ILLINOIS POWER COMPANY'S EXHIBITS IN SUPPORT OF PETITION FOR HEARING TO DETERMINE SPECIFIC THERMAL STANDARDS PURSUANT TO 35 ILL. ADM. CODE § 302.211(j)

Exhibit 1.	Condenser Cooling Water and Cooling Lake Discharge Temperature Evaluations.
Exhibit 2.	Illinois Power Company, Clinton Power Station, Environmental Monitoring Program Water Quality Report, 1978-1991. (Separately bound.)
Exhibit 3.	Illinois Power Company, Clinton Power Station, Environmental Monitoring Program Biological Report, Comparison of Preoperational Date (1983-1986) with Operational Data (1987-1991). (Separately bound, and including a separate appendix.)
Exhibit 4.	Clinton Power Station Artificial Cooling Lake Demonstration: Clinton Lake Hydrothermal Model Verification for 1989, 1990, 1991, and Determination of Adequacy of Variance Limits for Clinton Station, prepared by J.E. Edinger Associates, Inc.
Exhibit 5.	References Cited in Support of Evaluation of Thermal Impacts.
Exhibit 6.	Biological Evaluation of Predicted Thermal Discharges in Clinton Lake, prepared by Environmental Science & Engineering, Inc.
Exhibit 7.	Prepared Testimony of Richard E. Hall in Proceeding PCB 88-97.
Exhibit 8.	Study, entitled Supplemental Passive Cooling of Circulating Water at Clinton Power Station - Unit 1, prepared by Sargent & Lundy.
Exhibit 9.	Letter to Mr. T.L. Davis from Edward F. Stoneburg, regarding Clinton Power Station Electric Production Costs Associated with Constraining the Station to Not Exceed Current Discharge Flume Thermal Limit.
Exhibit 10.	Affidavit of Thomas L. Davis.
Exhibit 11.	Affidavit of John E. Edinger, Ph.D.
Exhibit 12.	Affidavit of Gary D. Matthews.
Exhibit 13.	Affidavit of James A. Smithson.
Exhibit 14.	Affidavit of Edward F. Stoneburg.

Clinton Power Station
Thermal Demonstration and Adjusted Standards Proceedings

Condenser Cooling Water and Cooling Lake Discharge Temperature Evaluations

NPDES permit IL0036919 issued by the IEPA on July 25, 1990 requires the recirculated condenser cooling water discharges from the Clinton Power Station to satisfy the temperature effluent limitations stipulated by the Illinois Pollution Control Board in its Orders 88-97 (dated June 22, 1989) and 89-213 (dated June 21, 1990). Compliance with these limitations is to be demonstrated by continuously measuring the temperature of the cooling water discharge to Clinton Lake. Special condition no. 8 of the NPDES permit also requires the station to conduct an Environmental Monitoring Program on Clinton Lake for purposes of collecting appropriate water quality and aquatic life data so as to assess the impact of the thermal effluents from the power station on the lake. In conjunction with this latter study IP has continuously monitored temperatures at several locations in Clinton Lake (Figure 1) as well as the temperature of Salt Creek immediately below the discharge from the Clinton Lake dam. Selected data developed pursuant to these monitoring programs is presented and evaluated in this report. The presentation of this data in this report supplements the larger body of Environmental Monitoring Program information recently published by IP (1,2).

Permit and Regulatory Requirements

Two temperature effluent limitations are specified in the station's NPDES permit for the recirculated condenser cooling water discharge to Clinton Lake (outfall 002), those being:

1) daily average discharge temperatures shall not exceed 99°F more than 90 days in any year, and

(2) the daily average discharge temperature shall never exceed 110.7°F on any day.

These limitations were ordered by the IPCB as variances from the temperature effluent limitations specified in an earlier IPCB order (81-82, dated May 28, 1981). The variance limits currently apply through September 30, 1992. If IP submits its petition for permanent condenser cooling water discharge temperature effluent limitations with its heated effluent cooling lake demonstration (as required by section 302.211(f) of the IPCB Subtitle C, Water Pollution Control regulations) to the IPCB by September 30, 1992 the IPCB will extend the duration of these variance limits to September 30, 1993.

The temperature water quality standards of the IPCB as set forth in section 302.211(b) through (e) of the water pollution control regulations previously cited apply to the discharge from Clinton Lake to Salt Creek. Those standards state:

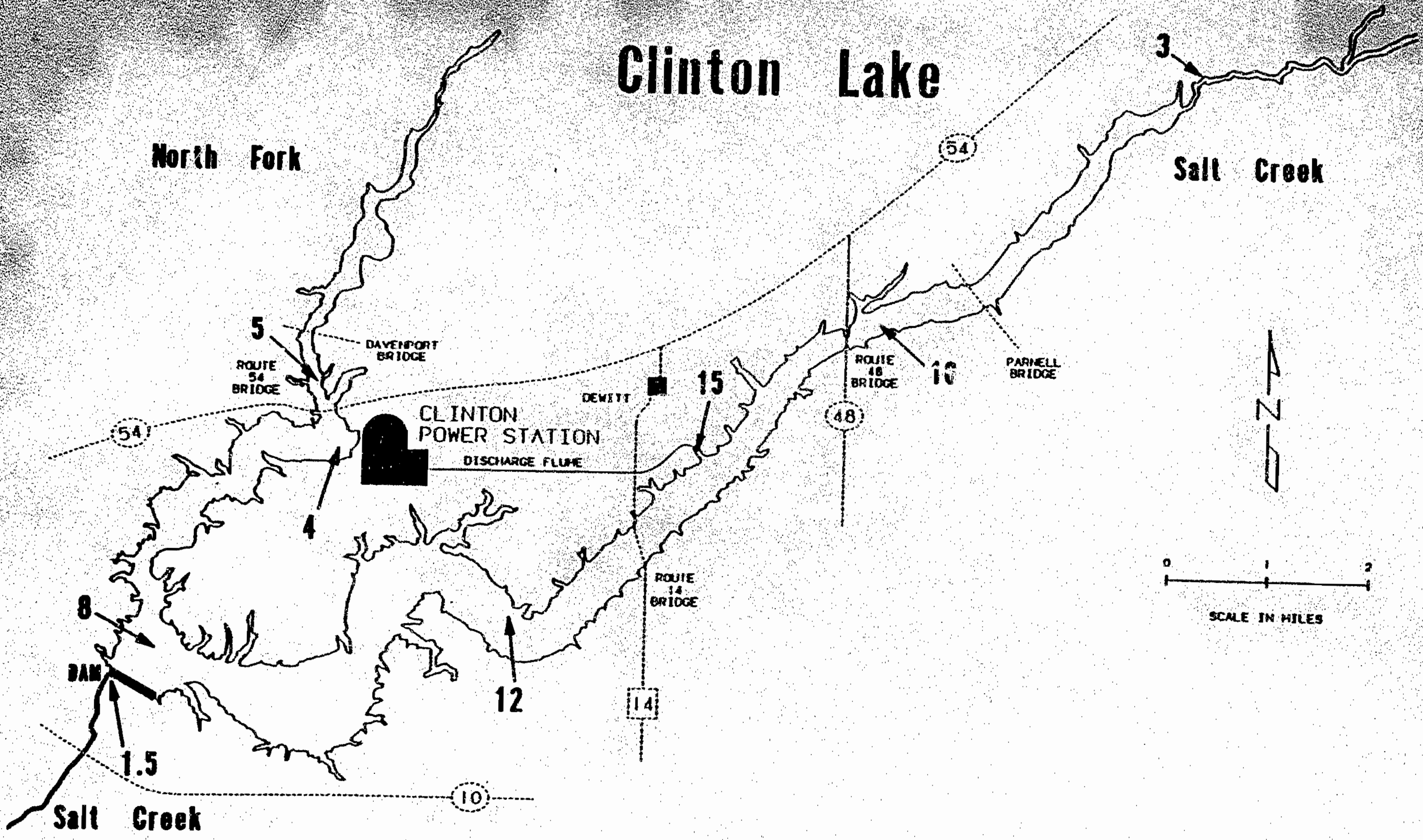

Figure 1 Continuous Temperature Monitoring Sites
Clinton Lake, Clinton, Illinois

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(1) there shall be no abnormal temperature changes that may adversely affect aquatic life unless caused by natural conditions;

(2) the normal daily and seasonal temperature fluctuations which existed before the addition of heat due to other than natural causes shall be maintained;

(3) the maximum temperature rise above natural temperatures shall not exceed 5°F; and

(4) water temperatures at representative locations in the stream shall not exceed:

   (a) 60°F more than one percent of the hours during December through March;

   (b) 63°F at any time during December through March;

   (c) 90°F more than one percent of the hours during April through November; and

   (d) 93°F at any time during April through November.

Summary of Findings and Conclusions

(1) Daily average flume discharge temperatures did not exceed the IPCB variance \NPDES permit effluent limits in 1988, 1989, 1990, or 1991.

Daily average condenser cooling water flume discharge temperatures exceeded 99°F only 50 days in 1988 (Table 1), 10 days in 1989 (Table 2), 7 days in 1990 (Table 3), and 58 days in 1991 (Table 4). Similarly, the maximum daily average flume discharge temperature was 108°F in 1988 (Table 1), 104°F in 1989 (Table 2), 100.1°F in 1990 (Table 3), and 103.5°F in 1991 (Table 4). Instantaneous maximum flume discharge temperatures observed during 1988, 1989, 1990, and 1991 were 109°F, 105°F, 102°F and 105°F, respectively (Table 1 through Table 4);

(2) No abnormal temperature changes occurred in the temperature of Salt Creek immediately below the Clinton Lake Dam (during the 1988 through 1991 period) that would adversely affect aquatic life. Temperatures in the discharge from Clinton Lake fluctuate slowly and within the range of naturally occurring temperatures.

(3) Normal seasonal temperature fluctuations occur in Salt Creek below the Clinton Lake Dam as evidenced by the range in daily and monthly average temperatures.

For the periods during which Salt Creek temperatures were monitored (Appendix A), daily average Salt Creek temperatures (as measured at site 1.5) ranged from 40.3°F to 84.7°F in 1988 (Table 5), from 32.5°F to 82.3°F in 1989 (Table 6), from 33.6°F to 82.4°F in 1990 (Table 7), and from 33.5°F to 84.8°F in 1991 (Table 8). Monthly average Salt Creek temperatures ranged from 40.8°F

(December) to 81.5°F (August) during the mid-June through early December period of 1988 (Table 5). During the end of March through early December 1989 period, monthly average Salt Creek temperatures ranged from 36°F (December) to 79.6°F (July)(Table 6). Monthly average Salt Creek temperatures ranged from 39.2°F (January) to 79.8°F (August) during 1990 (Table 7). During 1991, monthly average Salt Creek temperatures ranged from 34.3°F (January) to 81.9°F (July) (Table 8).

(4) Salt Creek temperature differences were more than 5°F greater than natural background temperatures on only four days during four years. Salt Creek temperatures are frequently equal to background temperatures.

The difference in daily average temperatures as measured in Salt Creek (site 1.5) and natural background temperatures (as measured at site 4) was never greater than 2°F in 1988 (Table 5), 5.4°F in 1989 (Table 6), 3.6°F in 1990 (Table 7), and 5.6°F in 1991 (Table 8). Temperature differences greater than 5°F were measured on two days in 1989 and two days in 1991 (Table 6, Table 8).

(5) Salt Creek temperatures never exceeded 60°F during the December through March periods of 1988 through 1991 nor did they exceed 90°F during the April through November period of those years (Table 5 through Table 8). The maximum monthly average temperature observed during the April through November period was 81.9°F (July, 1991). The maximum monthly average temperature observed during the December through March period was 45.1°F (March, 1990).

Monitoring Program Description

Condenser cooling water discharge temperatures to Clinton Lake are monitored continuously at the end of the 3.1-mile discharge flume (Figure 1). Two temperature monitoring probes are submerged in the cooling water discharge flow at the base of the concrete discharge structure (site 15, Figure 1). Temperatures are recorded on a strip chart from which hourly values are manually read. The daily average discharge temperature is computed as the arithmetic average of 24 hourly values. The instantaneous maximum temperature values are also reported.

Temperatures at various locations throughout Clinton Lake and the lake discharge to Salt Creek are also continuously recorded (Figure 1). Site 1.5 is the site at which Salt Creek temperatures are monitored. Site 4 was selected as the site at which naturally-occurring background temperatures would be collected. A description of these sites as well as the method used to monitor temperatures at each site is presented in section 6.4 of reference no. 2.

With the exception of infrequently-occurring periods of usually short duration, temperatures at these locations have been continuously monitored since July 1988. The discharge flume, site 1.5, and site 4 temperature data through 1991 are tabulated in Appendix A. It should be noted that the site 4 temperatures tabulated in Appendix A differ from those presented and discussed in the previously referenced water quality report (1). That site 4 data is temperature profile data that was collected over a period of several minutes at one-meter intervals during several days throughout the year. The site 4 data presented in Appendix A (and presented as well in Chapter 6 of the Biological report (2)) is that which was collected continuously of the lake waters being drawn at depth of approximately 12 to 15 feet from the lake into the station.

Discharge Flume Temperature Data

Measured average and maximum daily temperatures of the recirculated condenser cooling water discharge to Clinton Lake from January 1, 1988 through December 31, 1991 are tabulated in Appendix A. As these waters are actually discharged from the 3.1- mile long discharge flume, this discharge is most commonly referred to as the flume discharge. Graphical presentations of this data are presented as appendix figures B-2 through B-5.

Discharge flume temperatures are most directly influenced by station power levels. Discharge flume temperatures are also related to influent cooling water temperatures (site 4). Influent cooling water temperatures are for all practical purposes only affected by local meteorological conditions. These effects are somewhat lessened as intake cooling waters are drawn from approximately 12 to 15 feet beneath the surface of the lake. Daily station power levels are also tabulated in Appendix A. A graphical presentation of these station power levels is presented as appendix figure B-1.

1988

During 1988 average daily flume discharge temperatures ranged from 41°F (March; Table 1) to 108°F (July; Table 1). The instantaneous maximum temperature measured during 1988 was 109°F (August; Table 1). Monthly average flume discharge temperatures ranged from 55°F (March; Table 1) to 103°F (August; Table 1). Monthly average station power levels during July and August were 87.9 and 84.6 percent, respectively. Daily average flume discharge temperatures exceeded 99°F three days in June, 23 days in July, and 24 days in August (Table 1) for a yearly total of 50 days (Table 1).

1989

Average daily flume discharge temperatures ranged from 32.9°F (February; Table 2) to 104°F (July; Table 2) in 1989. The instantaneous maximum temperature measured during 1989 was 105°F (July; Table 2). Monthly average flume discharge temperatures ranged from 35.3°F (February; Table 2) to 92.6°F (August; Table 2). Monthly average station power levels during July and August were 51.8 and 69.7 percent, respectively. Daily average flume discharge temperatures exceeded 99°F eight days in July, and two days in August (Table 2) for a yearly total of 10 days.

1990

During 1990 average daily flume discharge temperatures ranged from 33°F (February and March; Table 3) to 100.1°F (August; Table 3). The instantaneous maximum temperature measured during 1990 was 102°F (July; Table 3). Monthly average flume discharge temperatures ranged from 38.3°F (December; Table 3) to 96.9°F (August; Table 3). Monthly average station power levels during July and August were 37.5 and 87.2 percent, respectively. Daily average flume discharge temperatures exceeded 99°F two days in July, and three days in August, and two days in September (Table 3) for a yearly total of seven days.

1991

Average daily flume discharge temperatures ranged from 34.9°F (February; Table 4) to 103.5°F (July; Table 4) in 1991. The instantaneous maximum temperature measured during 1991 was 105°F (July; Table 4). Monthly average flume discharge temperatures ranged from 37.2°F (January; Table 4) to 101.3°F (July; Table 4). Monthly average station power levels during July and August were 98.0 and 98.6 percent, respectively. Daily average flume discharge temperatures exceeded 99°F one day in May, 16 days in June, 27 days in July, 11 days in August, and three days in September (Table 4) for a yearly total of 58 days.

Site 1.5 Temperature Data

Measured average daily temperatures of Salt Creek immediately below the Clinton Lake dam discharge are tabulated in Appendix A. This data extends generally from mid-June 1988 through December 31, 1991 except for the January through March periods in 1989 and 1990. Stream temperatures were not measured during those periods because the temperature monitoring instrument was removed for servicing and calibration. Graphical presentations of this data are presented as appendix figures C-1 through C-5.

1988

During the mid-June through early December period of 1988 average daily stream temperatures ranged from 40.3°F (December; Table 5) to 84.7°F (August; Table 5). Monthly average stream temperatures ranged from 40.8°F (December; Table 5) to 81.5°F (August; Table 5). Daily average temperatures did not exceed the 60°F/90°F IPCB monthly temperature water quality standards on any day during 1988.

1989

During the end of March through December period of 1989 average daily stream temperatures ranged from 32.5°F (December; Table 6) to 82.3°F (July; Table 6). Monthly average stream temperatures ranged from 36°F (December; Table 6) to 79.6°F (July; Table 6). Daily average temperatures did not exceed the 60°F/90°F IPCB monthly temperature water quality standards on any day during 1989.

1990

Throughout all of 1990 average daily stream temperatures ranged from 33.6°F (December; Table 7) to 82.3°F (August; Table 7). Monthly average stream temperatures ranged from 39.2°F (January; Table 7) to 79.8°F (August; Table 7). Daily average temperatures did not exceed the 60°F/90°F IPCB monthly temperature water quality standards on any day during 1990.

1991

Throughout all of 1991 average daily stream temperatures ranged from 33.5°F (December; Table 8) to 84.8°F (June; Table 8). Monthly average stream temperatures ranged from 34.3°F (January; Table 8) to 81.9°F (July; Table 8). Daily average temperatures did not exceed the 60°F/90°F IPCB monthly temperature water quality standards on any day during 1991.

Comparison with Natural Background Temperatures

Waters in Salt Creek immediately below the dam have been discharged either from overtop the dam, i.e from the spillway, or from the underflow of the dam. IP is obligated by agreements with the Illinois Department of Transportation (Division of Water Resources) and the Illinois Department of Conservation to always release five cfs of water from the lake to Salt Creek. So as to assure compliance with this requirement, underflow waters are always released from the lake at a flow rate greater than five cfs. Underflow waters are drawn from the lake at a depth of approximately 22 feet. The presence of these underflow waters has two effects on the temperature of the waters in Salt Creek, those being (1) to cool Salt Creek stream temperatures below what those temperatures might otherwise be if only overflow waters from the surface of the lake were being discharged, and (2) to stabilize Salt Creek temperatures as the temperature of the underflow waters changes relatively slowly.

Recognizing these facts regarding the temperature characteristics of Salt Creek below the dam discharge, site 4 (Figure 1) temperatures (as tabulated in Appendix A) are considered to be most representative of what Salt Creek temperatures (below the dam) would be if the Clinton Power Station were not present. Please note that IP believes natural temperatures must reflect the reality of the presence of Clinton Lake. Natural temperatures should not be based upon stream temperatures, such as those which are measured at sites 3 and 5, as downstream Salt Creek temperatures would naturally be influenced by the impounding effects of the intervening lake. No discharge from any lake, cooling or noncooling, would be expected to exhibit temperature characteristics similar to a stream.

Site 4 is the site in Clinton Lake from which the station draws its intake waters for cooling and drinking. Located on what was formerly the North Fork Salt Creek leg of the lake, this site is essentially beyond the thermal influence of the condenser cooling water discharge (Site 15, Figure 1). It is the farthest point on the cooling loop of the lake. As noted previously, waters at this site are drawn from a depth of approximately 12 to 15 feet. Therefore, the Site 4 temperatures are considered most suitable for background comparisons because they are (1) representative of lake temperatures at significant depth, (2) beyond significant thermal influence of the flume discharge, and (3) not readily influenced by momentary meteorological effects. Continuously measured temperatures at the other lake sites (Figure 1) were measured at a depth of approximately one-half meter where they would be influenced by meteorological effects and/or the recirculated condenser cooling water discharge from the station.

Therefore, using site 4 temperatures as natural background temperatures, average daily Salt Creek temperatures were never more than 2°F warmer than site 4 temperatures during the mid-June through early December period of 1988 (Table 5). This maximum temperature difference occurred during June. For the approximate five and one-half month period when temperatures at both sites were being simultaneously monitored, average daily Salt Creek temperatures averaged 0.6°F cooler than site 4 temperatures (Table 5). Average daily Salt Creek temperatures never exceeded average daily site 4 temperatures by more than 5°F during any day in 1988.

During the late March through early December period of 1989, average daily Salt Creek temperatures were never more than 5.4°F warmer than the site 4 temperatures (Table 6). This maximum temperature difference also occurred during June. For the eight-month period when temperatures at both sites were being simultaneously monitored, average daily Salt Creek temperatures averaged 0.2°F cooler than site 4 temperatures (Table 6). Average daily Salt Creek temperatures exceeded average daily site 4 temperatures by more than 5°F during only two days in June of 1989.

During 1990, average daily Salt Creek temperatures were never more than 3.6°F warmer than the site 4 temperatures (Table 7). This maximum temperature difference occurred during May. The yearly average daily Salt Creek temperatures was essentially equal to the yearly average site 4 temperature (Table 7). Average daily Salt Creek temperatures never exceeded average daily site 4 temperatures by more than 5°F during 1990.

During 1991, average daily Salt Creek temperatures were never more than 5.6°F warmer than the site 4 temperatures (Table 8). This maximum temperature difference occurred during June. The yearly average daily Salt Creek temperatures was approximately 0.2°F warmer than the yearly average site 4 temperature (Table 8). Average daily Salt Creek temperatures exceeded average daily site 4 temperatures by more than 5°F during one day in May and one day in June.

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(1) Illinois Power Company. 1992. Clinton Power Station. Environmental Monitoring Program, Water Quality Report, 1978-1991. Decatur, Illinois.

(2) Illinois Power Company. 1992. Clinton Power Station. Environmental Monitoring Program, Biological Report, Comparison of Preoperational Data (1983-1986) with Operational Data (1987-1991). Decatur, Illinois.

Table 1 1988 Power Levels and Discharge Flume Temperature Summary

Parameter	Monthly Values												Yearly Values
	January	February	March	April	May	June	July	August	September	October	November	December	
Min. Daily Avg. Power Level (%)	53.1	50	0	0	0	0	17.7	50.5	64	76.4	0	50.9	0
Avg. Monthly Power Level (%)	93.6	95.5	52.3	0	74.7	88.3	87.9	84.6	95.1	93.9	45.7	68.5	73.4
Max. Daily Avg. Power Level (%)	100	100.2	99.6	0	100.7	100.1	100.5	99.8	100.1	99.4	90.2	84.9	100.7
Min. Daily Avg. Flume Temp. (F)	63	67	41	49	56	81	88	94	87	73.4	44.9	50	41
Avg. Monthly Flume Temp. (F)	76	77	63	55	82	94	101	103	92	81	60.9	56.4	78.4
Max. Daily Avg. Flume Temp. (F)	84	84	79	58	92	100	106	108	97	91	79.7	64.7	108
Max. Daily Max. Flume Temp. (F)	87	87	85	65	95	102	108	109	98	92	85	66	109
No. of Days Flume Daily Avg. Temp.> 99F	0	0	0	0	0	3	23	24	0	0	0	0	50

Table 2 1989 Power Levels and Discharge Flume Temperature Summary

Parameter	Monthly Values												Yearly Values
	January	February	March	April	May	June	July	August	September	October	November	December	
Min. Daily Avg. Power Level (%)	0	0	0	0	0	0	0	0	67.8	84	0	0	0
Avg. Monthly Power Level (%)	2.5	0	0	0	3.1	14	51.8	69.7	92.9	84.9	53.5	68.1	36.9
Max. Daily Avg. Power Level (%)	54.6	0	0	0	24.9	83.1	99.7	100.4	100.2	85.7	86.3	100.9	100.9
Min. Daily Avg. Flume Temp. (F)	33.4	32.9	38.7	43.8	57.3	71.6	75.9	81.1	82.3	75	44.7	33	32.9
Avg. Monthly Flume Temp. (F)	39.3	35.3	45.6	52.1	64.1	78	90.6	92.6	90.8	81.5	62.7	56.1	67.3
Max. Daily Avg. Flume Temp. (F)	52.6	43.8	58.1	63.2	79.1	95.1	104	99.4	97.3	86.7	78	69.4	104
Max. Daily Max. Flume Temp. (F)	53	45	60	64	81	100	105	101	98	87	78	70	105
No. of Days Flume Daily Avg. Temp.> 99F	0	0	0	0	0	0	8	2	0	0	0	0	10

Table 3 1990 Power Levels and Discharge Flume Temperature Summary

Parameter	Monthly Values												Yearly Values
	January	February	March	April	May	June	July	August	September	October	November	December	
Min. Daily Avg. Power Level (%)	68.6	0	0	0	0	83.3	0	81.8	72.5	0	0	0	0
Avg. Monthly Power Level (%)	97.2	42.5	0	18.4	63.3	96.6	37.5	87.2	77.2	28.9	0	0	45.7
Max. Daily Avg. Power Level (%)	100	99.6	0	99.7	100	99.4	93	92.9	81.5	72.3	0	0	100
Min. Daily Avg. Flume Temp. (F)	62.4	33	33	47.2	59.4	85.6	74.5	95.1	82.2	54.4	45.8	33.6	33
Avg. Monthly Flume Temp. (F)	67.8	49.5	48.2	56.5	76.5	91.8	86.2	96.9	91.2	68.1	50.4	38.3	68.8
Max. Daily Avg. Flume Temp. (F)	73.9	71.1	62.2	88	87	98.3	99.9	100.1	99.5	85.8	56.5	45	100.1
Max. Daily Max. Flume Temp. (F)	75	72	63	89	88	99	102	101	101	87	57	45	102
No. of Days Flume Daily Avg. Temp.> 99F	0	0	0	0	0	0	2	3	2	0	0	0	7

Table 4 1991 Power Levels and Discharge Flume Temperature Summary

Parameter	Monthly Values												Yearly Values
	January	February	March	April	May	June	July	August	September	October	November	December	
Min. Daily Avg. Power Level (%)	0	0	0	96.9	82.4	82.3	92.3	84.1	72.5	49.6	0	0	0
Avg. Monthly Power Level (%)	0	0	58.9	99.2	97.8	97.9	98	98.6	97.6	90.2	80.9	81.2	75.4
Max. Daily Avg. Power Level (%)	0	0	99.6	100.2	100.2	100.2	100.1	100	100.2	100	100.6	99.9	100.6
Min. Daily Avg. Flume Temp. (F)	35	34.9	39.5	77.4	80.5	94.3	97.8	95.8	80.2	74.3	45.3	36.5	34.9
Avg. Monthly Flume Temp. (F)	37.2	39.2	60.2	81.7	88.9	98.7	101.3	98.4	93	82.1	66.5	61.1	75.8
Max. Daily Avg. Flume Temp. (F)	38.8	42.2	80	87.6	100.6	102.2	103.5	102	99.4	89	79.8	70.1	103.5
Max. Daily Max. Flume Temp. (F)	39	44	80	89	103	104	105	103	101	90	83	71	105
No. of Days Flume Daily Avg. Temp.> 99F	0	0	0	0	1	16	27	11	3	0	0	0	58

Table 5 1988 Site 1.5 Temperature Summary

Parameter	Monthly Values												Yearly
	January	February	March	April	May	June	July	August	September	October	November	December	Values (a)
Min. Daily Avg. Temp. (F)	(b)	(b)	(b)	(b)	(b)	74.9	76.5	76.2	70.7	51	43	40.3	40.3
Avg. Monthly Temp. (F)	(b)	(b)	(b)	(b)	(b)	77	79.5	81.5	73.3	61.2	47.2	40.8	68.2
Max. Daily Avg. Temp. (F)	(b)	(b)	(b)	(b)	(b)	79.8	83.3	84.7	76.6	72.5	50.9	41.7	84.7
No. of Days Daily Avg. Temp. > 60/90 Std.	–	–	–	–	–	0	0	0	0	0	0	0	0
Comparison w/ Site 4 (c)													
Min. Daily Avg. Temp. Diff. (F)	(b)	(b)	(b)	(b)	(b)	-4.7	-5.9	-4.8	-1.1	0.1	-0.6	-1.0	-5.9
Avg. Monthly Temp. Diff. (F)	(b)	(b)	(b)	(b)	(b)	-1.0	-1.7	-1.7	0.1	0.4	0.1	-0.5	-0.6
Max. Daily Avg. Temp. Diff. (F)	(b)	(b)	(b)	(b)	(b)	2.0	1.4	1.0	1.8	1.1	0.7	0.1	2.0
No. of Days Daily Avg. Diff. > 5F Std.	–	–	–	–	–	0	0	0	0	0	0	0	0

(a) Based on available data
(b) No data available
(c) A negative temperature difference implies a cooler site 1.5 temperature

Table 6 1989 Site 1.5 Temperature Summary

Parameter	Monthly Values												Yearly Values (a)
	January	February	March	April	May	June	July	August	September	October	November	December	
Min. Daily Avg. Temp. (F)	(b)	(b)	40.3	46.2	57.7	69.4	77	77.7	67.1	55.1	41.8	32.5	32.5
Avg. Monthly Temp. (F)	(b)	(b)	44.2	51.5	62.2	74.7	79.6	78.5	73.6	60.8	49.1	36	62.2
Max. Daily Avg. Temp. (F)	(b)	(b)	48.3	62.4	68.3	81.6	82.3	80.2	78.5	69.1	56.4	41.3	82.3
No. of Days Daily Avg. Temp. > 60/90 Std.	–	–	0	0	0	0	0	0	0	0	0	0	0
Comparison w/ Site 4 (c)													
Min. Daily Avg. Temp. Diff. (F)	(b)	(b)	(b)	-3.1	-2.6	-2.3	-4.5	-2.9	-0.8	-1.5	-0.5	-6.2	-6.2
Avg. Monthly Temp. Diff. (F)	(b)	(b)	(b)	-1.6	-0.1	0.8	-0.1	-0.5	1.0	-0.1	0.5	-2.4	-0.2
Max. Daily Avg. Temp. Diff. (F)	(b)	(b)	(b)	0.6	3.8	5.4	3.2	2.1	3.0	2.5	1.9	1.1	5.4
No. of Days Daily Avg. Diff. > 5F Std.	–	–	–	0	0	2	0	0	0	0	0	0	2

(a) Based on available data
(b) No data available
(c) A negative temperature difference implies a cooler site 1.5 temperature

Table 7 1990 Site 1.5 Temperature Summary

Parameter	Monthly Values												Yearly Values (a)
	January	February	March	April	May	June	July	August	September	October	November	December	
Min. Daily Avg. Temp. (F)	37.7	38.5	38.4	46.8	59.8	67.5	75.3	77.7	67.7	53.9	49.1	33.6	33.6
Avg. Monthly Temp. (F)	39.2	41.3	45.1	50.1	62.6	73.9	78.6	79.8	75.8	61	50.8	40.5	58.3
Max. Daily Avg. Temp. (F)	40.1	43.9	50.2	60.2	68.2	80.3	82.2	82.4	82	68.2	54.8	48.2	82.4
No. of Days Daily Avg. Temp. > 60/90 Std.	0	0	0	0	0	0	0	0	0	0	0	0	0
Comparison w/ Site 4 (c)													
Min. Daily Avg. Temp. Diff. (F)	-6.7	-0.4	-1	-5	-1.7	-1.5	-1.4	-2.7	-1.5	-0.9	-1.3	(b)	-6.7
Avg. Monthly Temp. Diff. (F)	-2.7	0.9	0	-1.1	0.8	0.5	0.4	0.7	0.0	0.7	-0.9	(b)	0.0
Max. Daily Avg. Temp. Diff. (F)	0.6	2.8	0.8	2.3	3.6	3.5	2.9	3.1	1.1	2.9	-0.6	(b)	3.6
No. of Days Daily Avg. Diff. > 5F Std.	0	0	0	0	0	0	0	0	0	0	0	–	0

(a) Based on available data

(b) No data available

(c) A negative temperature difference implies a cooler site 1.5 temperature

Table 8 1991 Site 1.5 Temperature Summary

Parameter	Monthly Values												Yearly Values (a)
	January	February	March	April	May	June	July	August	September	October	November	December	
Min. Daily Avg. Temp. (F)	33.5	35.4	38.8	50.6	62	76.9	79.8	77.8	66.5	57.1	43.3	38.9	33.5
Avg. Monthly Temp. (F)	34.3	37	42.9	57.3	70.3	81.3	81.9	79.3	75.4	61.8	47	40.5	59.2
Max. Daily Avg. Temp. (F)	35.4	38.3	51	64.2	78.5	84.8	83.8	81.6	81	67.7	58.9	45.1	84.8
No. of Days Daily Avg. Temp. > 60/90 Std.	0	0	0	0	0	0	0	0	0	0	0	0	0
Comparison w/ Site 4 (c)													
Min. Daily Avg. Temp. Diff. (F)	(b)	-0.8	-2.1	-2	-2.7	-3.9	-3.6	-3.7	-1.7	-0.7	-0.5	-2.1	-3.9
Avg. Monthly Temp. Diff. (F)	(b)	-0.3	-0.7	0.6	1.3	0.9	-0.7	-0.7	-0.1	0.4	0.8	0.1	0.2
Max. Daily Avg. Temp. Diff. (F)	(b)	0.3	0.2	1.9	5.4	5.6	2.4	1.6	0.9	2.0	2.8	1.3	5.6
No. of Days Daily Avg. Diff. > 5F Std.	–	0	0	0	1	1	0	0	0	0	0	0	2

(a) Based on available data

(b) No data available

(c) A negative temperature difference implies a cooler site 1.5 temperature

Appendix A

CLINTON LAKE ENVIRONMENTAL MONITORING PROGRAM

Clinton Power Station Levels and Selected Temperature Monitoring Data

1988-1991

Date	Power Level (%)	Daily Avg. Flume Temp. (F)	Daily Max. Flume Temp. (F)	Daily Avg. Site 1.5 Temp. (F)	Daily Avg. Site 4 Temp. (F)	Daily Avg. Flume-Site 4 Diff. (F)	Sites 1.5 - 4 Diff. (F)
01/01/88	75.60	64.0	78		40.1	23.9	
01/02/88	97.25	63.0	72		43.6	19.4	
01/03/88	98.58	68.0	74		43.6	24.4	
01/04/88	99.63	63.0	66		41.3	21.7	
01/05/88	99.73	63.0	72		44.0	19.0	
01/06/88	99.33	75.0	78		45.1	29.9	
01/07/88	99.98	72.0	73		44.7	27.3	
01/08/88	99.10	74.0	74		45.4	28.6	
01/09/88	53.18	70.0	74		49.9	20.1	
01/10/88	64.18	67.0	69		49.3	17.7	
01/11/88	97.45	81.0	85		39.5	41.5	
01/12/88	98.30	81.0	84		38.1	42.9	
01/13/88	99.00	81.0	87		37.1	43.9	
01/14/88	99.88	83.0	87		36.3	46.7	
01/15/88	99.05	84.0	86		37.0	47.0	
01/16/88	98.85	82.0	86		38.8	43.2	
01/17/88	95.60	81.0	86		47.9	33.2	
01/18/88	99.05	82.0	83		46.8	35.2	
01/19/88	99.38	74.0	82		46.1	27.9	
01/20/88	99.48	79.0	81		49.9	29.2	
01/21/88	99.55	81.0	83		48.0	33.1	
01/22/88	99.33	77.0	82		46.1	30.9	
01/23/88	99.55	78.0	79		49.1	28.9	
01/24/88	74.33	77.0	85		44.4	32.6	
01/25/88	96.95	65.0	78		47.8	17.2	
01/26/88	98.33	74.0	77		47.4	26.7	
01/27/88	99.03	82.0	80		49.1	32.9	
01/28/88	99.10	83.0	84		49.3	33.7	
01/29/88	98.75	82.0	83		51.2	30.8	
01/30/88	72.70	80.0	82		51.9	28.1	
01/31/88	92.05	76.0	85		53.0	23.0	
02/01/88	95.77	84.0	85		48.2	35.8	
02/02/88	49.95	68.0	78		49.1	18.9	
02/03/88	81.90	67.0	76		49.5	17.5	
02/04/88	98.45	84.0	87		41.3	42.7	
02/05/88	98.85	77.0	83		38.1	38.9	
02/06/88	98.48	76.0	79		36.4	39.6	
02/07/88	92.78	78.0	79		36.6	41.4	
02/08/88	99.05	81.0	84		37.1	43.9	
02/09/88	98.78	81.0	82		37.4	43.7	
02/10/88	98.85	80.0	81		37.9	42.2	
02/11/88	98.85	79.0	80		38.2	40.8	
02/12/88	98.48	80.0	81		37.6	42.4	
02/13/88	98.18	81.0	84		41.1	39.9	
02/14/88	86.95	76.0	83		41.7	34.3	
02/15/88	94.90	78.0	85		38.1	39.9	
02/16/88	98.13	80.0	85		37.5	42.5	
02/17/88	99.28	81.0	87		43.1	37.9	
02/18/88	100.18	76.0	79		47.1	28.9	
02/19/88	99.80	75.0	78		44.3	30.8	
02/20/88	99.38	72.0	76		43.3	28.7	

