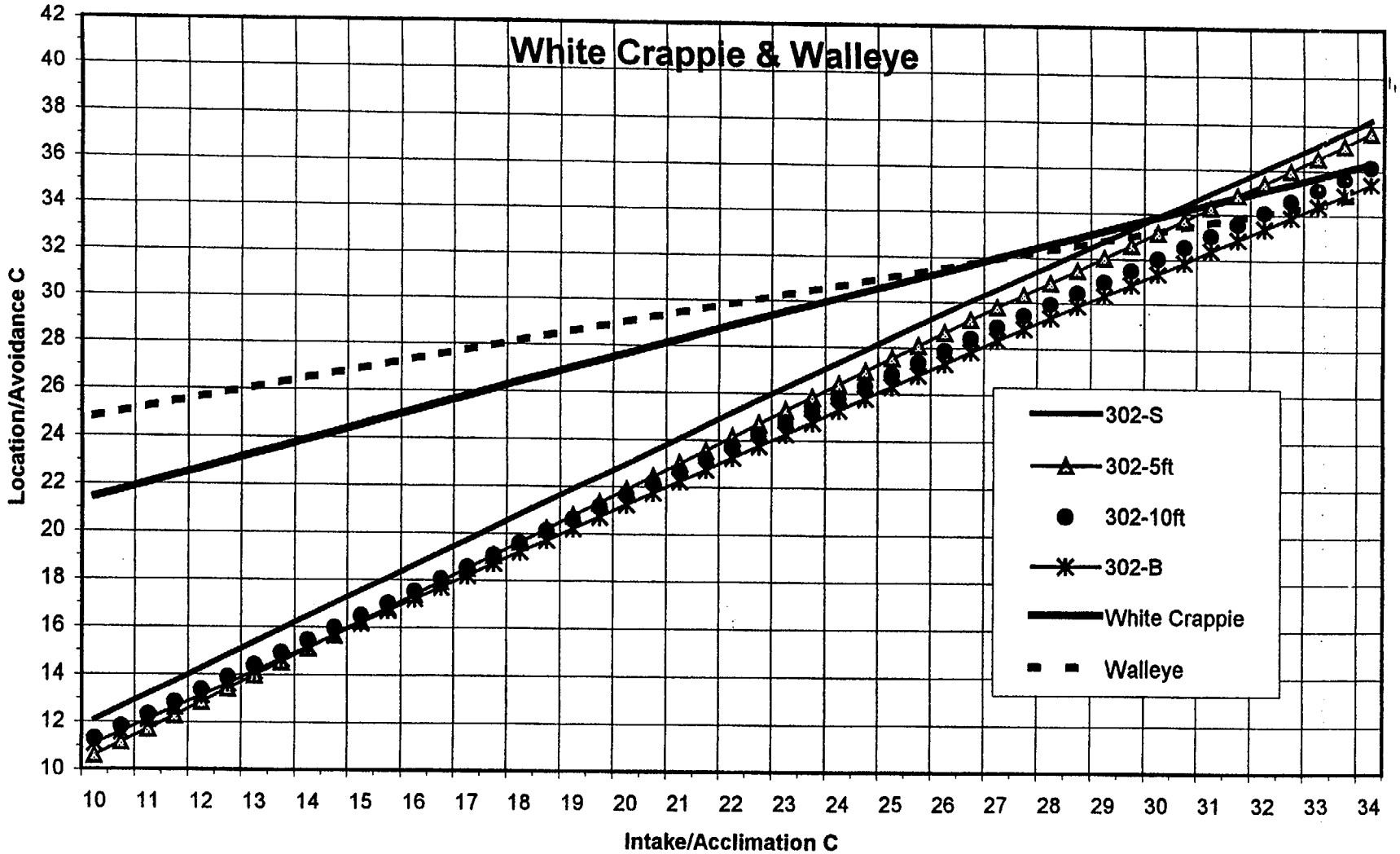
302 vs Avoidance C at 0 to 3 Tower Operations

ZERO Tower

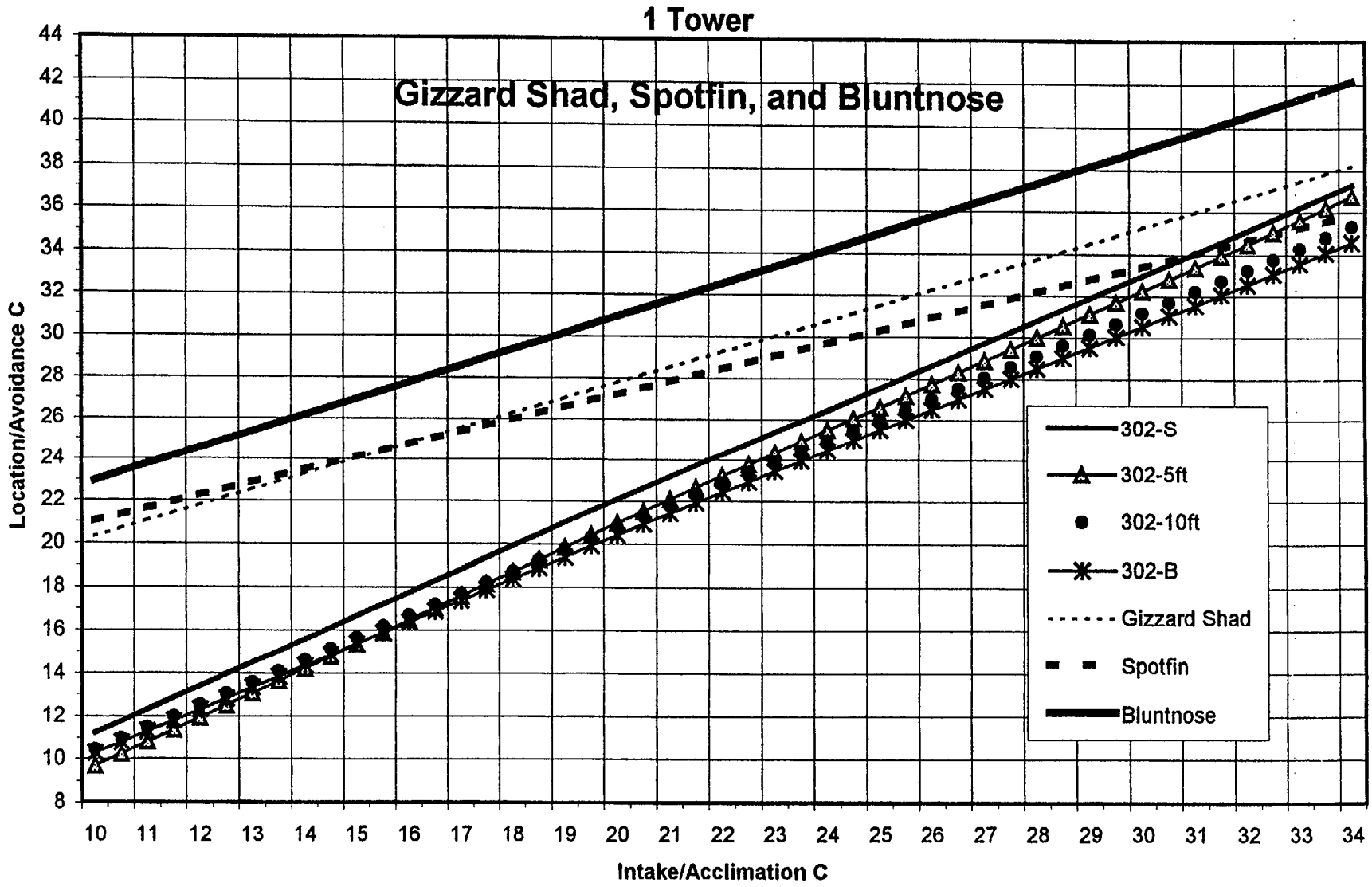


302 vs Avoidance C at 0 to 3 Tower Operations

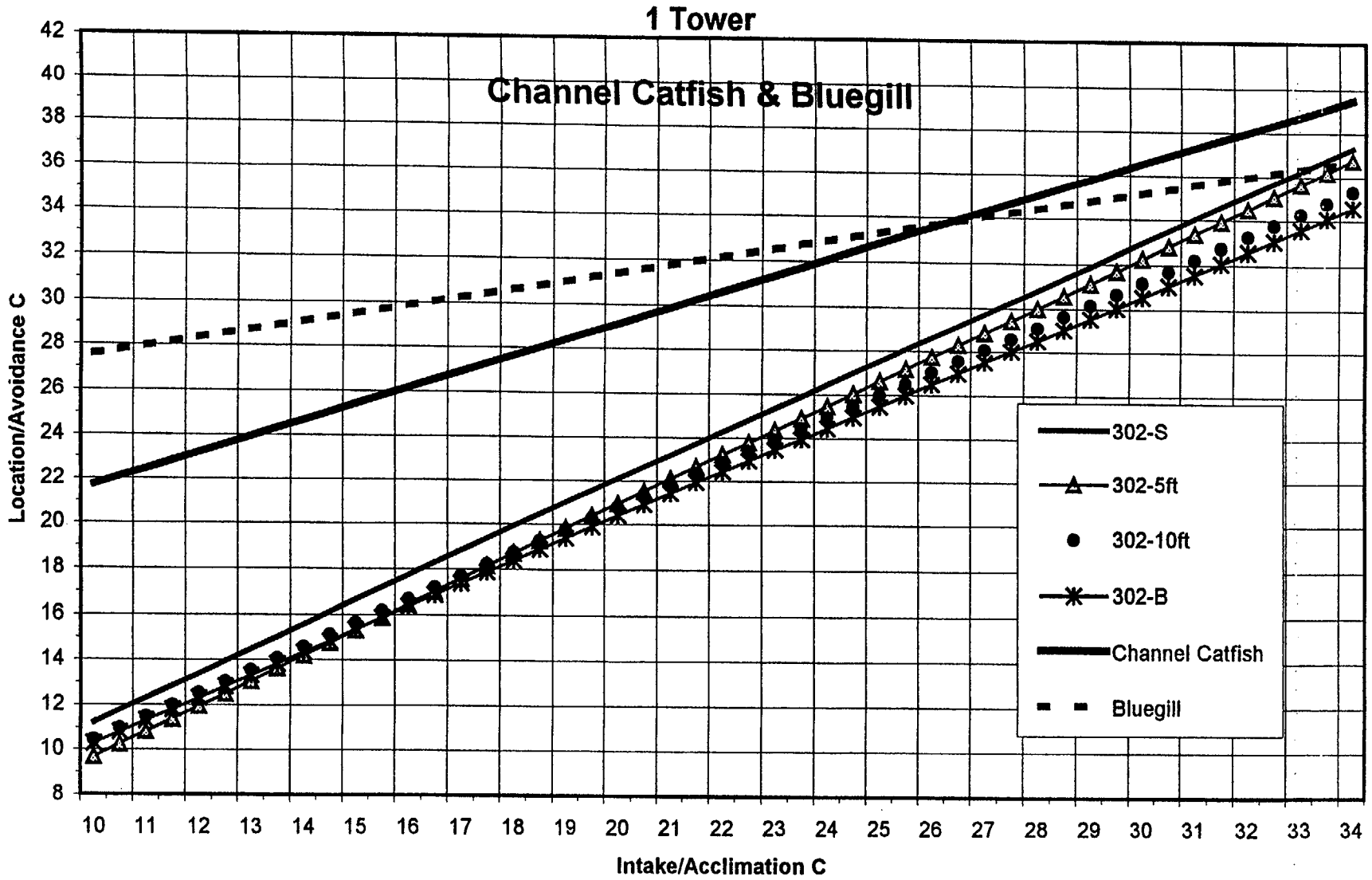
ZERO Tower



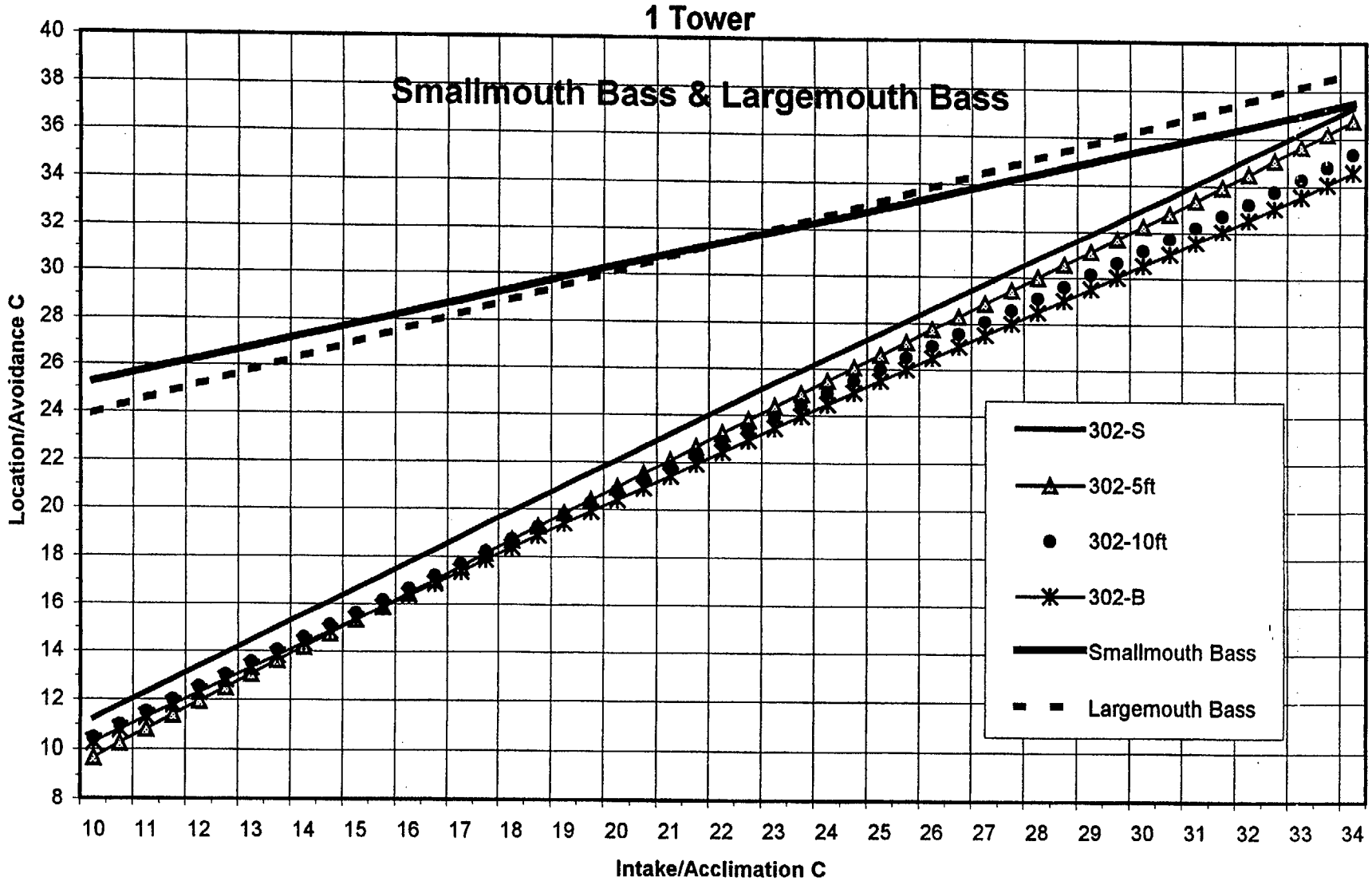
302 vs Avoidance C at 0 to 3 Tower Operations



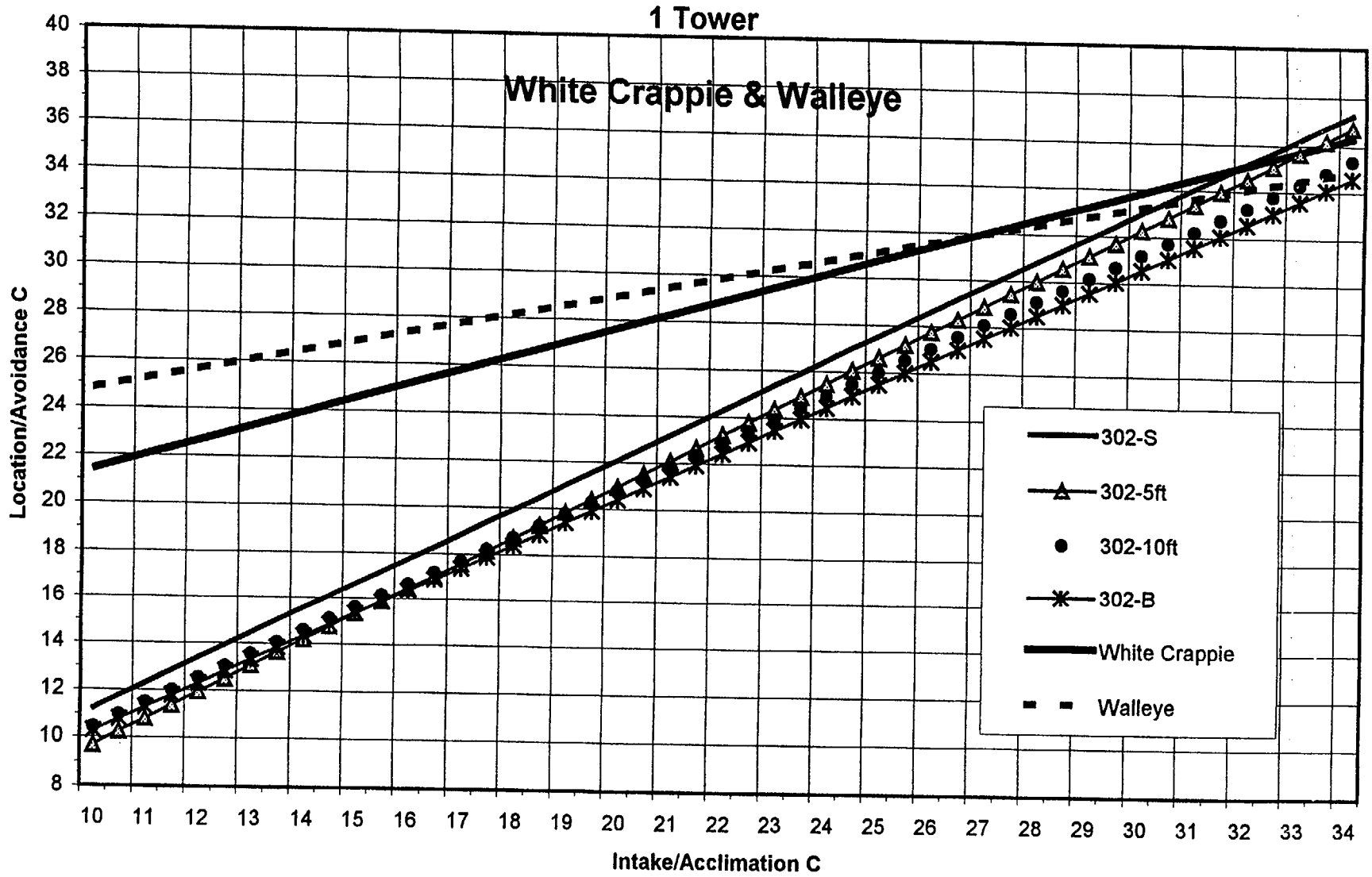
302 vs Avoidance C at 0 to 3 Tower Operations