CLINTON LAKE ENVIRONMENTAL MONITORING PROGRAM

Clinton Power Station Levels and Selected Temperature Monitoring Data

1988-1991

Date	Power Level (%)	Daily Avg. Flume Temp. (F)	Daily Max. Flume Temp. (F)	Daily Avg. Site 1.5 Temp. (F)	Daily Avg. Site 4 Temp. (F)	Daily Avg. Flume-Site 4 Diff. (F)	Sites 1.5 - 4 Diff. (F)
02/21/88	94.98	74.0	79		45.6	28.4	
02/22/88	99.95	75.0	78		44.7	30.3	
02/23/88	99.78	74.0	76		43.5	30.5	
02/24/88	99.70	73.0	75		43.1	29.9	
02/25/88	99.00	75.0	81		38.6	36.4	
02/26/88	99.10	70.0	72		39.6	30.4	
02/27/88	99.10	74.0	77		43.4	30.7	
02/28/88	93.20	77.0	82		41.4	35.6	
02/29/88	98.00	78.0	80		47.2	30.8	
03/01/88	98.70	79.0	79		47.4	31.7	
03/02/88	98.75	79.0	80		48.0	31.0	
03/03/88	98.73	74.0	77		47.5	26.5	
03/04/88	98.30	77.0	79		47.3	29.8	
03/05/88	71.03	77.0	79		47.1	29.9	
03/06/88	92.30	76.0	85		45.2	30.8	
03/07/88	98.28	78.0	79		45.8	32.2	
03/08/88	99.55	77.0	78		45.6	31.4	
03/09/88	75.70	75.0	76		47.7	27.3	
03/10/88	69.95	75.0	83		48.3	26.8	
03/11/88	90.43	73.0	85		47.9	25.2	
03/12/88	98.83	75.0	79		44.6	30.4	
03/13/88	99.08	71.0	72		44.2	26.8	
03/14/88	99.13	70.0	71		42.6	27.4	
03/15/88	98.68	71.0	72		41.6	29.4	
03/16/88	90.60	68.0	72		39.5	28.5	
03/17/88	91.00	68.0	69		39.7	28.3	
03/18/88	53.70	67.0	68		42.1	24.9	
03/19/88	0.00	58.0	65		41.0	17.0	
03/20/88	0.00	42.0	43		40.9	1.1	
03/21/88	0.00	41.0	42		41.1	-0.1	
03/22/88	0.00	42.0	45		41.7	0.3	
03/23/88	0.00	45.0	46		43.8	1.2	
03/24/88	0.00	47.0	48		45.6	1.4	
03/25/88	0.00	50.0	51		48.4	1.6	
03/26/88	0.00	49.0	50				
03/27/88	0.00	50.0	51				
03/28/88	0.00	49.0	50				
03/29/88	0.00	49.0	49				
03/30/88	0.00	47.0	48				
03/31/88	0.00	48.0	49				
04/01/88	0.00	49.0	49				
04/02/88	0.00	50.0	53				
04/03/88	0.00	50.0	51				
04/04/88	0.00	52.0	55				
04/05/88	0.00	58.0	61				
04/06/88	0.00	57.0	59				
04/07/88	0.00	56.0	57				
04/08/88	0.00	56.0	61				
04/09/88	0.00	55.0	65				
04/10/88	0.00	55.0	56				
04/11/88	0.00	54.0	56				

CLINTON LAKE ENVIRONMENTAL MONITORING PROGRAM

Clinton Power Station Levels and Selected Temperature Monitoring Data

1988-1991

Date	Power Level (%)	Daily Avg. Flume Temp. (F)	Daily Max. Flume Temp. (F)	Daily Avg. Site 1.5 Temp. (F)	Daily Avg. Site 4 Temp. (F)	Daily Avg. Flume-Site 4 Diff. (F)	Sites 1.5 - 4 Diff. (F)
04/12/88	0.00	54.0	55				
04/13/88	0.00	56.0	60				
04/14/88	0.00	53.0	61				
04/15/88	0.00	57.0	58				
04/16/88	0.00	57.0	59				
04/17/88	0.00	57.0	59				
04/18/88	0.00	57.0	58				
04/19/88	0.00	57.0	59				
04/20/88	0.00	56.0	57				
04/21/88	0.00	55.0	56				
04/22/88	0.00	54.0	55				
04/23/88	0.00	55.0	57				
04/24/88	0.00	55.0	56				
04/25/88	0.00	57.0	57				
04/26/88	0.00	56.0	58				
04/27/88	0.00	53.0	56		54.8	-1.8	
04/23/88	0.00	53.0	55		53.9	-0.9	
04/29/88	0.00	55.0	56		54.7	0.3	
04/30/88	0.00	56.0	59		55.0	1.0	
05/01/88	0.00	56.0	59		54.7	1.3	
05/02/88	0.00	56.0	58		54.4	1.6	
05/03/88	0.00	57.0	60		55.7	1.3	
05/04/88	0.00	58.0	60		56.8	1.2	
05/05/88	12.13	61.0	69		58.5	2.5	
05/06/88	26.85	71.0	76		58.8	12.3	
05/07/88	60.90	73.0	83		59.7	13.3	
05/08/88	81.88	84.0	85		61.4	22.7	
05/09/88	98.10	86.0	88		61.8	24.3	
05/10/88	99.18	87.0	89		62.1	24.9	
05/11/88	100.35	90.0	92		63.2	26.8	
05/12/88	100.25	91.0	92		64.4	26.6	
05/13/88	100.65	91.0	92		64.3	26.8	
05/14/88	65.60	84.0	89		63.6	20.4	
05/15/88	90.90	83.0	85		65.8	17.3	
05/16/88	98.08	84.0	85		66.2	17.8	
05/17/88	97.88	84.0	85		64.8	19.3	
05/18/88	98.50	87.0	91		64.0	23.0	
05/19/88	98.93	90.0	92		65.3	24.8	
05/20/88	98.58	92.0	95		67.1	25.0	
05/21/88	61.38	87.0	93		69.3	17.8	
05/22/88	83.98	84.0	87		70.5	13.5	
05/23/88	98.30	89.0	91		71.4	17.6	
05/24/88	98.53	89.0	90		71.1	18.0	
05/25/88	98.80	87.0	88		68.8	18.3	
05/26/88	98.45	87.0	89		69.3	17.8	
05/27/88	98.55	89.0	89		69.7	19.3	
05/28/88	98.58	89.0	91		70.6	18.5	
05/29/88	76.90	88.0	90		71.4	16.6	
05/30/88	79.45	88.0	89		72.2	15.8	
05/31/88	94.00	91.0	93		73.2	17.8	
06/01/88	98.48	94.0	95		74.8	19.3	

CLINTON LAKE ENVIRONMENTAL MONITORING PROGRAM

Clinton Power Station Levels and Selected Temperature Monitoring Data

1988-1991

Date	Power Level (%)	Daily Avg. Flume Temp. (F)	Daily Max. Flume Temp. (F)	Daily Avg. Site 1.5 Temp. (F)	Daily Avg. Site 4 Temp. (F)	Daily Avg. Flume-Site 4 Diff. (F)	Sites 1.5 - 4 Diff. (F)
06/02/88	99.13	95.0	95		74.8	20.2	
06/03/88	99.63	91.0	92		72.3	18.8	
06/04/88	99.68	92.0	93		72.3	19.8	
06/05/88	85.15	92.0	95		74.1	18.0	
06/06/88	98.98	95.0	96		75.4	19.6	
06/07/88	99.13	95.0	96		75.9	19.1	
06/08/88	99.33	95.0	96		75.4	19.6	
06/09/88	99.28	91.0	92		73.0	18.0	
06/10/88	99.23	91.0	92		71.8	19.3	
06/11/88	95.38	93.0	94		72.7	20.3	
06/12/88	78.48	90.0	94		73.7	16.3	
06/13/88	87.15	92.0	94		74.3	17.7	
06/14/88	96.00	94.0	96		75.1	19.0	
06/15/88	98.90	95.0	96		75.5	19.5	
06/16/88	98.83	95.0	96	75.7	75.1	20.0	0.7
06/17/88	99.75	95.0	96	75.6	75.4	19.6	0.2
06/18/88	100.10	96.0	98	75.3	76.6	19.5	-1.3
06/19/88	96.28	96.0	99	74.9	78.1	18.0	-3.1
06/20/88	100.00	99.0	100	74.9	79.2	19.8	-4.3
06/21/88	99.65	100.0	102	75.4	80.1	19.9	-4.7
06/22/88	99.55	99.0	100	75.2	79.9	19.1	-4.7
06/23/88	99.43	98.0	99	78.7	78.8	19.3	-0.0
06/24/88	90.00	97.0	99	79.8	77.9	19.1	1.9
06/25/88	0.00	85.0	96	79.1	80.4	4.6	-1.3
06/26/88	15.70	81.0	84	79.1	79.5	1.5	-0.4
06/27/88	58.78	91.0	97	78.5	77.8	13.3	0.8
06/28/88	77.03	95.0	99	78.6	78.2	16.8	0.4
06/29/88	82.83	92.0	95	77.5	77.5	14.5	0.0
06/30/88	96.75	93.0	95	76.9	76.0	17.0	1.0
07/01/88	99.83	94.0	96	76.5	75.1	18.9	1.4
07/02/88	100.45	94.0	96	76.6	75.3	18.8	1.3
07/03/88	98.00	95.0	96	76.8	75.8	19.2	1.0
07/04/88	100.38	96.0	98	77.6	76.8	19.3	0.8
07/05/88	100.15	98.0	100	77.6	78.3	19.8	-0.7
07/06/88	100.05	100.0	102	77.1	80.6	19.4	-3.5
07/07/88	99.83	101.0	103	77.1	81.4	19.6	-4.3
07/08/88	99.53	101.0	102	77.2	81.2	19.8	-4.0
07/09/88	100.25	102.0	103	77.1	82.6	19.4	-5.5
07/10/88	98.45	102.0	102	77.1	83.0	19.0	-5.9
07/11/88	99.50	102.0	102	78.0	81.5	20.5	-3.5
07/12/88	17.68	99.0	101	79.7	80.8	18.3	-1.0
07/13/88	23.18	88.0	92	79.3	82.0	6.0	-2.7
07/14/88	60.65	94.0	98	77.8	83.5	10.5	-5.7
07/15/88	74.65	98.0	100	79.1	83.5	14.5	-4.4
07/16/88	95.05	101.0	103	78.2	83.9	17.1	-5.7
07/17/88	89.13	103.0	106	80.8	83.3	19.8	-2.5
07/18/88	85.18	104.0	106	80.5	83.7	20.3	-3.2
07/19/88	87.00	106.0	107	81.1	83.1	22.9	-2.0
07/20/88	91.58	104.0	105	83.3	82.1	22.0	1.3
07/21/88	93.48	105.0	106	82.0	82.2	22.8	-0.2
07/22/88	92.98	105.0	106	81.8	81.9	23.1	-0.1

CLINTON LAKE ENVIRONMENTAL MONITORING PROGRAM

Clinton Power Station Levels and Selected Temperature Monitoring Data

1988-1991

Date	Power Level (%)	Daily Avg. Flume Temp. (F)	Daily Max. Flume Temp. (F)	Daily Avg. Site 1.5 Temp. (F)	Daily Avg. Site 4 Temp. (F)	Daily Avg. Flume-Site 4 Diff. (F)	Sites 1.5 - 4 Diff. (F)
07/23/88	92.75	105.0	106	82.1	81.6	23.5	0.5
07/24/88	91.55	105.0	106	81.9	82.0	23.0	-0.1
07/25/88	92.55	104.0	105	81.3	81.5	22.5	-0.2
07/26/88	93.03	104.0	106	81.3	80.8	23.2	0.5
07/27/88	93.53	105.0	107	81.6	81.3	23.8	0.3
07/28/88	85.45	104.0	106	81.5	82.1	21.9	-0.6
07/29/88	90.83	106.0	106	81.1	83.0	23.0	-1.9
07/30/88	89.18	105.0	106	80.6	82.9	22.1	-2.3
07/31/88	89.13	106.0	108	81.2	82.9	23.1	-1.7
08/01/88	89.13	106.0	108	81.8	83.5	22.5	-1.7
08/02/88	87.40	107.0	108	81.8	84.5	22.5	-2.7
08/03/88	86.23	107.0	109	81.4	85.3	21.8	-3.8
08/04/88	84.70	107.0	108	81.2	85.8	21.2	-4.6
08/05/88	84.25	107.0	107	80.9	85.7	21.3	-4.8
08/06/88	79.45	105.0	107	81.6	84.6	20.5	-3.0
08/07/88	86.53	106.0	107	82.3	84.2	21.8	-1.9
08/08/88	85.73	107.0	109	82.0	85.1	22.0	-3.0
08/09/88	85.73	107.0	109	82.2	85.0	22.0	-2.8
08/10/88	86.65	106.0	107	82.7	84.4	21.6	-1.7
08/11/88	86.53	107.0	109	83.0	84.5	22.5	-1.5
08/12/88	84.28	107.0	108	82.4	85.3	21.8	-2.8
08/13/88	62.43	103.0	106	82.9	85.7	17.3	-2.8
08/14/88	75.83	103.0	105	82.0	85.3	17.7	-3.3
08/15/88	80.85	107.0	108	83.1	85.7	21.3	-2.6
08/16/88	80.63	108.0	109	83.6	86.0	22.0	-2.4
08/17/88	79.18	107.0	109	83.6	87.2	19.8	-3.6
08/18/88	79.30	108.0	109	83.3	87.7	20.3	-4.4
08/19/88	70.80	106.0	107	84.2	85.9	20.1	-1.7
08/20/88	50.50	99.0	105	84.7	84.4	14.6	0.3
08/21/88	55.48	94.0	95	84.4	83.5	10.5	1.0
08/22/88	74.90	96.0	97	83.0	82.4	13.6	0.6
08/23/88	91.70	99.0	102	82.0	82.0	17.0	0.0
08/24/88	98.18	101.0	102	81.0	81.4	19.6	-0.4
08/25/88	99.78	99.0	100	80.0	80.4	18.6	-0.4
08/26/88	99.30	99.0	100	79.0	79.8	19.3	-0.8
08/27/88	98.90	98.0	100	78.2	78.5	19.5	-0.3
08/28/88	95.93	97.0	97	77.4	77.2	19.8	0.3
08/29/88	99.53	96.0	97	76.8	76.3	19.8	0.5
08/30/88	99.13	96.0	97	76.4	76.1	20.0	0.4
08/31/88	99.55	97.0	97	76.2	76.0	21.0	0.3
09/01/88	100.05	96.0	98	76.2	76.1	19.9	0.1
09/02/88	99.15	97.0	98	76.6	77.0	20.0	-0.4
09/03/88	70.63	94.0	97	76.3	77.1	17.0	-0.8
09/04/88	85.10	92.0	91	74.9	75.4	16.6	-0.5
09/05/88	97.50	93.0	94	73.8	74.0	19.0	-0.2
09/06/88	98.75	93.0	94	73.2	73.3	19.7	-0.1
09/07/88	99.95	93.0	93	73.0	72.8	20.3	0.3
09/08/88	99.43	94.0	92	72.3	72.0	22.0	0.3
09/09/88	99.08	92.0	93	72.4	72.2	19.8	0.3
09/10/88	99.40	92.0	93	72.7	71.8	20.2	0.9
09/11/88	96.83	92.0	93	73.7	72.6	19.5	1.2

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07/23/88	92.75	105.0	106	82.1	81.6	23.5	0.5
07/24/88	91.55	105.0	106	81.9	82.0	23.0	-0.1
07/25/88	92.55	104.0	105	81.3	81.5	22.5	-0.2
07/26/88	93.03	104.0	106	81.3	80.8	23.2	0.5
07/27/88	93.53	105.0	107	81.6	81.3	23.8	0.3
07/28/88	85.45	104.0	106	81.5	82.1	21.9	-0.6
07/29/88	90.83	106.0	106	81.1	83.0	23.0	-1.9
07/30/88	89.18	105.0	106	80.6	82.9	22.1	-2.3
07/31/88	89.13	106.0	108	81.2	82.9	23.1	-1.7
08/01/88	89.13	106.0	108	81.8	83.5	22.5	-1.7
08/02/88	87.40	107.0	108	81.8	84.5	22.5	-2.7
08/03/88	86.23	107.0	109	81.4	85.3	21.8	-3.8
08/04/88	84.70	107.0	108	81.2	85.8	21.2	-4.6
08/05/88	84.25	107.0	107	80.9	85.7	21.3	-4.8
08/06/88	79.45	105.0	107	81.6	84.6	20.5	-3.0
08/07/88	86.53	106.0	107	82.3	84.2	21.8	-1.9
08/08/88	85.73	107.0	109	82.0	85.1	22.0	-3.0
08/09/88	85.73	107.0	109	82.2	85.0	22.0	-2.8
08/10/88	86.65	106.0	107	82.7	84.4	21.6	-1.7
08/11/88	86.53	107.0	109	83.0	84.5	22.5	-1.5
08/12/88	84.28	107.0	108	82.4	85.3	21.8	-2.8
08/13/88	62.43	103.0	106	82.9	85.7	17.3	-2.8
08/14/88	75.83	103.0	105	82.0	85.3	17.7	-3.3
08/15/88	80.85	107.0	108	83.1	85.7	21.3	-2.6
08/16/88	80.63	108.0	109	83.6	86.0	22.0	-2.4
08/17/88	79.18	107.0	109	83.6	87.2	19.8	-3.6
08/18/88	79.30	108.0	109	83.3	87.7	20.3	-4.4
08/19/88	76.80	106.0	107	84.2	85.9	20.1	-1.7
08/20/88	50.50	99.0	105	84.7	84.4	14.6	0.3
08/21/88	55.48	94.0	95	84.4	83.5	10.5	1.0
08/22/88	74.90	96.0	97	83.0	82.4	13.6	0.6
08/23/88	91.70	99.0	102	82.0	82.0	17.0	0.0
08/24/88	98.18	101.0	102	81.0	81.4	19.6	-0.4
08/25/88	99.78	99.0	100	80.0	80.4	18.6	-0.4
08/26/88	99.30	99.0	100	79.0	79.8	19.3	-0.8
08/27/88	98.90	98.0	100	78.2	78.5	19.5	-0.3
08/28/88	95.93	97.0	97	77.4	77.2	19.8	0.3
08/29/88	98.53	96.0	97	76.8	76.3	19.8	0.5
08/30/88	99.13	96.0	97	76.4	76.1	20.0	0.4
08/31/88	99.55	97.0	97	76.2	76.0	21.0	0.3
09/01/88	100.05	96.0	98	76.2	76.1	19.9	0.1
09/02/88	99.15	97.0	98	76.6	77.0	20.0	-0.4
09/03/88	70.63	94.0	97	76.3	77.1	17.0	-0.8
09/04/88	85.10	92.0	91	74.9	75.4	16.6	-0.5
09/05/88	97.50	93.0	94	73.8	74.0	19.0	-0.2
09/06/88	98.75	93.0	94	73.2	73.3	19.7	-0.1
09/07/88	99.95	93.0	93	73.0	72.8	20.3	0.3
09/08/88	99.43	94.0	92	72.3	72.0	22.0	0.3
09/09/88	99.08	92.0	93	72.4	72.2	19.8	0.3
09/10/88	99.40	92.0	93	72.7	71.8	20.2	0.9
09/11/88	96.83	92.0	93	73.7	72.6	19.5	1.2

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09/12/88	99.45	94.0	95	74.2	74.0	20.0	0.3
09/13/88	99.80	95.0	95	74.0	74.3	20.7	-0.3
09/14/88	100.05	94.0	95	73.8	74.0	20.0	-0.2
09/15/88	99.28	93.0	94	74.8	73.1	20.0	1.8
09/16/88	98.85	92.0	94	74.6	73.2	18.8	1.4
09/17/88	98.28	94.0	96	74.4	74.7	19.3	-0.3
09/18/88	91.90	94.0	95	74.1	75.2	18.8	-1.1
09/19/88	98.38	93.0	94	73.6	74.1	18.9	-0.5
09/20/88	99.65	91.0	92	72.6	72.1	19.0	0.5
09/21/88	99.45	92.0	93	72.1	71.9	20.1	0.2
09/22/88	99.05	92.0	93	72.4	72.5	19.5	-0.0
09/23/88	97.68	92.0	92	72.5	72.7	19.3	-0.2
09/24/88	63.98	88.0	91	71.3	71.7	16.3	-0.4
09/25/88	74.02	87.0	90	70.7	70.8	16.2	-0.1
09/26/88	93.20	89.0	90	71.0	71.2	17.8	-0.2
09/27/88	98.08	91.0	92	71.4	71.5	19.5	-0.1
09/28/88	99.23	91.0	92	71.2	71.6	19.4	-0.4
09/29/88	98.75	91.0	92	71.8	71.8	19.3	0.0
09/30/88	98.55	92.0	92	72.6	72.0	20.0	0.6
10/01/88	92.10	91.0	92	72.5	72.1	19.0	0.5
10/02/88	94.15	89.0	90	71.7	71.4	17.6	0.3
10/03/88	98.93	89.0	91	70.6	70.6	18.5	0.0
10/04/88	99.33	88.0	89	69.2	68.8	19.2	0.4
10/05/88	99.08	86.0	87	67.5	67.1	18.9	0.4
10/06/88	98.95	86.0	86	66.5	66.4	19.6	0.1
10/07/88	98.90	85.0	86	65.8	65.8	19.3	0.0
10/08/88	76.43	82.0	85	65.2	65.1	17.0	0.2
10/09/88	91.25	82.0	84	64.9	64.7	17.3	0.2
10/10/88	99.38	83.0	83	64.4	63.7	19.3	0.8
10/11/88	98.33	82.0	83	63.6	62.9	19.2	0.8
10/12/88	99.38	82.0	82	62.6	61.9	20.2	0.8
10/13/88	98.20	81.0	82	61.6	60.9	20.2	0.8
10/14/88	97.88	79.0	80	60.8	60.2	18.8	0.6
10/15/88	97.18	80.0	80	61.0	60.4	19.7	0.6
10/16/88	96.40	80.0	81	61.3	61.0	19.0	0.3
10/17/88	96.03	81.0	81	61.7	61.5	19.5	0.3
10/18/88	96.18	80.4	81	61.4	61.4	19.1	0.0
10/19/88	95.80	79.5	80	60.8	60.4	19.2	0.4
10/20/88	94.80	78.3	79	59.9	59.5	18.8	0.4
10/21/88	94.63	77.8	78	59.0	58.7	19.1	0.3
10/22/88	94.25	77.6	78	58.4	58.3	19.3	0.1
10/23/88	93.25	75.6	77	58.0	57.5	18.1	0.5
10/24/88	93.48	73.4	74	56.8	55.8	17.7	1.0
10/25/88	93.35	74.2	80	55.9	55.0	19.3	0.9
10/26/88	80.58	76.9	80	54.7	54.3	22.7	0.5
10/27/88	93.60	80.1	81	54.0	53.7	26.4	0.3
10/28/88	92.00	78.4	80	53.2	52.9	25.6	0.4
10/29/88	82.10	77.7	79	52.3	52.3	25.5	0.0
10/30/88	82.28	76.4	77	51.5	51.3	25.2	0.3
10/31/88	91.53	78.0	80	51.0	50.9	27.2	0.1
11/01/88	90.23	79.7	81	50.7	50.6	29.1	0.1

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11/02/88	89.20	77.2	81	50.1	50.1	27.2	0.0
11/03/88	89.05	77.3	79	50.0	50.2	27.1	-0.2
11/04/88	88.43	79.0	79	50.9	51.2	27.8	-0.3
11/05/88	74.38	71.1	73	50.5	50.6	20.5	-0.1
11/06/88	76.68	68.0	68	49.2	48.6	19.4	0.6
11/07/88	90.03	72.9	75	48.4	48.1	24.9	0.3
11/08/88	87.48	73.7	75	48.3	48.2	25.5	0.1
11/09/88	86.95	72.8	73	48.2	48.5	24.3	-0.3
11/10/88	86.53	72.6	73	48.5	48.5	24.1	0.0
11/11/88	71.95	71.5	72	47.9	47.7	23.8	0.2
11/12/88	0.00	53.2	72	47.1	47.2	6.0	-0.1
11/13/88	0.00	47.9	48	47.4	47.4	0.5	0.0
11/14/88	0.00	49.1	53	47.7			
11/15/88	0.00	50.0	52	48.6			
11/16/88	0.00	50.0	52	49.2			
11/17/88	0.00	46.4	47	47.6			
11/18/88	0.00	45.5	46	47.1	47.0	-1.5	0.1
11/19/88	0.00	47.1	50	46.9	46.7	0.4	0.2
11/20/88	0.00	46.1	47	46.4	46.1	0.0	0.3
11/21/88	0.00	45.0	45	45.4	45.2	-0.2	0.2
11/22/88	0.00	44.9	46	45.1	45.7	-0.8	-0.6
11/23/88	0.00	45.3	46	44.8	44.4	0.9	0.4
11/24/88	9.95	46.6	52	44.8	44.4	2.2	0.4
11/25/88	24.70	59.7	61	45.1	45.0	14.8	0.1
11/26/88	71.23	69.1	85	45.9	46.1	23.0	-0.2
11/27/88	82.83	67.6	69	45.6	45.8	21.8	-0.1
11/28/88	81.30	64.0	64	44.2	43.8	20.3	0.5
11/29/88	85.88	66.9	67	43.4	43.3	23.7	0.1
11/30/88	85.03	65.6	66	43.0	42.9	22.7	0.1
12/01/88	84.89	64.7	66	41.7	41.6	23.1	0.1
12/02/88	84.30	64.0	64	41.0	41.3	22.8	-0.3
12/03/88	84.05	64.2	65	41.0	41.6	22.6	-0.6
12/04/88	82.68	64.5	66	40.4	41.4	23.2	-1.0
12/05/88	82.80	64.0	64	40.5	41.0	23.0	-0.5
12/06/88	82.00	64.1	65	40.3	41.1	23.0	-0.8
12/07/88	81.10	64.0	64	40.4	41.1	22.9	-0.7
12/08/88	77.98	63.0	64		40.4	22.7	
12/09/88	77.18	58.9	60		39.6	19.3	
12/10/88	76.73	57.7	59		38.8	18.9	
12/11/88	76.03	56.9	57		37.9	19.0	
12/12/88	77.30	55.8	56		36.9	18.9	
12/13/88	78.83	56.2	57		36.6	19.7	
12/14/88	77.25	57.0	57		37.2	19.8	
12/15/88	77.08	56.2	57		36.9	19.3	
12/16/88	76.93	54.3	55		35.3	19.0	
12/17/88	76.30	53.8	54		34.6	19.2	
12/18/88	50.93	50.0	55		34.7	15.3	
12/19/88	56.45	51.0	52		35.8	15.3	
12/20/88	56.15	53.5	54		38.2	15.3	
12/21/88	56.00	54.4	55		38.5	15.9	
12/22/88	55.90	53.9	54		38.2	15.7	

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12/23/88	55.58	53.9	55		38.3	15.6	
12/24/88	55.48	53.3	54		38.5	14.8	
12/25/88	55.53	52.5	53		37.7	14.8	
12/26/88	55.18	51.9	53		37.5	14.4	
12/27/88	55.15	52.2	53		37.0	15.3	
12/28/88	54.93	50.4	51		36.1	14.3	
12/29/88	55.00	50.3	51		35.9	14.4	
12/30/88	54.73	50.6	52		36.4	14.3	
12/31/88	54.65	51.9	53		36.9	15.0	
01/01/89	54.63	52.6	53		37.5	15.1	
01/02/89	24.20	48.9	53		37.5	11.4	
01/03/89	0.00	40.5	44		36.9	3.6	
01/04/89	0.00	36.8	37		36.9	-0.1	
01/05/89	0.00	37.1	38		37.0	0.1	
01/06/89	0.00	38.0	38		36.9	1.1	
01/07/89	0.00	38.5	40		36.7	1.8	
01/08/89	0.00	34.4	38				
01/09/89	0.00	33.4	34				
01/10/89	0.00	34.8	36				
01/11/89	0.00	35.7	36				
01/12/89	0.00	36.3	38				
01/13/89	0.00	37.5	39				
01/14/89	0.00	37.4	38				
01/15/89	0.00	37.8	39				
01/16/89	0.00	39.0	40				
01/17/89	0.00	40.4	41				
01/18/89	0.00	40.4	42				
01/19/89	0.00	39.7	41				
01/20/89	0.00	38.4	39				
01/21/89	0.00	37.4	38				
01/22/89	0.00	37.0	38				
01/23/89	0.00	37.4	38				
01/24/89	0.00	38.6	40				
01/25/89	0.00	40.7	42				
01/26/89	0.00	42.0	43				
01/27/89	0.00	41.0	42				
01/28/89	0.00	40.6	42				
01/29/89	0.00	41.6	42				
01/30/89	0.00	42.3	43				
01/31/89	0.00	43.6	45				
02/01/89	0.00	43.8	45				
02/02/89	0.00	41.3	42				
02/03/89	0.00	39.1	41				
02/04/89	0.00	35.6	37				
02/05/89	0.00	33.2	34				
02/06/89	0.00	33.0	33				
02/07/89	0.00	33.0	33				
02/08/89	0.00	33.3	34				
02/09/89	0.00	32.9	33				
02/10/89	0.00	33.2	34				
02/11/89	0.00	33.9	35				

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02/12/89	0.00	33.8	35				
02/13/89	0.00	33.5	34				
02/14/89	0.00	34.8	36				
02/15/89	0.00						
02/16/89	0.00						
02/17/89	0.00						
02/18/89	0.00						
02/19/89	0.00						
02/20/89	0.00						
02/21/89	0.00						
02/22/89	0.00						
02/23/89	0.00						
02/24/89	0.00						
02/25/89	0.00						
02/26/89	0.00						
02/27/89	0.00						
02/28/89	0.00						
03/01/89	0.00						
03/02/89	0.00						
03/03/89	0.00	39.7	41				
03/04/89	0.00	39.4	40				
03/05/89	0.00	38.9	39				
03/06/89	0.00	38.7	40				
03/07/89	0.00	39.6	42				
03/08/89	0.00	40.6	43				
03/09/89	0.00	41.6	43				
03/10/89	0.00	42.1	44				
03/11/89	0.00	43.4	45				
03/12/89	0.00	42.2	43				
03/13/89	0.00	42.9	46				
03/14/89	0.00	44.0	46				
03/15/89	0.00	43.7	44				
03/16/89	0.00	43.3	44				
03/17/89	0.00	45.8	48				
03/18/89	0.00	45.5	47				
03/19/89	0.00	44.7	48				
03/20/89	0.00	42.8	43				
03/21/89	0.00	42.4	43				
03/22/89	0.00	44.6	46	40.3			
03/23/89	0.00	44.3	45	40.6			
03/24/89	0.00	46.9	50	41.3			
03/25/89	0.00	51.6	56	41.9			
03/26/89	0.00	54.0	56	43.0			
03/27/89	0.00	55.8	57	44.7			
03/28/89	0.00	58.1	60	46.4			
03/29/89	0.00	57.6	59	48.2			
03/30/89	0.00	55.7	56	48.3			
03/31/89	0.00	52.3	54	47.2			
04/01/89	0.00	49.7	50	47.0			
04/02/89	0.00	45.0	45	47.2			
04/03/89	0.00	43.8	44	47.4			

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Date	Power Level (%)	Daily Avg. Flume Temp. (F)	Daily Max. Flume Temp. (F)	Daily Avg. Site 1.5 Temp. (F)	Daily Avg. Site 4 Temp. (F)	Daily Avg. Flume-Site 4 Diff. (F)	Sites 1.5 - 4 Diff. (F)
04/04/89	0.00	45.0	46	47.5			
04/05/89	0.00	44.9	46	47.5			
04/06/89	0.00	49.2	51	48.3			
04/07/89	0.00	50.5	55	48.2			
04/08/89	0.00	49.5	51	47.6			
04/09/89	0.00	47.5	48	46.9			
04/10/89	0.00	47.2	49	46.5	49.2	-2.0	-2.7
04/11/89	0.00	48.3	50	46.2	49.1	-0.8	-2.9
04/12/89	0.00	47.8	49	46.8	49.2	-1.4	-2.4
04/13/89	0.00	48.9	51	46.9	49.3	-0.4	-2.4
04/14/89	0.00	49.3	51	47.1	49.5	-0.2	-2.4
04/15/89	0.00	49.9	51	48.6	50.6	-0.7	-2.0
04/16/89	0.00	51.9	54	48.9	52.0	-0.1	-3.1
04/17/89	0.00	52.1	53	50.3	52.2	-0.1	-1.9
04/18/89	0.00	51.1	52	50.5	52.6	-1.5	-2.1
04/19/89	0.00	51.8	53	52.1	52.9	-1.1	-0.8
04/20/89	0.00	52.5	54	52.0	54.4	-1.9	-2.4
04/21/89	0.00	53.6	55	53.1	54.4	-0.8	-1.3
04/22/89	0.00	53.3	54	54.4	54.9	-1.6	-0.5
04/23/89	0.00	54.5	55	54.8	55.3	-0.8	-0.5
04/24/89	0.00	56.0	58	56.1	56.0	0.0	0.1
04/25/89	0.00	59.0	63	56.7	59.7	-0.7	-3.0
04/26/89	0.00	60.9	63	60.4	59.8	1.1	0.6
04/27/89	0.00	61.5	64	61.4	61.0	0.5	0.4
04/28/89	0.00	61.8	63	62.4	62.5	-0.7	-0.1
04/29/89	0.00	62.5	63	61.7	63.4	-0.9	-1.7
04/30/89	0.00	63.2	64	61.3	64.1	-0.9	-2.8
05/01/89	0.00	61.8	63	61.6	60.5	1.3	1.1
05/02/89	0.00	64.2	65	60.8	60.7	3.5	0.1
05/03/89	0.00	60.6	63	60.1			
05/04/89	0.00	59.7	62	59.3	59.8	-0.1	-0.5
05/05/89	0.00	59.3	60	59.2	59.4	-0.1	-0.2
05/06/89	0.00	57.4	58	58.4	58.0	-0.6	0.4
05/07/89	0.00	58.7	60	57.7	58.1	0.6	-0.4
05/08/89	0.00	59.6	61	57.8	58.0	1.6	-0.2
05/09/89	0.00	58.6	59	57.7	57.7	0.9	-0.0
05/10/89	0.00	58.2	60	58.0	57.3	0.9	0.7
05/11/89	0.00	57.3	59	58.6	57.4	-0.1	1.2
05/12/89	0.00	57.9	60	58.9	58.1	-0.2	0.8
05/13/89	0.00	59.3	60	60.1	58.1	1.2	2.0
05/14/89	0.00	58.2	60	61.2	58.0	0.2	3.2
05/15/89	0.00	59.0	61	61.4	58.7	0.3	2.7
05/16/89	0.00	60.3	63	63.7			
05/17/89	0.00	60.8	63	64.4	60.6	0.2	3.8
05/18/89	0.00	62.5	64	63.8	62.6	-0.1	1.2
05/19/89	0.00	64.0	65	62.7	64.3	-0.3	-1.6
05/20/89	0.00	65.9	67	62.8	65.3	0.6	-2.5
05/21/89	0.00	67.1	69	63.1	65.6	1.5	-2.5
05/22/89	0.45	65.5	66	63.6	64.2	1.3	-0.6
05/23/89	1.13	66.0	68	63.4	65.2	0.8	-1.8
05/24/89	3.50	69.3	73	64.0	66.0	3.3	-2.0