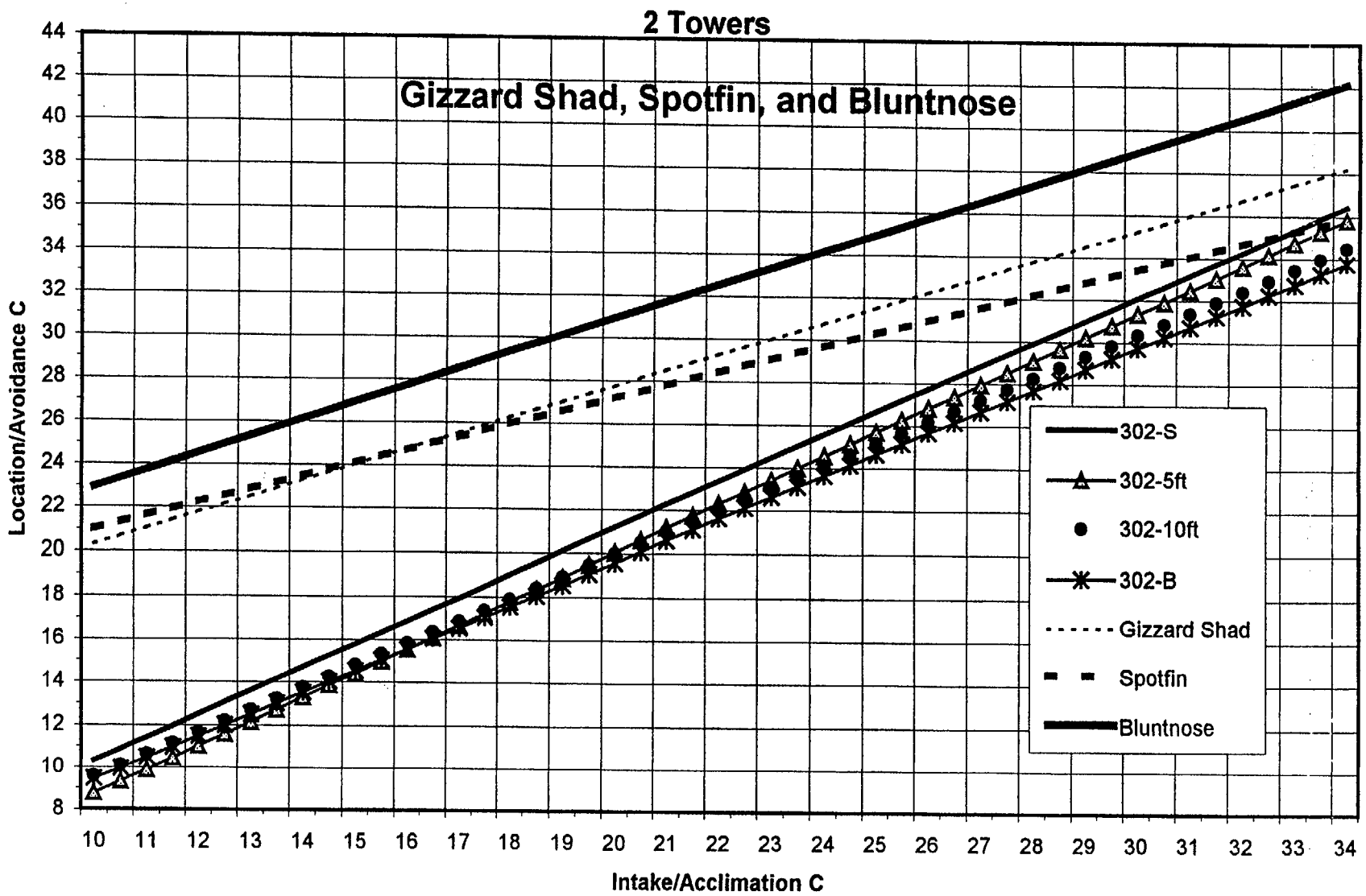
302 vs Avoidance C at 0 to 3 Tower Operations



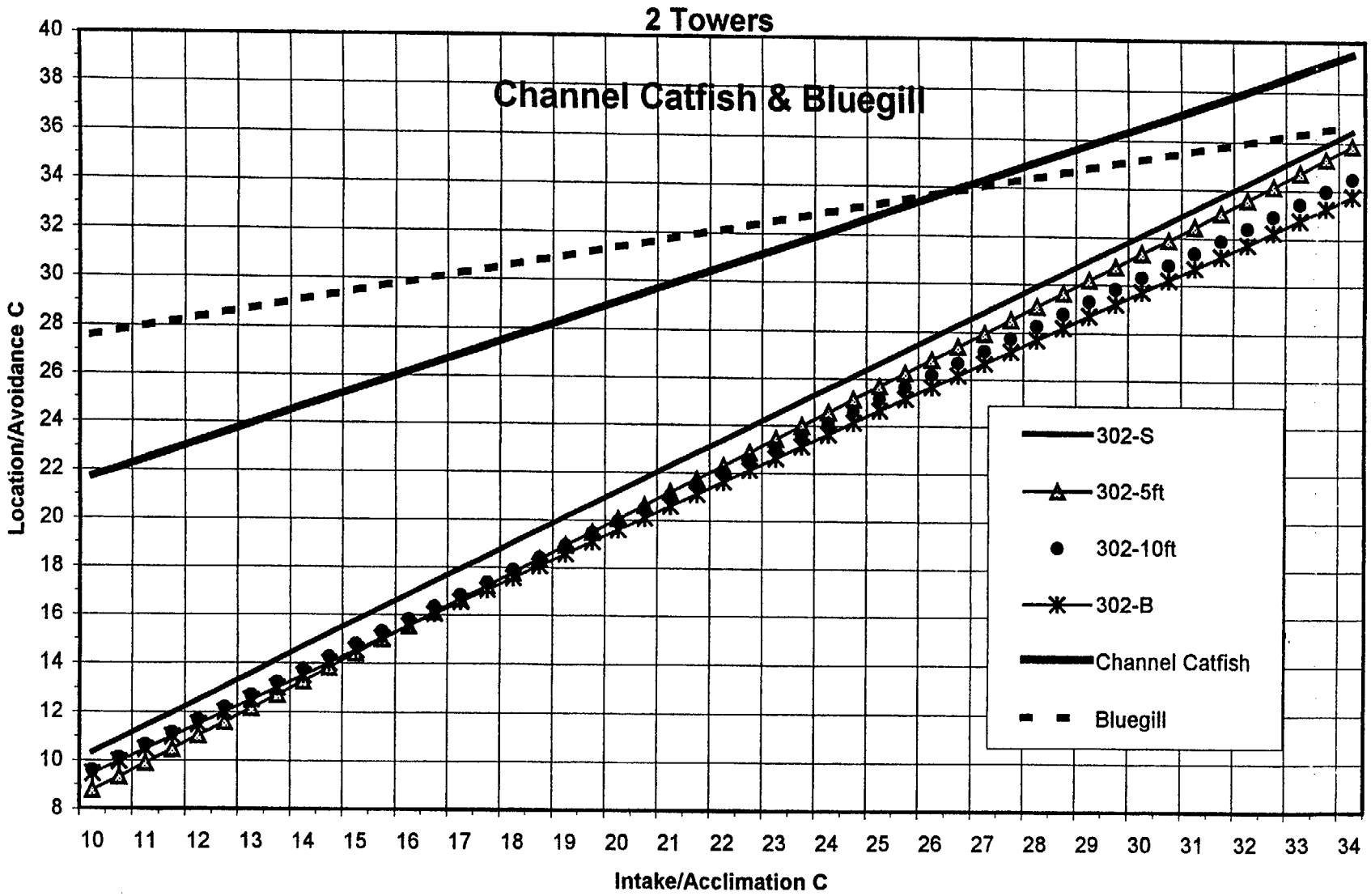
302 vs Avoidance C at 0 to 3 Tower Operations



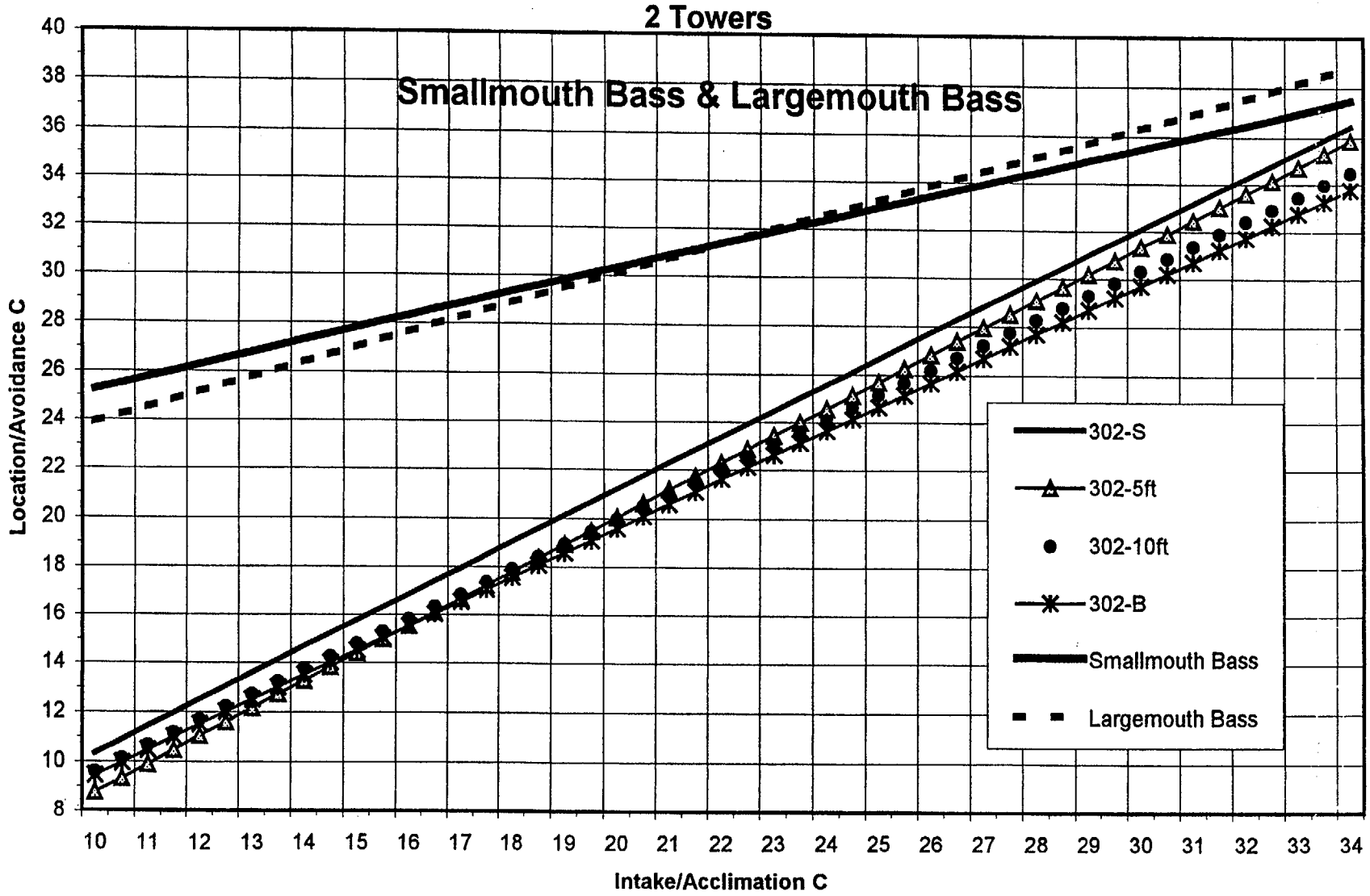
302 vs Avoidance C at 0 to 3 Tower Operations



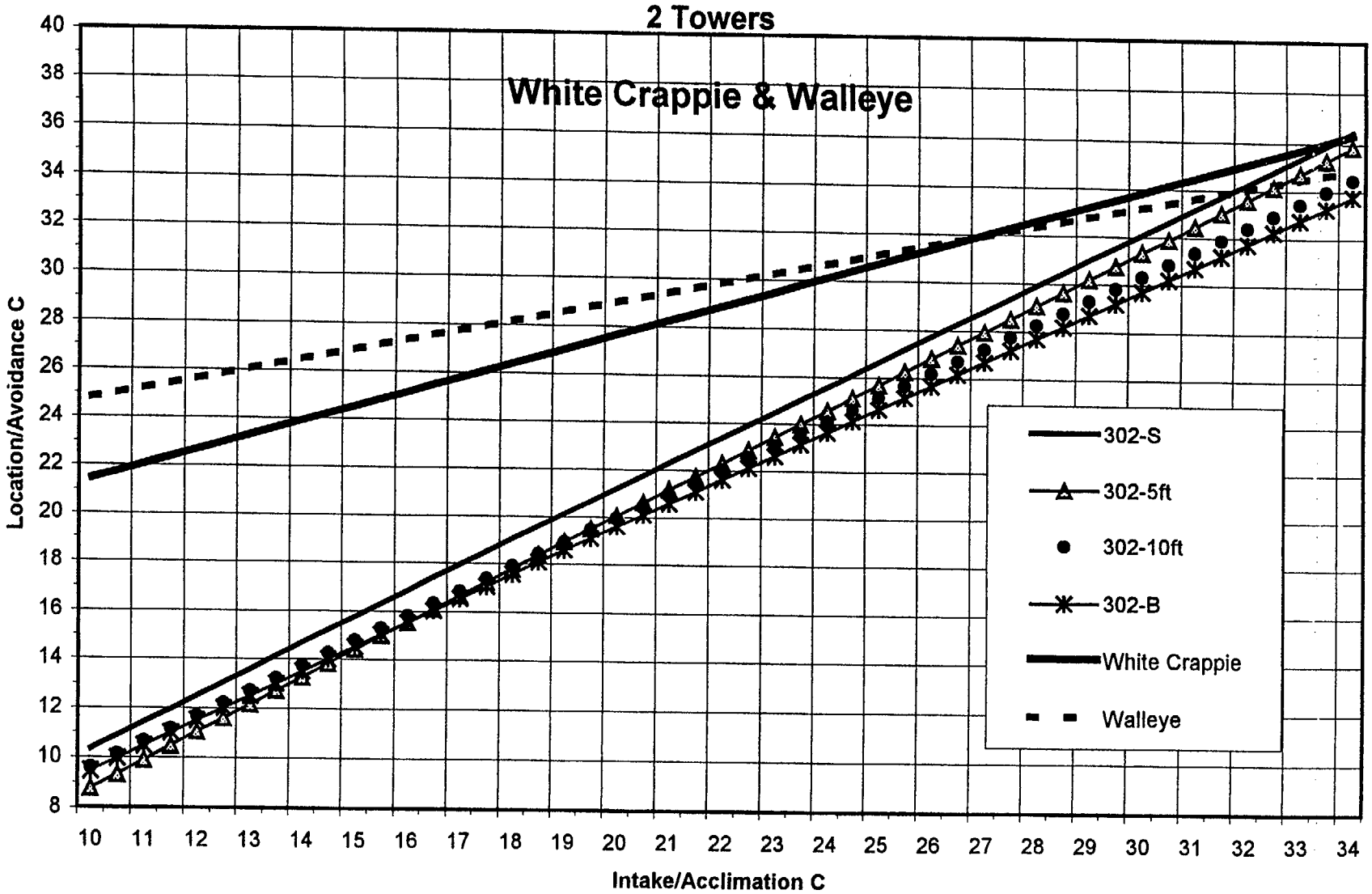
302 vs Avoidance C at 0 to 3 Tower Operations



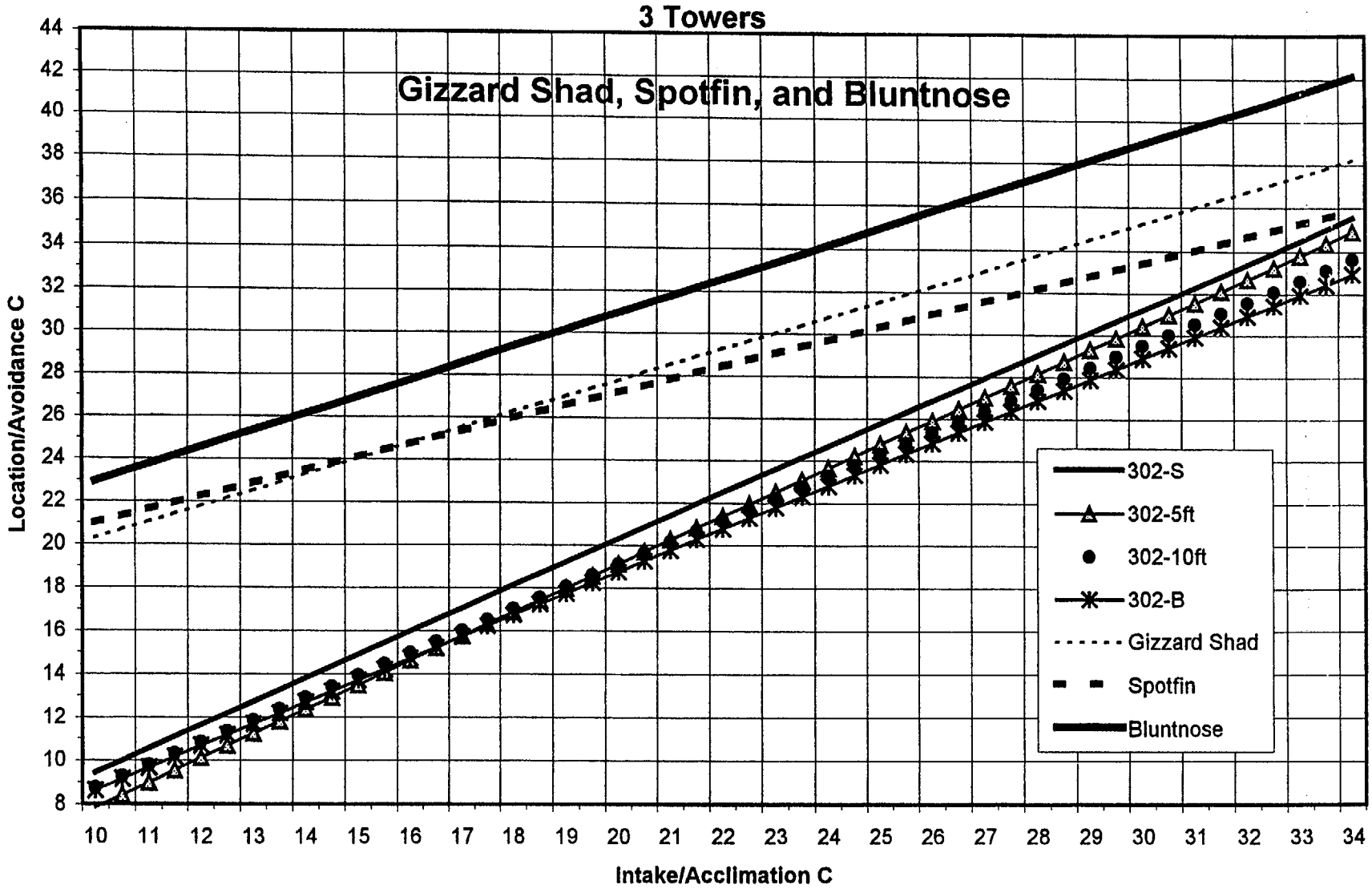
302 vs Avoidance C at 0 to 3 Tower Operations