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05/25/89	13.35	73.1	78	65.1	66.9	6.2	-1.8
05/26/89	2.60	75.6	81	65.4	67.4	8.2	-2.0
05/27/89	0.01	67.4	71	66.3	66.5	0.9	-0.2
05/28/89	8.25	66.7	72	66.7	66.2	0.5	0.5
05/29/89	21.35	77.0	80	66.5	66.5	10.5	-0.0
05/30/89	22.00	79.1	81	67.0	68.3	10.8	-1.3
05/31/89	24.66	77.0	79	68.3	69.9	7.1	-1.6
06/01/89	3.80	76.2	82	69.4	71.5	4.7	-2.1
06/02/89	0.00	73.0	75	71.1	71.7	1.3	-0.6
06/03/89	0.00	72.3	73	71.2	72.6	-0.3	-1.4
06/04/89	0.00	72.6	74	72.0	71.3	1.3	0.7
06/05/89	0.00	72.3	75	73.5	71.6	0.7	1.9
06/06/89	0.00	74.0	77	72.5	73.0	1.0	-0.5
06/07/89	0.00	74.5	76	72.7	73.6	0.9	-0.9
06/08/89	0.00	74.3	75	73.9	73.9	0.4	-0.0
06/09/89	0.00	74.7	76	73.2	74.6	0.1	-1.4
06/10/89	0.00	73.8	77	74.2	72.8	1.0	1.4
06/11/89	0.00	71.6	73	73.9	71.7	-0.1	2.2
06/12/89	0.00	72.6	74	72.7	72.9	-0.3	-0.2
06/13/89	0.00	74.9	77	72.7			
06/14/89	0.00	75.0	77	72.6			
06/15/89	0.00	72.9	75	71.9			
06/16/89	0.00	71.8	74	71.4	73.7	-1.9	-2.3
06/17/89	0.00	72.6	74	70.5	72.3	0.3	-1.8
06/18/89	0.00	73.2	74	71.0	72.2	1.0	-1.2
06/19/89	0.10	74.9	78	74.7	72.2	2.7	2.5
06/20/89	0.48	73.0	75	77.1	71.7	1.3	5.4
06/21/89	16.78	79.1	89	77.7	73.5	5.6	4.2
06/22/89	52.80	89.8	94	74.5	76.3	13.5	-1.8
06/23/89	54.33	90.5	93	75.6	76.6	13.9	-1.0
06/24/89	44.08	86.8	89	78.9	75.6	11.2	3.3
06/25/89	56.68	88.2	91	81.6	76.5	11.7	5.1
06/26/89	62.60	91.4	94	79.7	79.4	12.0	0.3
06/27/89	83.13	95.1	97	78.6	79.1	16.0	-0.5
06/28/89	36.01	92.5	100	80.6	77.7	14.8	2.9
06/29/89	0.00	76.5	78	81.1	76.3	0.2	4.8
06/30/89	10.65	79.2	89	80.8	77.2	2.0	3.6
07/01/89	53.33	88.0	93	80.7	78.7	9.3	2.0
07/02/89	76.50	93.4	95	79.9	79.1	14.3	0.8
07/03/89	97.05	95.9	97	78.9	78.7	17.2	0.2
07/04/89	95.23	96.9	98	80.0	78.6	18.3	1.4
07/05/89	97.85	97.8	100	80.8	78.4	19.4	2.4
07/06/89	96.03	98.5	100	82.3	79.1	19.4	3.2
07/07/89	98.68	99.8	102	81.7	80.7	19.1	1.0
07/08/89	98.60	100.8	102	81.9	80.1	20.7	1.8
07/09/89	96.85	101.9	104	79.1	81.2	20.7	-2.1
07/10/89	98.63	103.1	104	78.1	82.4	20.7	-4.3
07/11/89	98.98	104.0	105	78.7	83.1	20.9	-4.4
07/12/89	98.80	102.4	104	79.3	83.3	19.1	-4.0
07/13/89	99.73	101.7	103	81.6	81.8	19.9	-0.2
07/14/89	30.60	95.4	100	82.2	80.7	14.7	1.5

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07/15/89	0.00	80.6	81	81.1	79.9	0.7	1.2
07/16/89	0.00	81.5	83	80.9	79.3	2.2	1.6
07/17/89	0.00	81.3	84	80.4	80.3	1.0	0.1
07/18/89	0.00	80.1	81	79.4	80.2	-0.1	-0.8
07/19/89	0.00	79.8	80	79.2	79.5	0.3	-0.3
07/20/89	0.00	77.1	79	77.3	78.1	-1.0	-0.8
07/21/89	0.00	75.9	78	77.0	76.9	-1.0	0.1
07/22/89	0.00	77.7	82	77.2	76.9	0.8	0.3
07/23/89	0.00	78.5	80	78.0	77.1	1.4	0.9
07/24/89	0.20	79.3	82	79.4	77.5	1.8	1.9
07/25/89	1.30	80.3	85	79.4	78.5	1.8	0.9
07/26/89	16.23	87.5	94	78.7	80.2	7.3	-1.5
07/27/89	33.48	90.3	94	77.7	81.2	9.1	-3.5
07/28/89	58.13	90.4	93	78.8	79.7	10.7	-0.9
07/29/89	73.93	92.8	95	79.8	78.9	13.9	0.9
07/30/89	93.18	97.7	100	78.8	79.9	17.8	-1.1
07/31/89	91.15	99.1	100	79.5	79.5	19.6	0.0
08/01/89	0.00	87.3	99	80.1	78.9	8.4	1.2
08/02/89	0.00	81.3	85	80.2	79.5	1.8	0.7
08/03/89	0.00	82.0	84	79.6	80.9	1.1	-1.3
08/04/89	0.00	83.3	85	78.9	81.8	1.5	-2.9
08/05/89	0.00	83.8	86	80.0	82.2	1.6	-2.2
08/06/89	<1.00	83.0	84	79.7	82.1	0.9	-2.4
08/07/89	6.25	81.1	84	78.8	79.9	1.2	-1.1
08/08/89	21.13	86.2	92	78.4	79.1	7.1	-0.7
08/09/89	44.58	87.4	91	77.9	78.5	8.9	-0.6
08/10/89	49.00	89.4	91	77.7	78.0	11.4	-0.3
08/11/89	62.20	89.8	92	77.9	78.0	11.8	-0.1
08/12/89	93.05	94.7	97	77.8	78.2	16.5	-0.4
08/13/89	92.78	96.6	98	77.9	79.0	17.6	-1.1
08/14/89	99.93	98.2	99	77.7	79.7	18.5	-2.0
08/15/89	99.90	99.0	100	77.9	79.6	19.4	-1.7
08/16/89	99.98	97.7	99	77.9	78.4	19.3	-0.5
08/17/89	100.20	96.9	98	78.6	77.4	19.5	1.2
08/18/89	99.78	96.3	97	79.1	77.0	19.3	2.1
08/19/89	98.63	96.4	97	78.7	77.3	19.1	1.4
08/20/89	99.10	96.8	98	78.2	78.2	18.6	0.0
08/21/89	99.83	97.7	98	78.0	78.4	19.3	-0.4
08/22/89	100.03	98.0	99	78.0	78.7	19.3	-0.7
08/23/89	99.40	97.6	99	78.4	78.5	19.1	-0.1
08/24/89	100.03	96.5	97	78.0	77.8	18.7	0.2
08/25/89	100.38	96.0	96	77.8	77.0	19.0	0.8
08/26/89	77.62	95.5	96	78.1	77.6	17.9	0.5
08/27/89	58.10	89.8	92	78.5	78.2	11.6	0.3
08/28/89	93.20	95.8	99	78.0	79.5	16.3	-1.5
08/29/89	98.88	99.3	100	77.9	79.9	19.4	-2.0
08/30/89	98.58	99.4	101	78.3	79.2	20.2	-0.9
08/31/89	99.18	98.1	99	78.8	78.7	19.4	0.1
09/01/89	99.73	97.3	98	78.5	78.3	19.0	0.2
09/02/89	100.18	96.8	98	78.5	77.5	19.3	1.0
09/03/89	99.28	96.3	97	77.8	76.8	19.5	1.0

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09/04/89	90.95	94.2	95	77.0	76.5	17.7	0.5
09/05/89	100.18	96.7	98	77.1	76.9	19.8	0.2
09/06/89	99.60	96.7	97	77.9	77.1	19.6	0.8
09/07/89	99.73	97.0	98	77.3	77.5	19.5	-0.2
09/08/89	99.70	97.1	98	77.0	77.2	19.9	-0.2
09/09/89	68.20	92.0	96	76.9	76.8	15.2	0.1
09/10/89	81.33	90.6	92	76.4	76.0	14.6	0.4
09/11/89	98.28	93.7	95	76.4	75.6	18.1	0.8
09/12/89	99.03	93.4	95	75.9	74.7	18.7	1.2
09/13/89	98.98	90.9	92	74.0	73.0	17.9	1.0
09/14/89	99.03	89.2	90	72.7	71.1	18.1	1.6
09/15/89	98.98	88.0	88	71.5	69.7	18.3	1.8
09/16/89	98.18	88.9	90	71.8	69.8	19.1	2.0
09/17/89	96.18	90.0	92	72.3	70.5	19.5	1.8
09/18/89	99.40	90.5	92	73.5	70.5	20.0	3.0
09/19/89	99.60	91.0	92	73.8	71.2	19.8	2.6
09/20/89	99.18	91.9	93	74.1	72.1	19.8	2.0
09/21/89	99.48	92.5	93	74.9	72.5	20.0	2.4
09/22/89	99.30	92.3	93	74.3	73.3	19.0	1.0
09/23/89	85.13	87.3	91	71.0	68.8	18.5	2.2
09/24/89	85.30	86.5	87	69.9	70.6	15.9	-0.7
09/25/89	67.78	84.5	87	69.4	68.7	15.8	0.7
09/26/89	83.15	82.6	84	68.3	67.8	14.8	0.5
09/27/89	83.85	84.2	85	67.5	66.7	17.5	0.8
09/28/89	85.23	84.8	86	67.1	66.9	17.9	0.2
09/29/89	85.53	84.0	85	67.6	66.6	17.4	1.0
09/30/89	85.53	82.3	84	68.4	66.1	16.2	2.3
10/01/89	85.65	82.6	84	69.1	66.6	16.0	2.5
10/02/89	85.40	83.5	85	68.3	68.1	15.4	0.2
10/03/89	85.30	82.5	83	66.9	66.8	15.7	0.1
10/04/89	85.30	81.5	83	66.3	65.5	16.0	0.8
10/05/89	85.48	80.9	81	65.7	64.9	16.0	0.8
10/06/89	85.20	80.4	82	65.1	64.5	15.9	0.6
10/07/89	85.43	81.8	86	64.0	63.6	18.2	0.4
10/08/89	83.95	85.2	86	63.3	63.1	22.1	0.2
10/09/89	84.95	83.8	84	62.0	62.0	21.8	-0.0
10/10/89	84.95	84.2	85	62.1	61.6	22.6	0.5
10/11/89	85.15	84.6	86	61.7	61.5	23.1	0.2
10/12/89	85.08	84.5	86	62.7	61.6	22.9	1.1
10/13/89	84.93	85.8	87	62.9	62.6	23.2	0.3
10/14/89	84.85	86.5	87	62.8	63.7	22.8	-0.9
10/15/89	84.70	86.7	87	62.8	64.1	22.6	-1.3
10/16/89	84.70	86.1	87	63.2	64.0	22.1	-0.8
10/17/89	84.78	83.2	84	61.2	62.3	20.9	-1.1
10/18/89	84.98	80.0	82	58.9	59.6	20.4	-0.7
10/19/89	85.33	77.4	78	56.6	56.9	20.5	-0.3
10/20/89	85.35	75.0	75	56.0	54.7	20.3	1.3
10/21/89	84.93	75.5	77	55.2	54.0	21.5	1.2
10/22/89	84.83	76.3	77	55.1	54.1	22.2	1.0
10/23/89	85.08	77.8	80	55.3	55.2	22.6	0.1
10/24/89	84.78	79.1	80	55.8	56.2	22.9	-0.4

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10/25/89	84.15	79.7	81	56.9	57.3	22.4	-0.4
10/26/89	84.58	80.1	82	57.2	57.8	22.3	-0.6
10/27/89	84.53	80.6	81	57.8	58.4	22.2	-0.6
10/28/89	84.58	80.8	81	57.2	58.6	22.2	-1.4
10/29/89	84.40	81.3	82	57.5	58.9	22.4	-1.4
10/30/89	84.53	81.1	82	58.1	59.1	22.0	-1.0
10/31/89	84.55	78.8	80	57.1	57.8	21.0	-0.7
11/01/89	84.43	78.0	78	56.4	56.7	21.3	-0.3
11/02/89	84.43	76.5	78	55.2	55.7	20.8	-0.5
11/03/89	83.90	75.9	76	54.4	54.5	21.4	-0.1
11/04/89	60.98	69.6	75	53.3	53.2	16.4	0.1
11/05/89	79.75	72.1	74	53.2	52.7	19.4	0.5
11/06/89	86.28	76.1	78	53.2	52.7	23.4	0.5
11/07/89	84.80	74.9	76	53.3	52.5	22.4	0.8
11/08/89	84.98	74.5	75	53.0	52.3	22.2	0.7
11/09/89	85.35	72.1	73	52.4	51.2	20.9	1.2
11/10/89	85.33	72.8	74	51.8	50.6	22.2	1.2
11/11/89	81.38	73.2	74	51.4	50.5	22.7	0.9
11/12/89	21.60	62.8	74	51.3	50.3	12.5	1.0
11/13/89	0.00	51.8	53	51.9	50.9	0.9	1.0
11/14/89	0.00	52.6	53	52.5	52.0	0.6	0.5
11/15/89	0.00	52.2	53	52.3	51.9	0.3	0.4
11/16/89	0.00	48.8	51	50.5	49.4	-0.6	1.1
11/17/89	0.00	46.3	47	48.7	47.0	-0.7	1.7
11/18/89	0.00	44.7	46	47.2	45.3	-0.6	1.9
11/19/89	7.30	45.5	50	46.6	45.3	0.2	1.3
11/20/89	34.48	53.8	57	46.9	46.1	7.7	0.8
11/21/89	59.10	60.2	63	45.9	45.7	14.5	0.2
11/22/89	64.30	62.4	63	44.6	45.0	17.4	-0.4
11/23/89	63.93	61.8	63	44.1	43.8	18.0	0.3
11/24/89	64.40	61.0	61	43.7	43.3	17.7	0.4
11/25/89	64.45	60.0	61	43.3	42.9	17.1	0.4
11/26/89	64.68	61.0	62	43.3	43.1	17.9	0.2
11/27/89	64.90	61.3	63	44.0	43.9	17.4	0.1
11/28/89	64.65	60.6	61	43.5	43.8	16.8	-0.3
11/29/89	64.88	59.2	60	42.3	42.3	16.9	-0.0
11/30/89	64.88	58.7	60	41.8	41.5	17.2	0.3
12/01/89	64.95	59.3	60	41.3	41.4	17.9	-0.1
12/02/89	65.18	56.5	59	40.7	40.4	16.1	0.3
12/03/89	65.00	55.7	56	39.2	38.7	17.0	0.5
12/04/89	65.03	55.2	56	39.0	38.2	17.0	0.8
12/05/89	64.85	56.3	57	39.1	38.8	17.5	0.3
12/06/89	64.73	56.7	57	39.2	39.1	17.6	0.1
12/07/89	64.88	55.0	56	37.6	38.3	16.7	-0.7
12/08/89	64.80	55.4	56	37.2	37.7	17.7	-0.5
12/09/89	34.90	55.3	56	37.1	37.2	18.1	-0.1
12/10/89	64.85	55.0	56	37.3	37.0	18.0	0.3
12/11/89	48.05	54.0	55	36.5	36.5	17.5	-0.0
12/12/89	0.00	37.9	50	36.1	35.0	2.9	1.1
12/13/89	0.00	34.3	36	34.9	35.2	-0.9	-0.3
12/14/89	0.00	33.6	35	34.4	34.7	-1.1	-0.3

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12/15/89	0.00	33.0	34	32.8	34.3	-1.3	-1.5
12/16/89	9.23	33.0	37	32.5	34.0	-1.0	-1.5
12/17/89	42.73	42.3	49	32.7	35.5	6.8	-2.8
12/18/89	70.63	54.6	56	32.7	36.6	18.0	-3.9
12/19/89	92.30	59.6	61	32.7	36.7	22.9	-4.0
12/20/89	99.47	63.5	64	32.8	36.7	26.8	-3.9
12/21/89	100.00	61.6	64	32.8	36.6	25.0	-3.8
12/22/89	100.45	61.6	63	32.8	36.6	25.0	-3.8
12/23/89	100.40	64.7	67	33.5	39.7	25.0	-6.2
12/24/89	99.45	65.2	67	34.6	40.6	24.6	-6.0
12/25/89	100.85	67.5	68	35.5	41.1	26.4	-5.6
12/26/89	100.75	67.5	68	35.9	41.4	26.1	-5.5
12/27/89	100.40	68.1	69	36.4	41.8	26.3	-5.4
12/28/89	99.55	69.4	70	37.1	41.8	27.6	-4.7
12/29/89	99.70	69.3	70	37.3	42.0	27.3	-4.7
12/30/89	98.53	69.3	70	37.4	42.2	27.1	-4.8
12/31/89	99.20	68.0	69	37.6	42.7	25.3	-5.1
01/01/90	99.15	68.5	69	37.7	42.8	25.8	-5.0
01/02/90	99.40	69.0	70	38.0	42.6	26.4	-4.6
01/03/90	99.98	70.0	71	38.6	43.1	26.9	-4.5
01/04/90	87.68	67.2	71	38.8	43.0	24.3	-4.2
01/05/90	98.30	68.8	70	38.6	43.5	25.3	-4.9
01/06/90	68.63	63.5	69	38.9	42.6	20.9	-3.7
01/07/90	85.60	62.4	67	39.0	43.4	19.0	-4.4
01/08/90	98.90	69.5	71	39.0	44.2	25.3	-5.2
01/09/90	98.78	69.8	70	39.1	43.6	26.2	-4.5
01/10/90	98.93	69.3	72	39.0	44.7	24.6	-5.7
01/11/90	97.83	67.8	71	39.1	43.0	24.8	-3.9
01/12/90	99.75	66.6	69	38.8	42.8	23.8	-4.0
01/13/90	99.68	68.8	71	39.0	42.9	25.9	-3.9
01/14/90	97.83	68.5	70	39.2	43.0	25.5	-3.8
01/15/90	99.43	71.1	72	39.4	43.9	27.2	-4.5
01/16/90	99.43	72.3	73	39.7	44.9	27.4	-5.1
01/17/90	99.50	73.9	75	40.1	46.8	27.2	-6.6
01/18/90	99.53	72.5	74	39.1	43.9	28.7	-4.8
01/19/90	99.35	68.0	69	38.3	40.8	27.3	-2.5
01/20/90	99.00	67.5	68	40.1	40.0	27.5	0.1
01/21/90	98.15	65.1	66	39.7	39.2	25.9	0.5
01/22/90	98.75	65.6	66	39.5	39.0	26.6	0.5
01/23/90	98.58	65.7	67	39.9	39.4	26.4	0.5
01/24/90	99.80	66.9	68	40.1	39.9	27.1	0.3
01/25/90	99.60	64.3	67	39.6	39.6	24.7	0.0
01/26/90	99.85	65.5	67	39.5	39.1	26.4	0.4
01/27/90	99.58	64.9	66	39.5	39.3	25.7	0.3
01/28/90	94.75	65.2	66	39.4	39.4	25.9	0.0
01/29/90	99.27	67.9	68	39.3	39.8	28.2	-0.5
01/30/90	99.45	67.5	68	39.4	39.9	27.7	-0.5
01/31/90	99.08	67.5	68	39.7	39.9	27.7	-0.1
02/01/90	99.60	68.6	69	40.5	40.5	28.1	0.0
02/02/90	99.60	67.9	69	40.4	40.7	27.3	-0.3
02/03/90	99.50	68.3	69	40.9	40.7	27.6	0.2

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02/04/90	97.85	67.5	69	40.4	40.4	27.2	0.0
02/05/90	99.53	67.7	68	40.6	40.3	27.5	0.4
02/06/90	99.33	68.6	69	40.6	40.5	28.1	0.1
02/07/90	99.55	68.7	69	40.5	40.6	28.1	-0.1
02/08/90	99.48	68.5	69	41.3	41.1	27.4	0.2
02/09/90	99.63	70.3	71	42.6	42.7	27.6	-0.1
02/10/90	99.40	70.7	71	42.3	42.7	28.0	-0.4
02/11/90	98.05	70.5	72	42.6	42.9	27.7	-0.3
02/12/90	93.95	71.1	72	42.9	43.3	27.8	-0.4
02/13/90	4.60	53.9	71	43.9	43.2	10.8	0.8
02/14/90	0.00	40.6	43	43.7	42.3	-1.6	1.5
02/15/90	0.00	33.7	34	43.4	41.4	-7.7	2.0
02/16/90	0.00	33.0	33	43.1	40.6	-7.5	2.6
02/17/90	0.00	33.0	33	42.2	39.5	-6.5	2.8
02/18/90	0.00	33.0	33	41.6	39.4	-6.4	2.3
02/19/90	0.00	33.0	33	41.7	39.5	-6.5	2.3
02/20/90	0.00	33.0	33	41.2	39.4	-6.4	1.9
02/21/90	0.00	33.0	33	41.3			
02/22/90	0.00	33.0	33	41.8			
02/23/90	0.00	33.0	33	41.6	40.5	-7.5	1.1
02/24/90	0.00	33.0	33	40.8	39.0	-6.0	1.8
02/25/90	0.00	33.0	33	39.4	37.7	-4.6	1.8
02/26/90	0.00	33.0	33	38.7	37.5	-4.5	1.3
02/27/90	0.00	33.0	33	38.8	36.9	-3.9	1.9
02/28/90	0.00	33.0	33	38.5	37.3	-4.3	1.3
03/01/90	0.00	33.0	33	38.4	37.7	-4.6	0.8
03/02/90	0.00	34.2	35	38.8	38.4	-4.1	0.4
03/03/90	0.00	33.8	35	38.9	38.9	-5.1	0.0
03/04/90	0.00			38.9	39.2		-0.3
03/05/90	0.00			39.5	39.6		-0.0
03/06/90	0.00			39.0	40.0		-1.0
03/07/90	0.00			38.5			
03/08/90	0.00	40.6	42	38.8			
03/09/90	0.00	42.8	45	39.2			
03/10/90	0.00	48.2	51	40.7			
03/11/90	0.00	53.3	56	42.7			
03/12/90	0.00	54.8	57	45.1			
03/13/90	0.00	59.9	63	47.0			
03/14/90	0.00	62.2	63	48.6			
03/15/90	0.00	60.0	62	49.9			
03/16/90	0.00	57.8	59	50.2			
03/17/90	0.00	54.9	56	50.2			
03/18/90	0.00	51.7	53	49.8			
03/19/90	0.00	48.4	50	48.9			
03/20/90	0.00	46.7	47	48.2			
03/21/90	0.00	48.3	51	48.1			
03/22/90	0.00	49.1	50	48.5			
03/23/90	0.00	45.9	47	47.7			
03/24/90	0.00	45.3	46	47.8			
03/25/90	0.00	46.1	48	47.3			
03/26/90	0.00	45.9	47	47.4			

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03/27/90	0.00	46.7	48	47.9			
03/28/90	0.00	47.6	48	48.0			
03/29/90	0.00	48.0	48	47.1			
03/30/90	0.00	48.0	48	47.9			
03/31/90	0.00	48.0	49	47.6			
04/01/90	0.00	49.9	52	47.5			
04/02/90	0.00	49.6	50	47.2			
04/03/90	0.00	47.8	48	47.0			
04/04/90	0.00	47.2	49	47.1			
04/05/90	0.00	48.0	50	47.3	48.3	-0.3	-1.0
04/06/90	0.00	48.2	49	47.0	47.6	0.6	-0.6
04/07/90	0.00	48.1	50	46.8	47.5	0.6	-0.7
04/08/90	0.63	48.1	50	46.9	48.0	0.1	-1.1
04/09/90	1.58	48.4	49	47.3	48.2	0.2	-0.9
04/10/90	6.95	49.3	50	47.5	48.3	1.0	-0.8
04/11/90	29.83	54.4	58	47.1	47.7	6.8	-0.5
04/12/90	29.50	56.7	58	47.0	47.6	9.2	-0.5
04/13/90	26.00	56.4	57	46.9	47.7	8.8	-0.8
04/14/90	4.10	50.3	56	47.1	47.4	2.9	-0.3
04/15/90	0.00	50.3	56	47.1	47.5	2.8	-0.4
04/16/90	0.00	49.0	50	47.2	48.0	1.0	-0.8
04/17/90	0.00	49.4	51	47.7	48.4	1.0	-0.7
04/18/90	0.00	49.2	51	48.2	48.3	1.0	-0.0
04/19/90	0.00	49.1	50	48.3	48.7	0.5	-0.4
04/20/90	0.00	49.0	50	48.8	49.6	-0.5	-0.8
04/21/90	0.00	51.3	52	50.4	49.8	1.5	0.6
04/22/90	1.00	52.6	55	52.7	50.5	2.1	2.3
04/23/90	1.00	53.8	56	54.3	52.6	1.2	1.7
04/24/90	9.78	59.5	68	53.0	56.8	2.7	-3.8
04/25/90	23.98	65.3	68	54.2	59.1	6.2	-4.9
04/26/90	50.03	73.0	76	55.9	60.9	12.1	-5.0
04/27/90	74.48	80.2	82	58.4	61.6	18.6	-3.2
04/28/90	95.70	88.0	89	58.7	62.2	25.8	-3.5
04/29/90	97.98	86.6	88	58.8	60.5	26.1	-1.7
04/30/90	99.73	86.9	88	60.2	61.7	25.2	-1.5
05/01/90	100.03	87.0	87	59.8	61.1	25.9	-1.3
05/02/90	99.75	86.3	87	60.3	60.0	26.3	0.3
05/03/90	99.73	83.2	85	60.7	59.2	24.0	1.5
05/04/90	99.48	83.7	86	60.3	58.7	25.0	1.6
05/05/90	99.70	84.6	86	60.4	58.9	25.7	1.5
05/06/90	95.23	85.4	88	60.6	60.3	25.2	0.4
05/07/90	99.10	87.0	88	59.8	61.5	25.5	-1.7
05/08/90	96.20	87.0	88	60.5	61.9	25.1	-1.4
05/09/90	13.53	73.3	88	61.9	62.4	10.9	-0.5
05/10/90	0.00	59.4	61	61.1	60.7	-1.3	0.4
05/11/90	0.00	60.1	62	60.0	60.2	-0.1	-0.2
05/12/90	0.00	60.1	61	59.8	60.0	0.1	-0.2
05/13/90	0.00	60.6	62	60.8	59.8	0.9	1.0
05/14/90	0.13	61.3	63	60.8	60.3	1.0	0.5
05/15/90	2.50	60.6	61	61.8	61.1	-0.5	0.7
05/16/90	3.08	62.5	64	62.0	61.8	0.8	0.3

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05/17/90	16.45	66.4	72	62.2	62.1	4.3	0.1
05/18/90	0.10	62.2	64	62.1	62.7	-0.5	-0.6
05/19/90	20.13	66.7	70	62.7	63.2	3.5	-0.5
05/20/90	64.98	77.3	82	63.2	63.7	13.6	-0.5
05/21/90	71.45	80.7	82	62.8	63.1	17.7	-0.3
05/22/90	87.85	84.3	87	63.6	62.4	21.9	1.2
05/23/90	99.18	86.3	88	64.1	62.4	23.9	1.7
05/24/90	99.48	81.6	82	64.1	62.3	19.3	1.8
05/25/90	98.90	82.9	85	64.1	62.9	20.0	1.2
05/26/90	99.78	83.0	84	64.8	63.2	19.8	1.6
05/27/90	96.80	82.3	84	65.9	63.3	19.0	2.7
05/28/90	99.30	83.0	84	67.2	63.8	19.2	3.4
05/29/90	99.35	84.5	86	68.1	64.5	20.0	3.6
05/30/90	99.53	84.0	85	68.0	64.7	19.3	3.3
05/31/90	99.33	84.9	86	68.2	65.5	19.4	2.7
06/01/90	98.53	87.4	89	68.7	68.0	19.4	0.7
06/02/90	97.93	88.3	89	68.8	69.6	18.8	-0.8
06/03/90	83.30	85.6	89	67.6	68.5	17.1	-0.9
06/04/90	98.05	87.2	89	67.9	67.4	19.8	0.5
06/05/90	99.33	87.0	88	67.9	67.4	19.6	0.5
06/06/90	99.18	87.5	89	67.5	67.3	20.2	0.2
06/07/90	99.03	88.3	89	67.9	67.5	20.8	0.5
06/08/90	99.13	87.5	89	69.2	68.9	18.6	0.3
06/09/90	97.10	89.4	90	70.8	70.9	18.5	-0.1
06/10/90	98.48	88.8	90	72.7	70.0	18.8	2.7
06/11/90	98.48	88.5	90	74.1	70.6	17.9	3.5
06/12/90	99.38	90.3	92	74.0	73.1	17.3	1.0
06/13/90	99.38	92.0	93	73.4	74.6	17.4	-1.2
06/14/90	99.15	93.5	95	74.6	75.0	18.5	-0.4
06/15/90	98.23	94.0	95	78.1	75.7	18.3	2.4
06/16/90	98.03	94.5	95	80.3	76.8	17.7	3.5
06/17/90	94.38	96.0	98	79.5	79.0	17.0	0.5
06/18/90	97.88	98.3	99	78.6	80.0	18.3	-1.4
06/19/90	97.10	96.2	99	78.0	77.9	18.3	0.1
06/20/90	96.60	94.6	95	76.6	76.4	18.2	0.2
06/21/90	96.95	94.5	95	76.0	75.9	18.6	0.1
06/22/90	96.40	92.2	94	75.4	75.2	17.0	0.2
06/23/90	96.08	90.9	92	74.1	73.5	17.4	0.6
06/24/90	93.13	91.9	94	75.0	73.3	18.6	1.7
06/25/90	95.53	93.0	95	75.9	73.9	19.1	2.0
06/26/90	95.30	93.8	96	76.5	75.2	18.6	1.3
06/27/90	94.38	95.5	96	78.4	76.4	19.1	2.0
06/28/90	93.78	96.6	98	77.3	78.4	18.2	-1.1
06/29/90	93.52	95.6	97	76.8	78.0	17.6	-1.2
06/30/90	93.15	96.0	96	76.5	78.0	18.0	-1.5
07/01/90	91.65	95.8	97	78.4	77.3	18.5	1.1
07/02/90	93.00	94.8	96	79.7	76.8	18.0	2.9
07/03/90	92.98	96.0	98	79.9	78.3	17.7	1.6
07/04/90	92.88	99.0	101	79.5	80.4	18.6	-0.9
07/05/90	92.48	99.3	100	82.0	80.7	18.6	1.3
07/06/90	92.05	97.8	99	82.2	79.5	18.3	2.7

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07/07/90	91.48	97.2	99	81.6	79.3	17.9	2.3
07/08/90	89.23	98.7	101	81.0	81.1	17.6	-0.1
07/09/90	41.63	99.9	102	81.2	82.4	17.5	-1.2
07/10/90	0.20	83.1	84	82.0	82.0	1.1	0.0
07/11/90	21.95	86.7	90	81.4	81.1	5.6	0.3
07/12/90	3.50	82.4	86	79.6	78.9	3.5	0.7
07/13/90	0.00	76.4	78	77.6	77.0	-0.6	0.6
07/14/90	0.00	75.3	76	76.3	75.3	0.0	1.0
07/15/90	0.00	74.5	75	75.7	74.8	-0.3	0.9
07/16/90	0.00	75.2	77	75.3	75.2	0.0	0.1
07/17/90	0.00	76.5	78	75.3	75.8	0.7	-0.5
07/18/90	0.00	77.3	79	75.8	76.8	0.5	-1.0
07/19/90	0.00	78.6	80	76.5	77.9	0.7	-1.4
07/20/90	0.00	79.5	80	77.1	78.5	1.0	-1.4
07/21/90	0.00	78.0	79	78.2	77.1	0.9	1.1
07/22/90	0.00	76.5	77	77.7	76.3	0.2	1.4
07/23/90	0.00	77.9	80	77.4	77.2	0.8	0.3
07/24/90	0.00	78.3	80	77.0	77.2	1.1	-0.2
07/25/90	0.00	78.1	80	77.3	76.9	1.2	0.4
07/26/90	0.30	77.6	79	78.0	76.8	0.8	1.2
07/27/90	16.98	80.4	86	78.5	77.5	3.0	1.0
07/28/90	68.45	92.0	96	79.2	78.6	13.4	0.6
07/29/90	91.08	97.1	99	78.6	79.7	17.4	-1.1
07/30/90	90.75	97.8	99	78.5	79.6	18.2	-1.1
07/31/90	90.53	95.8	97	78.3	77.7	18.1	0.6
08/01/90	89.75	95.1	97	79.2	77.0	18.1	2.2
08/02/90	90.20	96.7	98	80.0	77.9	18.8	2.1
08/03/90	91.70	97.2	98	79.5	79.2	18.0	0.3
08/04/90	92.88	98.0	99	79.5	79.7	18.3	-0.2
08/05/90	91.28	97.6	99	79.4	79.3	18.3	0.1
08/06/90	91.28	95.8	96	78.3	77.9	17.9	0.4
08/07/90	91.03	95.2	96	78.5	76.8	18.4	1.7
08/08/90	90.48	95.5	97	79.9	77.1	18.4	2.8
08/09/90	90.73	96.3	98	81.1	78.1	18.3	3.0
08/10/90	90.13	97.4	99	79.1	79.0	18.4	0.1
08/11/90	89.73	98.4	99	79.1	79.1	19.3	0.0
08/12/90	87.63	96.4	97	78.6	78.7	17.7	-0.1
08/13/90	88.75	96.3	97	78.8	77.6	18.7	1.2
08/14/90	88.28	95.8	97	78.4	77.7	18.1	0.7
08/15/90	87.65	96.3	97	77.7	78.2	18.1	-0.5
08/16/90	87.50	96.5	97	77.7	78.1	18.4	-0.4
08/17/90	87.28	96.0	97	77.8	78.0	18.0	-0.2
08/18/90	86.93	96.0	97	78.5	79.3	16.7	-0.8
08/19/90	85.23	98.0	100	79.6	80.2	17.8	-0.6
08/20/90	86.15	97.0	98	81.4	79.8	17.2	1.6
08/21/90	85.48	96.7	97	81.0	80.2	16.5	0.8
08/22/90	85.23	95.9	96	79.9	78.9	17.0	1.0
08/23/90	84.93	95.6	96	80.6	78.3	17.3	2.3
08/24/90	84.53	96.3	98	81.1	78.8	17.5	2.3
08/25/90	84.03	96.7	98	81.1	79.8	16.9	1.3
08/26/90	83.10	98.2	100	81.0	80.7	17.5	0.3

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08/27/90	83.38	99.4	101	80.9	81.8	17.7	-0.8
08/28/90	82.55	100.1	101	80.2	82.9	17.2	-2.7
08/29/90	82.45	99.4	101	81.2	82.1	17.3	-0.9
08/30/90	81.89	97.8	99	82.2	80.7	17.1	1.5
08/31/90	81.78	96.9	98	82.4	80.4	16.5	2.0
09/01/90	81.45	98.3	100	81.8	81.5	16.8	0.3
09/02/90	80.88	98.3	99	82.0	81.6	16.7	0.4
09/03/90	81.00	97.4	98	82.0	81.0	16.4	1.0
09/04/90	80.33	98.2	100	81.9	81.5	16.7	0.4
09/05/90	80.85	99.3	101	82.0	82.5	16.8	-0.5
09/06/90	80.53	99.5	100	81.6	83.1	16.4	-1.5
09/07/90	80.33	98.3	100	80.7	82.2	16.1	-1.5
09/08/90	80.05	96.2	97	80.4	80.5	15.7	-0.1
09/09/90	79.55	96.0	96	80.3	79.8	16.2	0.5
09/10/90	79.45	95.4	96	80.4	79.7	15.8	0.8
09/11/90	78.93	95.3	96	80.7	79.6	15.7	1.1
09/12/90	78.93	95.6	96	80.9	80.0	15.6	0.9
09/13/90	78.10	96.1	97	80.4	80.6	15.5	-0.2
09/14/90	77.78	95.2	96	79.4	79.9	15.3	-0.5
09/15/90	77.50	94.7	95	78.0	78.7	16.0	-0.7
09/16/90	76.60	92.3	94	76.6	77.3	15.0	-0.7
09/17/90	76.60	90.5	91	74.7	75.5	15.0	-0.8
09/18/90	76.35	88.4	89	73.4	73.8	14.6	-0.4
09/19/90	76.20	87.3	88	73.0	72.5	14.8	0.5
09/20/90	75.28	87.5	88	72.6	72.5	15.0	0.1
09/21/90	75.33	87.0	88	72.2	72.4	14.6	-0.2
09/22/90	75.15	85.5	86	71.0	71.0	14.5	0.0
09/23/90	74.63	83.2	84	69.4	69.2	14.0	0.2
09/24/90	74.20	82.6	83	68.4	68.2	14.4	0.3
09/25/90	74.05	82.2	83	67.7	67.7	14.5	0.0
09/26/90	74.00	83.1	85	68.0	67.9	15.2	0.1
09/27/90	73.68	83.3	84	68.0	68.4	14.9	-0.4
09/28/90	73.58	83.4	84	68.2	68.9	14.5	-0.7
09/29/90	72.68	83.2	84	69.4	68.5	14.7	0.9
09/30/90	72.53	82.4	83	69.0	67.9	14.5	1.1
10/01/90	72.25	82.0	83	68.2	67.6	14.4	0.6
10/02/90	72.05	81.9	83	67.7	67.2	14.7	0.5
10/03/90	71.73	81.3	82	67.7	67.4	13.9	0.3
10/04/90	71.00	84.5	86	67.3	67.0	17.5	0.3
10/05/90	70.83	85.8	87	66.8	66.9	18.9	-0.1
10/06/90	70.60	84.3	86	66.7	67.0	17.3	-0.3
10/07/90	70.35	85.5	86	66.7	66.8	18.8	-0.0
10/08/90	69.80	84.1	85	66.0	65.8	18.3	0.2
10/09/90	69.68	82.1	83	64.7	64.2	17.9	0.5
10/10/90	70.03	79.6	81	63.3	61.6	18.0	1.7
10/11/90	69.73	79.3	81	62.7	59.8	19.5	2.9
10/12/90	69.20	78.8	80	62.7	59.8	19.0	2.9
10/13/90	46.53	79.2	80	62.2	60.3	18.9	1.9
10/14/90	3.63	72.0	80	61.9	60.7	11.3	1.2
10/15/90	0.00	60.5	62	61.9	60.5	0.0	1.4
10/16/90	0.00	60.3	61	61.6	60.2	0.1	1.4