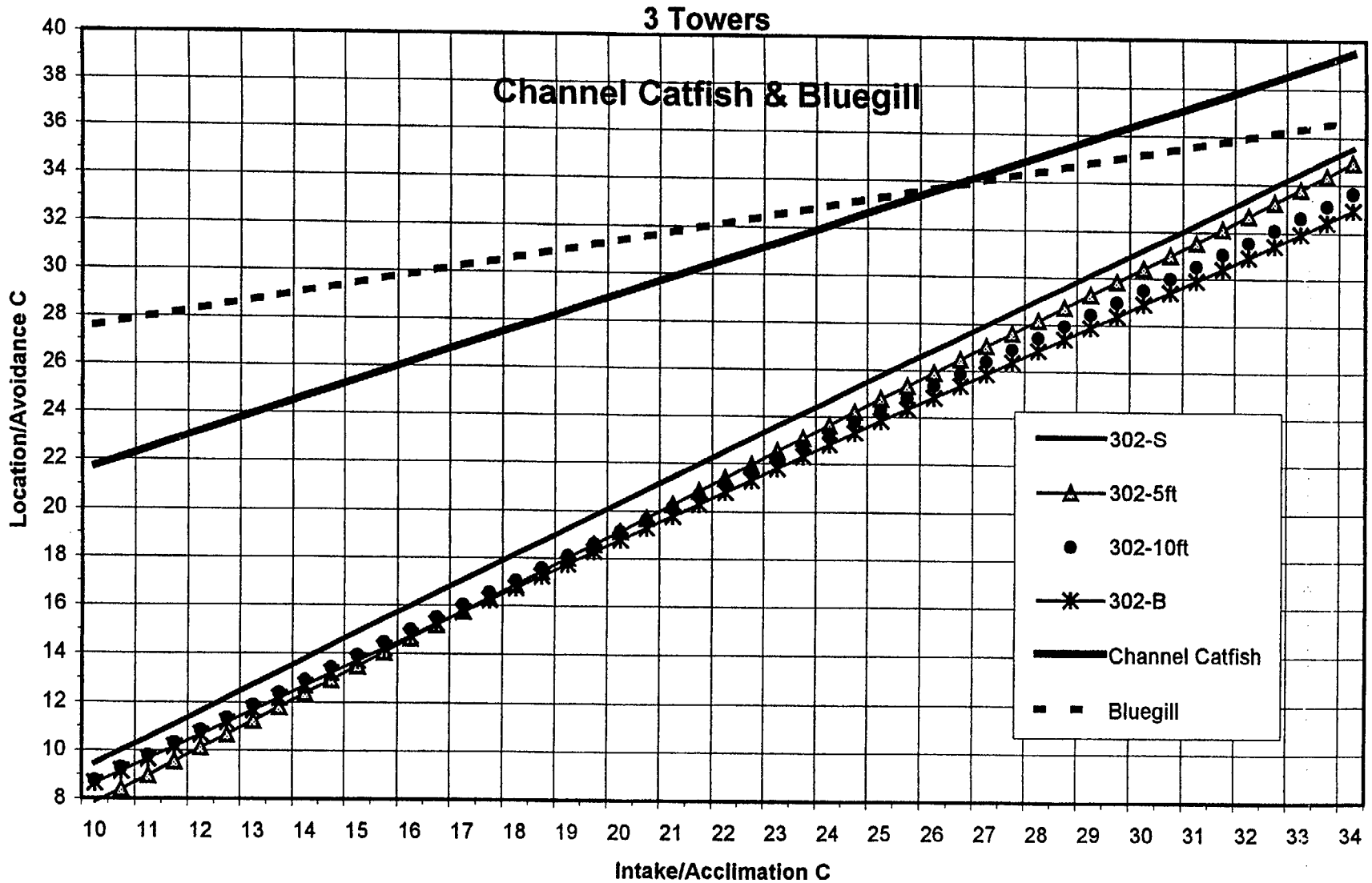
302 vs Avoidance C at 0 to 3 Tower Operations



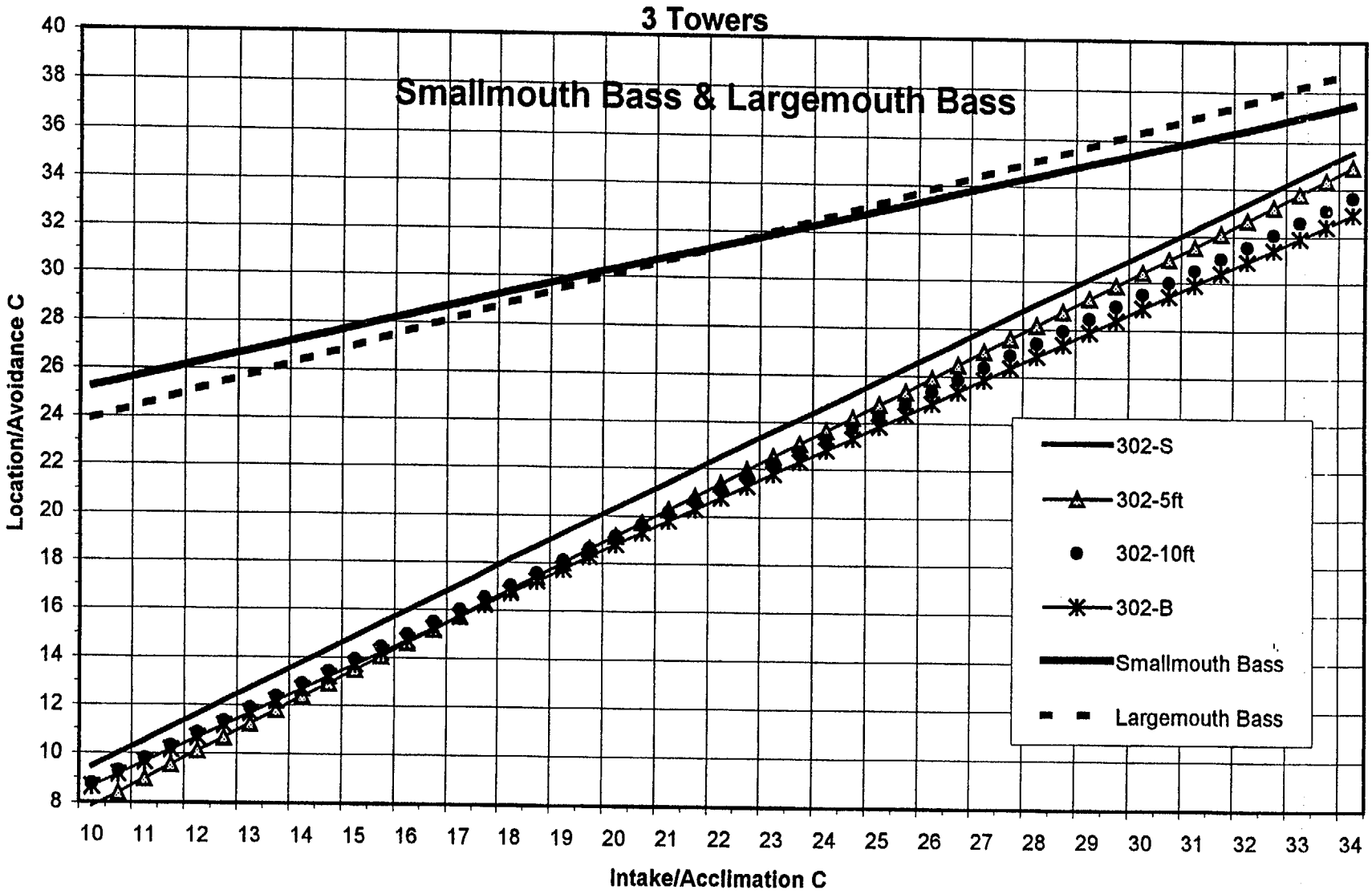
302 vs Avoidance C at 0 to 3 Tower Operations



302 vs Avoidance C at 0 to 3 Tower Operations



302 vs Avoidance C at 0 to 3 Tower Operations



302 vs Avoidance C at 0 to 3 Tower Operations

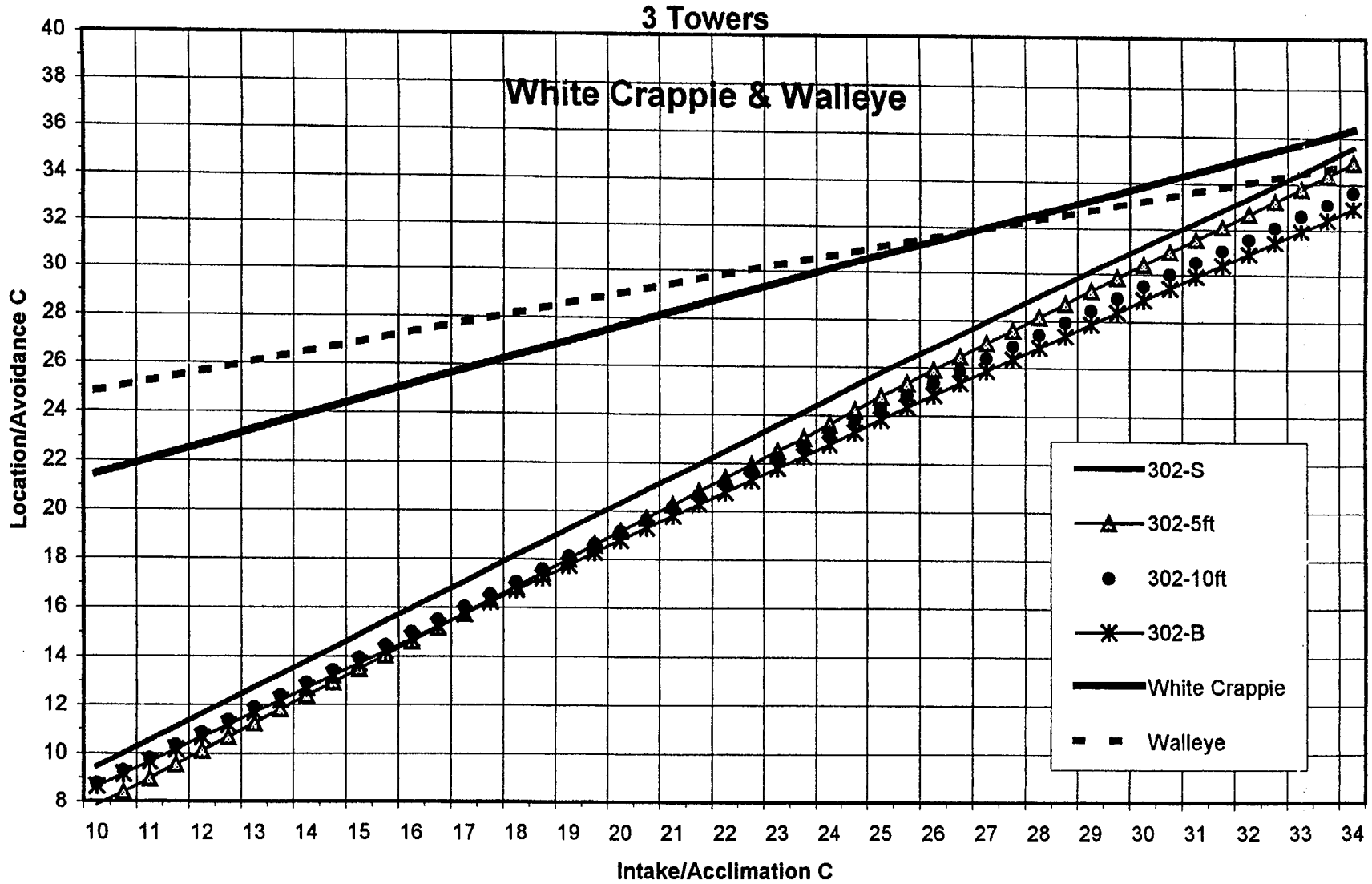
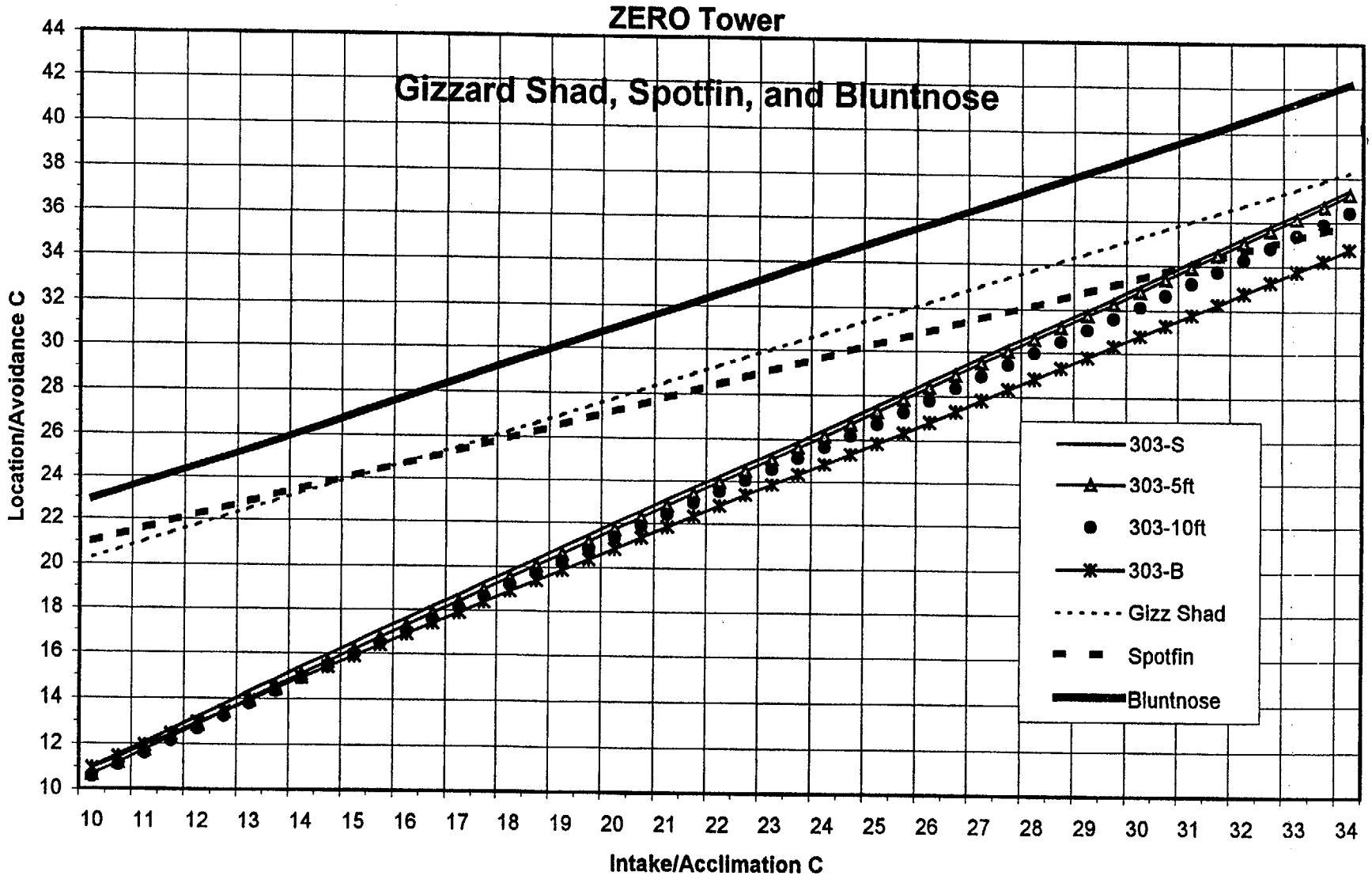


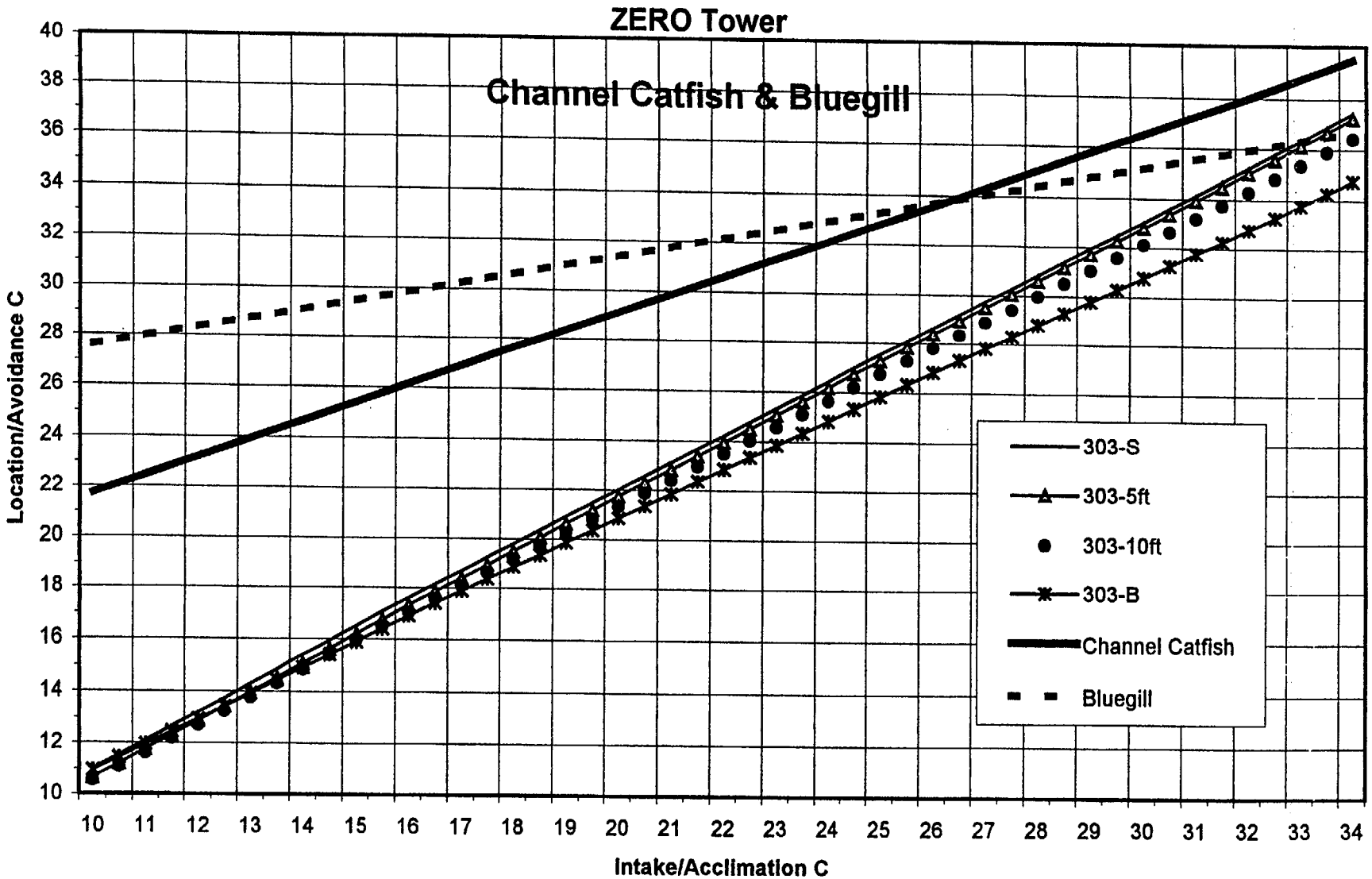
Figure A-6

Relationship of Station 303 Temperature versus Fish Avoidance Temperature (°C) at 0 to 3 Tower Operations

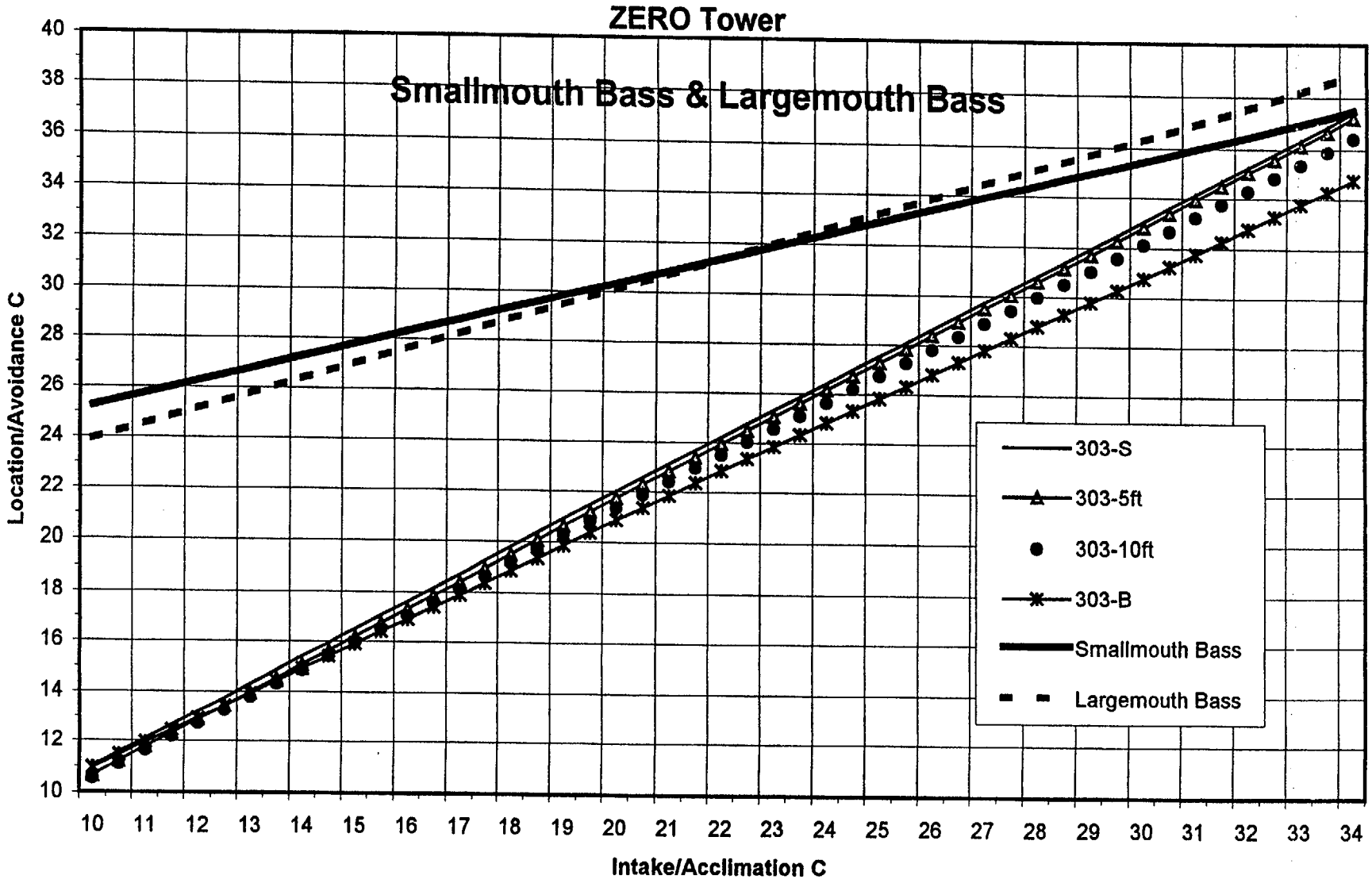
303 vs Avoidance C at 0 to 3 Tower Operations