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10/17/90	0.00	60.9	62	61.7	60.7	0.2	1.0
10/18/90	0.00	58.0	60	60.3	59.0	-1.0	1.3
10/19/90	0.00	57.8	59	59.1	57.9	-0.1	1.2
10/20/90	0.00	58.3	60	58.4	57.4	0.9	1.0
10/21/90	0.00	57.0	57	58.1	57.2	-0.2	0.9
10/22/90	0.00	56.8	58	57.8	56.8	0.0	1.0
10/23/90	0.00	56.6	58	57.3	57.2	-0.6	0.1
10/24/90	0.00	57.0	58	56.9	57.0	0.0	-0.1
10/25/90	0.00	55.8	57	56.3	55.8	0.0	0.5
10/26/90	0.00	56.7	57	55.6	55.4	1.3	0.2
10/27/90	0.00	56.3	57	55.1	54.9	1.4	0.2
10/28/90	0.00	54.5	55	54.8	54.5	0.0	0.3
10/29/90	0.00	54.4	56	54.3	53.9	0.5	0.4
10/30/90	0.00	54.8	56	53.9	54.0	0.8	-0.1
10/31/90	0.00	55.5	57	53.9	54.8	0.7	-0.9
11/01/90	0.00	56.0	57	54.1	55.4	0.6	-1.3
11/02/90	0.00	56.0	57	54.5	55.3	0.7	-0.8
11/03/90	0.00	56.5	57	54.8	55.4	1.1	-0.6
11/04/90	0.00	55.6	57	54.6			
11/05/90	0.00	52.9	54	53.7			
11/06/90	0.00	51.0	51	53.0			
11/07/90	0.00	49.3	51	52.4			
11/08/90	0.00	48.0	48	51.3			
11/09/90	0.00	47.0	47	50.9			
11/10/90	0.00	47.5	48	50.5			
11/11/90	0.00	46.7	47	50.1			
11/12/90	0.00	47.1	48	50.0			
11/13/90	0.00	46.8	48	49.5			
11/14/90	0.00	48.0	49	49.2			
11/15/90	0.00	49.8	51	49.5			
11/16/90	0.00	50.2	51	50.0			
11/17/90	0.00	49.9	51	49.8			
11/18/90	0.00	49.2	50	49.5			
11/19/90	0.00	49.5	50	49.5			
11/20/90	0.00	49.7	50	49.6			
11/21/90	0.00	51.3	52	49.9			
11/22/90	0.00	51.7	52	50.2			
11/23/90	0.00	49.6	50	49.7			
11/24/90	0.00	49.2	50	49.1			
11/25/90	0.00	49.6	51	49.1			
11/26/90	0.00	50.3	53	49.6			
11/27/90	0.00	55.5	57	51.1			
11/28/90	0.00	53.4	57	51.0			
11/29/90	0.00	48.7	50	50.0			
11/30/90	0.00	45.8	46	49.2			
12/01/90	0.00	45.0	45	48.2			
12/02/90	0.00	43.0	44	47.1			
12/03/90	0.00	41.3	42	46.1			
12/04/90	0.00	39.1	40	44.7			
12/05/90	0.00	37.3	38	43.7			
12/06/90	0.00	37.3	39	43.4			

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12/07/90	0.00	37.0	38	42.6			
12/08/90	0.00	37.0	39	42.3			
12/09/90	0.00	38.2	39	42.1			
12/10/90	0.00	39.2	40	42.2			
12/11/90	0.00	39.7	42	42.3			
12/12/90	0.00	43.6	44	42.9			
12/13/90	0.00	42.1	43	42.9			
12/14/90	0.00	40.9	41	42.0			
12/15/90	0.00	40.9	41	42.2			
12/16/90	0.00	39.8	40	41.9			
12/17/90	0.00	39.6	40	41.8			
12/18/90	0.00	39.8	40	41.7			
12/19/90	0.00	38.7	39	41.2			
12/20/90	0.00	36.0	39	40.7			
12/21/90	0.00	40.6	41	41.2			
12/22/90	0.00	37.6	39	39.3			
12/23/90	0.00	34.8	35	37.2			
12/24/90	0.00	34.0	34	36.4			
12/25/90	0.00	33.6	34	35.6			
12/26/90	0.00	34.2	35	34.0			
12/27/90	0.00	35.1	36	34.2			
12/28/90	0.00	34.8	35	34.4			
12/29/90	0.00	36.0	36	34.4			
12/30/90	0.00	35.7	36	33.6			
12/31/90	0.00	35.8	36	33.8			
01/01/91	0.00	35.4	36	33.8			
01/02/91	0.00	35.0	35	33.8			
01/03/91	0.00	35.0	35	33.7			
01/04/91	0.00	35.6	36	33.7			
01/05/91	0.00	37.0	38	33.5			
01/06/91	0.00	37.0	37	33.5			
01/07/91	0.00	37.0	37	33.6			
01/08/91	0.00	37.0	37	33.7			
01/09/91	0.00	37.0	37	33.6			
01/10/91	0.00	37.0	37	33.6			
01/11/91	0.00	37.0	37	33.6			
01/12/91	0.00	37.6	38	33.8			
01/13/91	0.00	38.0	38	33.8			
01/14/91	0.00	38.2	39	33.9			
01/15/91	0.00	37.8	39	33.9			
01/16/91	0.00	37.9	38	34.1			
01/17/91	0.00	37.0	37	34.1			
01/18/91	0.00	37.5	38	34.3			
01/19/91	0.00	38.0	38	34.4			
01/20/91	0.00	37.8	38	34.4			
01/21/91	0.00	36.3	37	34.5			
01/22/91	0.00	36.9	37	34.7			
01/23/91	0.00	37.5	38	34.9			
01/24/91	0.00	37.0	37	35.2			
01/25/91	0.00	37.5	38	35.1			
01/26/91	0.00	38.6	39	35.2			

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01/27/91	0.00	38.8	39	35.1			
01/28/91	0.00	38.4	39	35.4			
01/29/91	0.00	38.0	38	35.1			
01/30/91	0.00	38.0	38	34.9			
01/31/91	0.00	37.7	39	35.0			
02/01/91	0.00	37.5	39	35.4			
02/02/91	0.00	38.1	39	35.6			
02/03/91	0.00	39.0	40	35.7			
02/04/91	0.00			36.0			
02/05/91	0.00	39.5	40	36.3			
02/06/91	0.00	39.5	40	36.3			
02/07/91	0.00	40.0	41	36.3			
02/08/91	0.00	40.3	41	36.2			
02/09/91	0.00	40.8	42	36.4			
02/10/91	0.00	42.2	44	37.0			
02/11/91	0.00	41.6	42	37.2			
02/12/91	0.00	41.7	43	37.2			
02/13/91	0.00	40.8	41	37.2			
02/14/91	0.00	39.8	40	37.1			
02/15/91	0.00	36.8	39	36.9			
02/16/91	0.00	34.9	36	37.0			
02/17/91	0.00	36.3	37	37.1			
02/18/91	0.00	38.4	39	37.2			
02/19/91	0.00	39.0	39	37.2			
02/20/91	0.00	39.0	39	37.6			
02/21/91	0.00	40.3	42	37.8			
02/22/91	0.00	42.0	43	38.2			
02/23/91	0.00	41.5	42	37.8			
02/24/91	0.00	36.5	37	38.3	38.1	-1.6	0.2
02/25/91	0.00	38.5	40	37.9	37.9	0.6	0.0
02/26/91	0.00	37.8	39	37.4	38.0	-0.2	-0.6
02/27/91	0.00	38.5	39	37.7	38.3	0.2	-0.6
02/28/91	0.00	39.3	40	38.1	38.9	0.4	-0.8
03/01/91	0.00	40.3	41	39.1	39.7	0.6	-0.6
03/02/91	0.00	40.8	41	39.7	40.3	0.5	-0.5
03/03/91	0.00	39.5	40	39.1	39.6	-0.1	-0.5
03/04/91	0.25	39.5	41	38.8	38.9	0.6	-0.1
03/05/91	0.38	40.2	41	39.2	39.2	1.0	0.0
03/06/91	9.45	42.1	45	39.4	39.8	2.3	-0.4
03/07/91	12.83	45.5	48	39.1	39.4	6.1	-0.3
03/08/91	15.08	46.8	49	39.2	39.8	7.0	-0.5
03/09/91	21.55	49.0	55	39.4	39.9	9.1	-0.5
03/10/91	21.83	47.8	49	39.1	39.9	7.9	-0.8
03/11/91	30.15	48.5	50	39.8	40.3	8.3	-0.5
03/12/91	34.90	50.0	50	40.2	40.8	9.3	-0.5
03/13/91	34.45	49.7	50	39.6	40.2	9.5	-0.6
03/14/91	42.18	50.0	51	39.4	39.6	10.4	-0.2
03/15/91	64.35	56.4	59	40.0	39.9	16.5	0.1
03/16/91	76.95	62.7	65	40.6	40.7	22.0	-0.1
03/17/91	81.33	64.2	65	40.9	41.4	22.8	-0.5
03/18/91	97.23	68.2	72	41.0	42.3	25.9	-1.3

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03/19/91	98.55	71.5	73	41.7	43.2	28.3	-1.5
03/20/91	97.80	71.2	73	42.3	44.2	27.0	-1.9
03/21/91	99.27	74.1	76	43.7	45.8	28.3	-2.0
03/22/91	99.03	75.3	76	45.6	46.8	28.5	-1.1
03/23/91	99.48	73.4	74	46.6	48.0	25.5	-1.4
03/24/91	98.35	75.2	77	47.0	48.0	27.2	-1.0
03/25/91	99.63	76.8	78	47.5	47.3	29.5	0.2
03/26/91	99.20	77.9	80	48.9	50.0	27.9	-1.1
03/27/91	99.33	80.0	80	50.9	52.7	27.3	-1.8
03/28/91	99.00	79.5	80	51.0	51.8	27.7	-0.8
03/29/91	98.93	77.1	80	50.5	50.8	26.3	-0.3
03/30/91	99.08	78.3	80	50.5	50.6	27.7	-0.1
03/31/91	95.25	76.6	79	50.0	50.0	26.6	0.0
04/01/91	99.18	78.7	80	50.6	50.2	28.5	0.4
04/02/91	89.85	77.4	78	51.1	50.0	27.4	1.1
04/03/91	99.78	78.5	80	51.7	50.2	28.3	1.5
04/04/91	99.55	78.7	80	52.0	50.9	27.8	1.1
04/05/91	99.40	82.1	83	52.3	52.6	29.5	-0.3
04/06/91	99.50	83.4	85	52.6	54.5	29.0	-1.9
04/07/91	98.00	84.8	86	54.2	56.2	28.6	-2.0
04/08/91	100.08	86.5	87	56.3	57.6	28.9	-1.3
04/09/91	99.60	84.8	87	56.2	58.2	26.6	-2.0
04/10/91	99.50	84.0	86	56.3	56.3	27.7	-0.0
04/11/91	99.30	82.2	85	56.7	55.7	26.5	1.0
04/12/91	99.30	81.0	82	56.1	54.7	26.3	1.4
04/13/91	99.23	83.7	85	56.5	54.7	29.0	1.8
04/14/91	96.90	84.9	87	57.1	56.1	28.8	1.0
04/15/91	99.65	85.2	87	57.3	57.7	27.5	-0.4
04/16/91	99.68	87.6	89	57.7	58.5	29.1	-0.8
04/17/91	99.50			60.0	58.5		1.5
04/18/91	99.48	86.6	88	60.5	58.8	27.8	1.7
04/19/91	99.33	78.4	79	59.9	58.3	20.1	1.6
04/20/91	99.40	78.0	78	59.3	57.7	20.3	1.6
04/21/91	98.38	78.1	79	59.0	57.4	20.7	1.6
04/22/91	99.43	79.2	80	58.6	57.9	21.3	0.7
04/23/91	99.28	78.3	79	58.4	58.0	20.3	0.4
04/24/91	99.05	78.9	81	59.0	57.7	21.2	1.3
04/25/91	99.10	78.9	79	59.7	57.8	21.1	1.9
04/26/91	99.00	79.4	01	60.3	58.6	20.8	1.7
04/27/91	98.90	80.7	82	61.6	60.5	20.2	1.1
04/28/91	97.43	82.1	84	62.7	61.6	20.5	1.1
04/29/91	100.23	83.1	84	64.2	63.3	19.8	0.9
04/30/91	99.78	82.9	84	61.9	63.2	19.7	-1.3
05/01/91	90.45	82.1	84	62.6	63.2	18.9	-0.6
05/02/91	95.35	81.0	84	62.6	63.4	17.6	-0.8
05/03/91	99.88	81.9	84	62.8	63.1	18.8	-0.3
05/04/91	82.35	80.5	82	63.3	62.5	18.0	0.8
05/05/91	89.83			63.5	62.4		1.1
05/06/91	96.55			62.5	60.2		2.3
05/07/91	97.30			62.0	59.4		2.6
05/08/91	96.60			63.1	60.6		2.5

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05/09/91	95.13	80.5	82	64.8	61.6	18.9	3.2
05/10/91	97.78	81.2	83	66.6	63.4	17.8	3.2
05/11/91	98.45	84.8	86	68.7	65.6	19.2	3.1
05/12/91	96.25	86.1	88	70.8	67.9	18.2	2.9
05/13/91	100.13	88.3	89	71.1	69.5	18.8	1.6
05/14/91	100.23	88.3	90	70.2	69.6	18.7	0.6
05/15/91	100.13	88.0	90	72.7	69.2	18.8	3.5
05/16/91	100.23	90.0	91	75.0	71.6	18.4	3.4
05/17/91	100.05	91.0	93	74.9	71.7	19.3	3.2
05/18/91	99.95	87.9	89	74.6	69.9	18.0	4.7
05/19/91	98.80	85.0	87	72.8	67.4	17.6	5.4
05/20/91	99.75	86.1	87	72.4	67.5	18.6	4.9
05/21/91	99.73	87.5	89	72.7	69.4	18.1	3.3
05/22/91	99.98	90.3	92	73.0	71.7	18.6	1.3
05/23/91	99.68	91.5	92	72.5	73.1	18.4	-0.6
05/24/91	99.73	92.5	94	71.8	74.5	18.0	-2.7
05/25/91	99.68	93.4	95	73.5	75.2	18.3	-1.7
05/26/91	98.60	93.7	95	73.1	75.6	18.1	-2.5
05/27/91	98.88	95.3	97	73.9	76.0	19.3	-2.1
05/28/91	99.90	96.8	98	76.3	77.0	19.8	-0.7
05/29/91	99.78	97.3	98	78.5	77.5	19.8	1.0
05/30/91	100.05	97.9	99	77.4	78.8	19.2	-1.3
05/31/91	99.88	100.6	103	78.1	79.7	20.9	-1.6
06/01/91	99.73	101.5	103	80.1	80.0	21.5	0.1
06/02/91	96.35	101.0	104	80.8	80.9	20.1	-0.1
06/03/91	99.55	100.0	101	84.5	79.6	20.4	4.9
06/04/91	99.40	96.3	97	83.6	78.0	18.3	5.6
06/05/91	99.58	95.6	96	81.0	77.8	17.8	3.2
06/06/91	99.55	95.3	96	79.4	77.6	17.7	1.8
06/07/91	99.58	96.0	98	79.2	77.6	18.4	1.6
06/08/91	98.75	96.3	98	79.7	78.1	18.2	1.6
06/09/91	98.80	97.1	99	79.2	78.9	18.2	0.3
06/10/91	99.95	97.6	98	77.7	79.3	18.3	-1.6
06/11/91	99.90	96.9	98	76.9	78.7	18.2	-1.8
06/12/91	98.93	97.4	100	80.5	78.3	19.1	2.2
06/13/91	99.78	97.0	98	82.2	78.9	18.1	3.3
06/14/91	99.75	99.4	101	80.6	81.3	18.1	-0.7
06/15/91	95.60	100.1	102	78.3	82.2	17.9	-3.9
06/16/91	99.53	99.5	101	79.1	80.9	18.6	-1.8
06/17/91	99.55	98.9	100	81.2	79.2	19.7	2.0
06/18/91	100.00	98.4	100	83.7	79.8	18.6	3.9
06/19/91	100.20	99.5	100	84.3	80.6	18.9	3.7
06/20/91	97.38	100.0	102	84.8	81.7	18.3	3.1
06/21/91	97.38	100.5	102	84.3	83.1	17.4	1.2
06/22/91	90.78	99.6	101	82.5	82.8	16.8	-0.3
06/23/91	82.28	94.3	96	81.5	80.7	13.6	0.8
06/24/91	98.38	98.3	100	82.3	80.1	18.2	2.2
06/25/91	99.65	99.2	101	83.5	80.8	18.5	2.8
06/26/91	98.10	100.0	102	82.7	82.4	17.6	0.3
06/27/91	98.05	100.8	102	81.5	83.2	17.6	-1.7
06/28/91	98.03	101.1	102	81.2	83.2	17.9	-2.0

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06/29/91	97.63	101.6	103	81.2	83.4	18.2	-2.2
06/30/91	95.88	102.2	104	82.2	83.7	18.5	-1.5
07/01/91	96.35	102.9	105	82.3	84.2	18.7	-1.9
07/02/91	97.08	103.0	104	82.2	83.8	19.2	-1.6
07/03/91	98.68	102.7	104	82.2	83.5	19.2	-1.3
07/04/91	99.43	102.1	103	81.6	83.1	19.0	-1.5
07/05/91	98.78	102.4	104	81.9	83.1	19.3	-1.2
07/06/91	98.93	102.5	103	81.6	83.3	19.2	-1.7
07/07/91	96.85	102.0	103	81.5	83.4	18.6	-1.9
07/08/91	98.53	102.9	105	82.5	83.4	19.5	-0.9
07/09/91	99.95	102.7	103	82.0	82.3	20.4	-0.3
07/10/91	99.75	101.6	102	82.1	81.3	20.3	0.8
07/11/91	99.55	101.3	102	82.1	81.3	20.0	0.8
07/12/91	99.58	101.1	102	82.1	81.7	19.4	0.4
07/13/91	99.48	102.0	102	81.9	82.0	20.0	-0.0
07/14/91	97.73	99.8	101	82.1	81.5	18.3	0.6
07/15/91	99.58	101.0	103	83.5	81.1	19.9	2.4
07/16/91	99.40	101.3	102	83.8	82.1	19.2	1.7
07/17/91	97.73	102.0	104	83.2	83.6	18.4	-0.4
07/18/91	96.25	103.2	104	82.2	84.2	19.0	-2.0
07/19/91	95.65	103.5	104	81.7	84.6	18.9	-2.9
07/20/91	94.98	102.0	103	81.8	84.8	17.2	-3.0
07/21/91	92.30	102.0	104	82.0	84.9	17.1	-2.9
07/22/91	93.78	102.4	103	81.8	85.4	17.0	-3.6
07/23/91	94.90	101.9	103	81.8	84.8	17.1	-3.0
07/24/91	98.18	100.9	101	82.2	83.2	17.7	-1.0
07/25/91	99.20	99.8	101	81.7	81.6	18.2	0.1
07/26/91	99.35	99.3	100	81.4	80.7	18.6	0.7
07/27/91	99.20	98.6	100	81.2	80.1	18.5	1.1
07/28/91	97.80	97.8	99	81.1	80.3	17.5	0.8
07/29/91	98.98	98.0	98	80.6	80.5	17.5	0.1
07/30/91	99.80	98.5	99	79.9	80.3	18.2	-0.4
07/31/91	100.05	99.1	100	79.8	80.5	18.6	-0.7
08/01/91	99.95	100.3	101	80.2	81.1	19.2	-0.9
08/02/91	99.83	100.6	102	80.1	82.3	18.3	-2.2
08/03/91	95.13	100.3	101	80.2	82.1	18.2	-1.9
08/04/91	84.18	96.3	100	81.4	81.4	14.9	0.0
08/05/91	99.80	97.5	98	81.6	80.1	17.4	1.5
08/06/91	99.70	95.8	96	79.1	78.6	17.2	0.5
08/07/91	99.90	96.9	98	78.9	78.2	18.7	0.7
08/08/91	99.65	97.8	99	79.1	79.1	18.7	-0.0
08/09/91	99.75	96.8	98	78.2	78.6	18.2	-0.4
08/10/91	99.55	96.6	98	78.4	78.0	18.6	0.4
08/11/91	99.25	96.3	97	78.5	78.0	18.3	0.5
08/12/91	99.80	96.3	97	78.8	78.0	18.3	0.8
08/13/91	99.30	96.9	98	79.3	78.5	18.5	0.8
08/14/91	99.33	97.9	99	79.0	80.0	18.0	-1.0
08/15/91	99.43	100.3	101	78.6	80.4	19.9	-1.8
08/16/91	99.25	98.8	100	78.9	80.5	18.3	-1.6
08/17/91	99.38	98.8	99	78.7	80.3	18.5	-1.5
08/18/91	98.28	99.2	100	78.4	79.7	19.5	-1.3

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08/19/91	99.05	98.0	100	78.3	78.9	19.1	-0.6
08/20/91	99.23	97.1	98	77.8	77.9	19.2	-0.1
08/21/91	99.30	97.5	99	78.0	78.0	19.5	0.0
08/22/91	99.40	97.6	100	78.0	78.3	19.3	-0.3
08/23/91	99.33	96.1	98	79.1	77.9	18.2	1.2
08/24/91	99.33	97.3	99	80.3	78.8	18.5	1.5
08/25/91	98.75	98.8	101	80.6	80.1	18.7	0.5
08/26/91	99.10	99.9	102	80.1	81.2	18.7	-1.1
08/27/91	99.28	102.0	103	79.9	82.4	19.6	-2.5
08/28/91	97.95	102.0	103	79.7	83.3	18.7	-3.6
08/29/91	97.55	101.3	102	79.6	83.3	18.0	-3.7
08/30/91	98.60	100.8	102	80.0	82.8	18.0	-2.8
08/31/91	99.25	99.9	101	80.0	82.3	17.6	-2.3
09/01/91	98.25	99.4	100	81.0	80.6	18.8	0.4
09/02/91	99.78	98.0	99	80.4	79.8	18.2	0.6
09/03/91	99.80	97.8	98	79.8	80.2	17.6	-0.4
09/04/91	99.88	97.4	98	79.4	79.4	18.0	0.0
09/05/91	100.18	96.9	98	79.1	79.0	18.0	0.1
09/06/91	100.05	97.5	99	79.0	79.1	18.4	-0.1
09/07/91	99.83	97.8	99	79.2	79.5	18.3	-0.3
09/08/91	97.03	96.5	97	79.1	79.3	17.3	-0.2
09/09/91	99.65	97.9	99	79.2	79.9	18.0	-0.7
09/10/91	100.10	97.9	99	78.7	79.8	18.1	-1.1
09/11/91	100.13	97.4	99	78.9	79.0	18.5	-0.0
09/12/91	99.98	97.5	100	79.7	79.5	18.0	0.3
09/13/91	97.63	99.4	101	79.5	80.6	18.8	-1.1
09/14/91	94.90	98.5	101	79.4	81.1	17.4	-1.7
09/15/91	99.83	99.2	100	79.3	80.8	18.4	-1.5
09/16/91	99.78	97.8	99	79.0	79.9	17.9	-0.9
09/17/91	99.73	97.2	98	78.1	78.7	18.5	-0.6
09/18/91	99.78	94.5	96	76.9	76.8	17.7	0.1
09/19/91	99.40	91.5	93	74.3	74.2	17.3	0.1
09/20/91	98.85	89.9	91	72.9	72.5	17.5	0.5
09/21/91	99.55	89.2	90	72.3	71.7	17.5	0.6
09/22/91	98.35	87.8	89	71.1	70.8	17.0	0.3
09/23/91	99.25	87.5	88	70.4	70.1	17.4	0.3
09/24/91	72.48	84.0	88	69.8	69.3	14.7	0.5
09/25/91	78.58	80.2	82	69.1	68.4	11.8	0.7
09/26/91	97.08	83.4	84	68.0	67.2	16.3	0.8
09/27/91	99.70	84.0	85	66.9	66.3	17.7	0.6
09/28/91	99.78	83.3	85	66.5	65.8	17.5	0.8
09/29/91	99.00	84.6	86	66.8	66.5	18.1	0.3
09/30/91	99.60	85.3	86	66.8	67.2	18.1	-0.4
10/01/91	99.58	85.5	86	66.8	67.3	18.2	-0.5
10/02/91	99.38	85.6	86	66.7	67.4	18.2	-0.7
10/03/91	99.20	86.1	87	67.2	67.9	18.2	-0.7
10/04/91	99.43	85.9	87	67.7	67.7	18.2	0.0
10/05/91	99.50	82.6	85	66.9	66.1	16.5	0.8
10/06/91	98.85	80.3	82	65.2	63.9	16.4	1.3
10/07/91	99.33	84.6	85	64.0	63.1	21.5	0.9
10/08/91	99.85	79.5	80	63.1	62.7	16.8	0.4

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10/09/91	100.03	80.5	82	63.2	63.1	17.4	0.1
10/10/91	100.00	80.4	81	62.9	63.0	17.4	-0.1
10/11/91	89.93	79.8	81	62.7	62.5	17.3	0.3
10/12/91	50.45	75.4	76	62.1	61.8	13.6	0.3
10/13/91	49.60	75.6	76	61.5	60.9	14.7	0.6
10/14/91	50.18	74.6	75	61.2	60.4	14.2	0.8
10/15/91	49.83	74.5	75	60.4	59.6	14.9	0.8
10/16/91	49.90	74.3	75	59.4	59.1	15.2	0.3
10/17/91	72.05	75.4	81	59.2	58.8	16.7	0.5
10/18/91	98.10	80.8	84	59.3	58.6	22.2	0.7
10/19/91	99.28	82.8	84	58.5	57.8	25.0	0.7
10/20/91	98.90	82.4	83	57.7	57.4	25.1	0.4
10/21/91	99.15	81.9	83	57.1	57.0	24.9	0.1
10/22/91	99.80	82.8	84	57.5	57.4	25.4	0.1
10/23/91	99.93	84.0	85	58.3	58.2	25.8	0.1
10/24/91	99.70	87.8	88	59.2	59.5	28.3	-0.3
10/25/91	99.70	88.8	90	59.8	60.3	28.5	-0.5
10/26/91	99.53	89.0	89	60.7	60.4	28.6	0.3
10/27/91	99.18	85.6	86	61.5	60.5	25.1	1.0
10/28/91	99.45	84.3	85	62.2	60.2	24.1	2.0
10/29/91	99.38	86.0	87	62.5	60.7	25.3	1.8
10/30/91	99.55	84.0	86	61.1	60.1	23.9	1.0
10/31/91	98.98	83.0	83	59.4	58.6	24.4	0.8
11/01/91	99.18	79.8	83	58.9	57.6	22.2	1.3
11/02/91	99.03	75.4	76	56.1	53.7	21.7	2.4
11/03/91	98.28	73.6	75	53.1	50.3	23.3	2.8
11/04/91	98.98	73.0	73	50.6	48.3	24.7	2.3
11/05/91	99.88	71.8	72	49.0	47.4	24.4	1.6
11/06/91	99.95	72.5	73	48.2	46.7	25.8	1.5
11/07/91	99.85	71.5	73	45.9	45.5	26.0	0.4
11/08/91	99.63	69.7	71	44.6	44.4	25.3	0.2
11/09/91	100.15	69.4	70	44.0	44.1	25.3	-0.1
11/10/91	92.90	70.5	73	43.6	43.9	26.6	-0.3
11/11/91	98.98	70.8	71	43.5	44.0	26.8	-0.5
11/12/91	99.85	69.2	70	43.4	43.6	25.7	-0.2
11/13/91	99.88	69.9	71	43.3	43.7	26.2	-0.4
11/14/91	99.53	70.7	71	43.8	44.2	26.5	-0.4
11/15/91	99.73	72.0	73	44.7	45.0	27.0	-0.3
11/16/91	69.35	57.8	73	45.6	45.2	12.6	0.4
11/17/91	0.00	45.3	46	46.2	45.2	0.1	1.0
11/18/91	0.00	47.3	49	47.1	47.1	0.2	0.0
11/19/91	0.00	48.8	50	48.3	48.2	0.6	0.1
11/20/91	29.33	54.7	58	49.1	48.6	6.1	0.5
11/21/91	70.45	63.3	67	48.7	48.5	14.8	0.2
11/22/91	98.13	72.3	75	49.0	48.5	23.8	0.5
11/23/91	100.03	71.4	75	48.5	47.5	23.9	1.0
11/24/91	99.48	69.2	70	46.1	44.6	24.6	1.5
11/25/91	100.55	69.5	70	45.2	42.9	26.7	2.4
11/26/91	94.15	69.3	70	43.7	42.4	26.9	1.3
11/27/91	27.95	55.2	67	43.5	42.5	12.7	1.0
11/28/91	62.53	54.8	61	44.3	43.1	11.7	1.2

CLINTON LAKE ENVIRONMENTAL MONITORING PROGRAM

Clinton Power Station Levels and Selected Temperature Monitoring Data

1988-1991

Date	Power Level (%)	Daily Avg. Flume Temp. (F)	Daily Max. Flume Temp. (F)	Daily Avg. Site 1.5 Temp. (F)	Daily Avg. Site 4 Temp. (F)	Daily Avg. Flume-Site 4 Diff. (F)	Sites 1.5 - 4 Diff. (F)
11/29/91	89.88	66.7	71	45.6	44.2	22.5	1.4
11/30/91	99.30	70.0	71	45.9	45.4	24.6	0.5
12/01/91	97.93	70.1	71	45.1	44.4	25.7	0.7
12/02/91	99.35	68.7	70	43.8	43.6	25.1	0.2
12/03/91	99.88	66.7	69	42.8	41.9	24.8	0.9
12/04/91	99.83	63.2	66	40.6	40.2	23.0	0.4
12/05/91	99.93	65.4	66	39.4	39.9	25.5	-0.5
12/06/91	99.63	65.3	66	39.2	39.5	25.8	-0.3
12/07/91	99.73	66.9	69	39.6	41.4	25.5	-1.8
12/08/91	96.70	68.1	69	40.4	42.5	25.6	-2.1
12/09/91	99.80	68.5	69	41.0	42.1	26.4	-1.1
12/10/91	99.55	67.1	68	41.0	41.1	26.0	-0.1
12/11/91	99.85	67.8	69	41.3	41.3	26.5	-0.0
12/12/91	99.70	67.7	68	42.0	42.1	25.6	-0.1
12/13/91	99.38	69.7	71	42.9	42.8	26.9	0.1
12/14/91	99.20	61.8	64	42.7	42.4	19.4	0.3
12/15/91	98.20	65.4	66	42.0	40.9	24.5	1.1
12/16/91	97.70	65.3	66	41.3	40.1	25.2	1.2
12/17/91	99.48	65.2	66	41.0	39.8	25.5	1.3
12/18/91	95.73	63.5	64	39.9	38.9	24.7	1.0
12/19/91	95.70	63.5	65	39.0	40.1	23.4	-1.1
12/20/91	95.70	64.5	65	38.9	40.2	24.3	-1.3
12/21/91	95.73	65.8	67	39.1	41.0	24.8	-1.9
12/22/91	13.35	50.7	65	39.2	38.3	12.4	0.9
12/23/91	0.00	37.6	38	39.1	38.0	-0.4	1.1
12/24/91	0.00	36.5	37	38.9	37.6	-1.1	1.3
12/25/91	0.00	37.9	39	38.9	37.9	0.0	1.0
12/26/91	10.93	38.3	40	39.3	38.1	0.2	1.2
12/27/91	46.93	46.6	53	39.3	38.4	8.2	0.9
12/28/91	79.18	58.9	61	39.1	39.4	19.5	-0.3
12/29/91	98.58	65.1	67	39.2	39.6	25.5	-0.4
12/30/91	99.45	67.0	67	39.1	39.6	27.4	-0.5
12/31/91	99.48	66.3	67	38.9	38.6	27.7	0.3

Appendix B

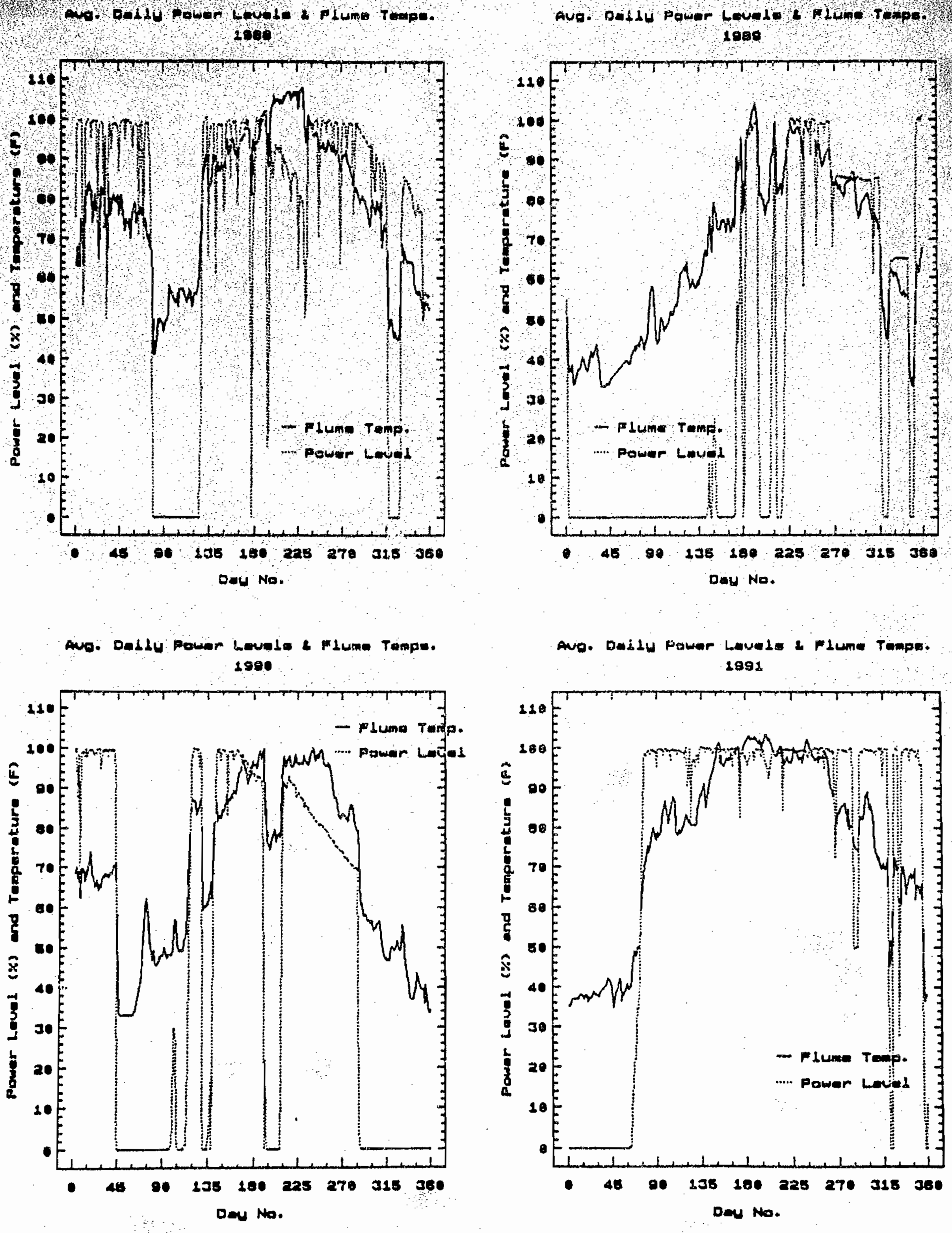
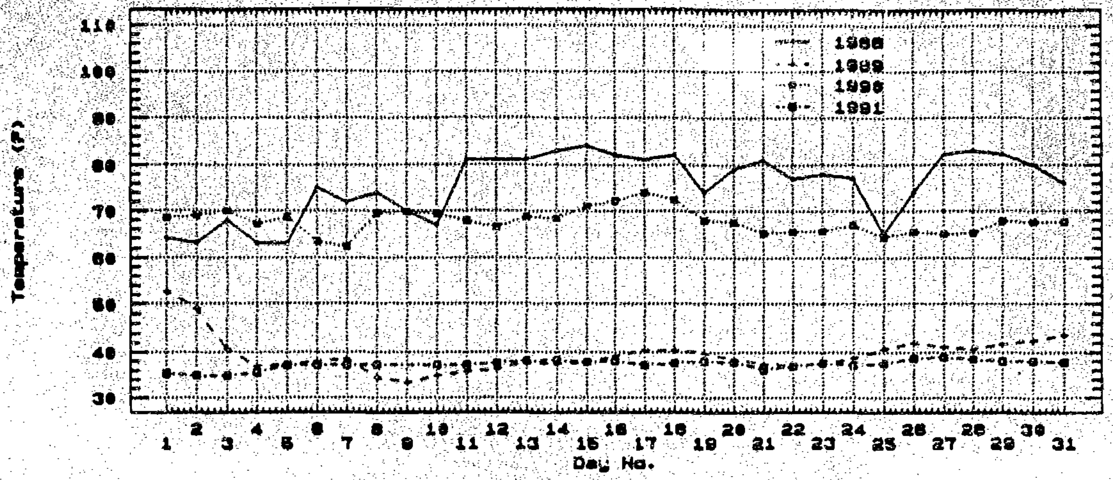
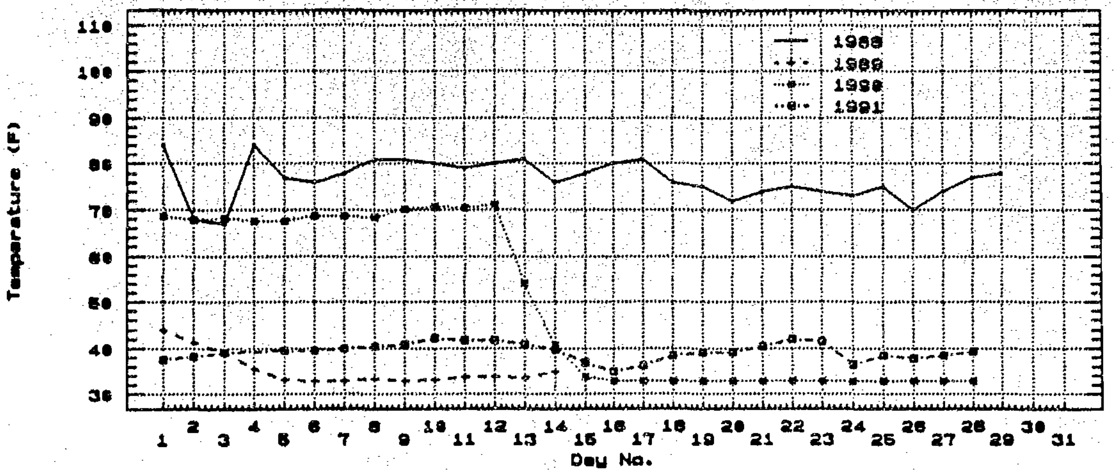