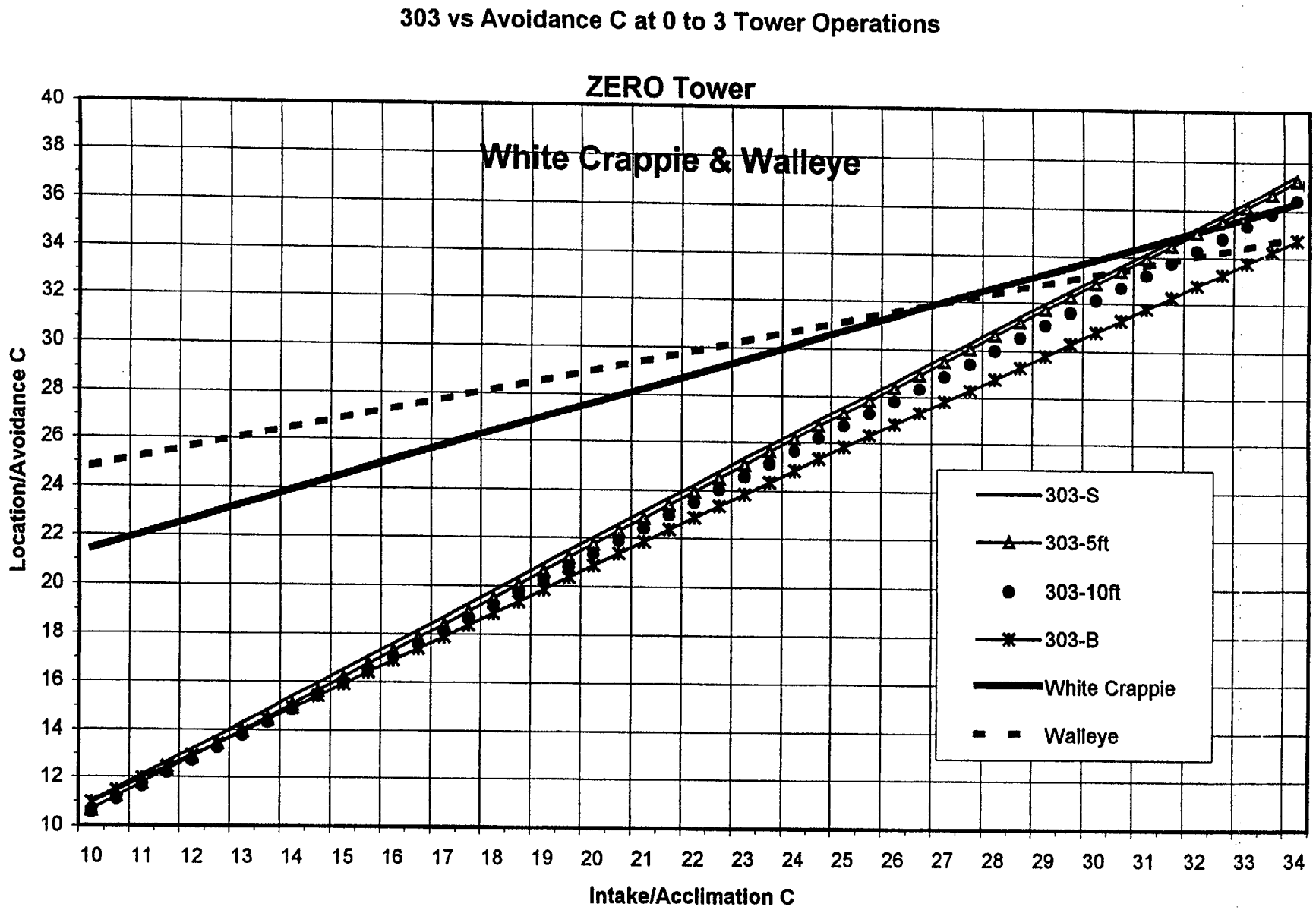


303 vs Avoidance C at 0 to 3 Tower Operations

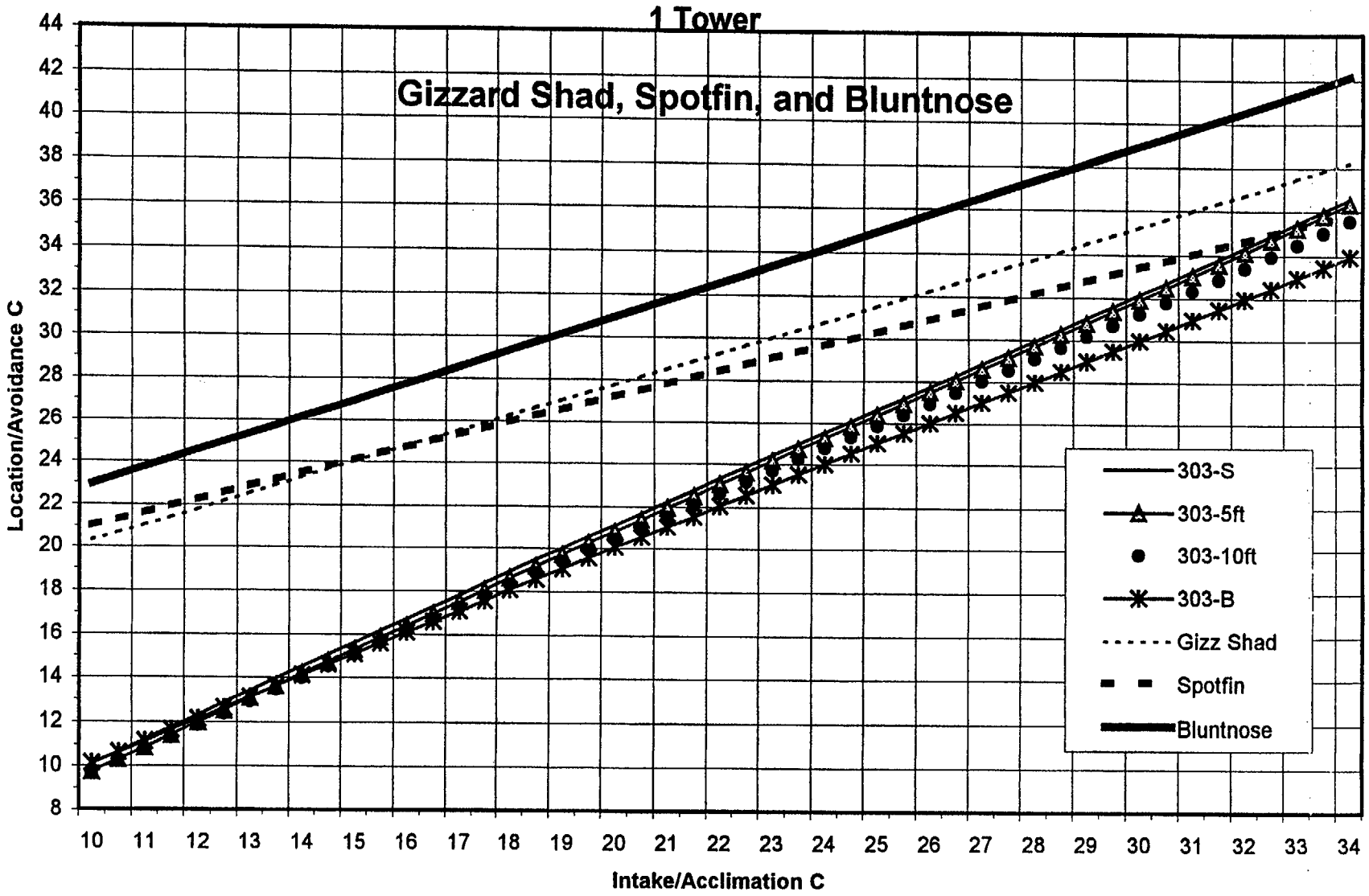


303 vs Avoidance C at 0 to 3 Tower Operations

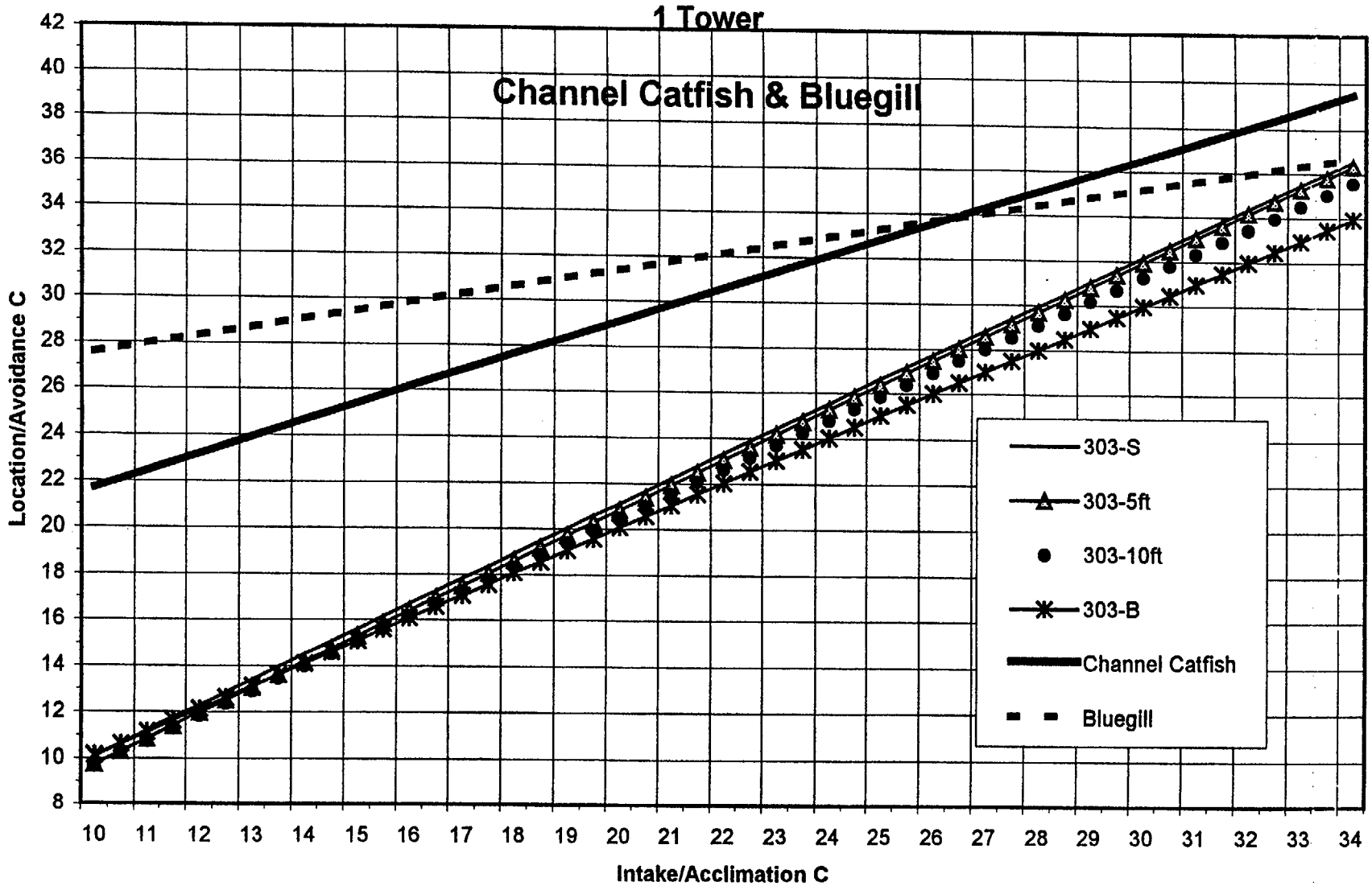


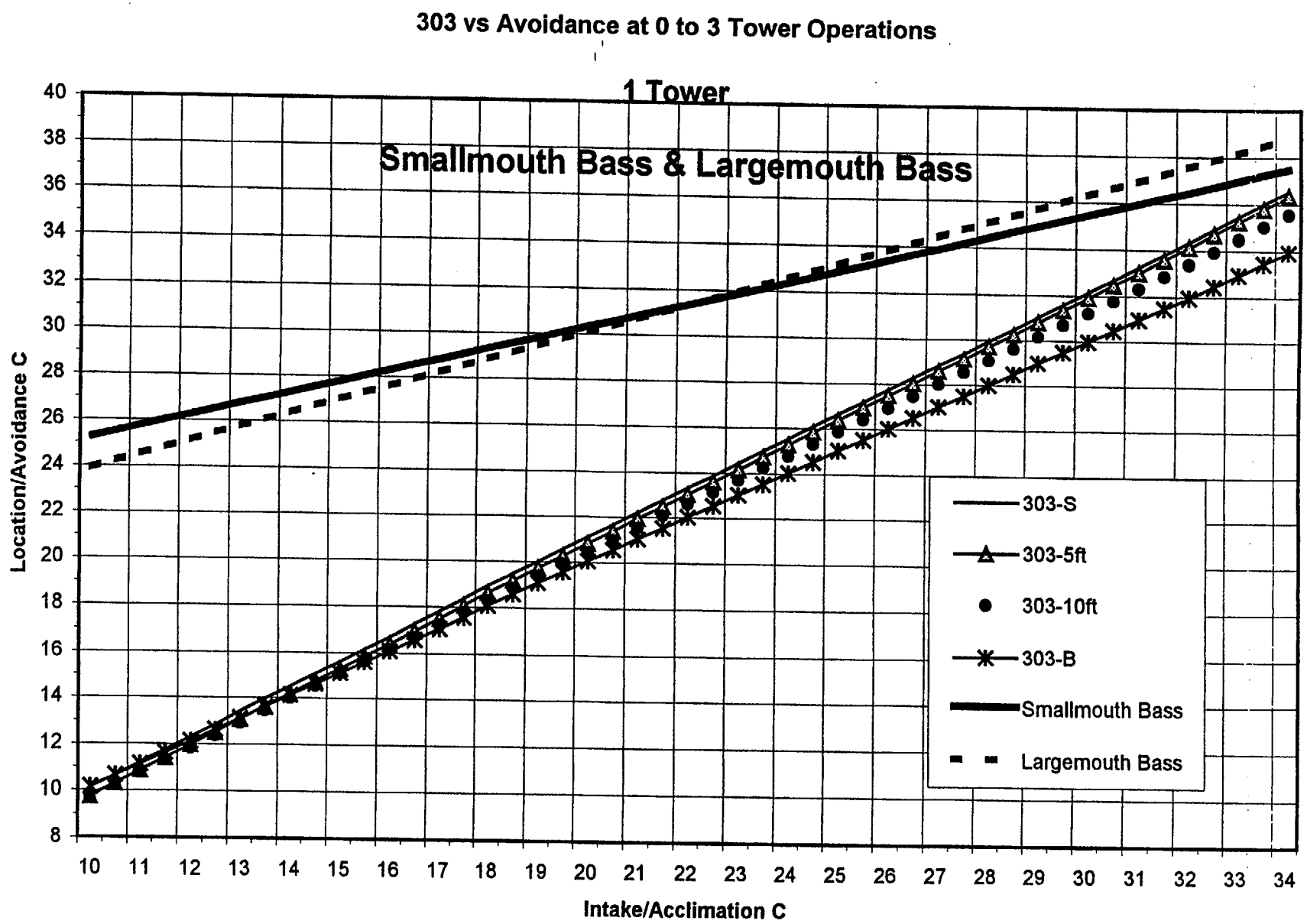

303 vs Avoidance C at 0 to 3 Tower Operations
ZERO Tower
White Crappie & Walleye
Location/Avoidance C
Intake/Acclimation C
40
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34
303-S
303-5ft
303-10ft
303-B
White Crappie
Walleye

303 vs Avoidance at 0 to 3 Tower Operations

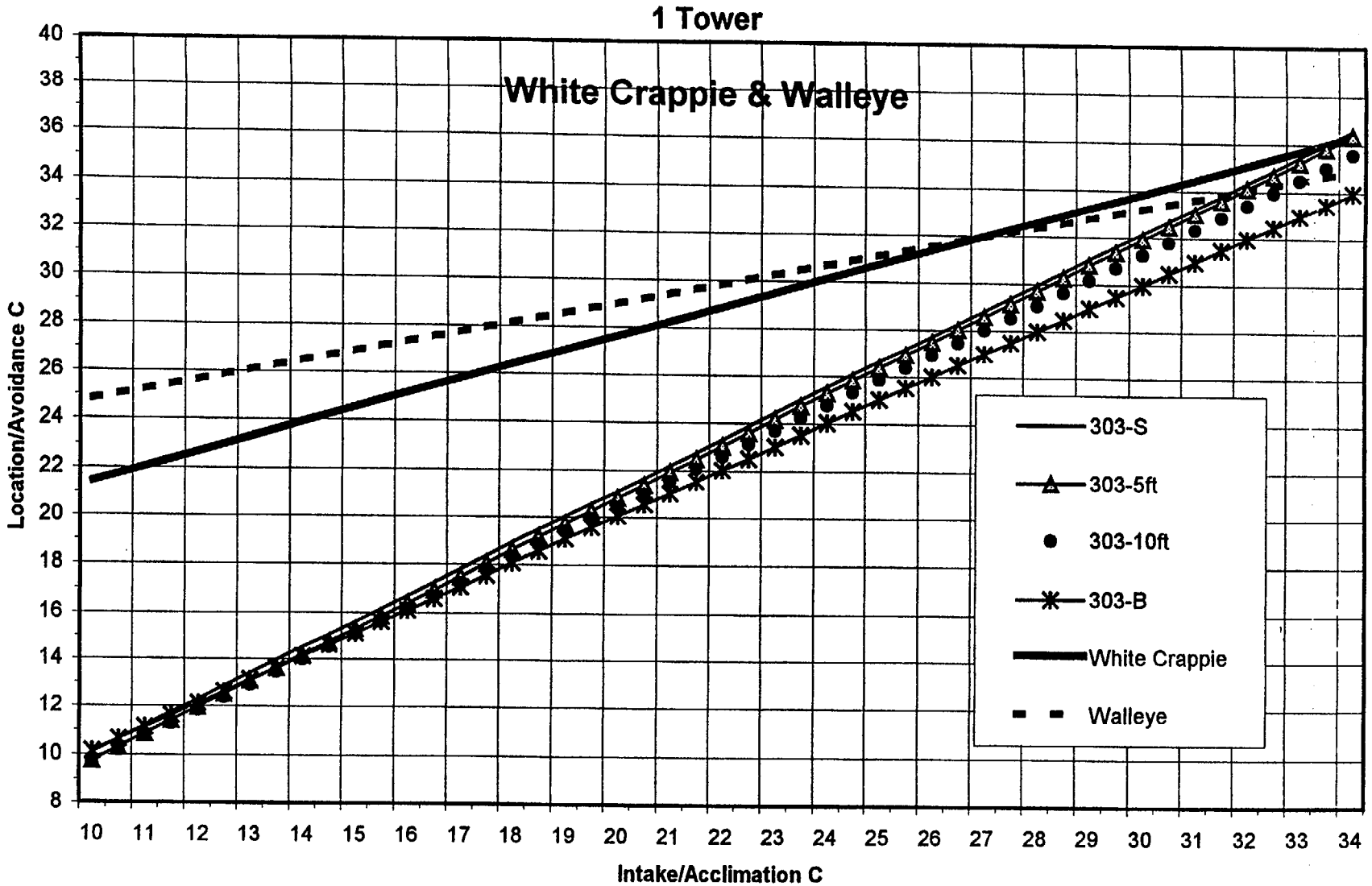


303 vs Avoidance at 0 to 3 Tower Operations

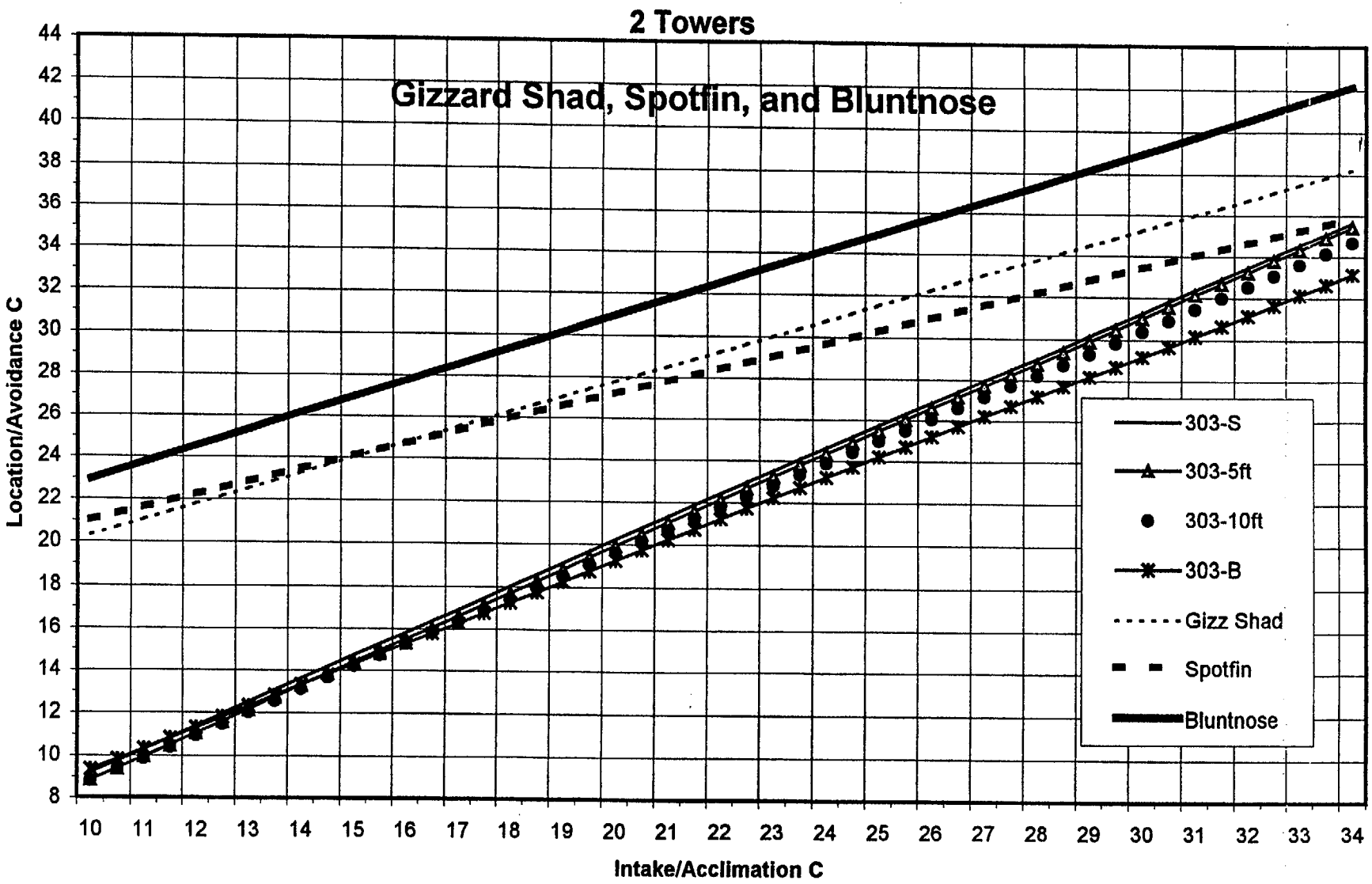



303 vs Avoidance at 0 to 3 Tower Operations
1 Tower
Smallmouth Bass & Largemouth Bass
Location/Avoidance C
Intake/Acclimation C
40
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
303-S
303-5ft
303-10ft
303-B
Smallmouth Bass
Largemouth Bass

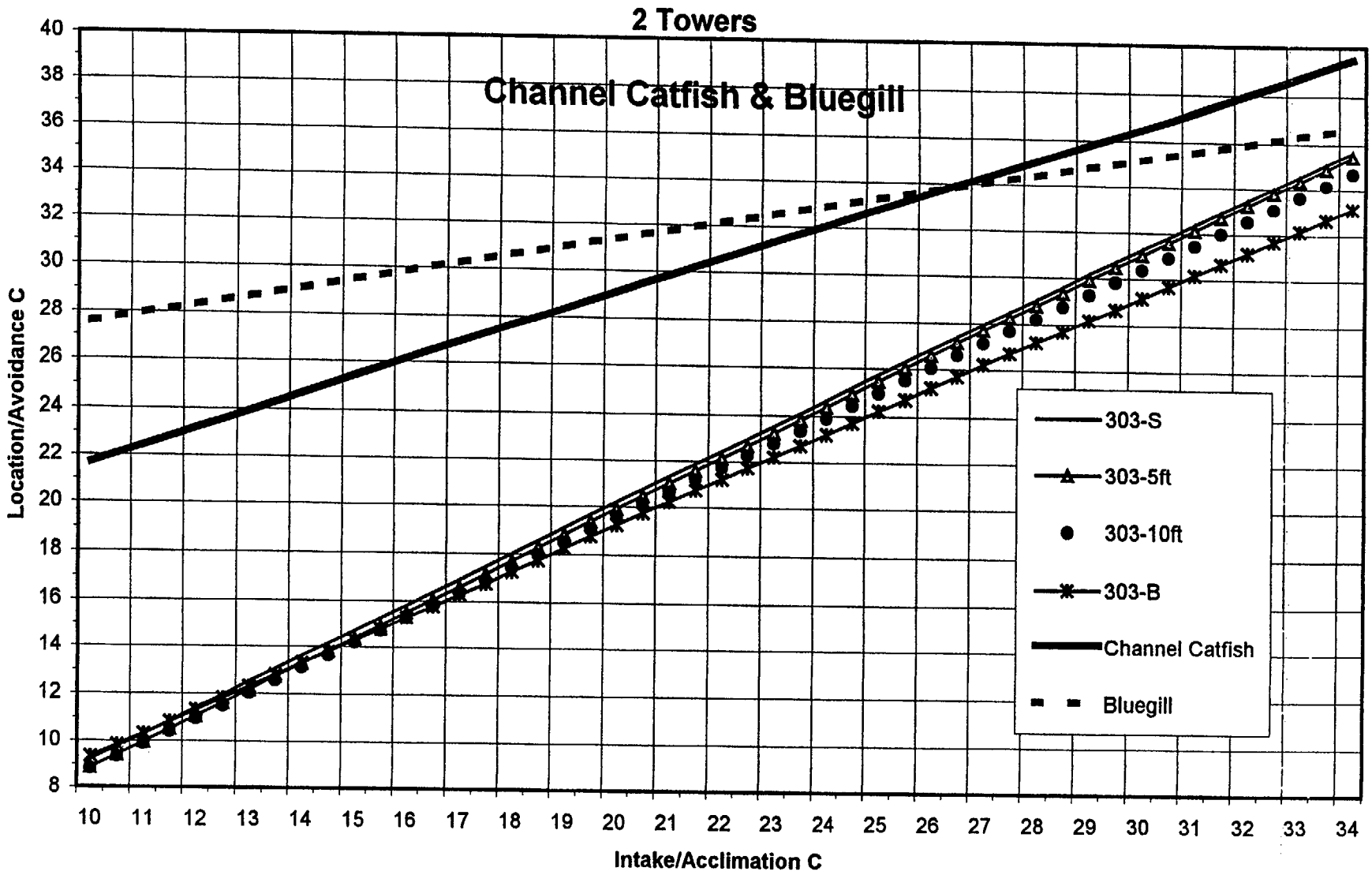
303 vs Avoidance at 0 to 3 Tower Operations



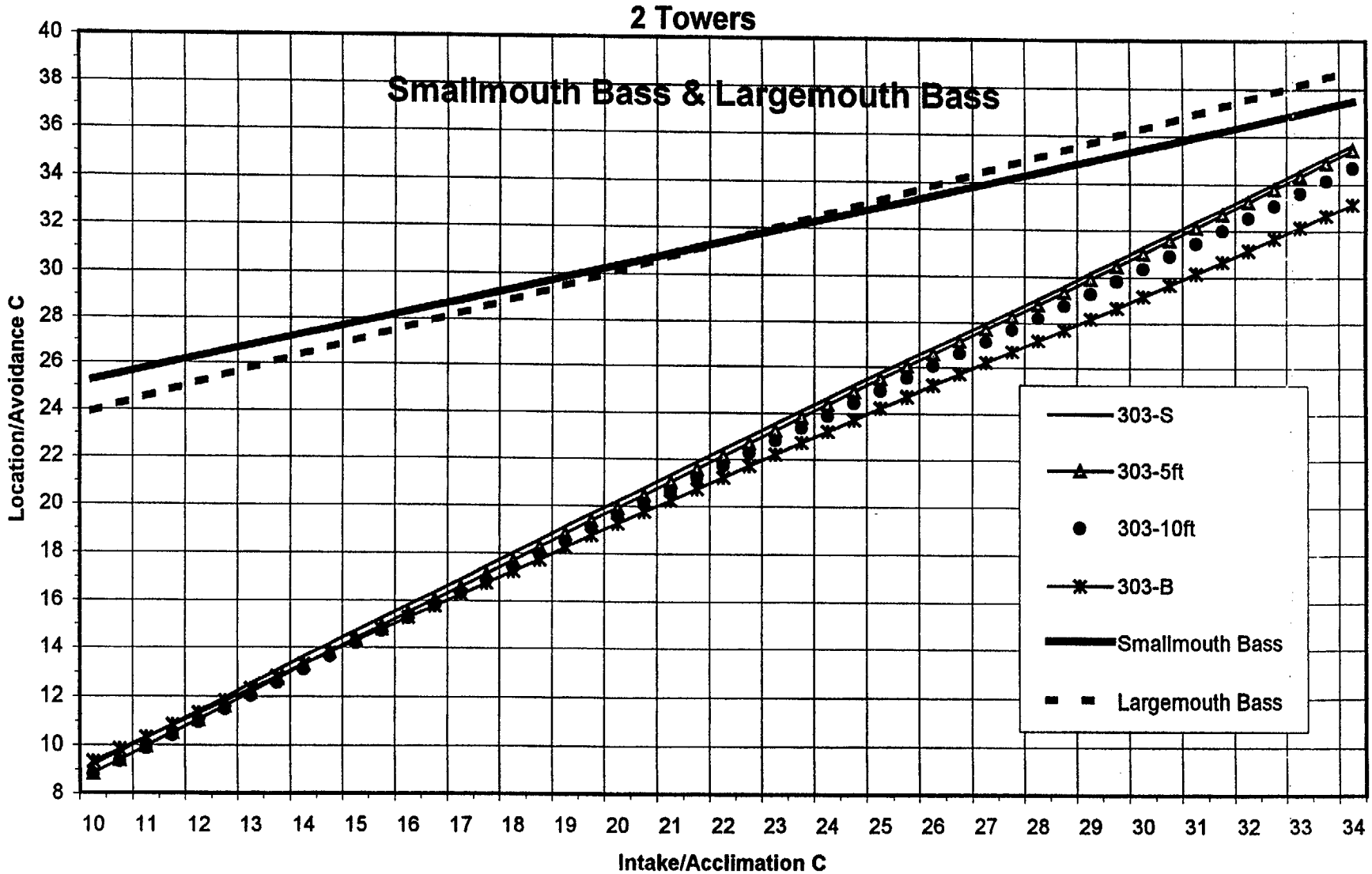
303 vs Avoidance C at 0 to 3 Tower Operations