Figure B-1 Clinton Power Station Average Daily Power Levels (%) and Discharge Flume Temperatures (F) during 1988, 1989, 1990, and 1991

Avg. Daily Flume Discharge Temperatures
January



Avg. Daily Flume Discharge Temperatures
February



Avg. Daily Flume Discharge Temperatures
March

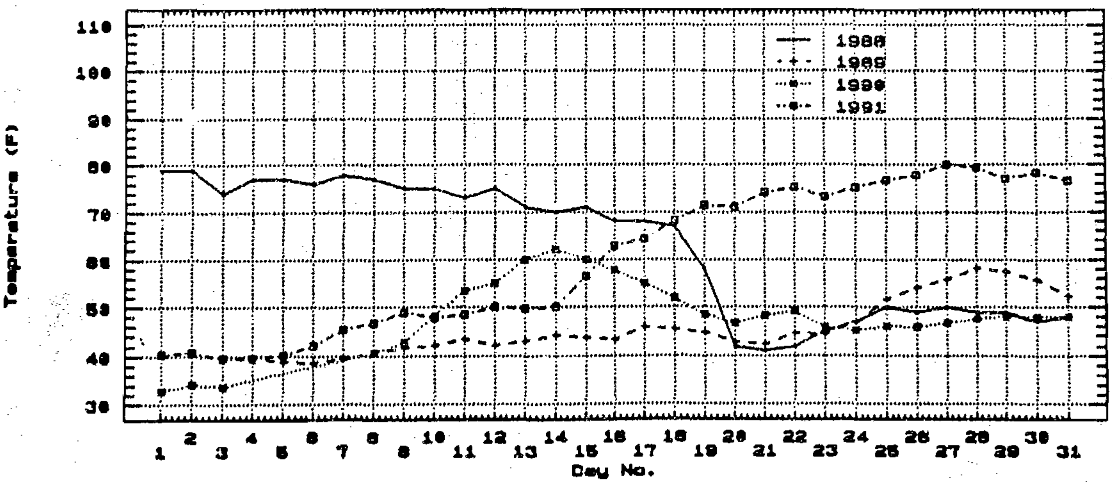


Figure B-2 Clinton Power Station Average Daily Flume Discharge Temperatures (F) during January, February, and March of 1988, 1989, 1990, and 1991

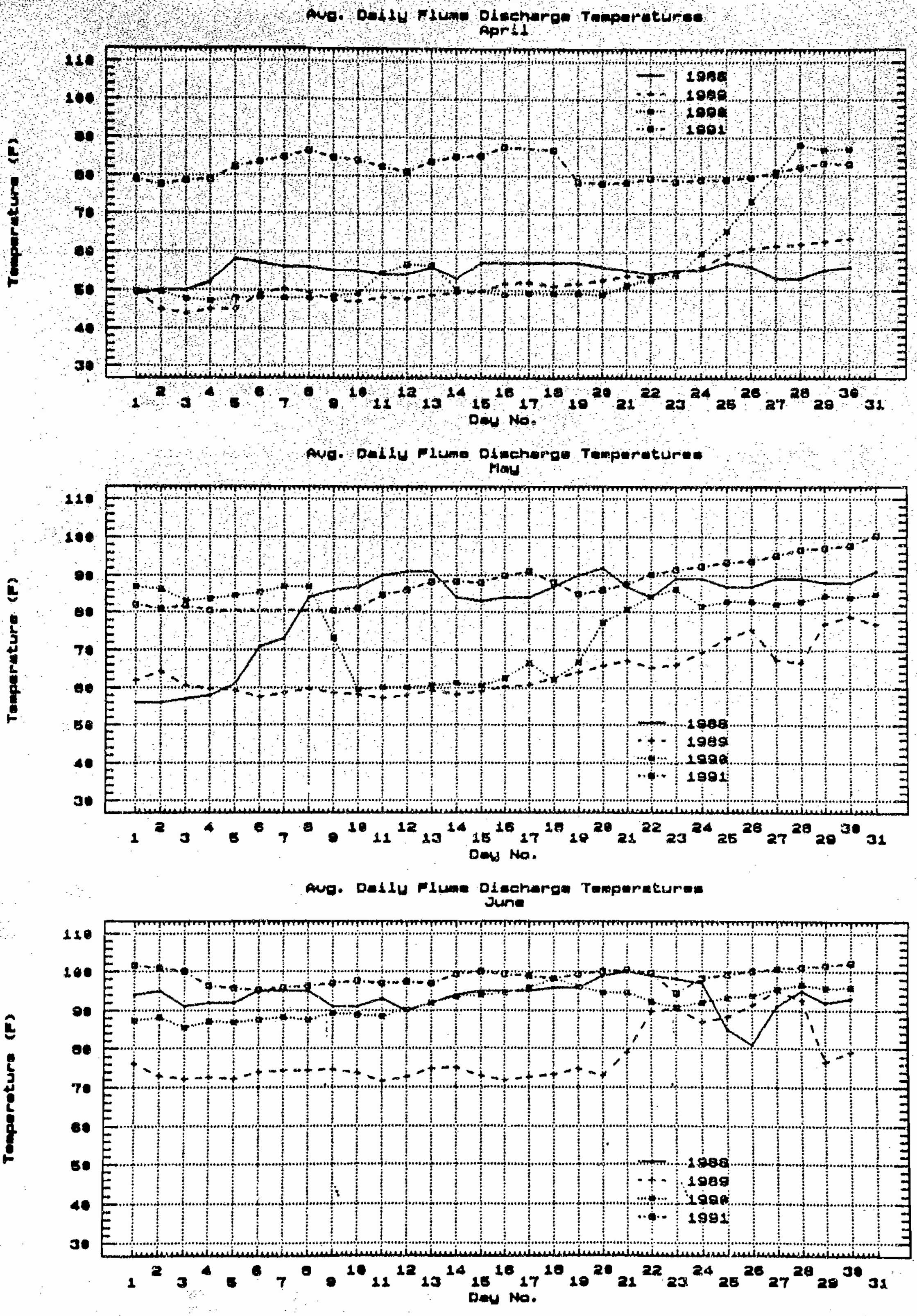


Figure B-3 Clinton Power Station Average Daily Flume Discharge Temperatures (F) during April, May, and June of 1988, 1989, 1990, and 1991

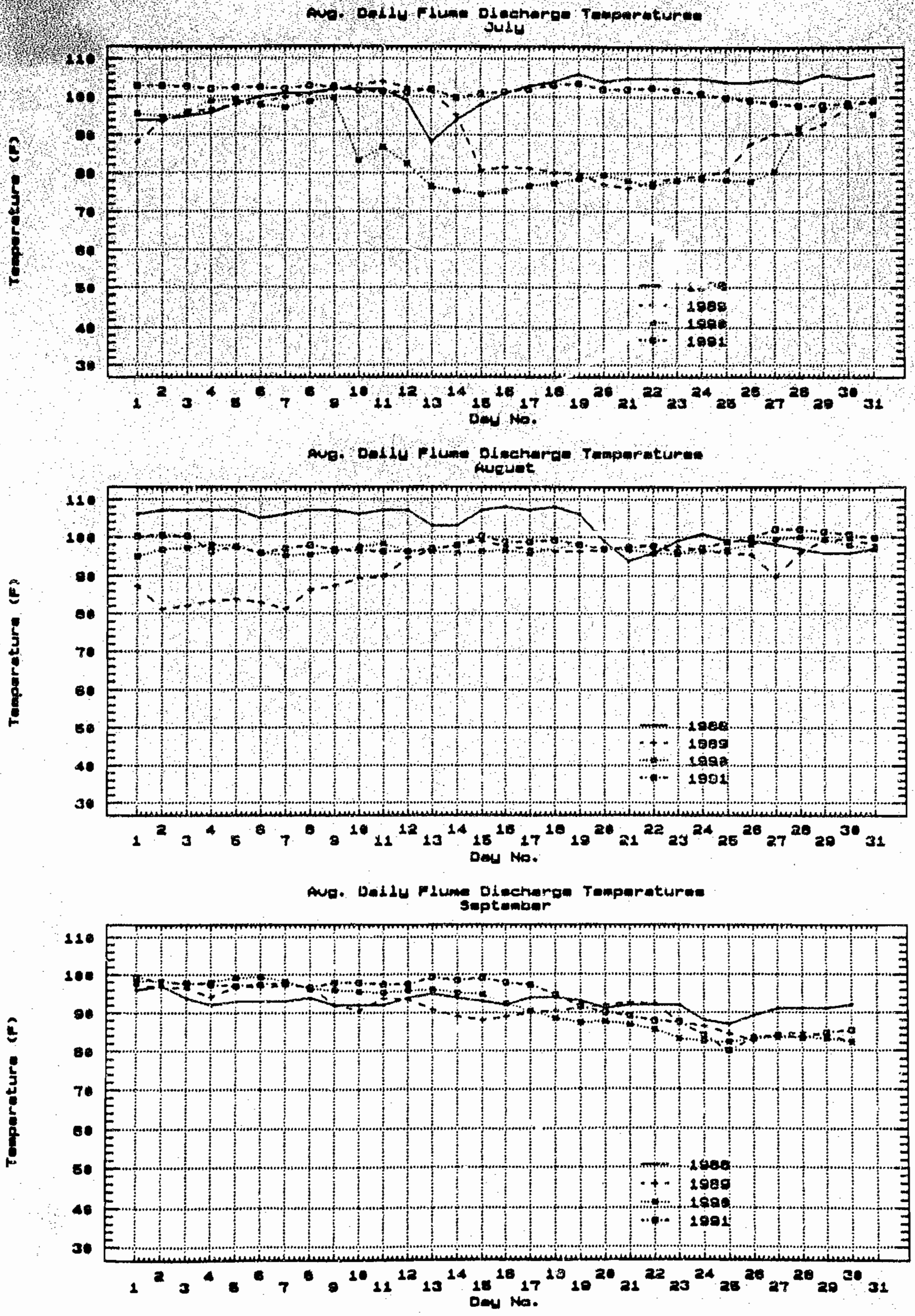
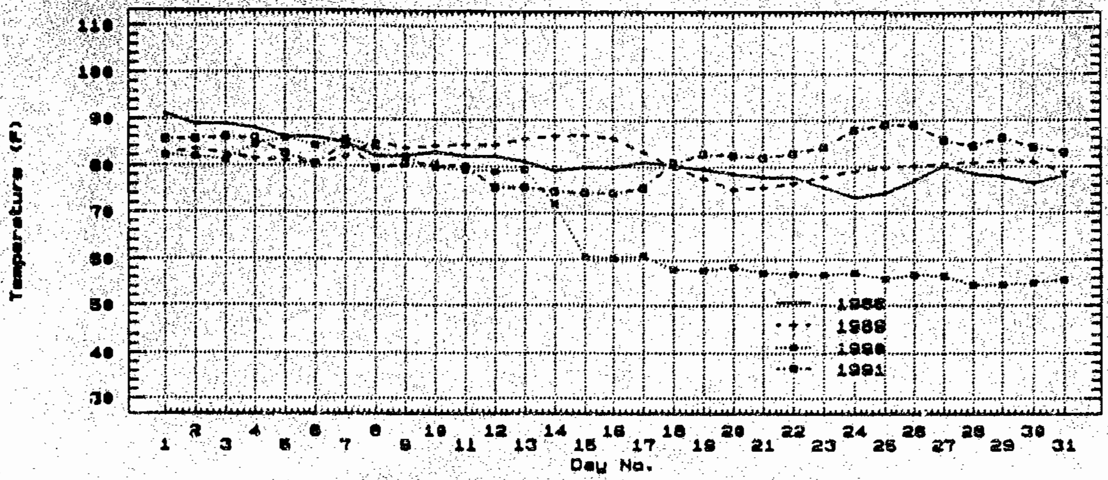
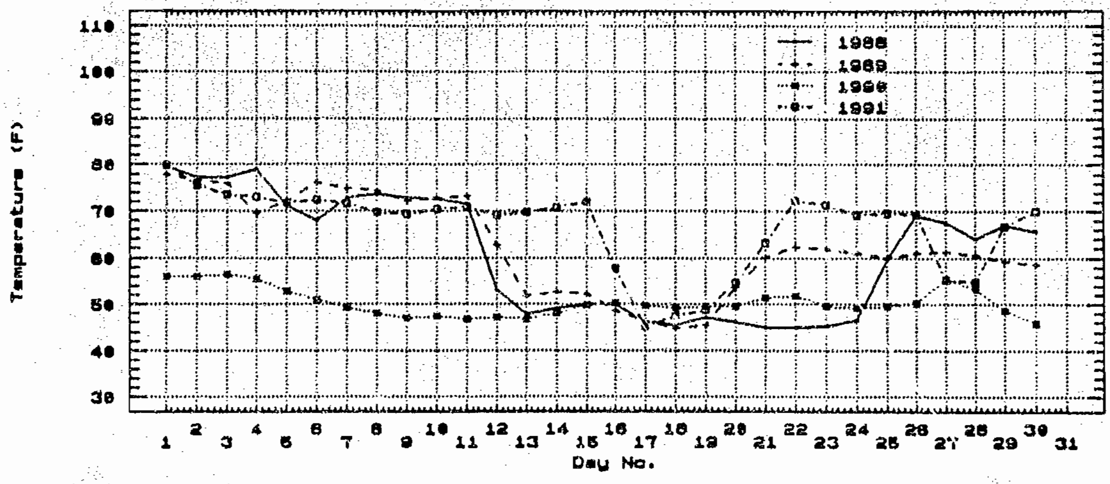


Figure B-4 Clinton Power Station Average Daily Flume Discharge Temperatures (F) during July, August, and September of 1988, 1989, 1990, and 1991

Avg. Daily Flume Discharge Temperatures
October



Avg. Daily Flume Discharge Temperatures
November



Avg. Daily Flume Discharge Temperatures
December

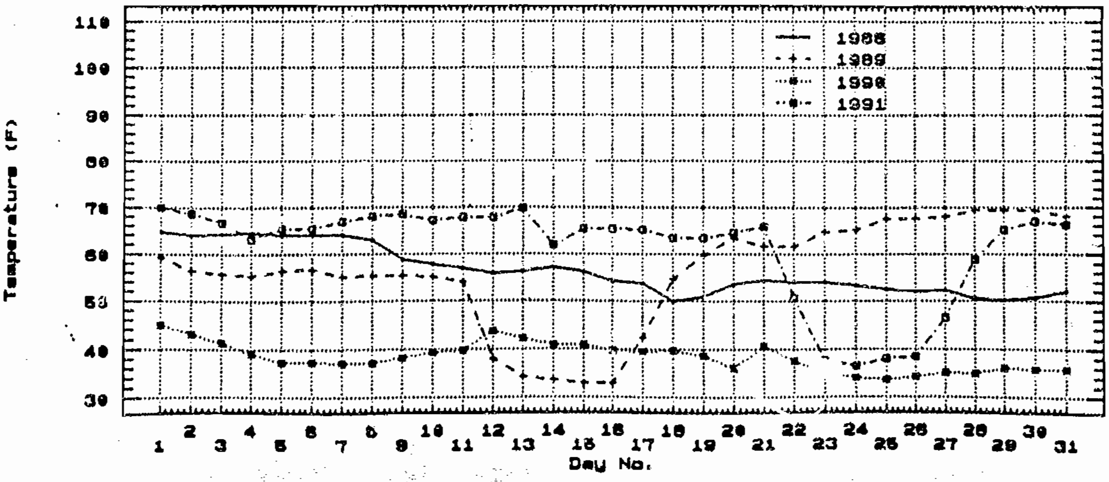


Figure B-5 Clinton Power Station Average Daily Flume Discharge Temperatures (F) during October, November, and December of 1988, 1989, 1990, and 1991

Appendix C

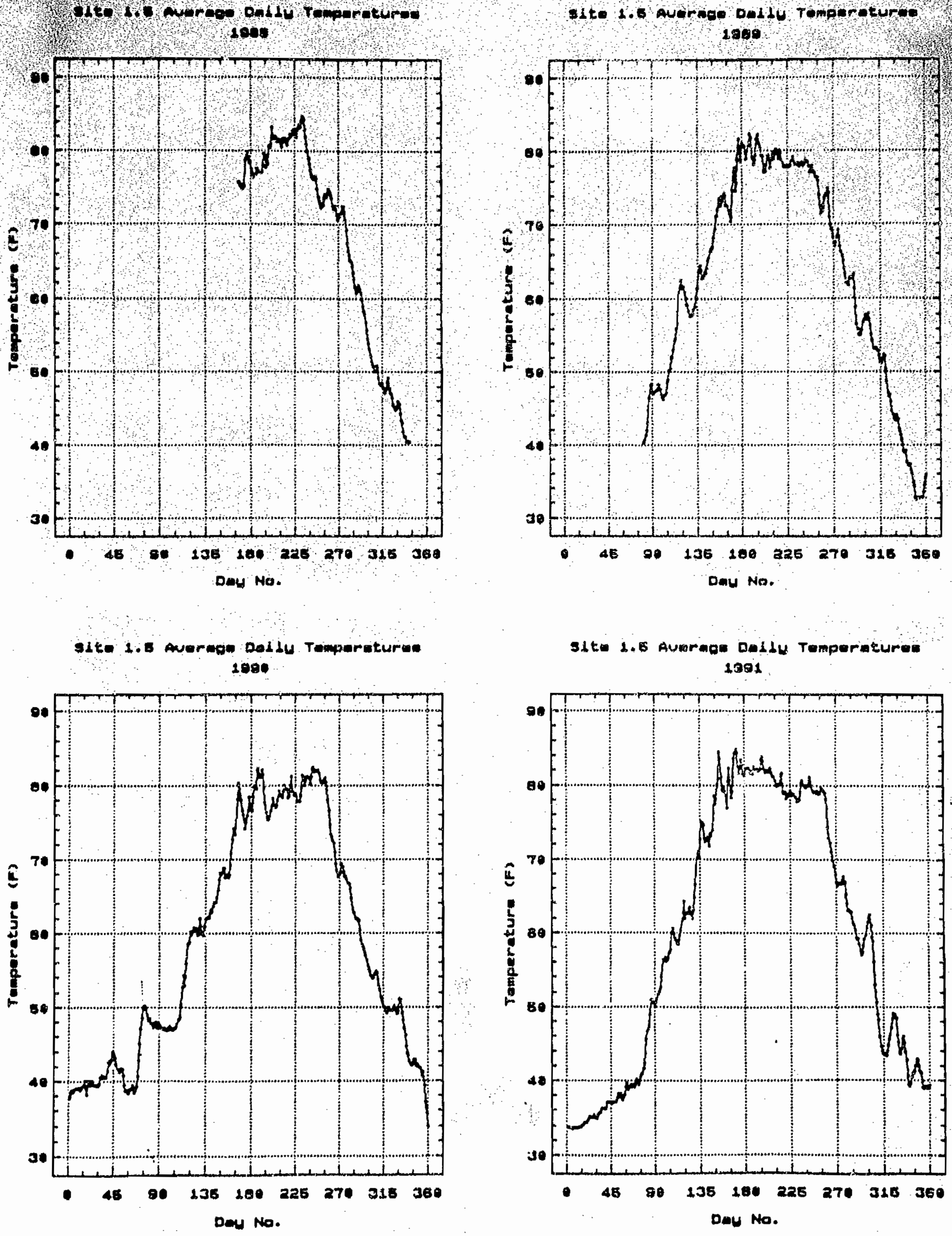


Figure C-1 Site 1.5 Average Daily Temperatures during 1988, 1989, 1990, and 1991

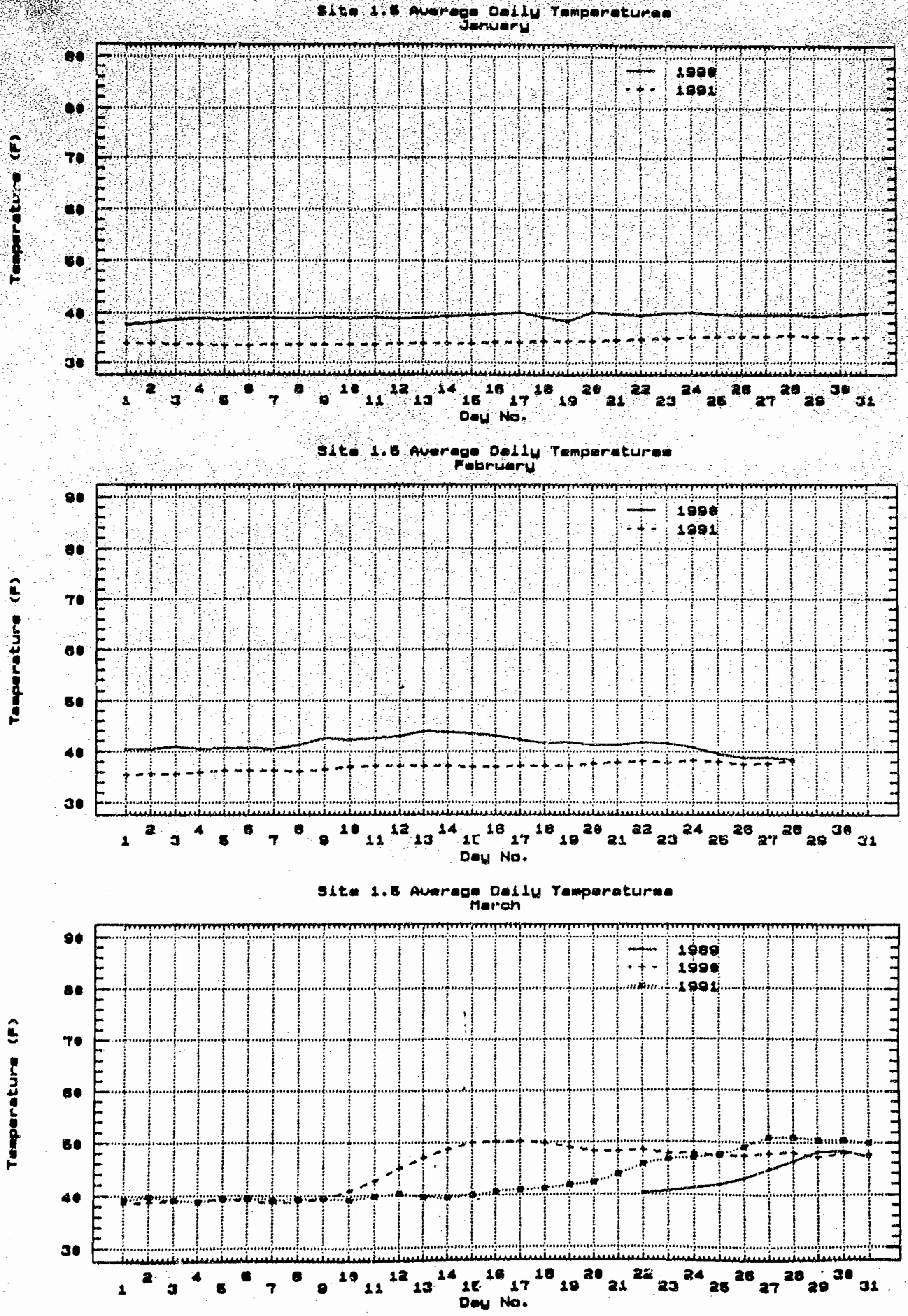


Figure C-2 Site 1.5 Average Daily Temperatures (F) during January, February, and March of 1988, 1989, 1990, and 1991

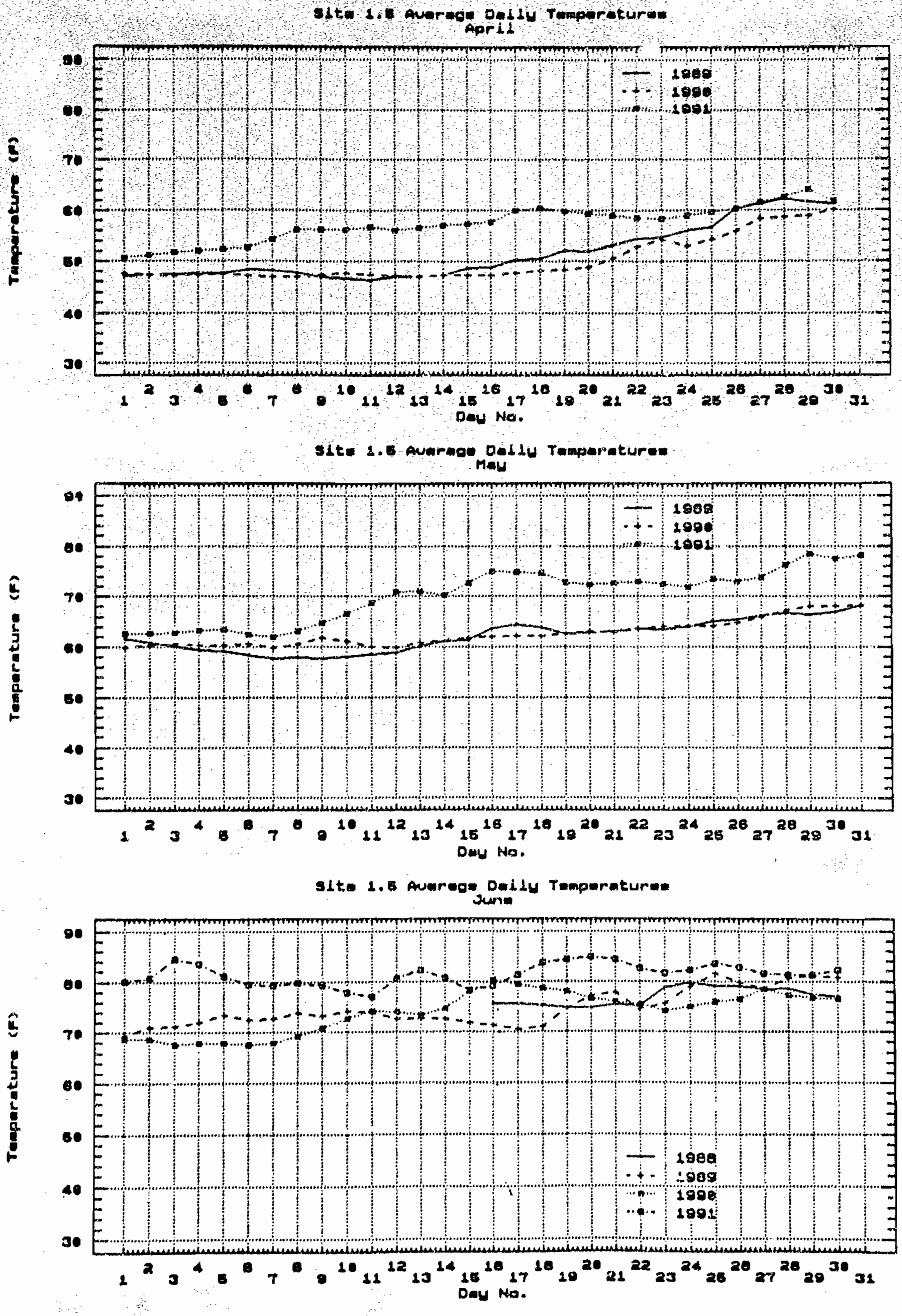
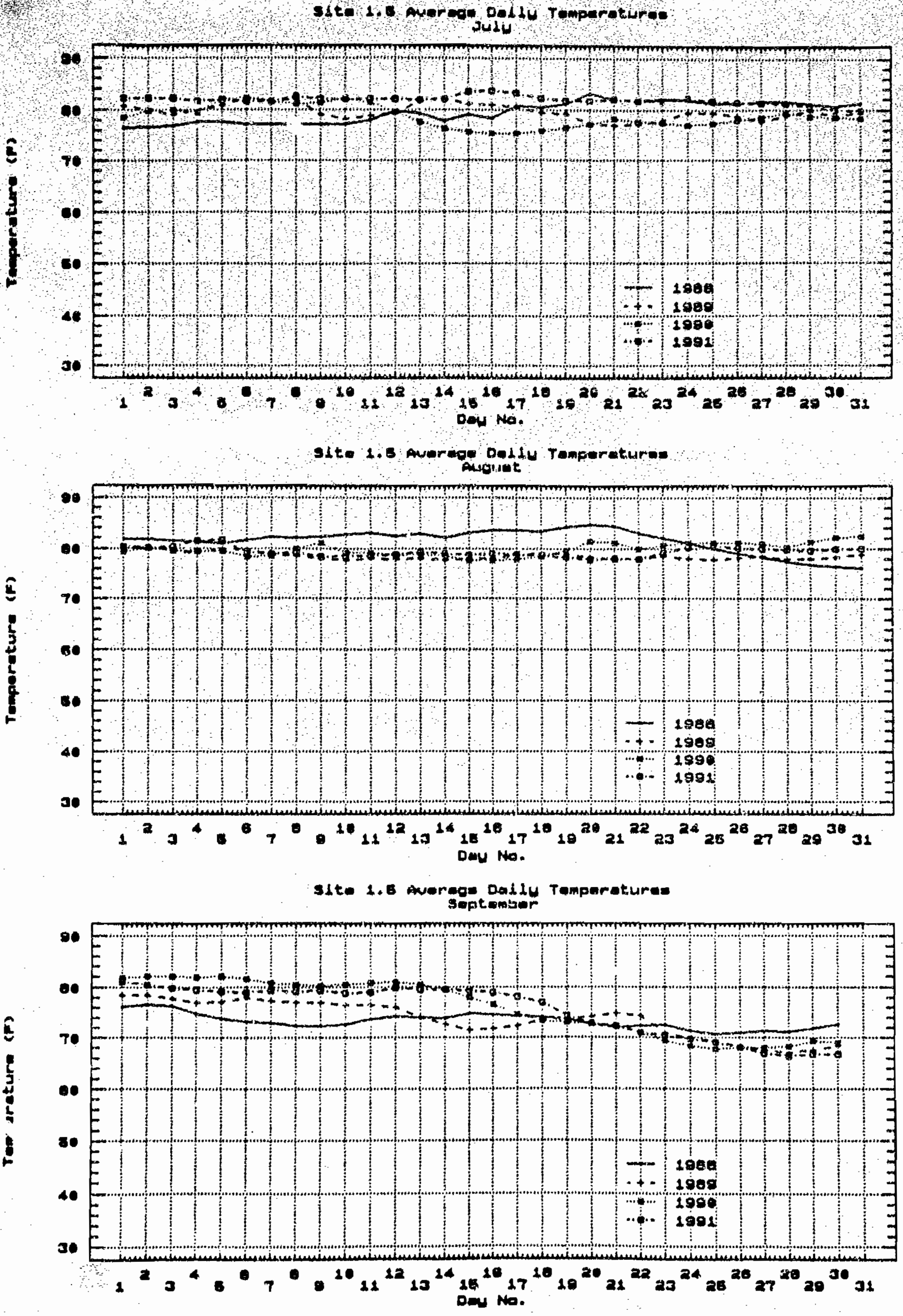


Figure C-3 Site 1.5 Average Daily Temperatures (F) during April, May, and June of 1988, 1989, 1990, and 1991



Site 1.5 Average Daily Temperatures
July

Site 1.5 Average Daily Temperatures
August

Site 1.5 Average Daily Temperatures
September

Figure C-4 Site 1.5 Average Daily Temperatures (F) during July, August, and September of 1988, 1989, 1990, and 1991

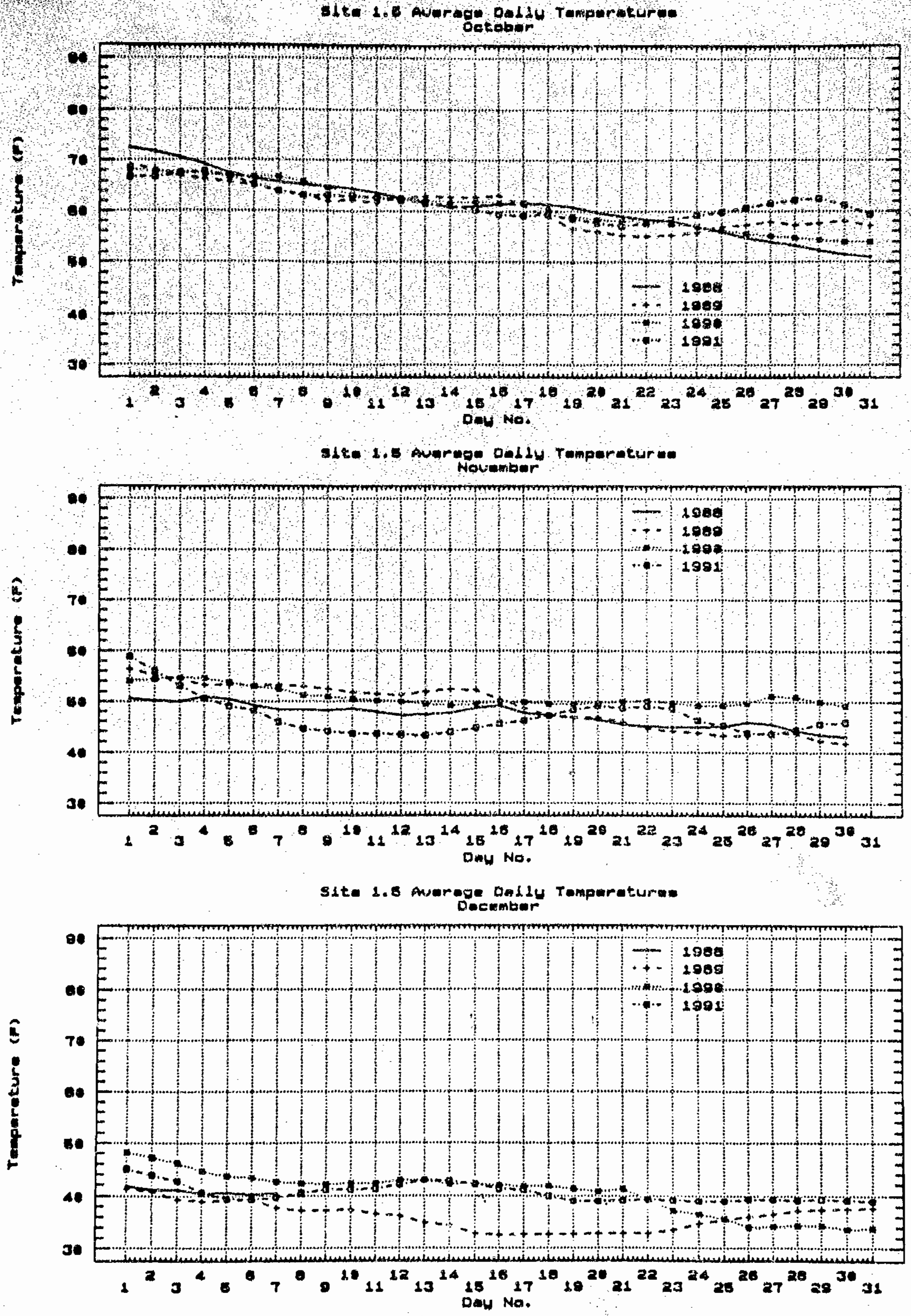


Figure C-5 Site 1.5 Average Daily Temperatures (F) during October, November, and December of 1988, 1989, 1990, and 1991

Clinton Power Station
Artificial Cooling Lake Demonstration

Clinton Lake Hydrothermal Modeling Verification for 1989, 1990, 1991

and

Determination of Adequacy of Variance Limits for Clinton Station

Prepared for

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September 28, 1992

Document No. 92-120-R

Contents

1. Executive Summary

Detailed temperature monitoring of Clinton Lake was conducted by IPC during the Spring, Summer and Fall of 1989, 1990 and 1991. These data have been used to provide further independent verification of the modeling used in establishing the Clinton Station thermal variance limits. The modeling has been more than sufficiently verified to re-assess the thermal variances and to support the conclusions of the assessment study.