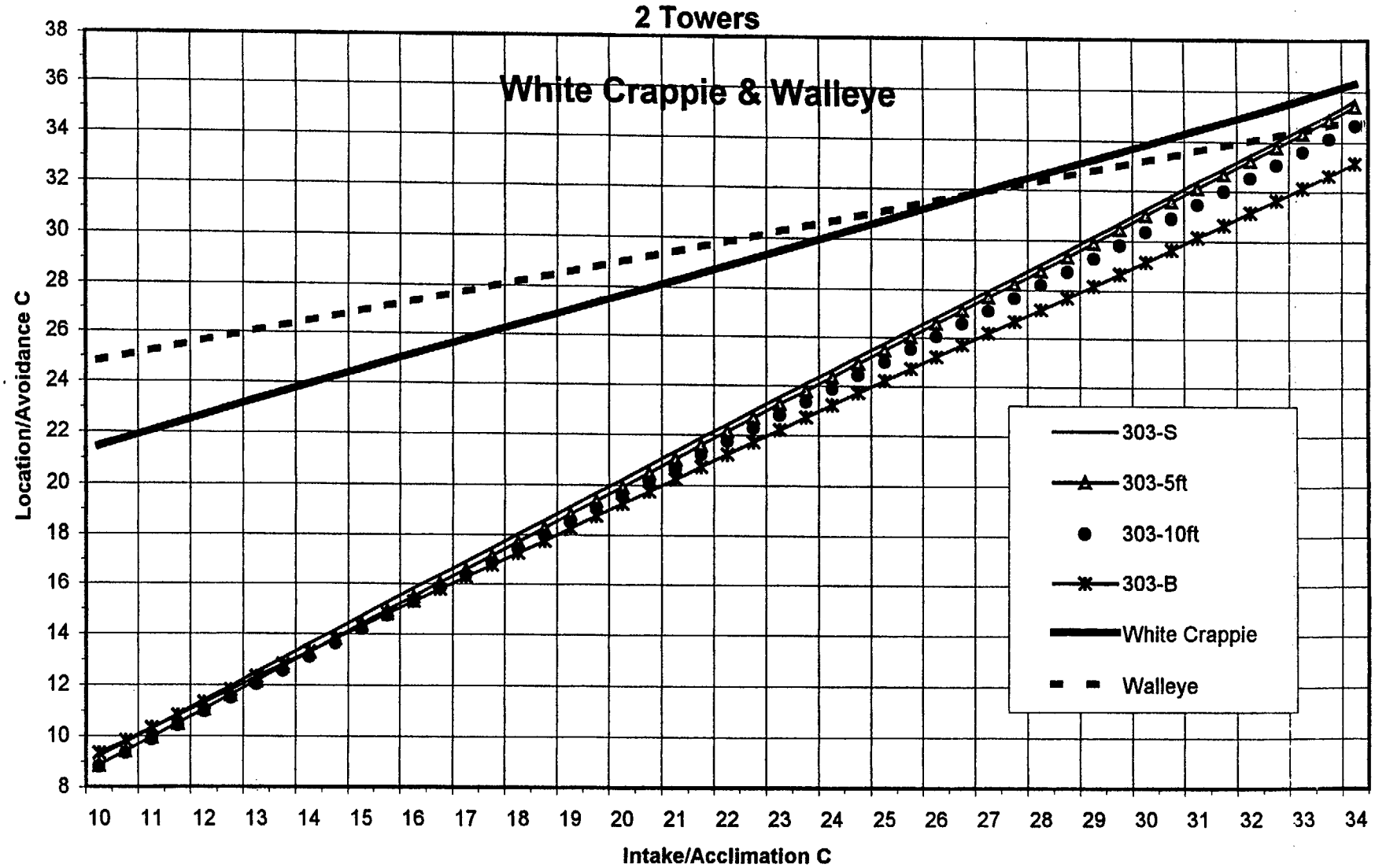
303 vs Avoidance C at 0 to 3 Tower Operations



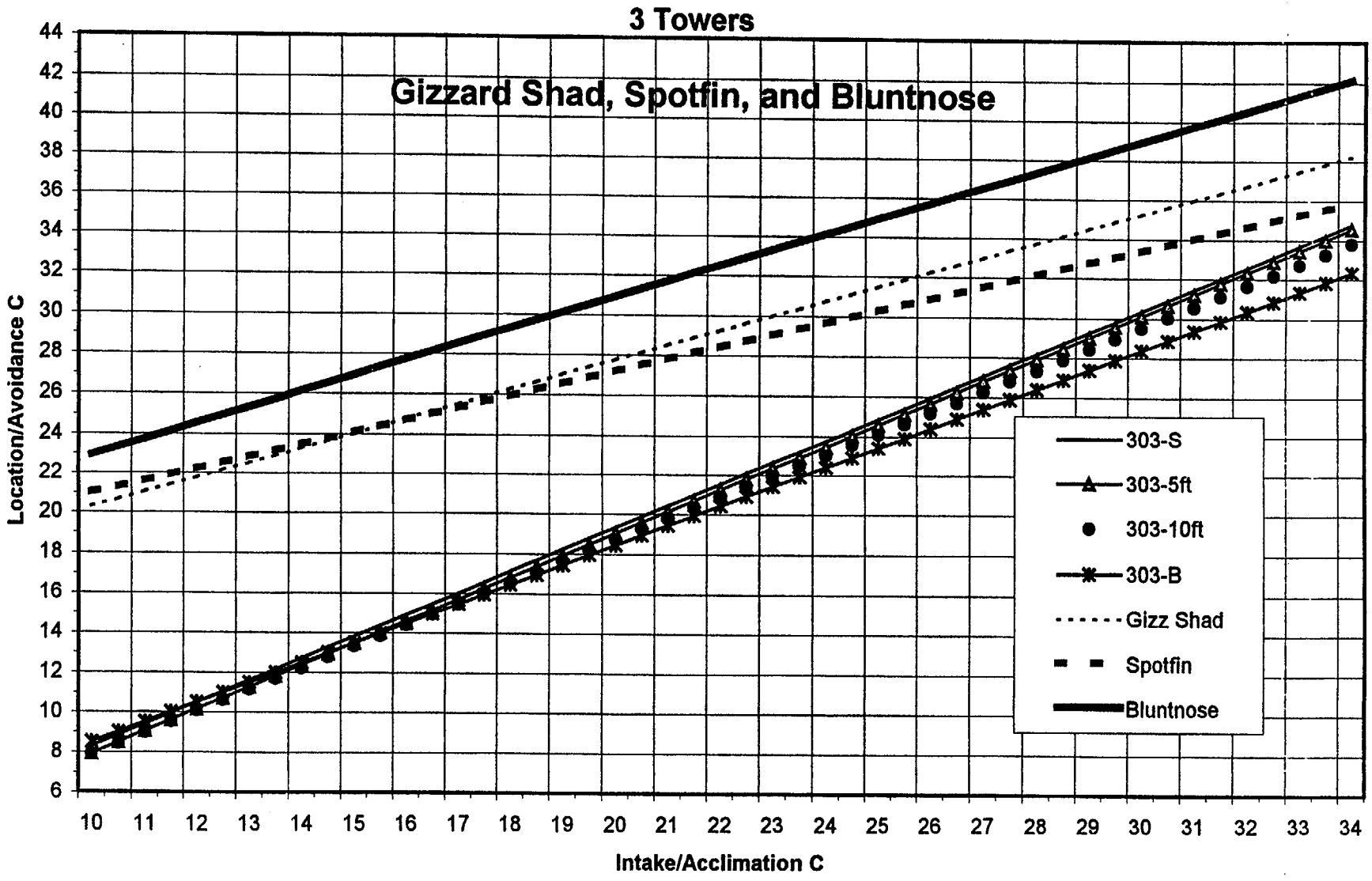
303 vs Avoidance C at 0 to 3 Tower Operations



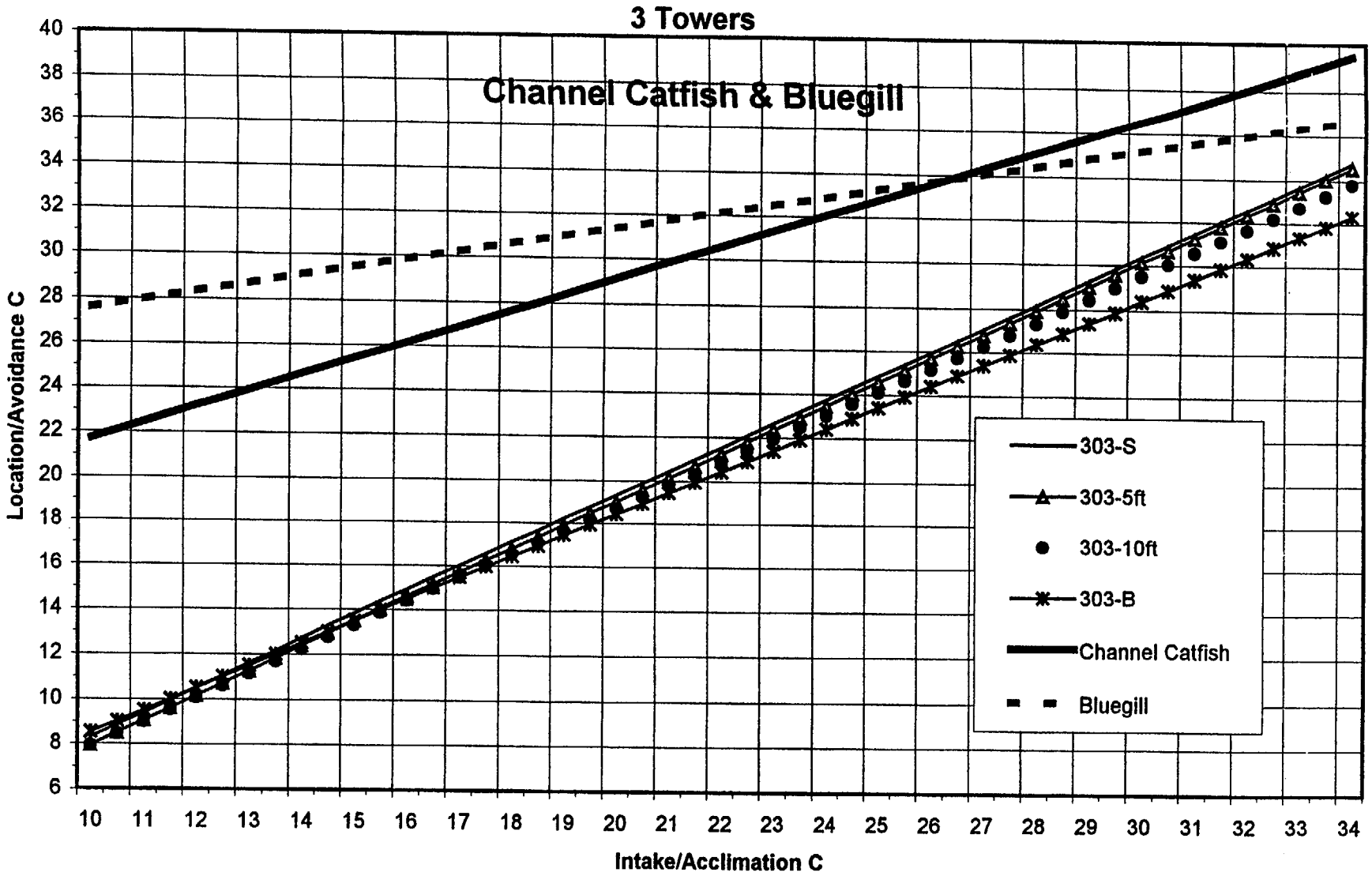
303 vs Avoidance C at 0 to 3 Tower Operations



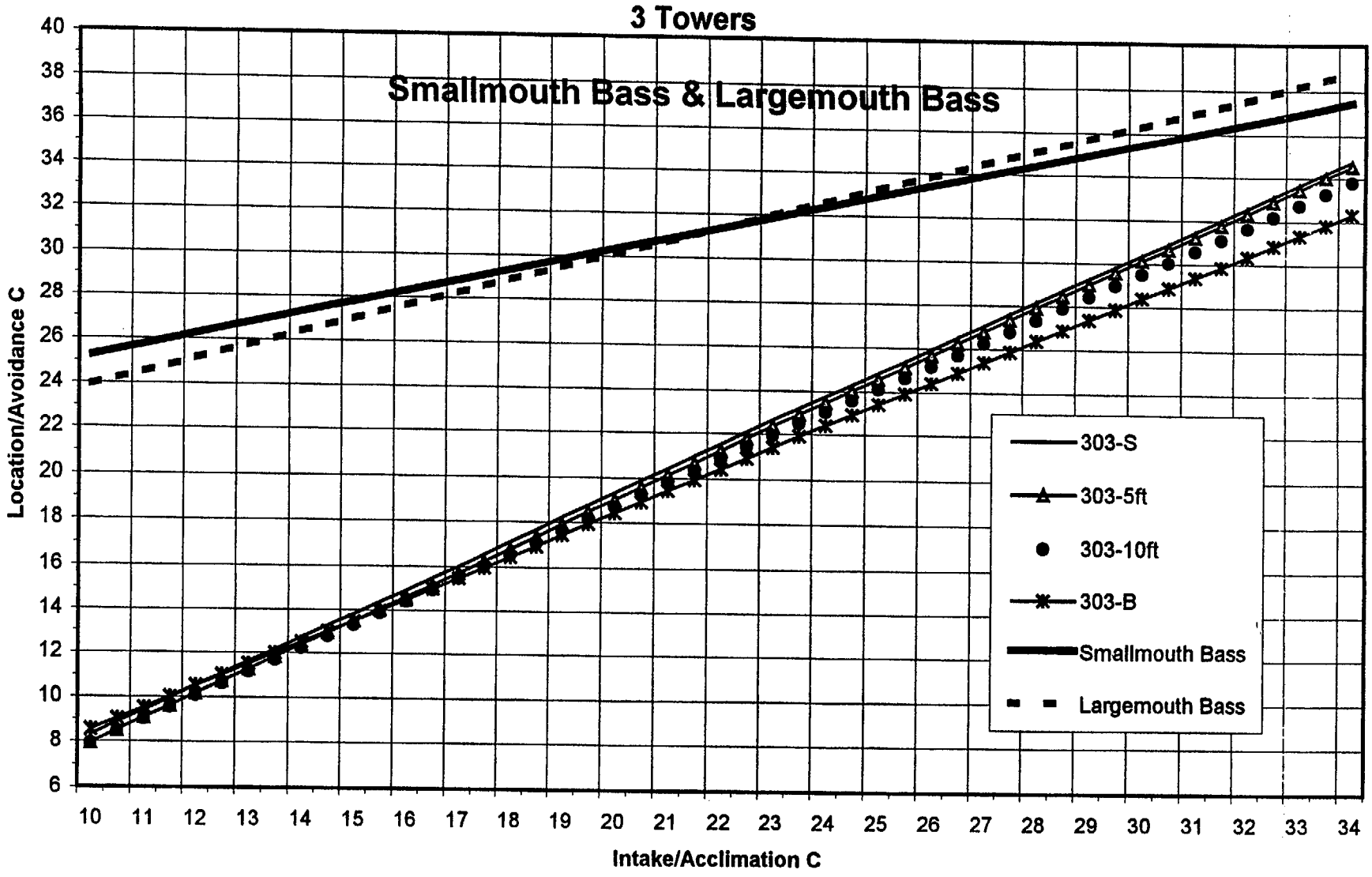
303 vs Avoidance C at 0 to 3 Tower Operation



303 vs Avoidance C at 0 to 3 Tower Operation



303 vs Avoidance C at 0 to 3 Tower Operation



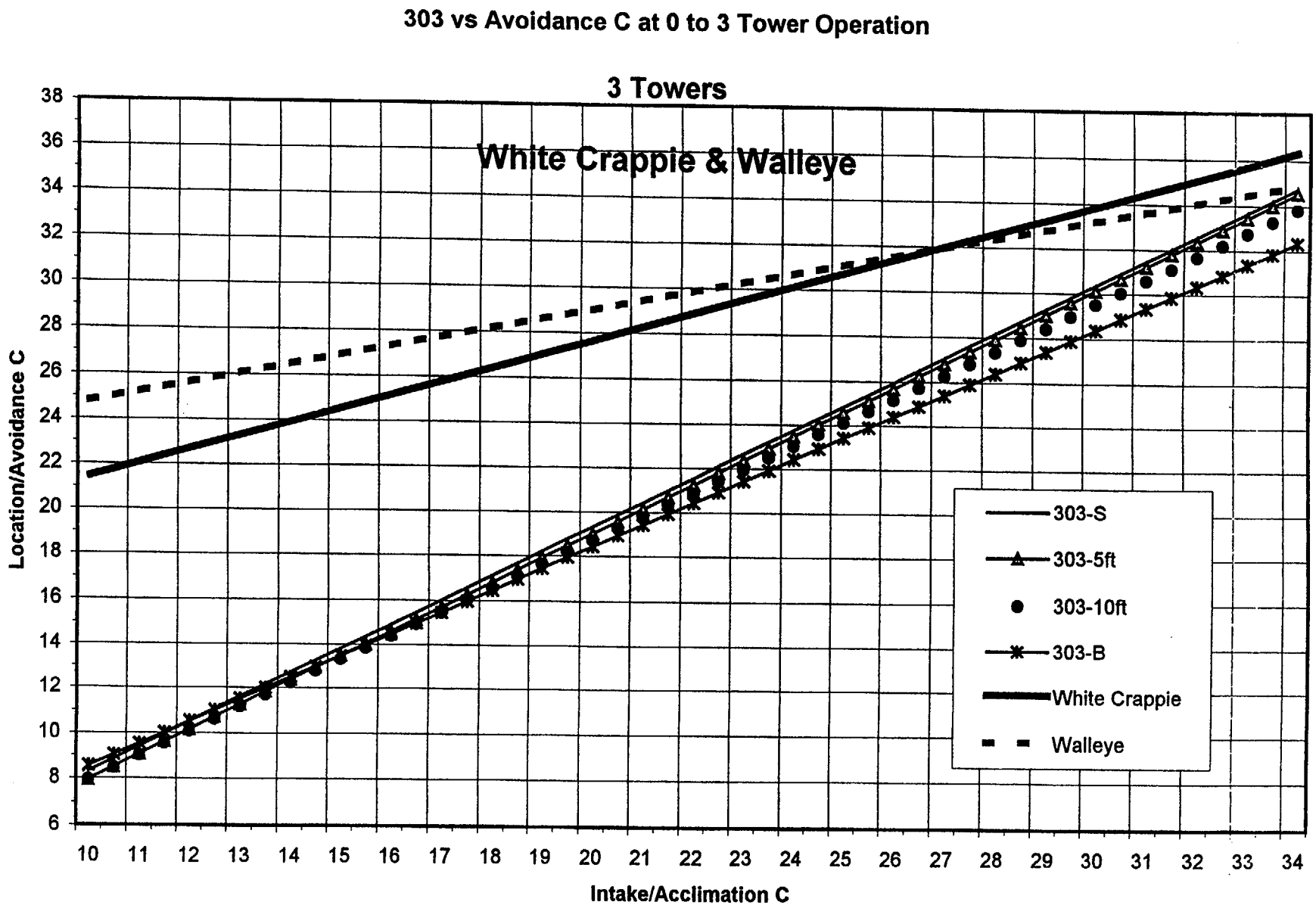
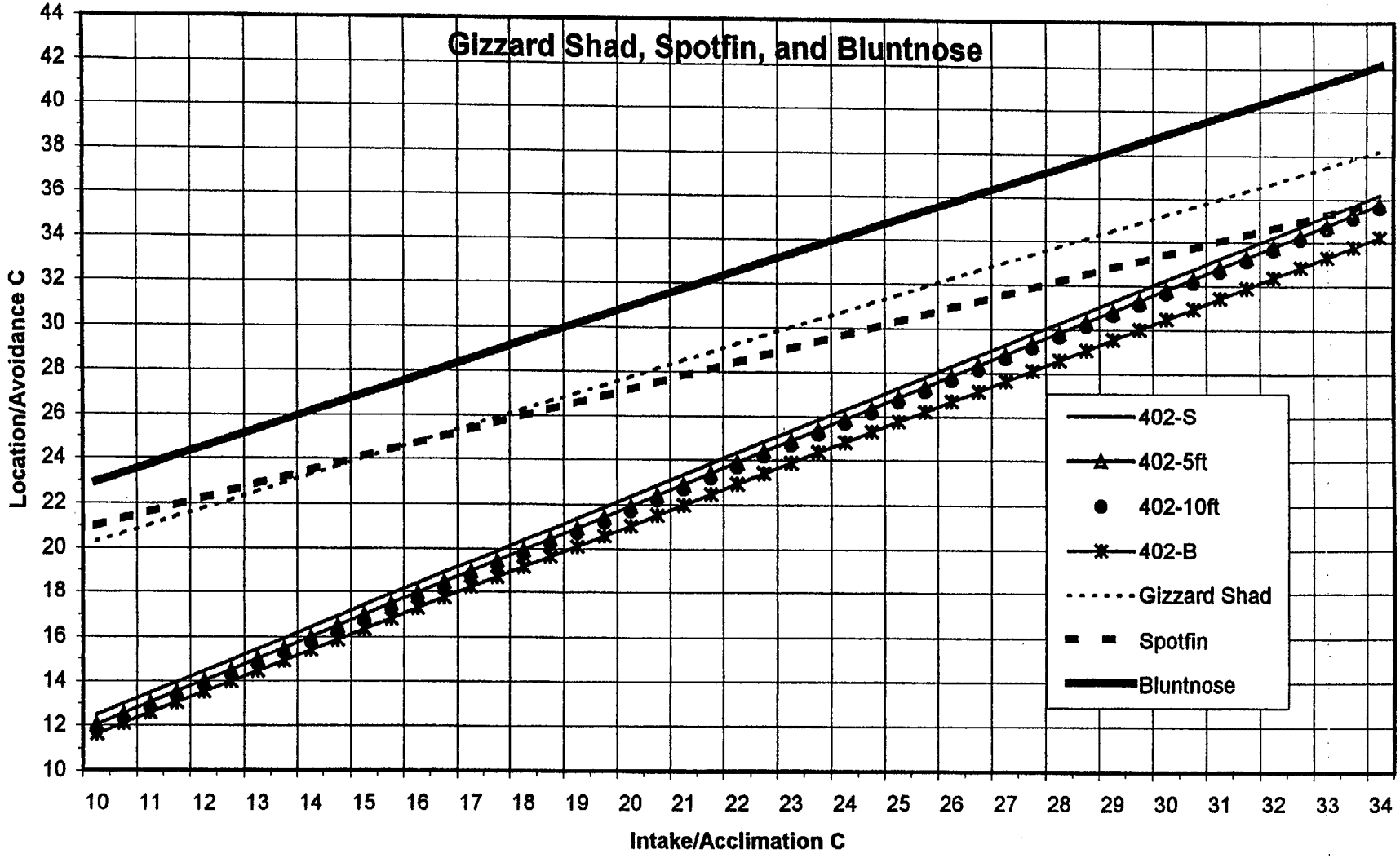

303 vs Avoidance C at 0 to 3 Tower Operation
3 Towers
White Crappie & Walleye
Location/Avoidance C
Intake/Acclimation C
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
303-S
303-5ft
303-10ft
303-B
White Crappie
Walleye

Figure A-7

Relationship of Station 402 Temperature versus Fish Avoidance Temperature (°C) at 0 to 3 Tower Operations

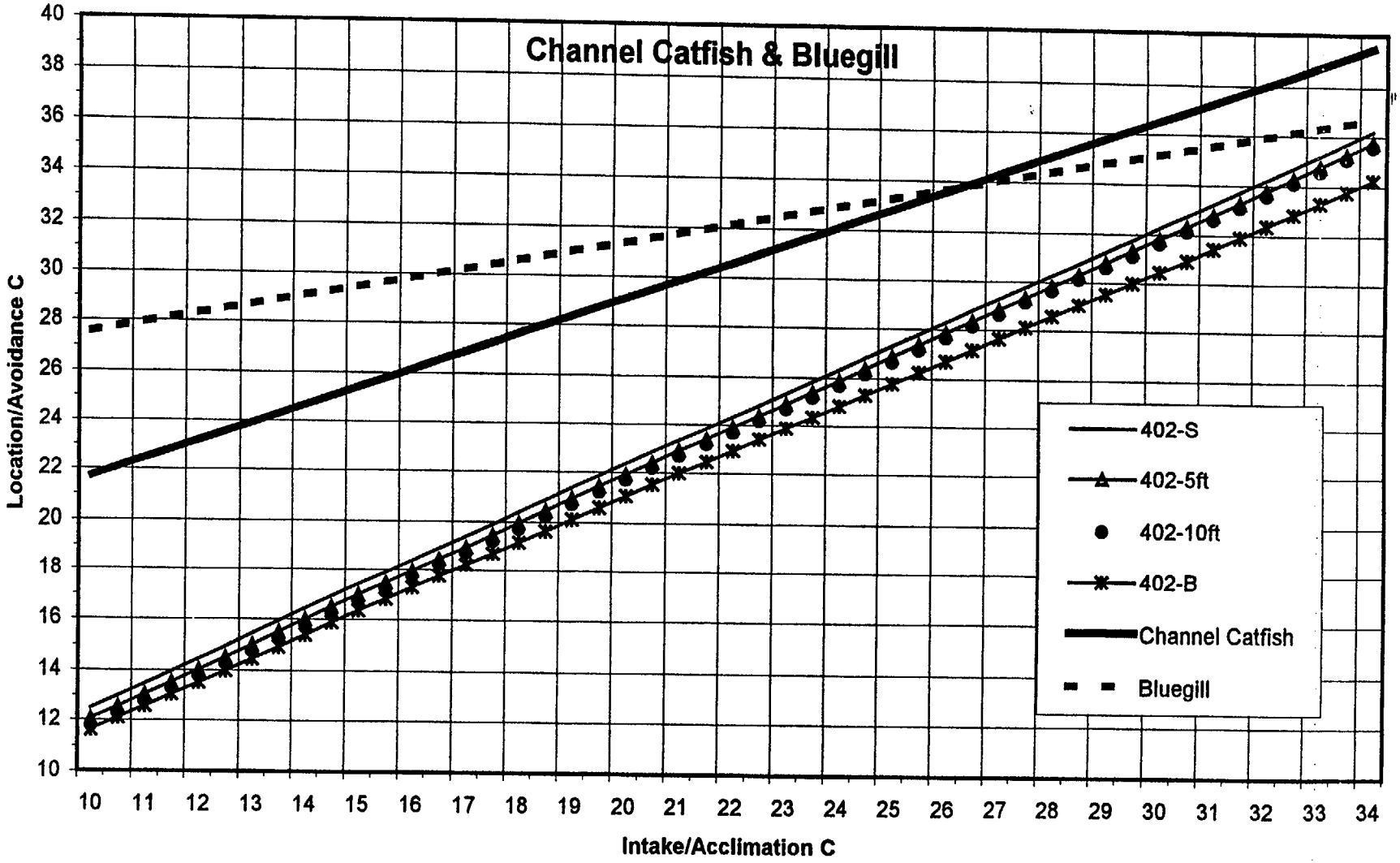
402 vs Avoidance C at 0 to 3 Tower Operations

ZERO Tower



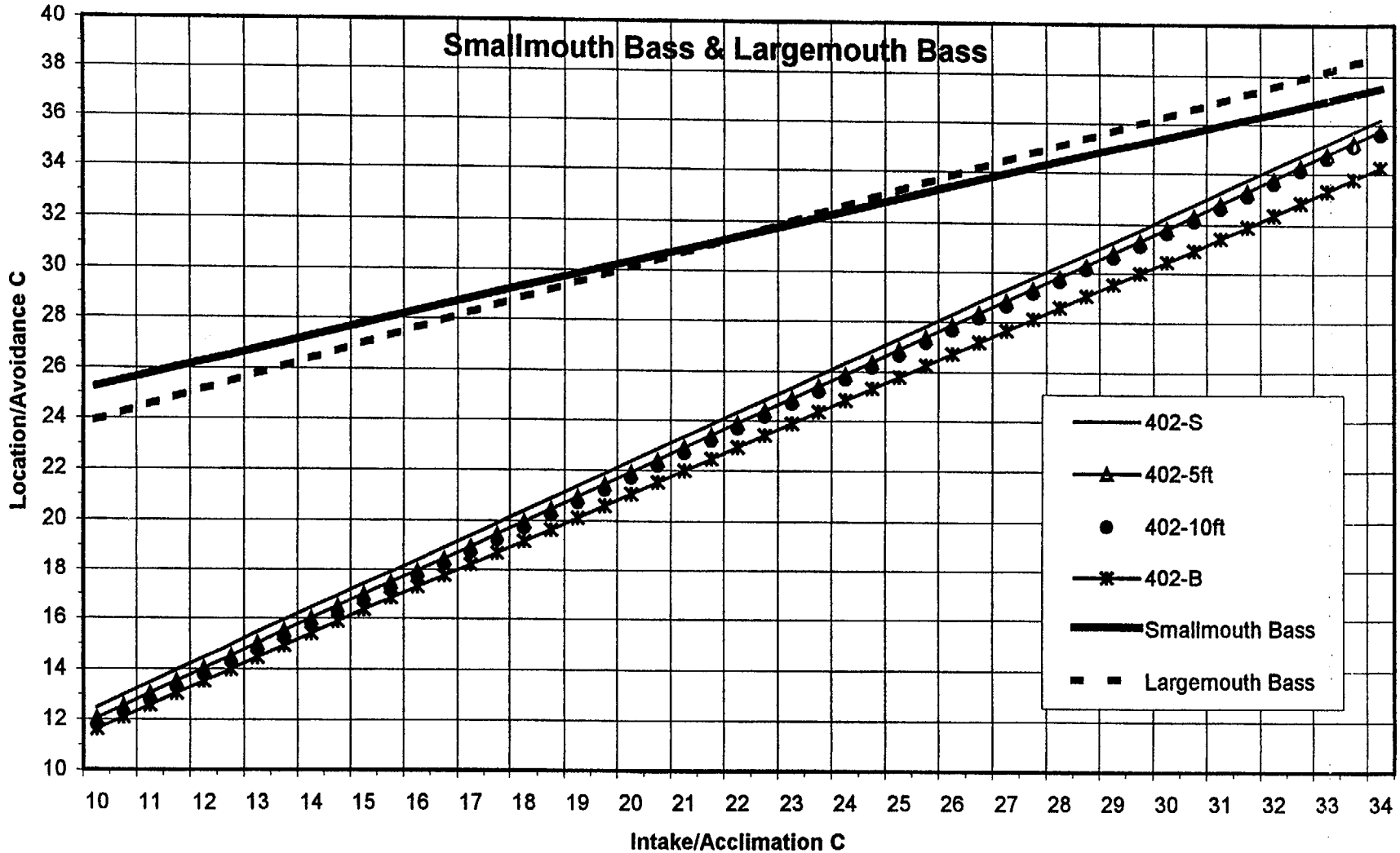
402 vs Avoidance C at 0 to 3 Tower Operations

ZERO Tower



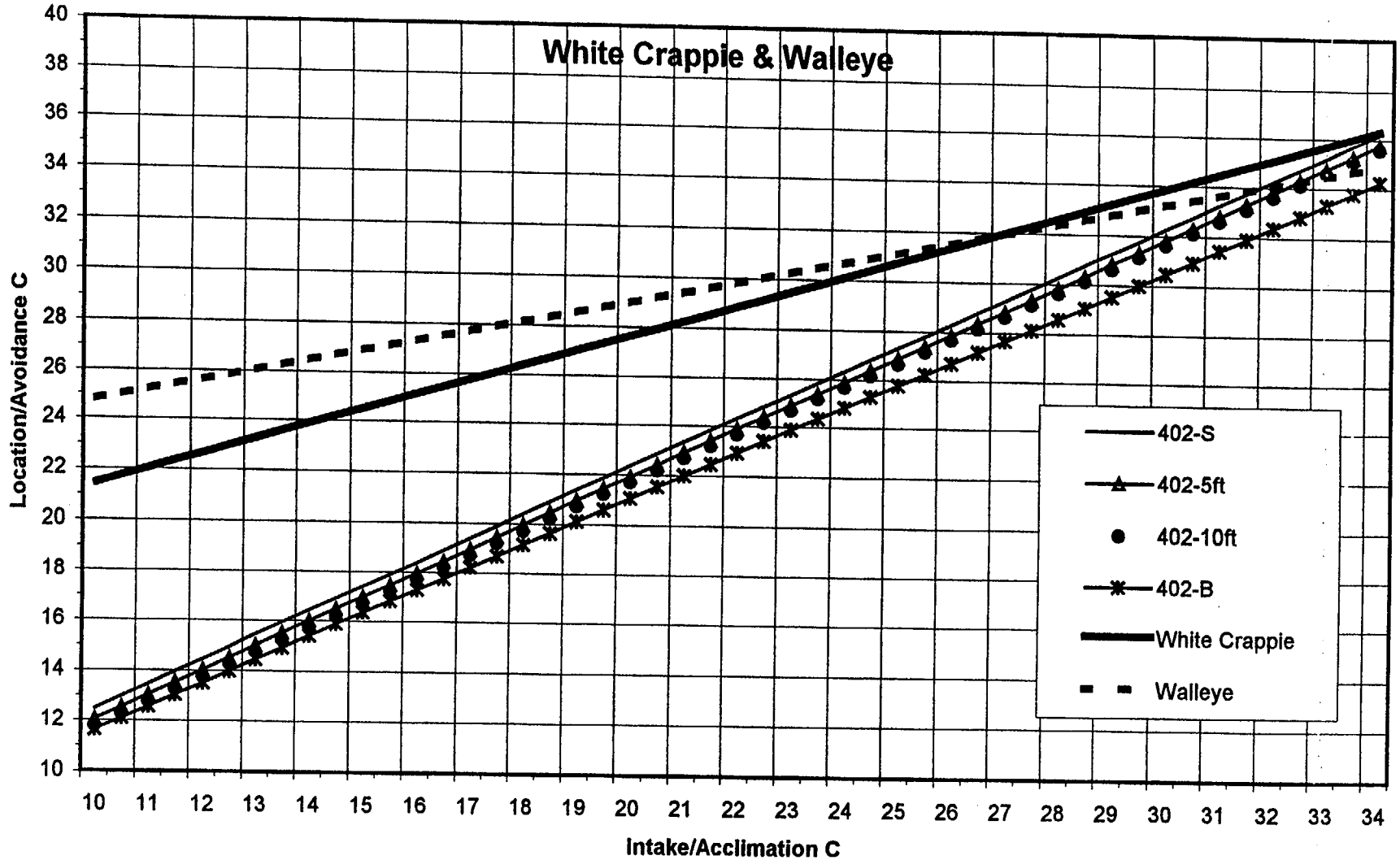
402 vs Avoidance C at 0 to 3 Tower Operations