The discharge flume temperature limitation of not exceeding 99 F for more than 90 days has been found to be adequate. However, the maximum temperature limit of 110.7 F can be exceeded by time-varying factors such as condenser cleanliness, circulating water flow rates, and heat rejection rates that directly affect the condenser temperature rise. Limitations on operations due to these variables are assessed and found to be reasonable.

2. Introduction

In its proceeding before the Illinois Pollution Control Board (IPCB) in June, 1989 (PCB 88-97), Illinois Power's Clinton Power Station was granted a variance from the temperature effluent standards that were applied at that time to the recirculating condenser cooling water and service water discharges to Clinton Lake. The variance limits ordered by the IPCB (daily average discharge temperature not exceeding 99 F more than 90 days per calendar year or 110.7 F on any day) were developed in Appendix A based upon 1988 Station operating data provided by Illinois Power and long-term meteorological data for the Central Illinois area. The IPCB also ordered in this proceeding that the variance limits extend only until October 1, 1990. In a subsequent proceeding before the IPCB (PCB 89-213) IP requested and the IPCB approved an extension of the duration of these limits until October 1, 1992 with a further extension to be granted until October 1, 1993 if IP filed its request for site-specific thermal standards by October 1, 1992.

During the period of the variance, IP personnel collected additional Station operating and Clinton Lake temperature data for 1989, 1990 and 1991 (1989-1991). Edinger Associates was retained to evaluate these data and to reassess the adequacy of the variance limits relative to the Station operations during spring, summer, and fall periods of various return frequencies. The investigations and conclusions regarding the adequacy of those limits are set forth in this report.

The establishment of the maximum temperature limit in Appendix A was based on examining the statistics of a long-term series of response temperatures (1955 to 1988) computed from Springfield, Illinois meteorological data. The hydrothermal modeling of the lake based on the 1988 conditions showed that the response temperatures were nearly identical to the Station intake temperatures when the Station was operating near to full load. The maximum temperature limit was determined by adding the Station discharge excess temperature rise (20°F or 11.1°C) to the one day-one year in thirty response temperature (intake temperature) as determined from the meteorological conditions (90.7 F or 32.6 C). Determination of the adequacy of the maximum temperature limit is performed in this study by further verifying the 1988 modelling, further demonstrating the relationship between Station intake temperatures and response temperatures, and investigation of the actual Station temperature rises that occurred during 1989, 1990 and 1991.

The number of days the discharge flume temperature would exceed 99 F was determined in the previous study by adding the mean Station excess temperature as determined from the GLVHT model (20°F or 11.1°C for full load conditions) to daily response temperatures for the years 1955 through 1988. The number of days exceeding 99 F in each year were counted and ranked to determine the annual frequencies of occurrences of days. Determination of the adequacy of the 90-day limit is performed in this study by comparing computations of excess temperatures for each of the 1989, 1990 and 1991 summer periods under actual operating conditions to the theoretical full load excess temperatures in the previous study.

Verification of the model for 1989-1991 and the resulting excess temperature statistics for each year is presented in Section 3. Results from the previous analyses including the long term response temperature statistics and full load excess temperatures that are required in the adequacy assessment are presented in Section 4. The assessment of adequacy of the thermal limits is presented in Section 5. Presented in Section 6 is the determination of mean monthly temperatures for different annual return periods.

3. Description and Verification of the Model

The GLVHT model design, development and examples of past applications are presented in Buchak and Edinger (1984). It is a continuously maintained model that is supported by routines to perform different types of analyses of model output.

The GLVHT model is based on the longitudinal and vertical, laterally averaged equations of momentum, continuity and constituent transport. The formulation includes the vertically varying longitudinal momentum balance, the vertical momentum in the form of the hydrostatic approximation, local continuity, the free-water surface condition based on vertically integrated continuity, and longitudinal and vertical transport of any number of constituents. Constituents that determine density such as temperature and salinity are related to momentum through an equation of state. The vertically varying longitudinal momentum includes local acceleration of horizontal velocity, horizontal and vertical advective momentum transfer, the horizontal pressure gradient, and horizontal and vertical shear stress. Included in the latter are the surface wind stress and the bottom stress due to friction. The horizontal pressure gradient includes the barotropic surface slope and the baroclinic vertical integral of the horizontal density gradient which is the dominant term of density induced convective circulation.

The time-varying solution technique of the model is based on an implicit scheme that results from the simultaneous solution of the horizontal momentum equation and the free-water surface equation of vertically integrated continuity. This technique results in the surface long wave equation that is solved on each time step to give the water surface profiles, from which the vertical pressure distribution can be determined. The horizontal momentum is then computed, followed by internal continuity and then constituent transport. Upwind differencing is used for the advective processes in the momentum and constituent transport balances. Vertical turbulent transfer of momentum and constituents is determined from the vertical shear of horizontal velocity and a density gradient dependent Richardson number function.

Surface heat exchange is incorporated in the model using the term by term surface heat exchange relationship. For this relationship, the net rate of surface heat exchange is given as:

$$Hn=(Hs+Ha-Hsr-Har)-(Hbr+He+Hc)$$

where Hn (watts/m^2) is the net rate of surface heat exchange; Hs is incoming shortwave radiation; Ha is incoming atmospheric radiation; Hsr and Har are reflected shortwave and longwave radiation; Hbr is back radiation from the water surface; He is evaporative heat loss; and Hc is conductive heat exchange. The individual terms are evaluated from the meteorological data of cloud cover, air temperature, dewpoint temperature, windspeed, and atmospheric pressure. The methods of evaluation of the terms in Equation (2) are from Wunderlich (1972), Edinger, et al. (1974) and Jirka, et al. (1978).

The only change made in the GLVHT model computations applied to the 1988 data and the present analysis for 1989, 1990 and 1991 is to the overflow spillway formula. This formula could be more accurately calibrated because flows were going over the spillway during the present study periods.

3.1 Model Setup and Data Sources

The GLVHT model was set up for the same lake geometry as used in the previous studies (Appendix A). The longitudinal lake segmentation and numbering is shown in Exhibit 1. The longitudinal segments are each 1518.5 m long. Also shown in Exhibit 1 is the location of the bi-monthly vertical profiling sites used for model verification.

The geometry required in the model is the laterally averaged widths of the lake over the vertical in each longitudinal segment. These widths are shown in Exhibit 2. The vertical thickness of the layers is 1.1 m with variable surface layer thickness. The relationship between lake elevation and model layers is given in Exhibit 2.

The time series input data required to run the model over realtime periods are the meteorological data of cloud cover, air temperature, dewpoint temperature, windspeed and wind direction; the Station operating data of heat rejection rates, condenser cooling water pumping and service water pumping; and, the hydrological data of tributary surface inflows and temperatures and groundwater inflows and temperature.

The 1989-1991 meteorological data were obtained hourly from the National Climatic Data Center for Springfield, Illinois. The 1989-1991 Station operating data were provided as daily average values of power factors, condenser pumping rates and service water pumping rates by IPC personnel. The heat rejection rate was established as 6.713×10^9 Btu/Hr at 100% power level and assumed to be proportional to the power level. Operational input data for the case simulations described in section 4 were provided by IPC personnel.

Hydrological surface inflow data that was not available for 1988 was available for 1989-1991. Groundwater inflow data for the lake were not available. There were flows over the spillway during 1989, 1990 and 1991 that did not occur in 1988. The lake outflow to lower Salt Creek varied with depth over the spillway. The minimum release of 0.14 m^3/s (5 cfs) was maintained from the low level outlet.

3.2 Model Verification for 1989, 1990 and 1991

The accuracy of the longitudinal-vertical hydrodynamic and transport model GLVHT that was applied to Clinton Lake and the CPS cooling system was demonstrated using data collected in 1988 in a previously submitted document (Appendix A). To further assess the model, additional field studies were conducted in the years 1989, 1990 and 1991. Simulations using time-varying boundary condition data for those years were made using the longitudinal-vertical model for independent comparison to the observed field data. The model verification is a truly independent comparison of observed and computed results.

Both point recorder continuous data and instantaneous vertical profile data sets were part of the observation program in Clinton Lake. The continuous data set consists of continuous temperature monitors at eight locations in Clinton Lake and one location immediately below the dam on Salt Creek (Exhibit 3). Additionally, there are several other time series records available that provide opportunities to examine the model's performance. These records include Clinton Lake elevation, intake temperature, and discharge temperature. All of these data were compared to computed values in order to assess the accuracy of the model over long periods of time.

The vertical profile data set consists of monthly observations for the IPC Environmental Monitoring Program and the bi-monthly observations whose locations coincide with the longitudinal-vertical model segments. Since the bi-monthly data set is more frequent and its sites correspond to the model segments, it was used exclusively to assess the accuracy of the model at many locations and depths throughout the lake at specific times. Sites for the bi-monthly vertical temperature observations sets are shown on Exhibit 1.

Comparisons for the Continuous Data Set

The performance of the model with respect to its ability to reproduce continuous temperature measurements over long time periods can be summarized by examining four subsets of the entire continuous data set: discharge flume temperature (Exhibit 3, Site 15); two locations between the discharge and intake, the main beach (Exhibit 3, Site 12) and the lake side spillway temperature (Exhibit 3, Site 8); and, intake temperature (Exhibit 3, Site 4). These sites present the entire cycle of circulating water flow in Clinton Lake from the heated discharge through the main body of the lake to the intake. They also correspond to the figures shown in the previous report (Appendix A).

Exhibit 4 shows flume discharge temperature comparisons for the years 1989, 1990 and 1991. The flume discharge temperature has three components: the intake temperature, the increase in temperature due to condenser cooling, and cooling in the discharge canal. The comparisons show very good qualitative agreement with observed values, especially in 1991 when CPS load is nearly steady at 100%. CPS load was lowest and most variable in 1989, particularly in the early part of the year when there are deviations of up to 1.5°C between observed and computed values.

Exhibit 5 shows comparisons of observed and computed temperatures at the main beach (Site 12). As similarly shown in the previous study, the model slightly under-predicts temperatures at this location, most noticeably at the end of the year 1990.

That under-prediction at Site 12 is a local phenomenon is shown by the next down-lake Station, Site 8, which is on the lake side of the spillway (Exhibit 6). This exhibit shows good qualitative agreement of computed and observed temperatures, including the late 1990 period when deviations at Site 12 were largest.

The final continuous recording site is shown in Exhibit 7. Agreement between observed and computed intake temperatures is quite good, as it was in the 1988 study.

The statistics of the computed minus observed temperatures (C-O) are given in Exhibit 8. The results are good to excellent, particularly for 1991 when the Station was at or near 100 percent load most of the time. Also shown is the comparison between intake temperatures and response temperatures which will be discussed later.

Comparisons for the Vertical Profile Data Set

The performance of the model with respect to its ability to reproduce temperatures at many locations and depths throughout the lake at specific times can be assessed by examining the vertical temperature profile data. There are six dates available for comparison in 1989, nine dates in 1990 and eight dates in 1991. Computed and observed values for one date from each of these years when the CPS load has been near 100% for at least several days prior to the survey are discussed here.

Exhibit 9 shows computed and observed temperature profiles at eight sites in Clinton Lake for July 11, 1989. Agreement at all sites and depths is quite good, except for the deepest part of the profiles. This discrepancy does not persist (see, for example the other 100% load survey, August 22, 1989) and, as noted in the previous report, may be due to unaccounted groundwater inflow at low temperatures. The discrepancy does not effect the model's performance at the shallow sites, the Station intake and intake temperatures, or at the surface stations throughout the lake, nor is it carried over to other survey days.

Exhibits 10 and 11 show computed and observed temperature profiles for August 29, 1990 and for August 22, 1991, respectively. These dates were selected to illustrate other times of the summer when the CPS load is near 100%. Agreement in both cases is quite good. The remaining profile data at lower Station loads and different seasons showed equally good comparisons.

Comparison of Intake and Response Temperatures for 1989, 1990, 1991

Use of the long term meteorological records to establish the time series statistics necessary to evaluate the maximum temperature limit and the 99 F exceedence limit requires establishing a relationship between the response temperature which is computed from the meteorological data and temperatures on the lake. The response temperature can be interpreted to be the ambient temperature of the fully mixed lake with the Station operating (Edinger and Buchak, 1992). The results of the previous study showed that response temperatures best represented the Station intake temperature. This comparison is shown for 1989,1990 and 1991 in Exhibit 12. The computed minus observed statistics for the difference in response temperature and the intake temperature are given in Exhibit 8. The results further confirm that the response temperature is an excellent representation of the Station intake temperature.

3.3 Excess Temperatures for 1989, 1990, 1991

The GLVHT model enables excess temperatures to be calculated throughout the lake due to the Station operations. The excess temperatures are the temperature rise above response temperatures due to the heat source, Station pumping, surface heat dissipation, recirculation, and meteorological conditions (primarily windspeed).

A summary of the summer of 1989, 1990 and 1991 (June through August) excess temperatures as the mean excess temperatures throughout the lake, their standard deviation over the summer due to time-varying Station operations and meteorological conditions, and the maximum value attained at any point in the lake over the summer are given in Exhibit 13.

Mean excess temperatures decay up and down the lake away from the point of discharge due to surface heat dissipation and decrease vertically due to re-entrainment and mixing of cooler water in the lake. The mean values of excess temperatures are low and standard deviations are high in 1989 and 1990 when there were large variations in Station output. The reverse is true for 1991 when the Station was near 100% power most of the time. The standard deviations decrease up and down the lake and in the vertical along with the mean excess temperatures.

The excess temperature distributions as determined for continuous full load operation in the previous study are given in Exhibit 14. One evaluation of the adequacy of the thermal limits is that the excess temperatures computed for 1989-1991 should be equal to or less than the values found for the full load computations. Comparison of the excess temperature distributions and statistics for 1989, 1990 and 1991 as given in Exhibit 13 with Exhibit 14 shows that the excess temperatures are slightly higher for the latter than for any of the former. The excess temperatures in Exhibit 14 were, therefore, a reliable basis for establishing the variance limits.

4. Meteorological Data Analysis and Statistics

Long term meteorological records were obtained from Springfield, Illinois for June through August from 1955 through 1988. The hourly 1988 records were used in the above GLVHT simulations. The records consisted of hourly, and in some years tri-hourly, data of cloud cover, air temperature, dewpoint temperature, windspeed and wind direction. These lengthy records were converted into hourly waterbody response temperatures which as mentioned previously would be the water temperature that would result from meteorological conditions alone without accounting for inflow hydrology, stratification, or Station operations.

The records for each year were subjected to a duration analysis to determine the temperature equalled or exceeded for a specified number of days. The results of the duration analysis for each year are shown in Exhibit 15. The 1 day duration (maximum daily average temperature) for 1955 was 31.4 C (88.5 F) and did not recur until after 1978. However, as Exhibit 15 shows, temperatures near or at this value would have also occurred in 1980 and 1987 making the 31.4 C the worst temperature in 7 to 8 years.

Exhibit 16 shows 1-, 5-, 7-, 10-, 20-, and 30-day waterbody response temperature for 1989, 1990 and 1991 in the current study period. Comparing these temperatures to the period of record statistics given in Exhibit 15 shows that 1991 (with respect to its effect on a waterbody) is a normal year, i.e., very close to the one in two year return period, for all durations (Exhibit 17). The years 1989 and 1990 were cooler than normal.

Adequacy of the thermal limits would require that the 1989-1991 results not change the long term statistics. Exhibit 16 shows that there were no extreme conditions during 1989-1991 that would have altered the statistics derived from the 1955 through 1988 data set.

Statistics for Maximum Temperature Limits

In order to determine the annual return periods of temperatures at each duration, the temperatures within each duration were subjected to a Gumbel extreme value statistical analysis. The Gumbel analysis was tested for this data and found to describe the annual frequency or return period with which the temperatures occur. The Gumbel analysis states that the probability, or annual frequency, of equalling or exceeding a given temperature at a given duration is

$$P(T) = 1\text{-}\mathrm{Exp}[-\mathrm{Exp}(-(T-b)/a)]$$

where T is the temperature; $b = Tm + 0.45S$ where Tm is the mean temperature in the duration and S is the standard deviation; and, $a = S/1.283$. The mean temperature (Tm) and standard deviation (S) for each duration are given in Exhibit 15. The return period, in years, is $R = 1/P(T)$ from the above equation.

The overall frequency-duration analysis of the records from 1955 to 1988 can be generalized as shown in Exhibit 17 to give the maximum response temperature for a given return period and duration. In Exhibit 17, a given temperature would move diagonally downward for increasing durations and return periods; for example, 31.0 C (87.8 F) is the maximum temperature expected for one day once in 5 years, for 5 days once in 8 years, for 10 days once in 18 years and so on. The one day once in 30 year value of 32.6 C (90.7 F) was used to establish the maximum temperature limit of 110.7 F for a Station 20 F temperature rise.

Statistics for Durational Temperature Limit

~~The number of days the discharge flume temperatures would exceed 99 F was determined~~

~~by adding the mean excess temperature (20°F) to daily response temperatures for the years 1955 through 1988. The number of days exceeding 99 F in each year were counted and ranked to determine the annual frequencies of occurrences of days.~~

Two operating cases were identified: (1) 100 percent power, 100 percent circulating water flow, and the lake at normal elevation; and, (2) 100 percent power, 100 percent circulating water flow, and the lake at a lower elevation of 685.5 ft. These cases were evaluated to determine temperature effects in the lake for normal Station operations over the extremes of lake level conditions reasonably anticipated. The results of these analyses are given in Exhibit 18 and will be compared to the 1989, 1990 and 1991 conditions in Section 5.

5. Adequacy of Thermal Variance Limits

Adequacy of the thermal variance limits can be assessed based on the following: (a) observed discharge flume temperatures for 1989, 1990 and 1991 relative to the variance limits; (b) further verification of the modeling used to evaluate the thermal limits; and, (c) re-evaluation of the variance limits relative to the statistics from which they were originally derived.

Direct comparison of the observed conditions for 1989, 1990 and 1991 are made to the thermal variance limits in IPC (1992). They showed that the flume temperatures for all three years were within 110.7 F and that flume temperatures did not exceed 99 F for more than 90 days for all three years.

Numerous model verification results have been presented in previous sections of this report which support the accuracy of the model. As shown in Section 3.2, the GLVHT model accurately reproduces temperatures throughout the lake for three additional years. Second, as demonstrated in the previous study, response temperatures are further shown to be an accurate representation of Station intake temperatures and can be used in the long term statistical analyses. Third, as shown in Section 3.3, the full load modeled excess temperatures are an upper limit to the values computed in 1989-1991.

The final step in the adequacy evaluation is to examine the flume discharge temperatures and the maximum temperature limits relative to the statistics from which they were derived. These are presented in detail below.

90-Day Flume Discharge Temperature Limit

Exhibit 19 gives the number of days that actual flume discharge temperatures exceeded

99 F for each year 1989, 1990 and 1991.

As shown in Section 4, the year 1991 was a near-normal year for its temperature statistics. Comparing the 58 observed days in 1991 (IPC, 1992) with the discharge flume predictions in Exhibit 18 shows that the statistical estimates of 60 to 63 days for a normal year are quite accurate. Similarly, Section 4 shows that 1989 and 1990 ambient waterbody temperatures were cooler than normal and Exhibit 19 for 1989 and 1990 gives fewer observed days than shown for the predicted flume discharge temperature in Exhibit 18. Therefore, the 90-day variance limit appears adequate based upon observed 1989, 1990, and 1991 flume discharge temperatures.

Maximum Daily Average Flume Discharge Temperature Limit

The maximum daily average temperature limit was derived from the one day, one year in thirty response temperature of 32.6 C (Exhibit 17) added to the maximum rise across the Station of 11.1°C, for a total of 43.7 C (110.7 F). Since the previous study had shown that response temperature closely follows intake temperature, response temperature plus the full load Station rise of 11.1°C was used as an estimate of flume discharge temperatures.

Exhibit 19 shows the maximum observed flume temperature for each of the three study years. The highest temperature was recorded on July 11, 1989. Although the 40.0 C observed is less than the maximum of 43.7 C, it is important to note that the 40.0 C is composed of the intake temperature of 28.4 C and the Station temperature rise of 11.6°C. This Station temperature rise is obtained by subtracting the observed flume temperature from the intake temperature and includes the condenser temperature rise, cooling in the discharge canal and the time of travel between the intake and discharge flume. Note that the condenser temperature rise of 14.0°C is higher than the computed maximum used in the 1989 study. The period during which these observations were obtained was at the end of a run-up in CPS reactor power from 0% to 100% and back to 0% in a period of 16 days. Had such an event occurred during a particularly hot period, it is quite possible that the maximum flume temperature would have exceeded the 43.7 C limit.

Lower pumping rates may cause the 110.7 F limit to be exceeded. The 110.7 F was determined for a Station excess temperature rise of 20°F at a circulating cooling water pumping rate of 1410 cfs. Recent results (Davis, 1992) indicate that the circulating cooling water pumping rate could be as low as 1305 cfs giving a full load condenser rise of 22.9°F. Assuming that the cooling through the drop structures would remain at 3°F for this lower pumping rate, then the 110.7 F would not be changed. Exhibit 19 shows a maximum condenser temperature rise of 25.2°F (14°C) which gives a Station excess temperatures rise of 22.2°F (12.3°C). From Exhibit 17 the latter would result in the 110.7 F being exceeded 7 to 10 days one year in thirty.

A long term factor that may affect the maximum temperature limit of 110.7 F is sedimentation buildup in the lake. Its effect on the maximum temperature limit has been evaluated (Edinger, 1992). The evaluation shows that the 1 day in 30 year maximum temperature could reach 111.2 F. The return period of the present 110.7 F would be reduced to 1 day in 21 years.

6. April through September Mean Monthly Full Load Station Values Temperatures

Much of the fisheries assessment of Clinton Lake in the IPC Environmental Program can be performed from mean monthly temperatures throughout the lake. The mean monthly temperatures at any location in the lake can be determined by adding the mean monthly response temperatures to the excess temperatures.

The mean monthly response temperatures for all months for 1955 through 1991 are given in Exhibit 20. The summary statistics of the normal year, the 1 in 10 year and the 1 in 30 year full load Station values for April through September are given in Exhibit 21. The values of the response temperatures should be added to the mean excess temperatures given in Exhibit 14 to obtain the mean monthly temperature at any location in the lake for the Station at full load conditions.

7. Conclusions

The modeling techniques used to establish the Clinton Station thermal variances have been re-verified for 1989, 1990 and 1991 and have been found to be accurate and reliable.

The modeling results used to determine the discharge flume temperature limits, Exhibit 14, require no revisions and the statistical predictions of the discharge flume limits, Exhibit 18, have proven accurate for 1989, 1990 and 1991.

The statistical basis of the maximum temperature limit does not need revisions. However, time-varying factors such as condenser cleanliness, circulating water flow rates, and heat rejection rates affect Station excess temperature rise. This variability could require load curtailment of 7 to 10 days one year in thirty to stay within the 110.7 F. Secondly, long term sediment buildup in the lake could reduce the return period of the 110.7 F to 1 day in 21 years.

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List of Exhibits

maxima by lake segments and elevations for Case 1 conditions (normal lake elevation and 1410 cfs pumping).

Exhibit 15. Maximum response temperatures (C) for a given duration for each year 1955 to 1988 with means and standard deviations for each duration.

Exhibit 16. 1-, 5-, 7-, 10-, 20-, and 30-day waterbody response temperatures (C) for 1989, 1990 and 1991.

Exhibit 17. Table of response (intake) temperatures (C) as a function of annual frequency and duration computed from Springfield, Illinois climatological data for 1955 to 1988.

Exhibit 18. Days exceeding 99 F at the discharge flume and at the mixing zone for Case 1 and Case 2 for normal year, one year in five, one year in ten, one year in twenty and one year in thirty.

Exhibit 19. Maximum observed flume temperature for each of the three study years.

Exhibit 20. Mean of the daily average response temperature in the month and year.

Exhibit 21. April through September mean monthly response temperatures for the normal year, the 1 in 10 year, and the 1 in 30 year.

Exhibit 1. GLVHT model segments and bi-monthly sampling sites, Clinton Lake, Clinton, Illinois.

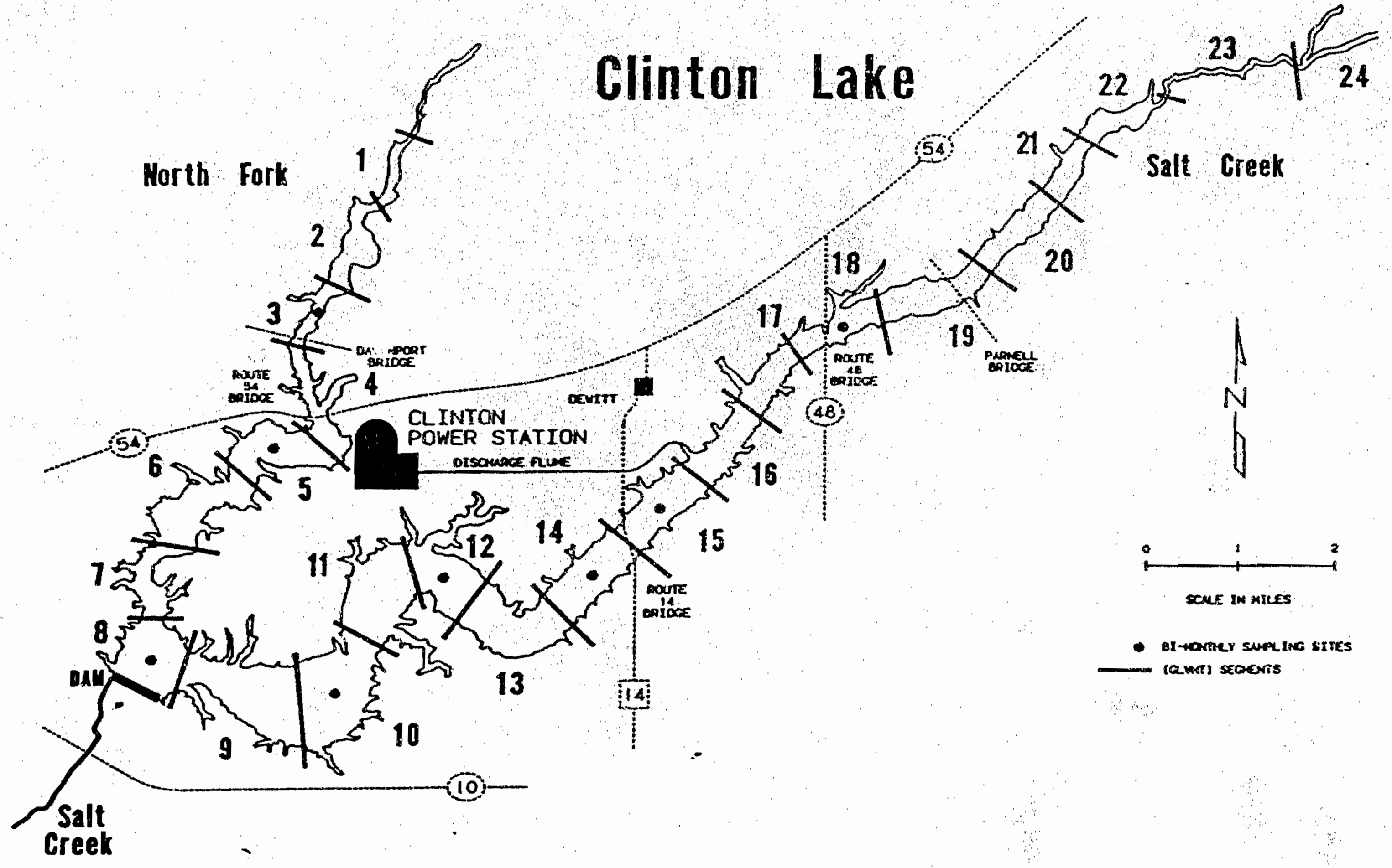

Exhibit 2. GLVHT finite difference grid with Clinton Lake widths in meters shown for each segment and layer. Segment locations are shown in Exhibit 1. Elevations at the top of each layer are also shown on the second part of this exhibit. Normal pool elevation is 210.31 m (690 ft), with the water surface in layer 5. Data based on 1978 geometry.

	Segment Number																
Layer	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
2	0.	335.	377.	467.	580.	652.	709.	821.	972.	1074.	1075.	1016.	919.	789.	697.	661.	638.
3	0.	303.	353.	450.	567.	641.	699.	810.	957.	1051.	1043.	977.	883.	701.	672.	628.	591.
4	0.	256.	319.	428.	550.	627.	686.	797.	941.	1028.	1005.	928.	836.	726.	644.	592.	540.
5	0.	151.	234.	367.	511.	597.	660.	773.	913.	985.	932.	828.	733.	640.	564.	490.	401.
6	0.	151.	234.	367.	511.	597.	660.	773.	913.	985.	932.	828.	733.	640.	564.	490.	401.
7	0.	54.	138.	278.	437.	542.	622.	740.	873.	923.	838.	701.	585.	480.	396.	308.	200.
8	0.	24.	81.	188.	331.	457.	574.	708.	826.	854.	747.	584.	449.	338.	256.	184.	100.
9	0.	9.	38.	101.	212.	347.	492.	633.	735.	747.	625.	441.	285.	192.	128.	85.	41.
10	0.	3.	15.	54.	135.	253.	389.	516.	603.	609.	489.	305.	164.	82.	40.	23.	11.
11	0.	0.	8.	31.	85.	176.	298.	416.	486.	475.	358.	192.	78.	27.	0.	0.	0.
12	0.	0.	3.	14.	42.	104.	210.	321.	372.	336.	226.	102.	29.	6.	0.	0.	0.
13	0.	0.	0.	0.	15.	45.	110.	184.	212.	170.	96.	36.	7.	0.	0.	0.	0.
14	0.	0.	0.	0.	3.	11.	31.	59.	69.	47.	20.	5.	0.	0.	0.	0.	0.
15	0.	0.	0.	0.	0.	0.	3.	7.	9.	6.	0.	0.	0.	0.	0.	0.	0.
16	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

	Segment Number						
Layer	18	19	20	21	22	23	24
1	0.	0.	0.	0.	0.	0.	0.
2	621.	606.	558.	470.	397.	372.	0.
3	565.	548.	500.	413.	341.	316.	0.
4	504.	485.	438.	353.	282.	257.	0.
5	342.	319.	279.	206.	145.	124.	0.
6	342.	319.	279.	206.	145.	124.	0.
7	129.	109.	89.	53.	23.	12.	0.
8	45.	31.	25.	13.	4.	0.	0.
9	13.	6.	5.	3.	0.	0.	0.
10	0.	0.	0.	0.	0.	0.	0.
11	0.	0.	0.	0.	0.	0.	0.
12	0.	0.	0.	0.	0.	0.	0.
13	0.	0.	0.	0.	0.	0.	0.
14	0.	0.	0.	0.	0.	0.	0.
15	0.	0.	0.	0.	0.	0.	0.
16	0.	0.	0.	0.	0.	0.	0.

Exhibit 7. Comparison of observed and computed intake temperatures (Site 4) for 1989, 1990 and 1991. The horizontal scale is a combination of a two-digit year and a three-digit Julian date. The intervals are approximately monthly, beginning with May and ending with September. Observed intake temperatures are represented by the solid line, computed temperatures by the dashed line.

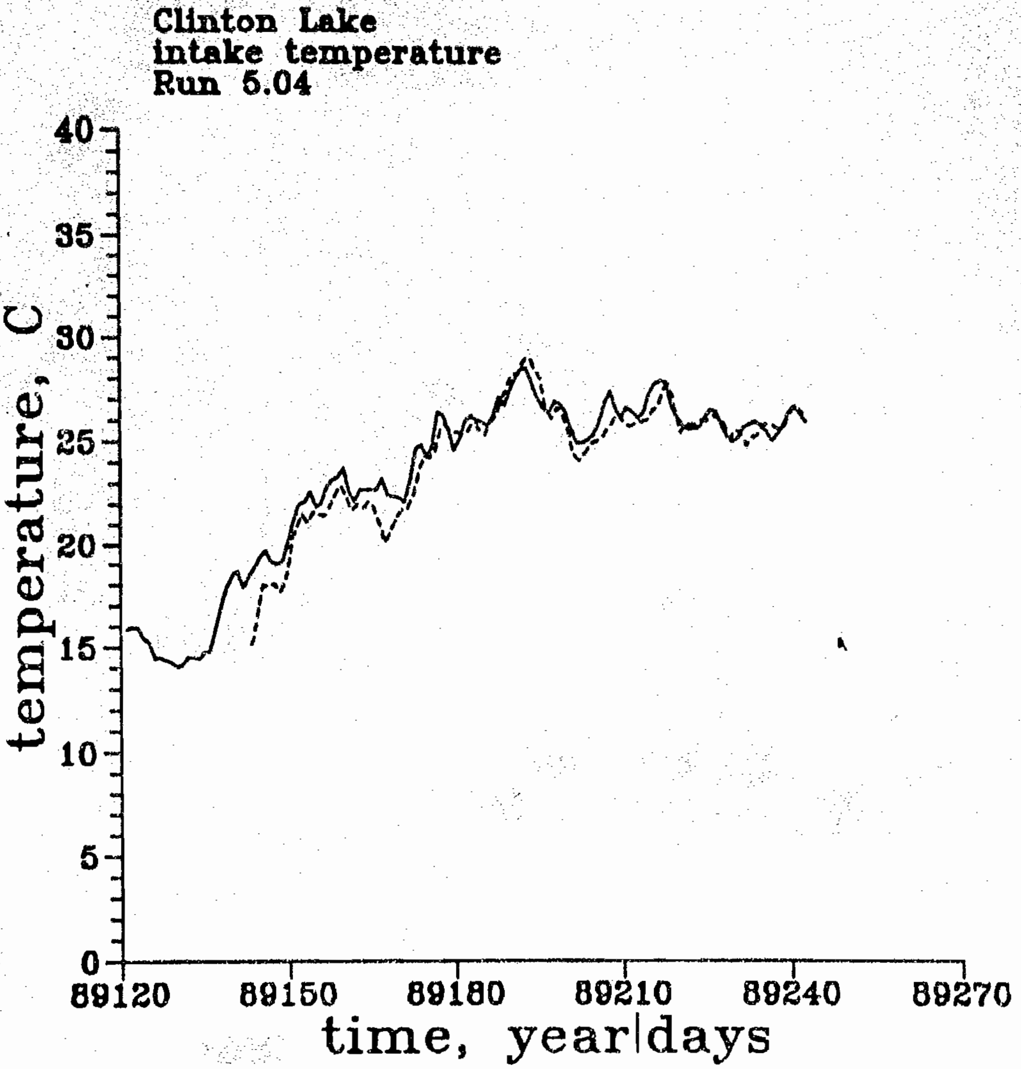

Exhibit 2 (continued).

Layer	Thickness m	Elevation m	Area Millions of m2	Cumulative Volume Millions of m3
2	1.1	213.36	22.480	157.371
3	1.1	212.26	21.366	132.643
4	1.1	211.16	20.080	109.140
5	1.1	210.06	16.998	87.052
6	1.1	208.96	16.998	68.354
7	1.1	207.86	12.954	49.656
8	1.1	206.76	10.357	35.407
9	1.1	205.66	7.814	24.014
10	1.1	204.56	5.605	15.419
11	1.1	203.46	3.993	9.254
12	1.1	202.36	2.681	4.861
13	1.1	201.26	1.328	1.912
14	1.1	200.16	.372	.451
15	1.1	199.06	.038	.042

Map References	Segments	Layers
Davenport Bridge	3/4	
Route 54 Bridge	4/5	
Intake	5	7, 8, 9
Dam overflow	8	5
Dam underflow	8	10
Route 14 Bridge	14/15	
Discharge flume	16	
Route 48 Bridge	17/18	
Parnell Bridge	19/20	
Iron Bridge	23/24	

Exhibit 3. Continuous temperature monitoring sites, Clinton Lake, Clinton, Illinois.

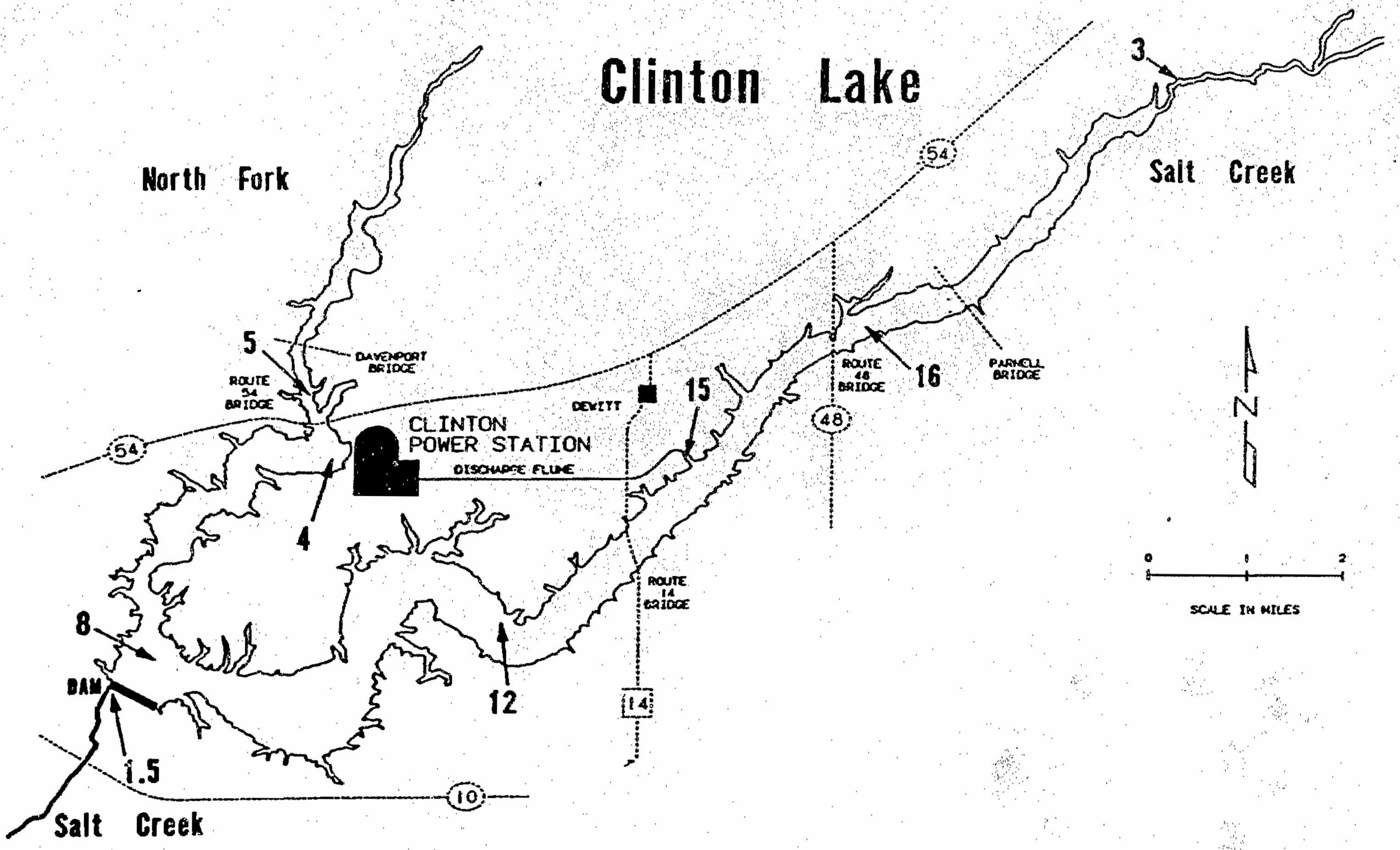

Exhibit 4. Comparison of observed (Site 15) and computed flume discharge temperatures for 1989, 1990 and 1991. The horizontal scale is a combination of a two-digit year and a three-digit Julian date. The intervals are approximately monthly, beginning with May and ending with September. Observed discharge temperatures are represented by the solid line or asterisks, computed temperatures by the dashed line.

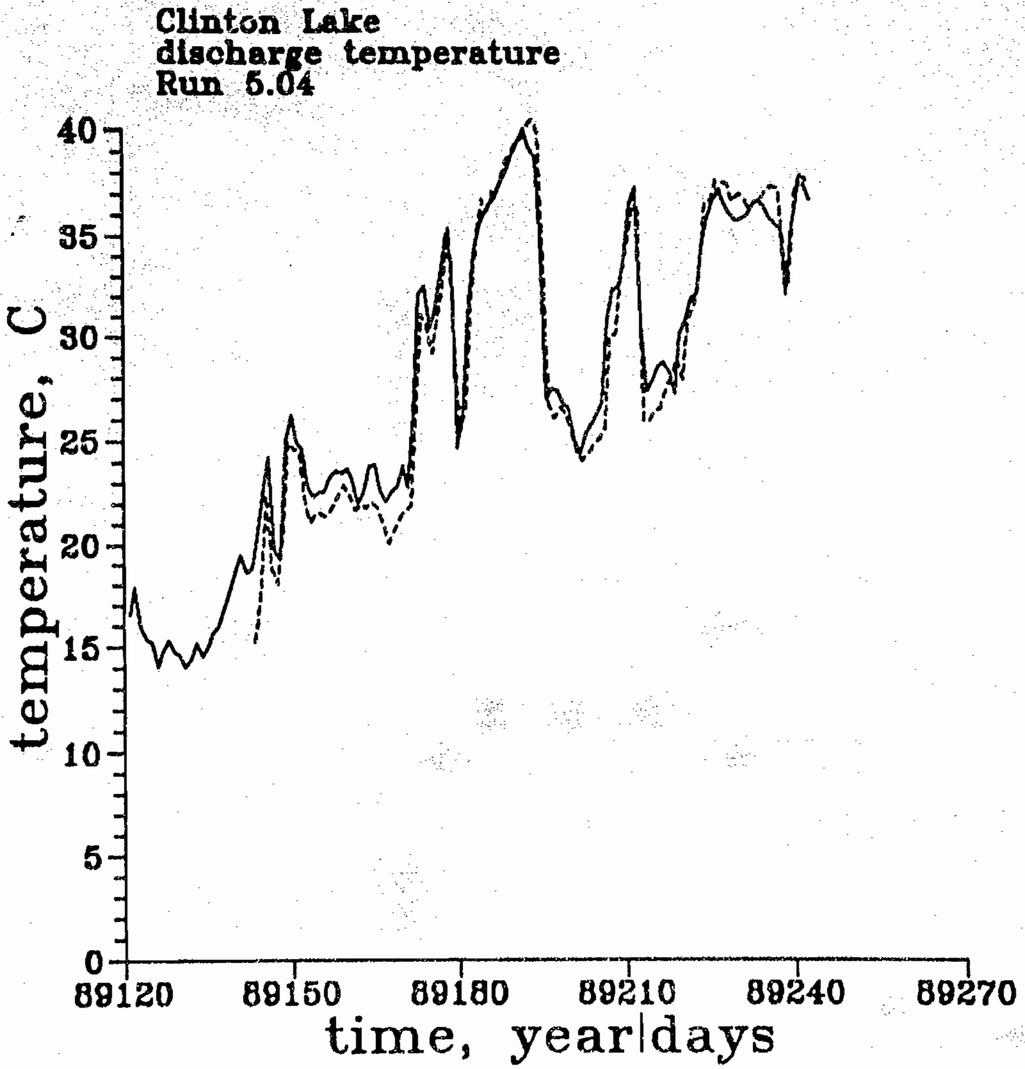

Exhibit 4 (continued).

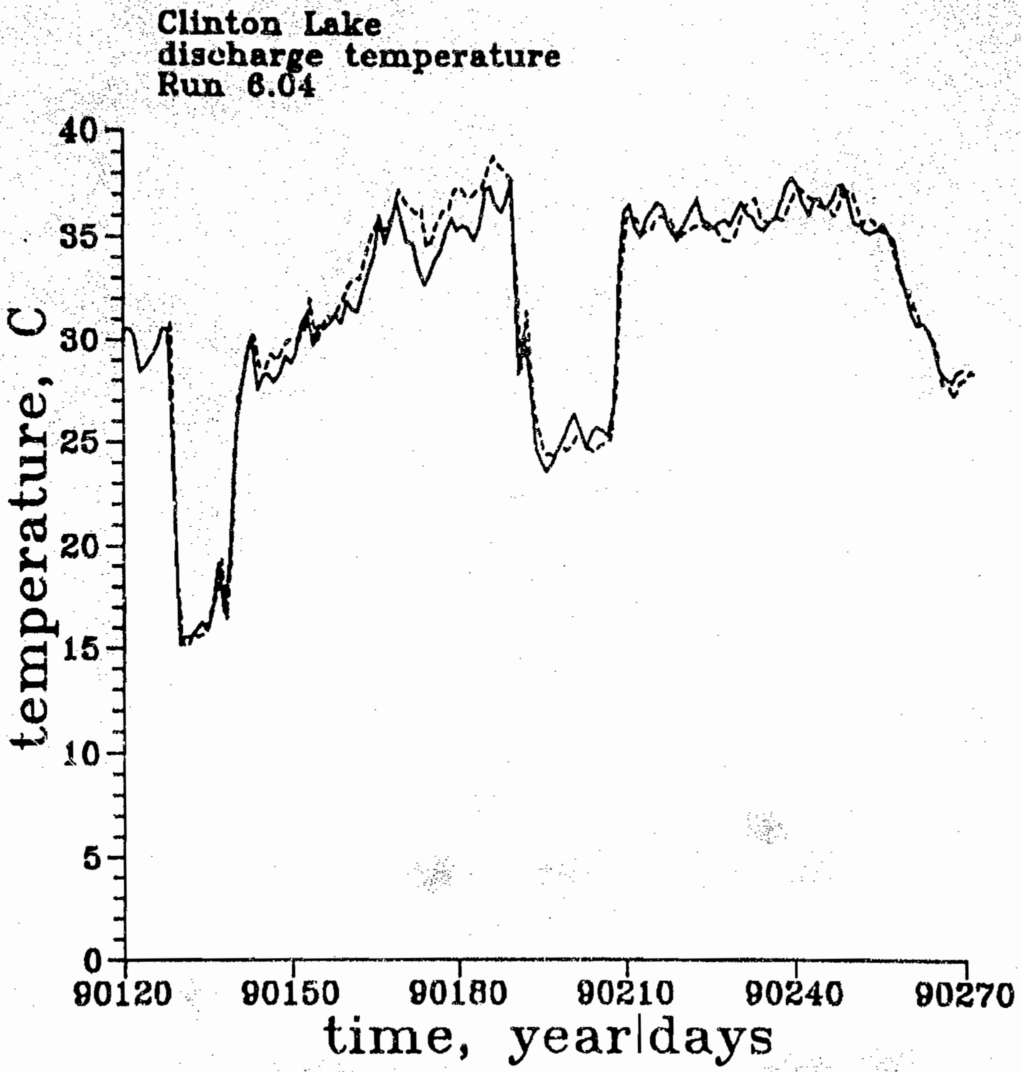

Exhibit 4 (continued).

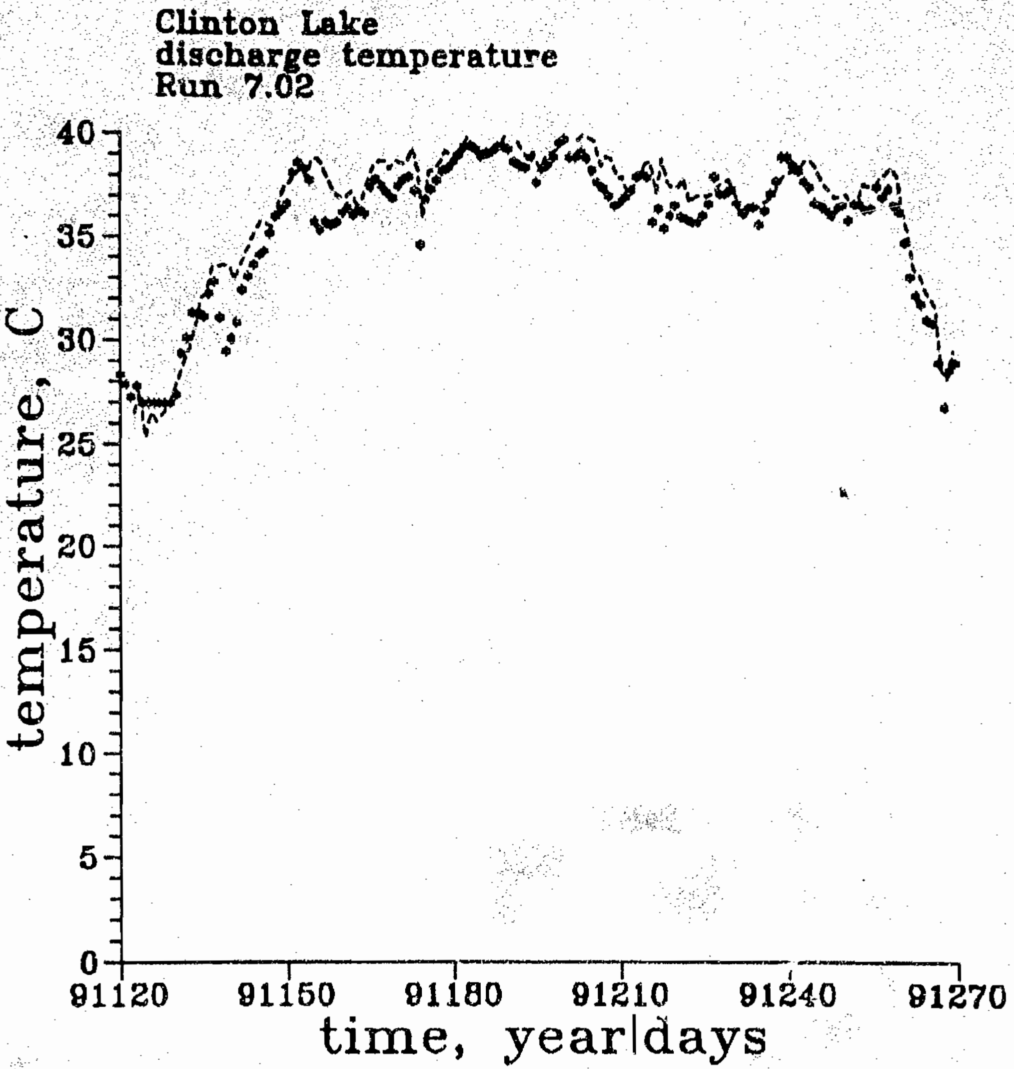

Exhibit 5. Comparison of observed and computed temperatures at the main beach (Site 12) for 1989, 1990 and 1991. The horizontal scale is a combination of a two-digit year and a three-digit Julian date. The intervals are approximately monthly, beginning with May and ending with September. Observed main beach temperatures are represented by the dots, computed temperatures by the solid line. The vertical bars show dates of the bi-monthly surveys.

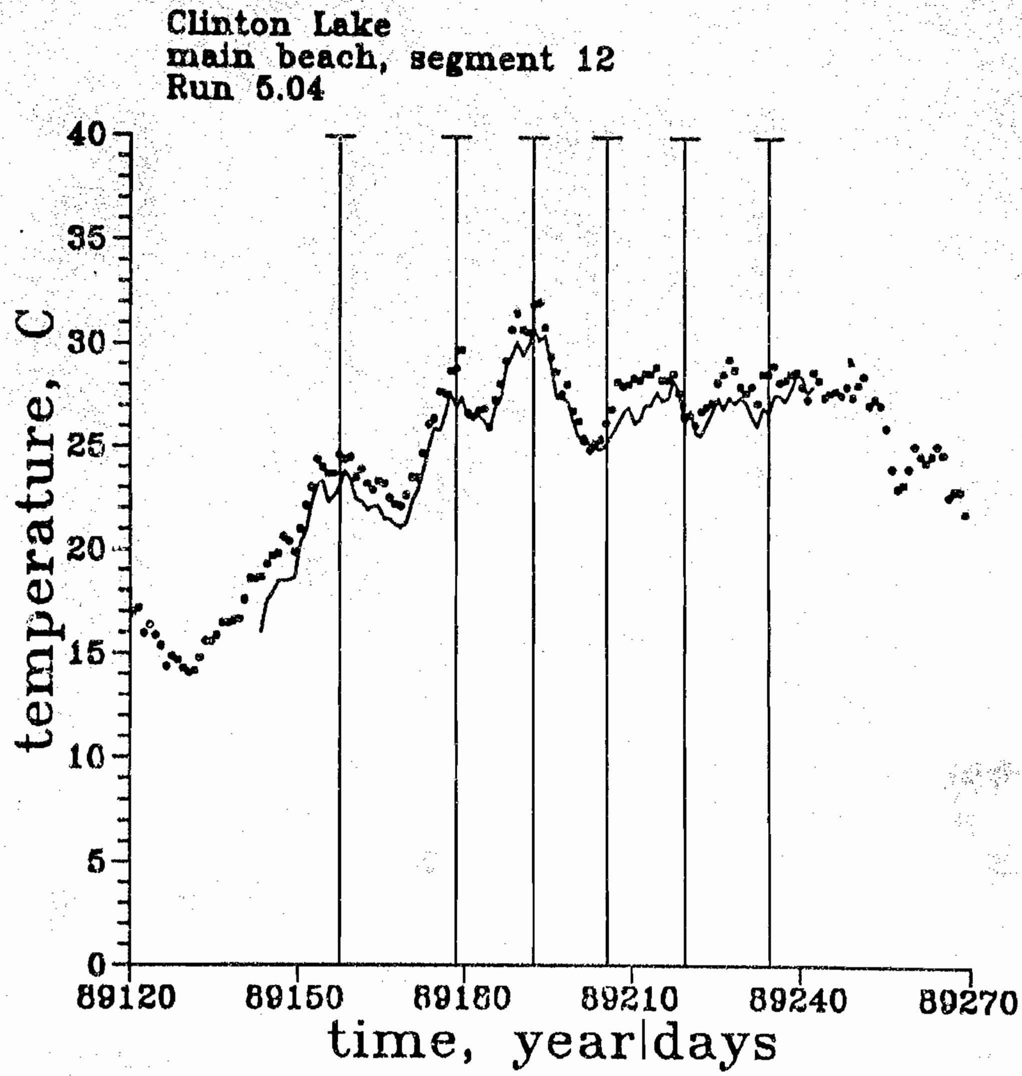

Exhibit 5 (continued).

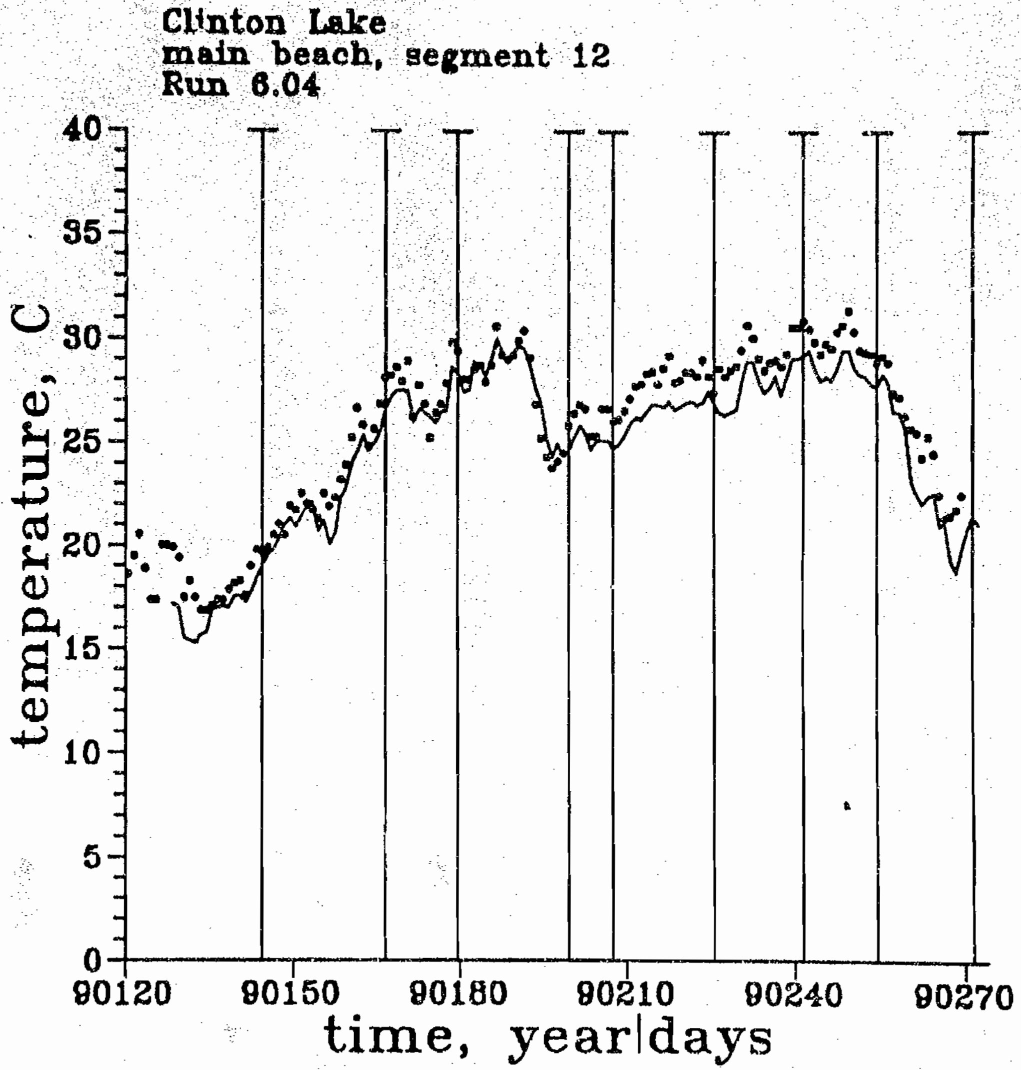

Exhibit 5 (continued).

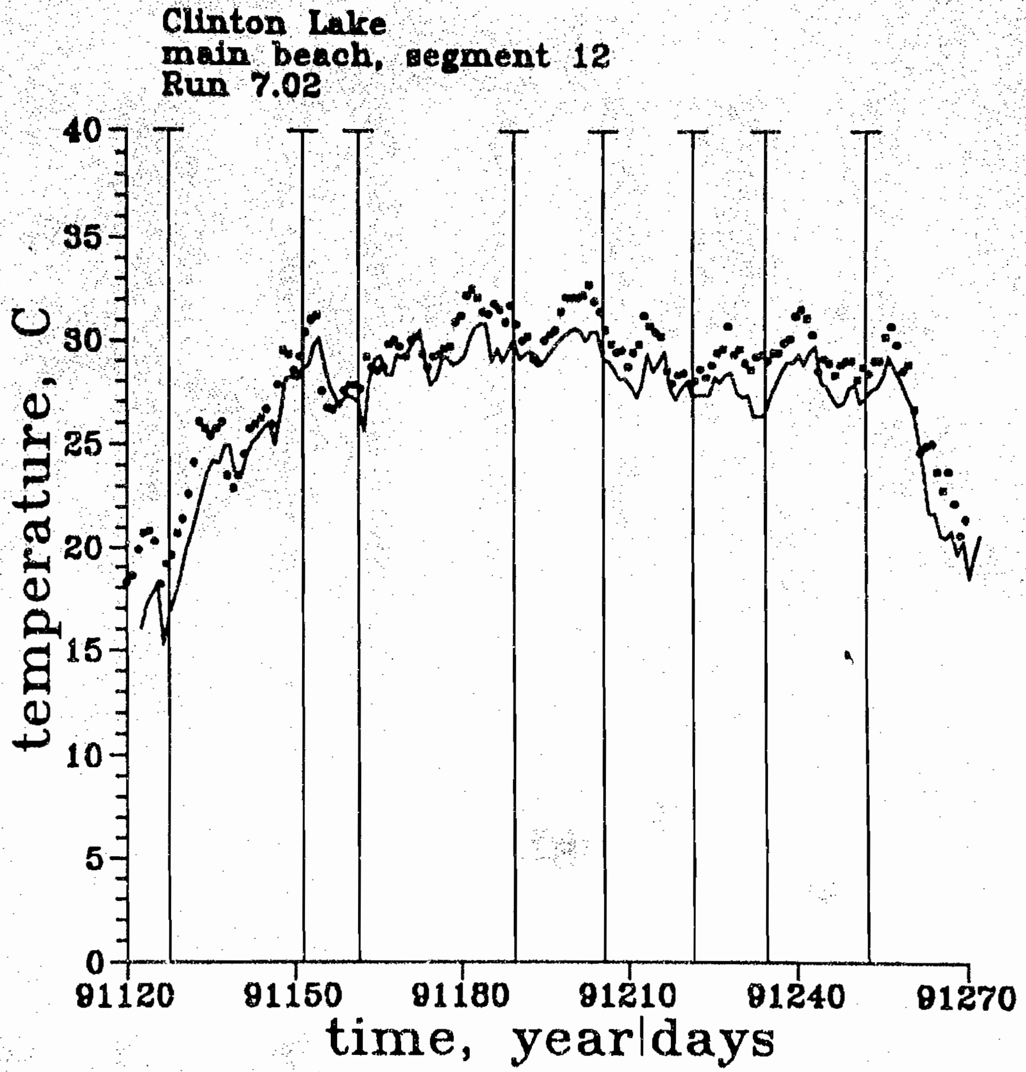

Exhibit 6. Comparison of observed and computed temperatures at the lake side spillway lake (Site 8) for 1989, 1990 and 1991. The horizontal scale is a combination of a two-digit year and a three-digit Julian date. The intervals are approximately monthly, beginning with May and ending with September. Observed spillway temperatures are represented by the dots, computed temperatures by the solid line. The vertical bars show dates of the bi-monthly surveys.

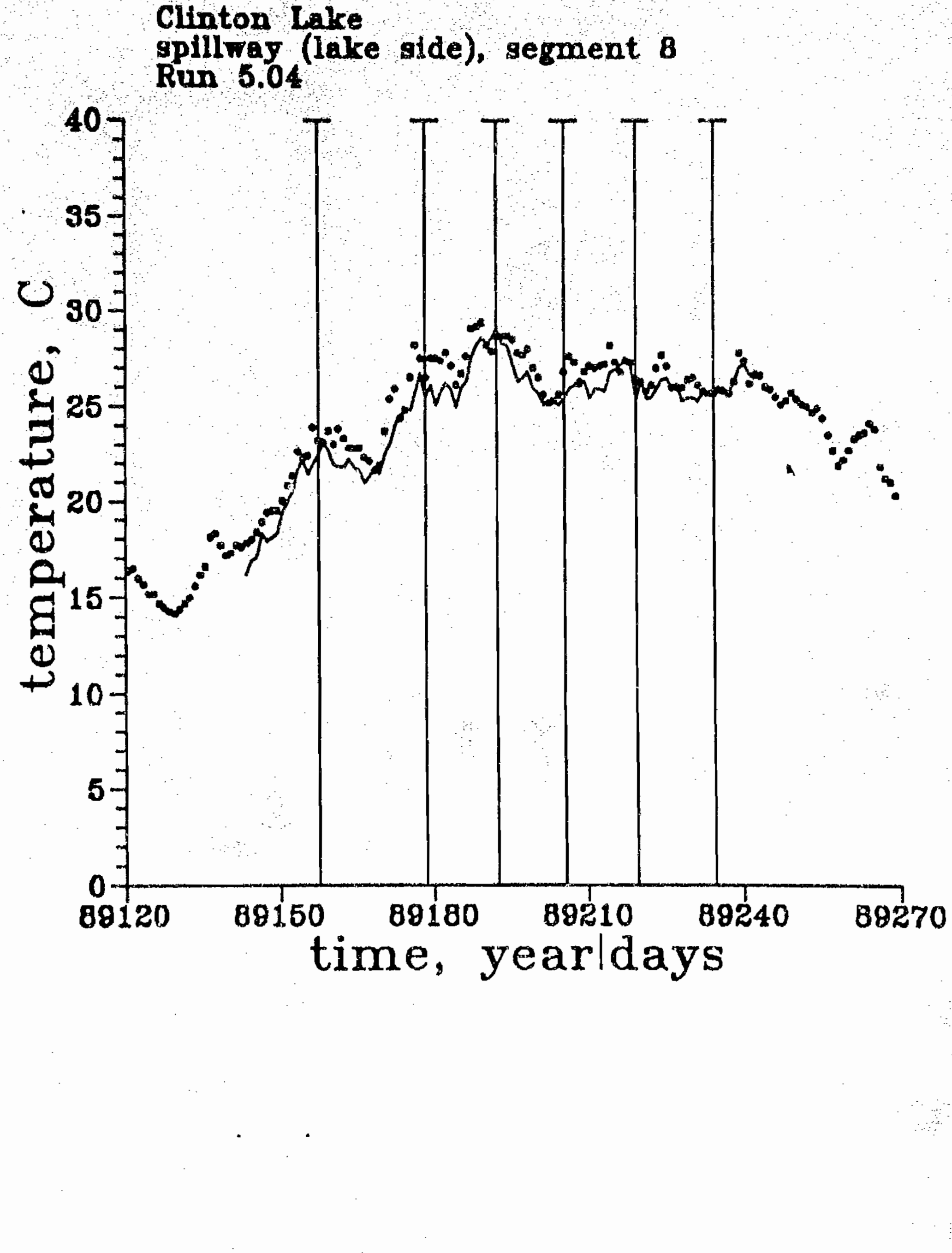

Exhibit 6 (continued).

Clinton Lake
spillway (lake side), segment 8
Run 6.04

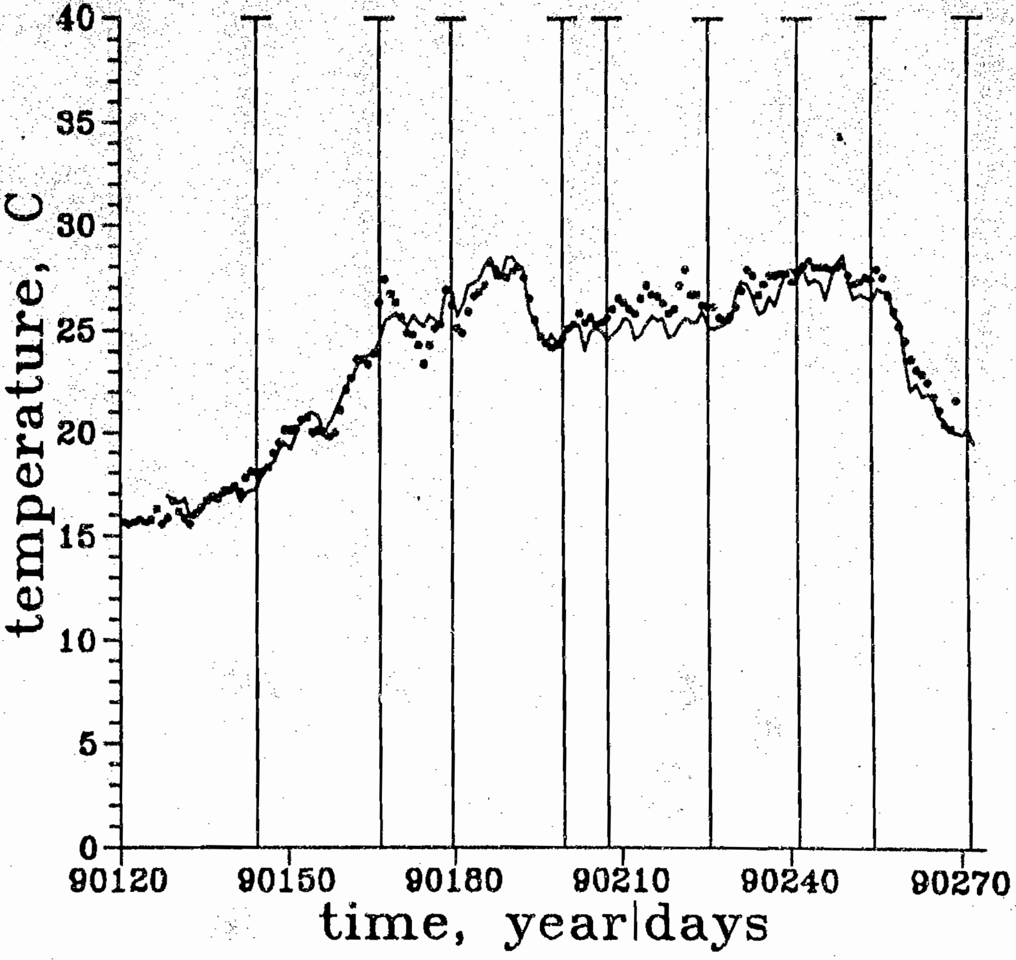

Exhibit 6 (continued).

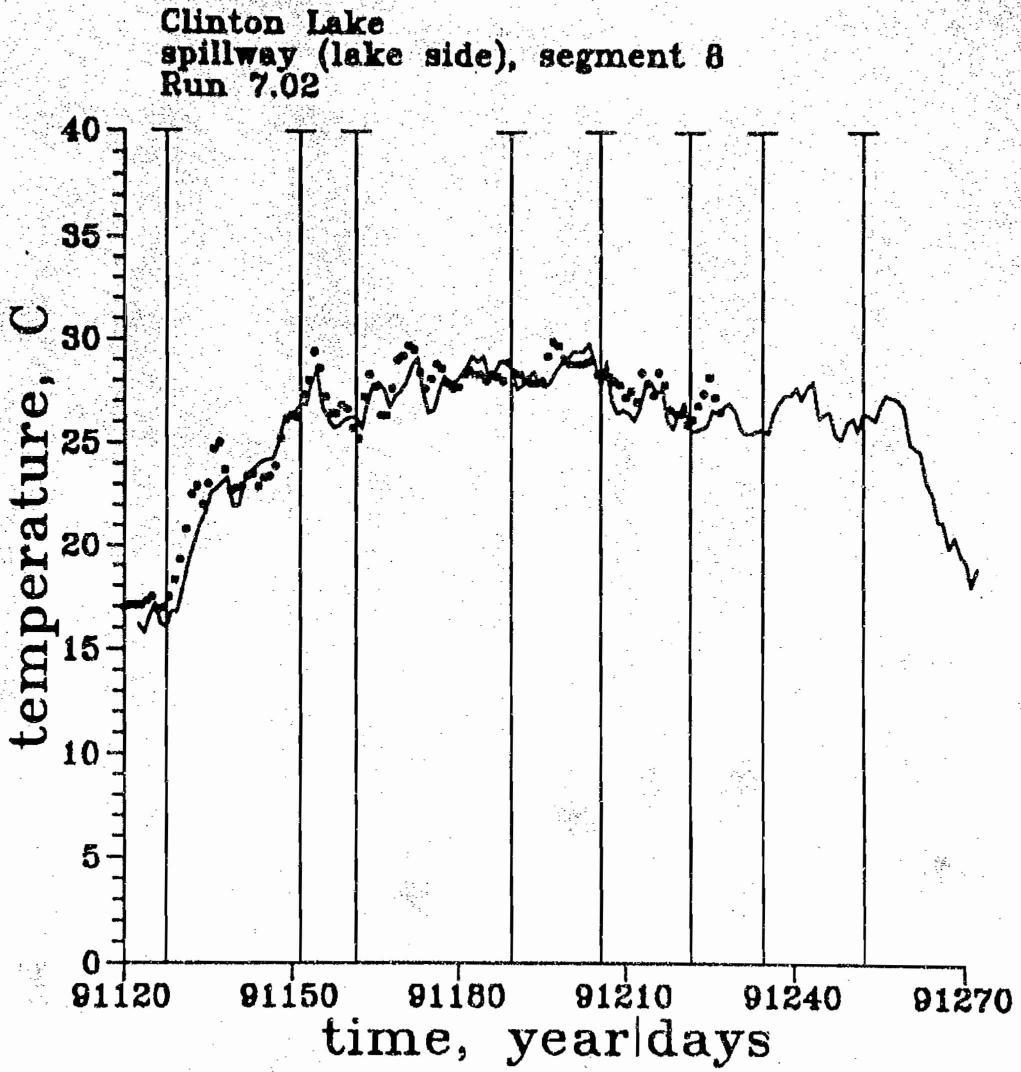

Exhibit 7. Comparison of observed and computed intake temperatures (Site 4) for 1989, 1990 and 1991. The horizontal scale is a combination of a two-digit year and a three-digit Julian date. The intervals are approximately monthly, beginning with May and ending with September. Observed intake temperatures are represented by the solid line, computed temperatures by the dashed line.