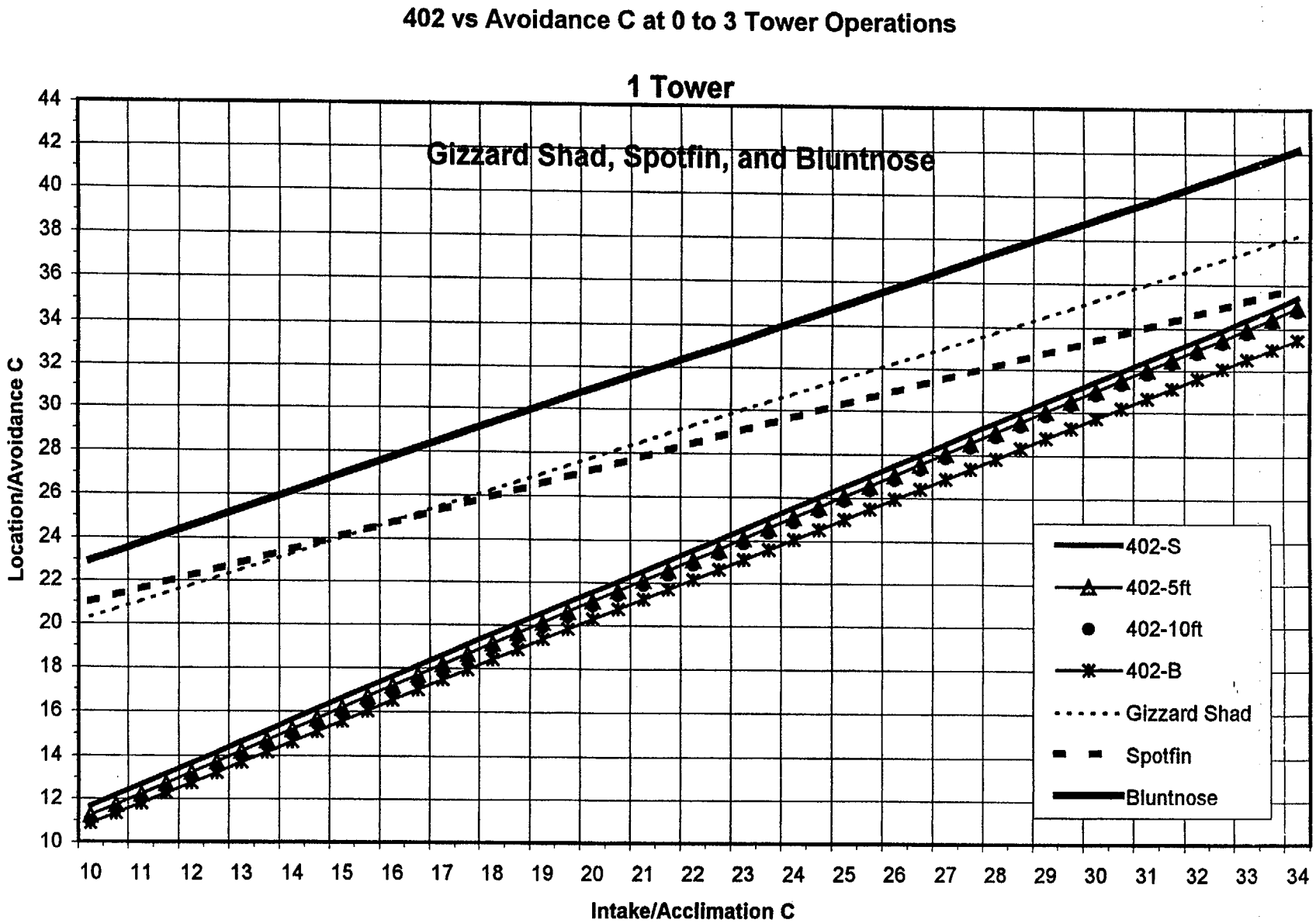
ZERO Tower



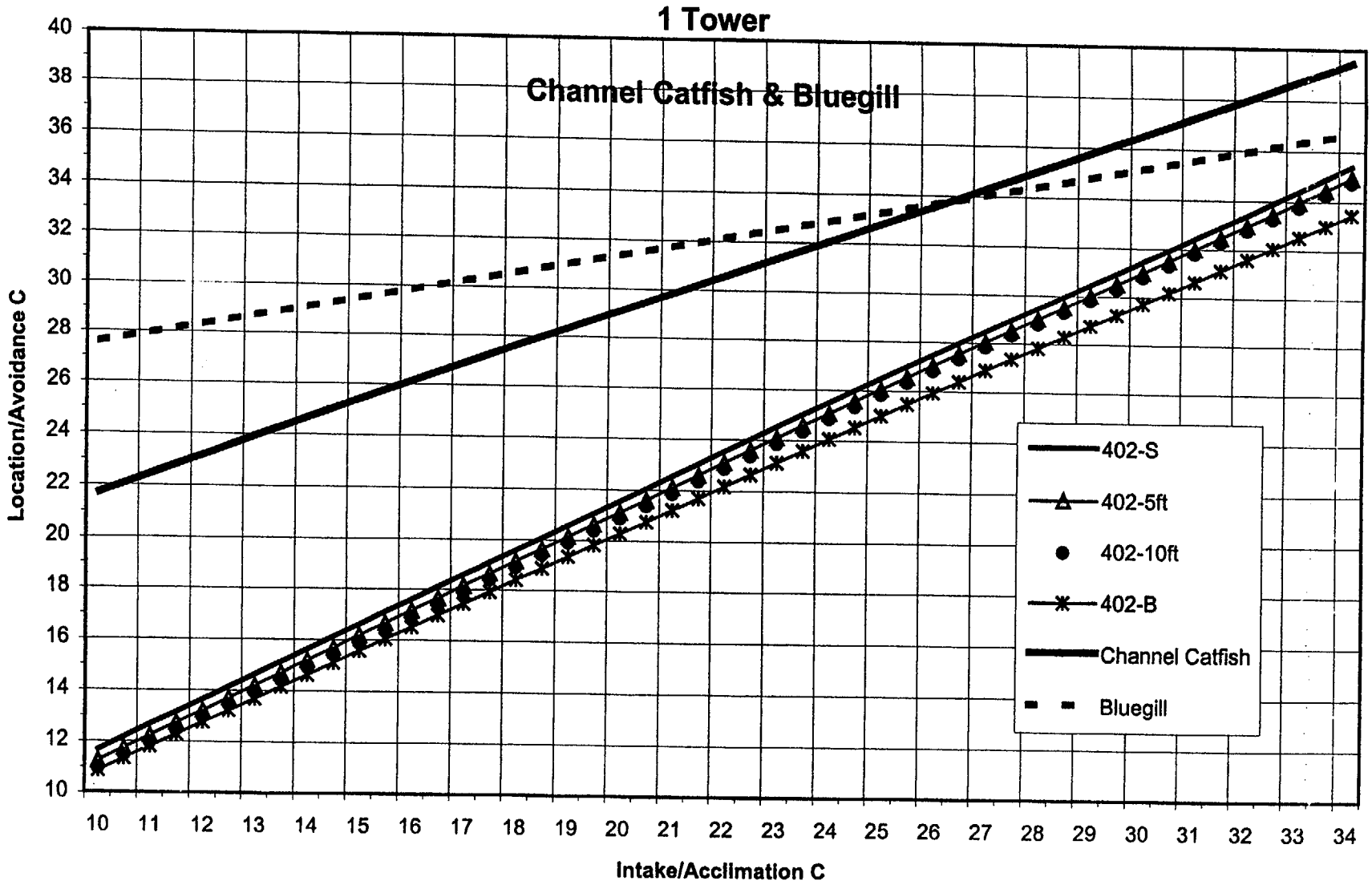
402 vs Avoidance C at 0 to 3 Tower Operations

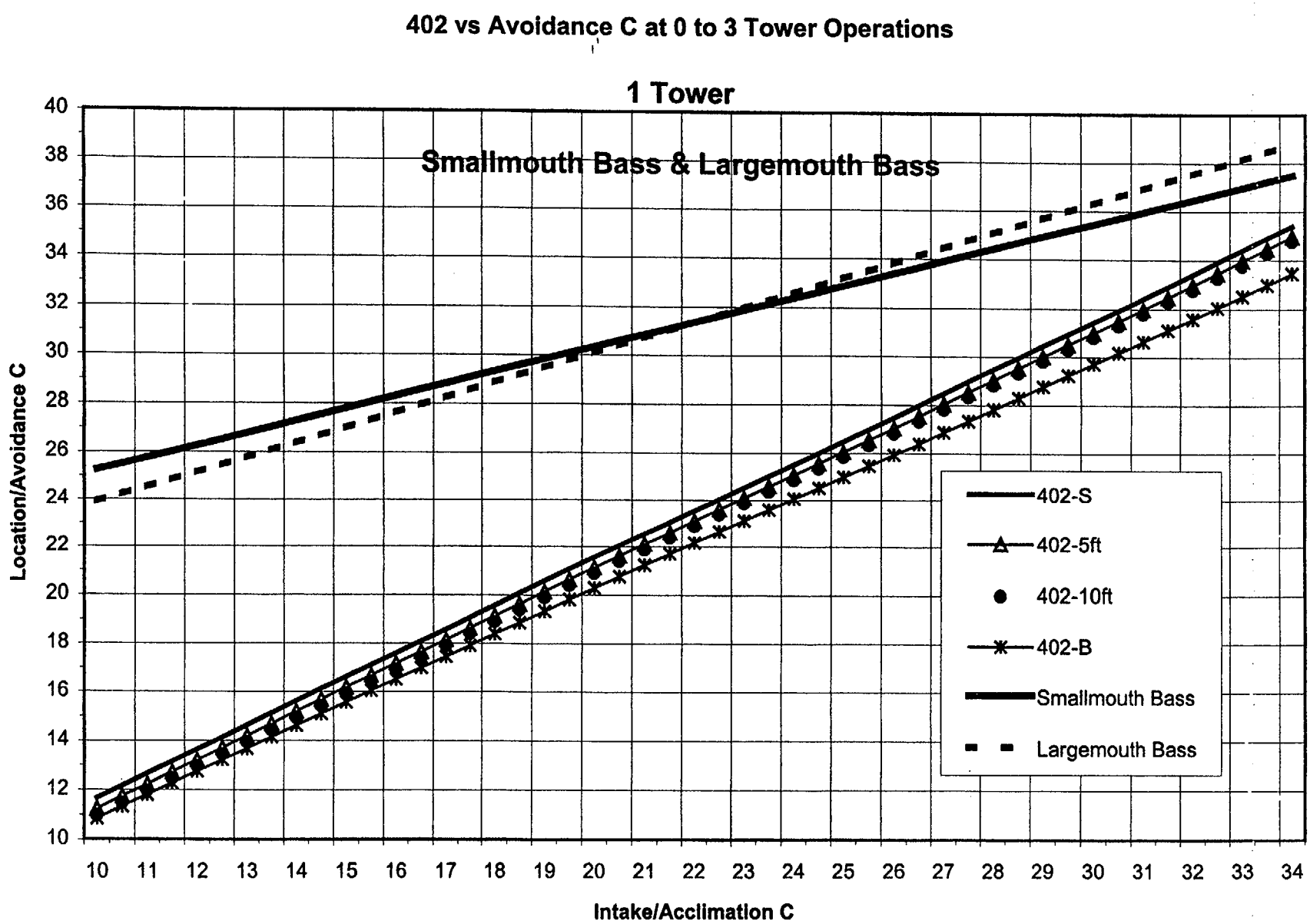
ZERO Tower



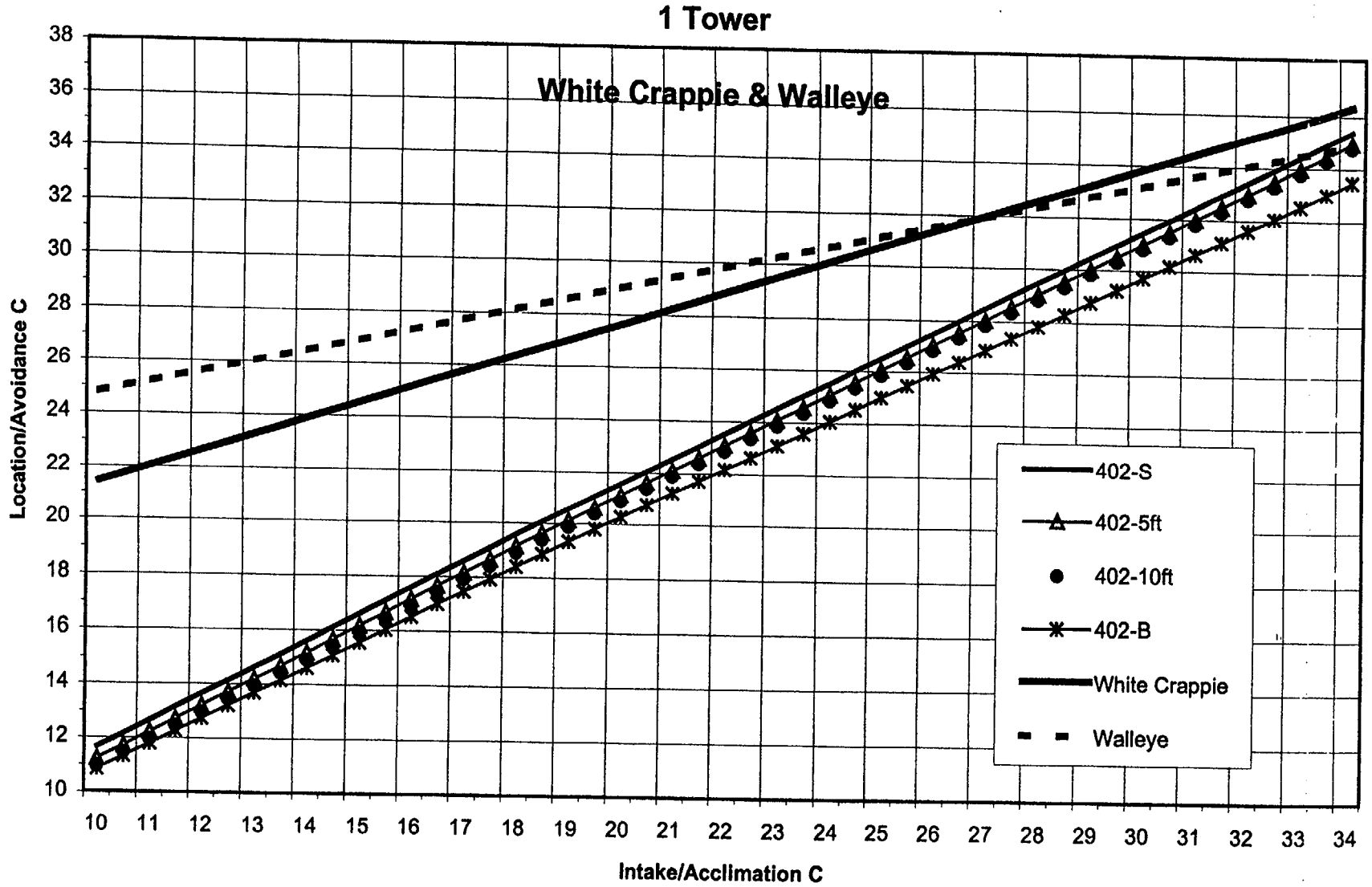

402 vs Avoidance C at 0 to 3 Tower Operations
1 Tower
Gizzard Shad, Spotfin, and Bluntnose
Location/Avoidance C
Intake/Acclimation C
44
42
40
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34
402-S
402-5ft
402-10ft
402-B
Gizzard Shad
Spotfin
Bluntnose

402 vs Avoidance C at 0 to 3 Tower Operations

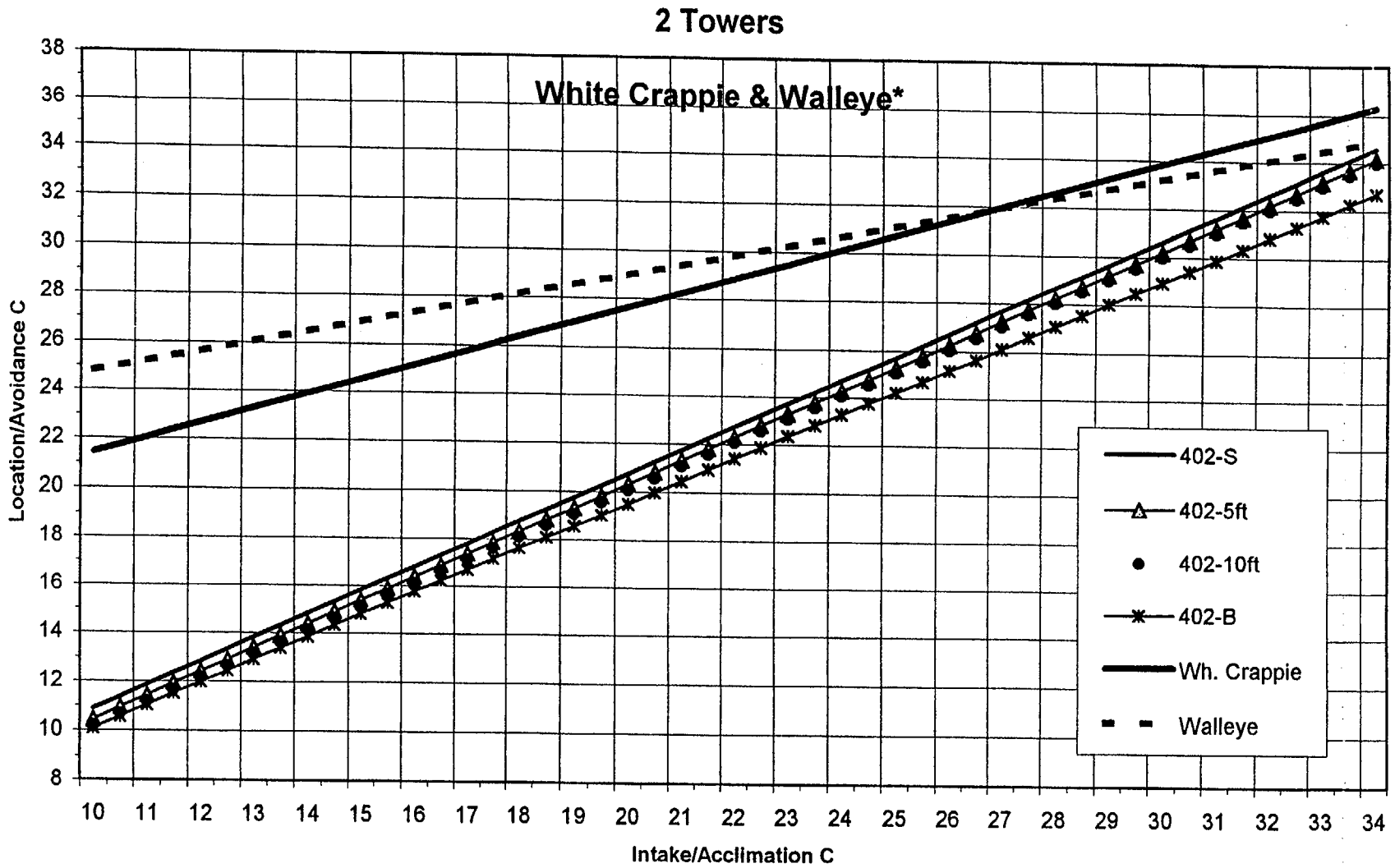



402 vs Avoidance C at 0 to 3 Tower Operations
1 Tower
Smallmouth Bass & Largemouth Bass
Location/Avoidance C
Intake/Acclimation C
402-S
402-5ft
402-10ft
402-B
Smallmouth Bass
Largemouth Bass
40
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34

402 vs Avoidance C at 0 to 3 Tower Operations



402 vs Avoidance at 0 to 3 Tower Operations



* Other resident important species (RIS) displayed no avoidance at this location at 2 tower operation. No RIS displayed avoidance at 3 tower operation.