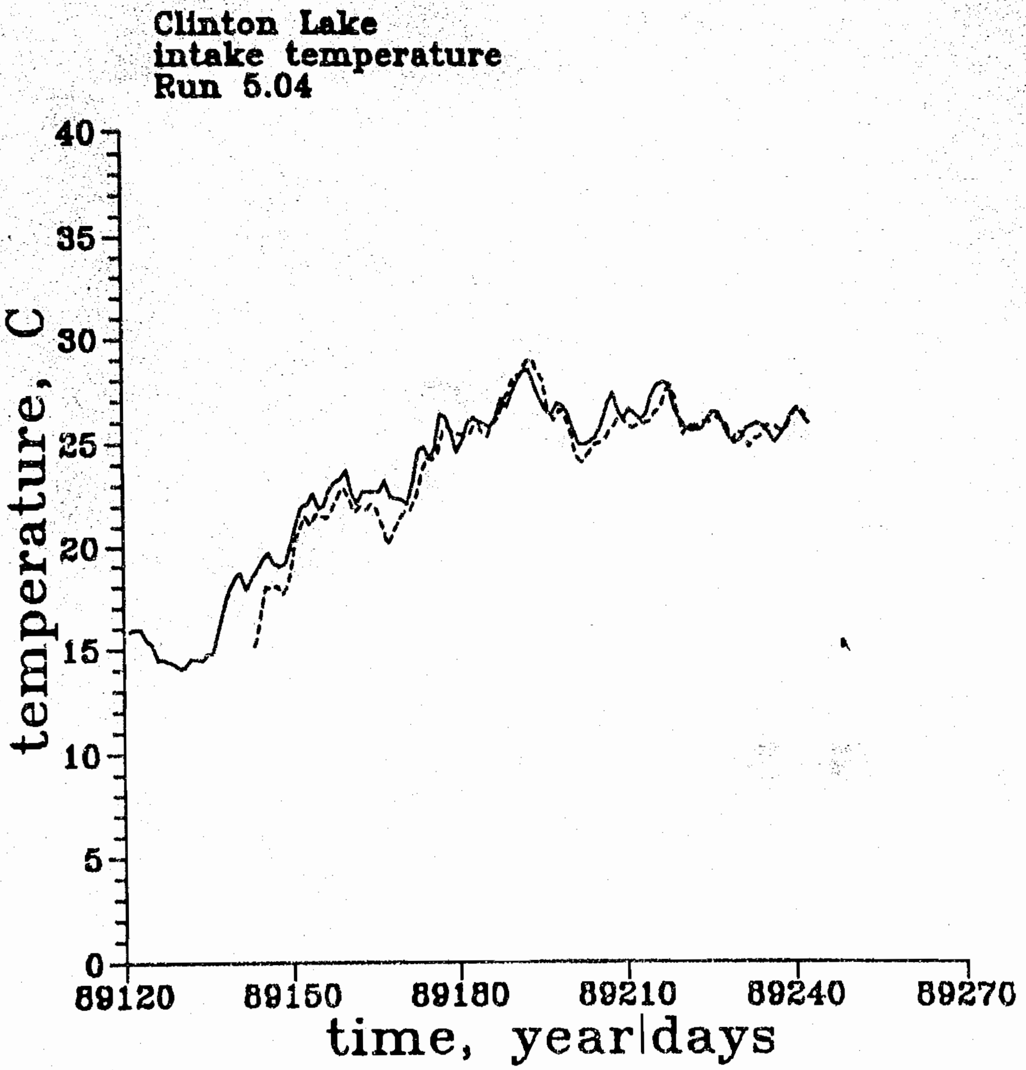

Exhibit 7 (continued).

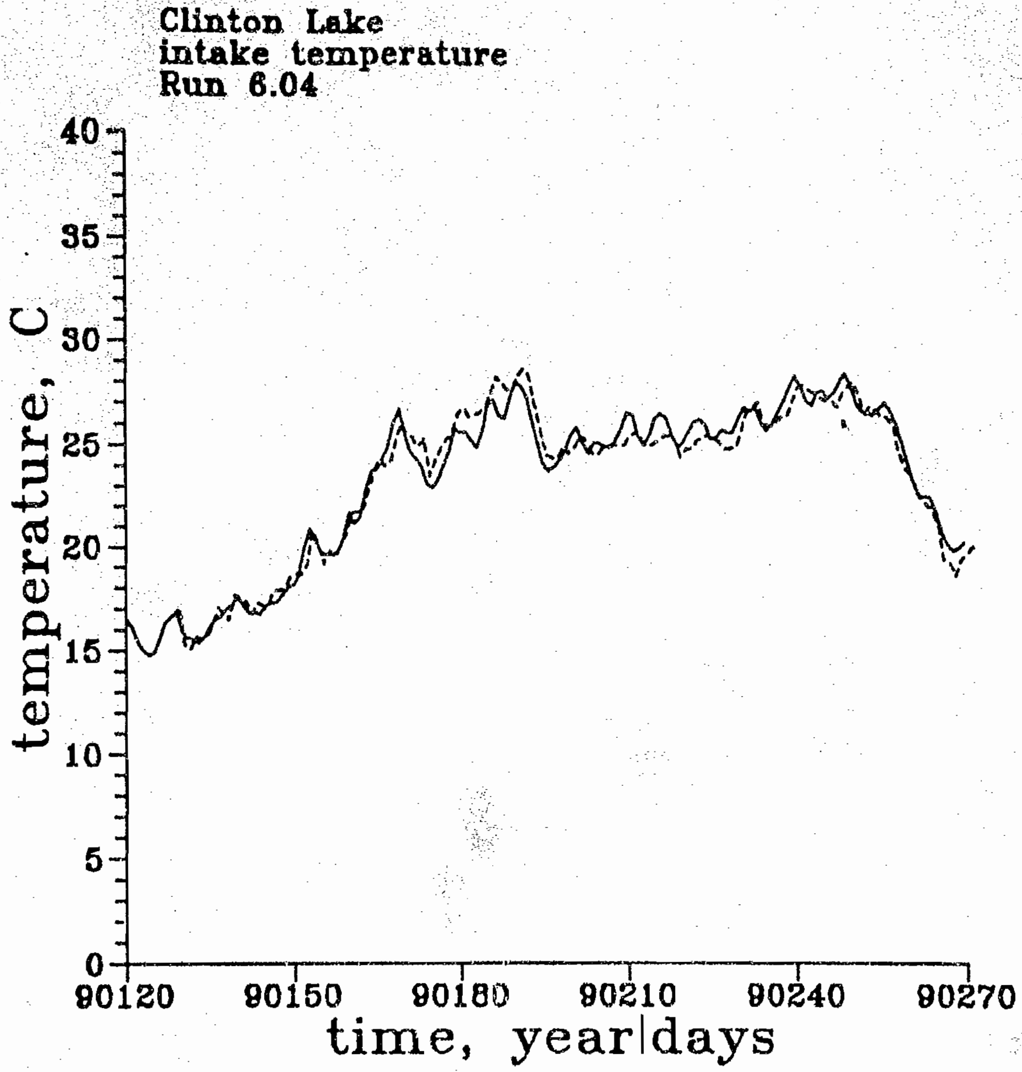

Exhibit 7 (continued).

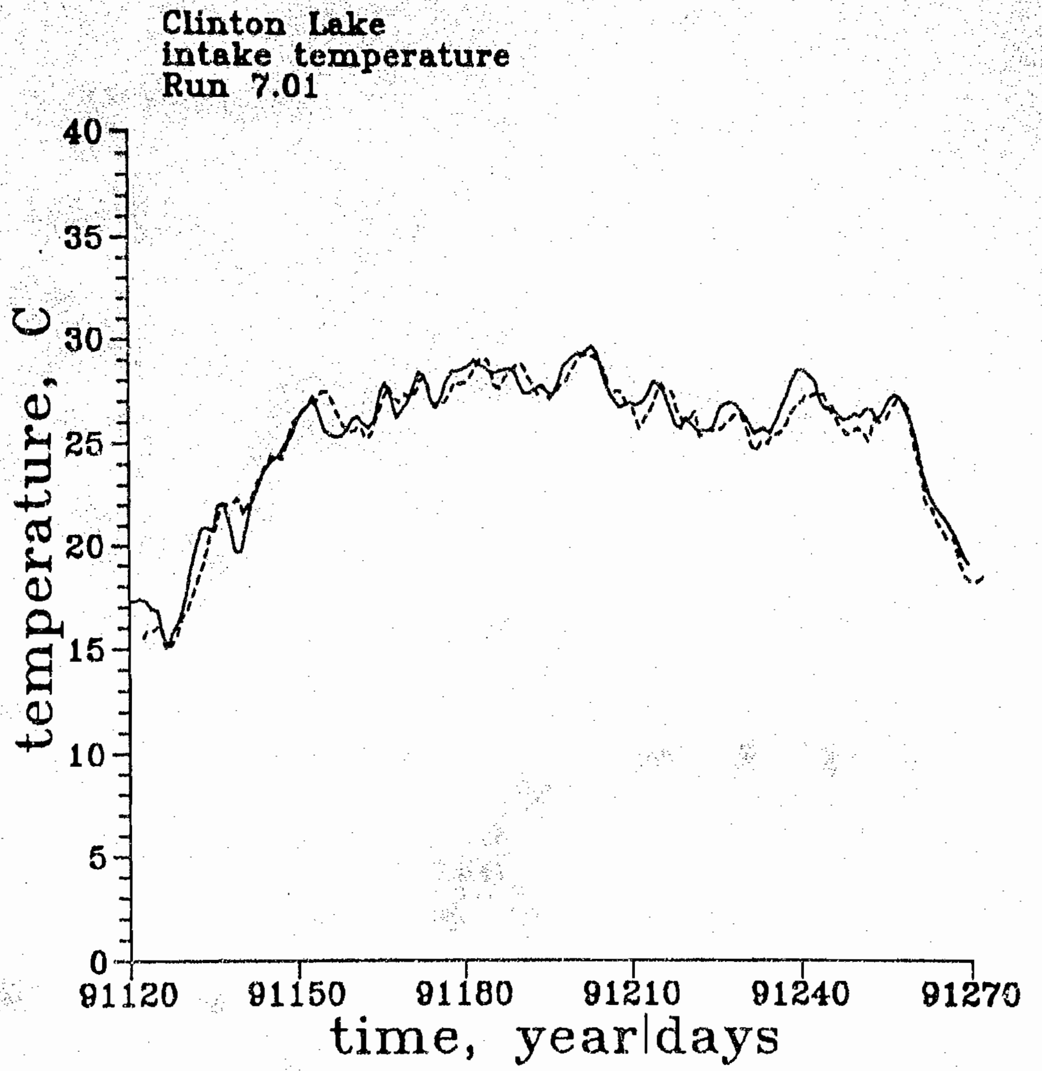

Exhibit 8. Statistics of computed minus observed temperatures for various Clinton Lake sites. Observed temperatures are those continuously measured at the sites noted. Also shown is the comparison between intake temperatures and response temperatures.

Station	1989		1990		1991	
	Mean	Stdev	Mean	Stdev	Mean	Stdev
Flume discharge	-0.54	1.36	0.22	0.99	0.78	0.83
Main beach	-0.99	0.63	-1.06	0.85	-1.33	0.96
Spillway (lake side)	-0.79	0.68	-0.30	0.80	-0.40	0.82
Intake (compared to intake recorder)	-0.45	0.74	-0.04	0.64	-0.25	0.70
Intake (compared to response temperature)	0.67	0.64	0.23	0.61	0.06	0.62

Exhibit 9. Computed and observed temperature profiles at eight sites in Clinton Lake for July 11, 1989.

observed temperatures (C) for 7/11/89

	site							
	3	5	8	10	12	14	16	18
Surf.	29.6	28.7	28.6	29.1	30.9	33.3	37.3	31.0
0.5	29.7	28.7	28.6	29.1	30.9	33.3	37.3	31.1
1.5	29.5	28.7	28.3	29.1	30.9	32.7	37.0	31.0
2.5	28.9	28.7	28.1	29.1	30.8	32.0	36.0	30.1
3.5		28.7	28.0	28.8	30.7	31.8	33.4	29.9
4.5		28.6	26.4	28.5	30.2	30.9	32.4	
5.5		27.4	25.7	28.1	25.5	28.1		
6.5		26.1	25.0		24.6			
7.5			23.8					
8.5			22.5					
9.5			20.8					
10.5								

computed temperatures (C) for 7/11/89

	seg.															
depth, m	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	21
0.6	29.9	29.7	29.3	29.1	29.1	29.1	29.3	29.7	30.3	30.8	31.4	32.4	34.1	37.3	34.3	32.4	30.5
1.7	29.2	29.2	28.8	28.6	28.4	28.4	28.7	29.2	29.8	30.4	31.1	32.1	33.5	34.9	33.1	31.6	29.8
2.8	29.4	29.2	28.7	28.6	28.4	28.3	28.6	29.1	29.6	30.3	31.1	32.0	33.2	33.9	32.7		
3.9	29.5	29.2	28.8	28.7	28.4	28.2	28.4	28.8	29.4	30.0	30.8	31.8	32.9				
5.0		29.1	28.9	28.6	28.2	28.0	28.2	28.5	29.1	29.6	30.5						
6.1			28.7	28.4	28.1	27.9	27.9		28.8	29.2							
7.2				28.3	27.9	27.7	27.7										
8.3					27.8	27.5											
9.4						27.3											
10.5																	
11.6																	

Exhibit 10. Computed and observed temperature profiles at eight sites in Clinton Lake for August 29, 1990.

observed temperatures (C) for 8/29/90

	site							
	3	5	8	10	12	14	16	18
Surf.	28.9	28.2	27.8	28.5	30.5	32.3	35.7	30.8
0.5	28.2	28.2	27.8	28.4	30.5	32.2	35.3	30.6
1.5	27.8	27.8	27.4	28.0	29.8	31.4	32.9	29.3
2.5	27.7	27.8	27.2	27.5	29.7	30.7	32.2	28.6
3.5	27.7	27.7	27.0	27.4	28.6	30.5	31.6	
4.5		27.5	27.0	27.4	28.1	29.5	31.2	
5.5		27.4	26.6	27.4	26.6	27.9		
6.5		26.5	25.8		26.0			
7.5			25.3					
8.5			25.2					
9.5			24.8					
10.5								

computed temperatures (C) for 8/29/90

	seg.																
depth, m	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	21
0.6	28.1	28.0	27.9	27.8	27.6	27.4	27.8	28.2	28.7	29.2	30.0	31.1	32.5	34.7	31.4	29.6	28.1
1.7	28.0	28.0	27.7	27.6	27.4	27.2	27.5	28.0	28.5	29.0	29.8	30.8	32.0	33.2	31.0	29.6	28.0
2.8	28.2	28.1	27.9	27.7	27.4	27.3	27.5	28.0	28.4	28.7	29.5	30.4	31.4	32.1	31.0		
3.9	28.2	28.0	27.8	27.6	27.4	27.3	27.5	27.8	28.1	28.5	29.2	30.1	31.0				
5.0		27.9	27.7	27.4	27.3	27.3	27.5	27.7	27.9	28.2	28.8						
6.1			27.4	27.2	27.1	27.2	27.3		27.6	27.9							
7.2				27.0	26.9	27.0	27.2										
8.3					26.8	26.9											
9.4						26.7											
10.5																	
11.6																	

Exhibit 11. Computed and observed temperature profiles at eight sites in Clinton Lake for August 22, 1991.

observed temperatures (C) for 8/22/91

	site							
Depth	3	5	8	10	12	14	16	18
Surf.	26.6	26.7	27.2	27.7	29.3	31.5	35.1	29.0
0.5	24.8	26.2	26.7	27.3	28.7	31.4	34.2	28.5
1.5	24.7	25.4	26.1	26.3	27.9	29.6	33.5	26.5
2.5	24.7	25.3	26.0	26.3	27.8	29.0	31.7	25.4
3.5		25.3	25.7	26.2	27.7	28.7	29.7	
4.5		25.2	25.6	26.1	26.6	27.5		
5.5		25.1	25.5	25.7	26.4			
6.5			25.4		26.3			
7.5			25.3					
8.5			25.2					
9.5			25.1					
10.5								

computed temperatures (C) for 8/22/91

	seg.																
depth, m	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	21
0.6	24.9	25.2	25.3	25.4	25.6	25.7	25.6	25.9	26.1	26.4	27.4	28.2	29.7	33.4	29.9	27.4	24.0
1.7	24.2	24.6	24.9	25.1	25.3	25.5	25.4	25.7	26.0	26.0	27.3	28.2	29.3	31.2	28.8	26.2	23.1
2.8	24.1	24.6	24.9	25.3	25.5	25.6	25.6	25.9	26.2	26.0	27.3	28.3	29.1	29.3	27.7		
3.9	24.3	24.7	25.0	25.4	25.6	25.6	25.6	25.9	26.3	26.2	27.0	28.1	28.9				
5.0		24.7	25.0	25.4	25.5	25.6	25.6	25.7	26.2	26.3	26.8						
6.1			25.0	25.3	25.5	25.5	25.5		26.1	26.5							
7.2				25.1	25.3	25.5	25.4										
8.3					25.2	25.5											
9.4						25.5											
10.5																	
11.6																	

Exhibit 12. Comparison of observed intake temperatures (Site 4) with response temperature for 1989, 1990 and 1991. The horizontal scale is a combination of a two-digit year and a three-digit Julian date. The intervals are approximately monthly, beginning with May and ending with September. Observed intake temperatures are represented by the solid line, response temperatures by the dashed line.

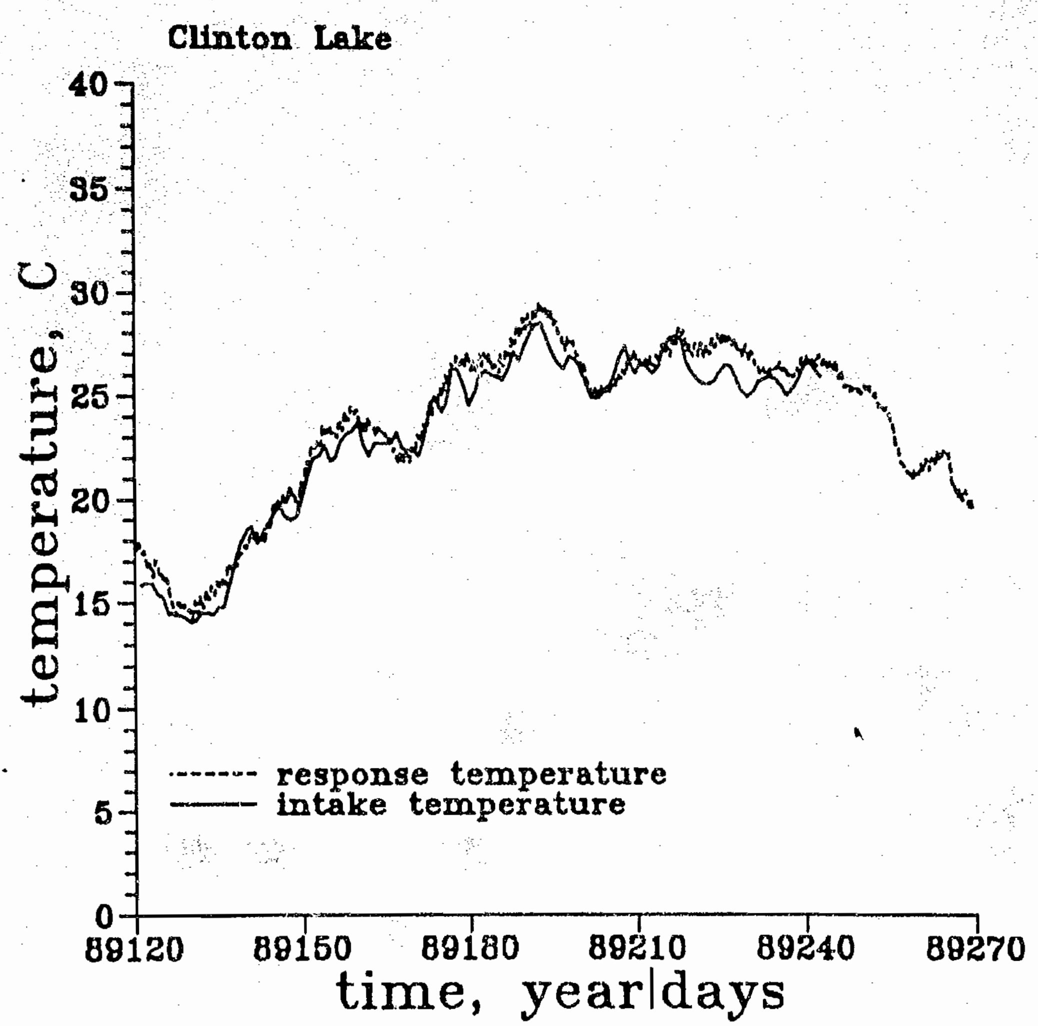

Exhibit 12 (continued).

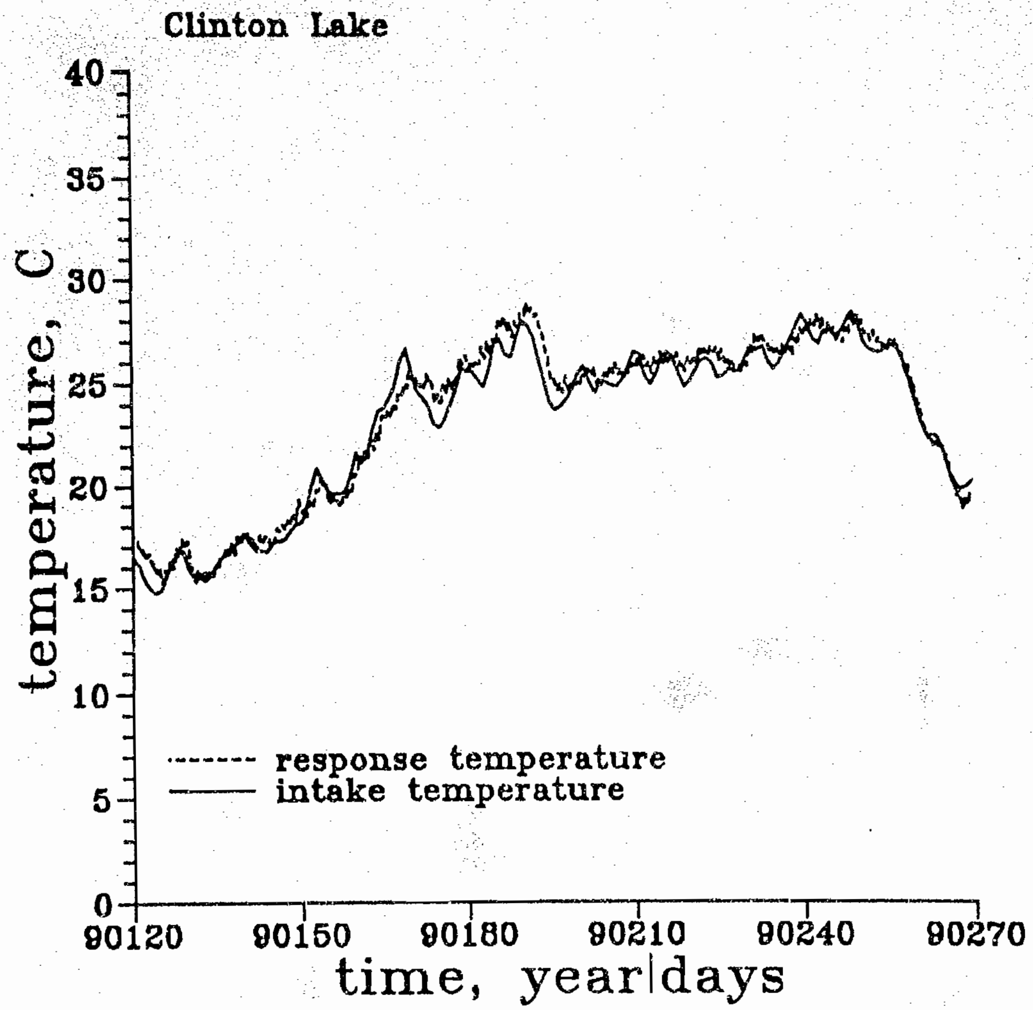

Exhibit 12 (continued).

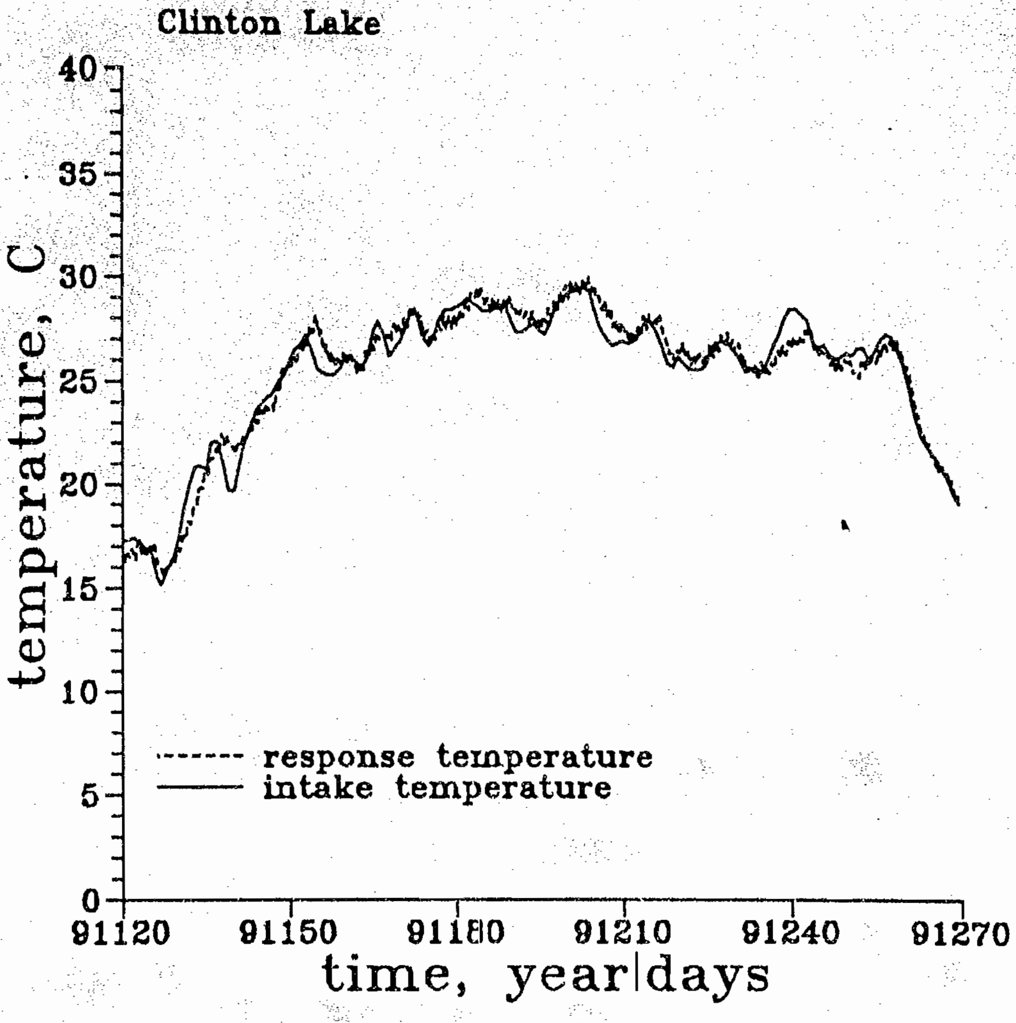

Exhibit 13. June through August (Summer) excess temperatures for 1989, 1990 and 1991, presented as the mean excess temperatures throughout the lake, their standard deviation due to time-varying CPS operations and meteorological conditions, and the maximum value attained at any point in Clinton Lake.

1989

Mean excess temperature (°C)

	Segment Number																	
Layer	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	21	
5	.1	.1	.2	.2	.3	.3	.4	.5	.7	1.0	1.3	1.8	2.5	3.8	1.9	.9	.0	5
6	.1	.1	.2	.3	.3	.4	.5	.6	.7	1.0	1.3	1.8	2.4	3.0	1.8	.8	.1	6
7	.1	.1	.2	.3	.3	.4	.5	.6	.7	.9	1.2	1.5	2.1	2.4	1.6			7
8	.1	.1	.2	.3	.3	.4	.5	.5	.6	.8	1.0	1.4	1.8					8
9		.1	.2	.3	.3	.4	.4	.5	.6	.7	.9							9
10			.2	.3	.3	.4	.4		.5	.6								10
11				.3	.3	.3	.4											11
12					.3	.3												12
13						.3												13

Standard deviation of excess temperature (°C)

	Segment Number																	
Layer	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	21	
5	.07	.10	.16	.20	.24	.31	.39	.47	.60	.81	1.14	1.57	2.15	3.32	1.79	.91	.07	5
6	.08	.11	.17	.23	.27	.34	.41	.49	.60	.79	1.11	1.51	2.01	2.61	1.61	.79	.07	6
7	.09	.11	.18	.24	.28	.33	.39	.46	.55	.68	.94	1.30	1.77	2.11	1.43			7
8	.10	.11	.17	.24	.28	.32	.37	.43	.50	.61	.83	1.15	1.57					8
9		.12	.17	.23	.27	.31	.34	.39	.46	.55	.71							9
10			.16	.22	.26	.29	.32		.42	.50								10
11				.21	.25	.28	.30											11
12					.24	.26												12
13						.25												13

Maximum excess temperature (°C)

	Segment Number																	
Layer	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	21	
5	.3	.4	.6	.8	1.1	1.2	1.4	1.7	2.1	2.8	3.6	4.7	6.2	8.9	5.7	3.4	.4	5
6	.3	.4	.7	.9	1.1	1.3	1.5	1.7	2.1	2.7	3.4	4.3	5.8	7.5	4.8	2.8	.3	6
7	.3	.4	.7	.9	1.1	1.2	1.4	1.6	1.9	2.4	3.3	4.2	5.4	6.4	4.5			7
8	.4	.4	.7	.9	1.1	1.2	1.4	1.6	1.8	2.2	3.2	4.0	4.9					8
9		.5	.7	.9	1.1	1.2	1.3	1.5	1.7	2.1	2.9							9
10			.6	.9	1.0	1.2	1.3		1.6	2.0								10
11				.8	1.0	1.1	1.2											11
12					.9	1.0												12
13						.9												13

Exhibit 13 (continued).

1990

Mean excess temperature (°C)

	Segment Number																	
Layer	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	21	
5	.2	.4	.5	.6	.7	.8	.9	1.1	1.3	1.8	2.3	3.0	4.1	6.2	3.5	1.8	.1	5
6	.3	.4	.5	.7	.8	.9	1.0	1.2	1.4	1.8	2.4	3.1	4.0	5.0	3.2	1.6	.1	6
7	.3	.4	.6	.7	.8	.9	1.0	1.2	1.4	1.7	2.2	2.8	3.7	4.1	2.9			7
8	.3	.4	.5	.7	.8	.9	1.0	1.1	1.3	1.6	2.0	2.5	3.3					8
9		.4	.5	.7	.8	.8	.9	1.1	1.3	1.5	1.8							9
10			.5	.7	.7	.8	.9		1.2	1.4								10
11				.6	.7	.8	.9											11
12					.7	.8												12
13						.7												13

Standard deviation of excess temperature (°C)

	Segment Number																	
Layer	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	21	
5	.15	.18	.23	.26	.30	.35	.39	.46	.60	.83	1.10	1.46	1.95	2.89	1.70	1.00	.18	5
6	.14	.18	.24	.27	.31	.37	.41	.48	.62	.83	1.08	1.42	1.84	2.32	1.48	.81	.16	6
7	.15	.17	.23	.27	.31	.36	.41	.47	.60	.78	.98	1.29	1.69	1.92	1.31			7
8	.16	.18	.22	.26	.30	.35	.40	.46	.58	.75	.91	1.17	1.53					8
9		.19	.22	.26	.29	.34	.39	.45	.56	.71	.85							9
10			.23	.25	.28	.33	.38		.53	.67								10
11				.24	.27	.31	.37											11
12					.26	.30												12
13						.29												13

Maximum excess temperature (°C)

	Segment Number																	
Layer	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	21	
5	.7	.9	1.0	1.2	1.3	1.6	1.6	2.0	2.6	3.5	4.3	5.4	6.6	9.2	6.1	4.4	1.3	5
6	.7	.8	1.0	1.2	1.4	1.7	1.7	2.0	2.5	3.4	4.1	5.3	6.4	7.8	4.8	3.1	1.0	6
7	.7	.8	1.0	1.2	1.4	1.8	1.8	1.9	2.4	3.3	3.7	4.9	6.1	6.7	4.8			7
8	.7	.8	1.0	1.1	1.3	1.8	1.9	2.0	2.3	3.0	3.6	4.6	5.8					8
9		.8	1.0	1.1	1.2	1.8	2.0	2.2	2.3	2.9	3.7							9
10			1.0	1.1	1.2	1.8	2.1		2.5	3.0								10
11				1.1	1.1	1.7	2.1											11
12					1.1	1.6												12
13						1.5												13

Exhibit 13 (continued).

1991

Mean excess temperature (°C)

	Segment Number																	
Layer	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	21	
5	.2	.4	.5	.7	.8	.9	1.1	1.4	1.7	2.2	2.9	3.9	5.2	8.1	4.5	2.2	.2	5
6	.3	.4	.6	.8	.9	1.0	1.2	1.5	1.8	2.2	3.0	3.9	5.0	6.5	4.1	2.1	.2	6
7	.3	.4	.6	.8	.9	1.1	1.2	1.5	1.7	2.0	2.7	3.5	4.5	5.3	3.7			7
8	.3	.4	.6	.8	.9	1.0	1.2	1.4	1.6	1.9	2.4	3.1	4.1					8
9		.4	.6	.8	.9	1.0	1.2	1.3	1.5	1.7	2.1							9
10			.6	.8	.9	1.0	1.1		1.4	1.6								10
11				.7	.8	.9	1.1											11
12					.8	.9												12
13						.9												13

Standard deviation of excess temperature (°C)

	Segment Number																	
Layer	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	21	
5	.09	.10	.11	.12	.16	.18	.24	.27	.35	.45	.50	.63	.79	.54	.76	.65	.13	5
6	.08	.08	.12	.12	.16	.18	.21	.23	.28	.36	.35	.44	.56	.60	.51	.39	.12	6
7	.09	.08	.12	.13	.15	.18	.18	.19	.24	.31	.36	.49	.56	.59	.40			7
8	.12	.09	.12	.14	.15	.18	.17	.18	.24	.30	.40	.52	.56					8
9		.11	.13	.15	.15	.18	.16	.17	.22	.29	.39							9
10			.15	.16	.16	.18	.16		.21	.28								10
11				.17	.17	.18	.16											11
12					.17	.18												12
13						.18												13

Maximum excess temperature (°C)

	Segment Number																	
Layer	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	21	
5	.5	.6	.8	1.0	1.2	1.4	1.7	2.1	2.5	3.1	4.0	5.1	6.6	9.0	5.8	4.0	.9	5
6	.5	.6	.9	1.1	1.2	1.4	1.8	2.2	2.5	3.0	3.8	4.8	6.0	7.6	5.2	2.9	.7	6
7	.6	.6	1.0	1.1	1.3	1.4	1.8	2.0	2.3	2.9	3.5	4.6	5.5	6.6	4.5			7
8	.7	.7	1.0	1.2	1.3	1.4	1.7	1.9	2.2	2.7	3.5	4.4	5.1					8
9		.9	1.1	1.2	1.3	1.4	1.7	1.8	2.0	2.4	3.4							9
10			1.1	1.3	1.3	1.4	1.6		1.9	2.3								10
11				1.3	1.3	1.4	1.5											11
12					1.3	1.4												12
13						1.3												13

Exhibit 14. June through August (Summer) excess temperature means, standard deviations and maxima by lake segments and elevations for Case 1 conditions (normal lake elevation and 1410 cfs pumping). Layer elevations and landmark locations are shown in Exhibit 2.

Discharge excess temperature is 11.1°C
Mixing zone excess temperature is 8.8°C

Mean excess temperature (°C)

	Segment Number																
Layer	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	21
5	.4	.5	.8	1.0	1.1	1.3	1.5	1.8	2.1	2.7	3.4	4.5	5.9	8.8	5.1	2.7	.3
6	.4	.5	.8	1.0	1.1	1.2	1.5	1.7	2.1	2.7	3.5	4.6	5.9	7.8	4.8	2.5	.2
7	.4	.6	.8	1.0	1.1	1.3	1.5	1.8	2.1	2.6	3.4	4.4	5.6	6.6	4.5		
8	.4	.6	.8	1.0	1.2	1.3	1.5	1.8	2.0	2.4	3.0	3.9	5.2				
9		.6	.8	1.0	1.1	1.3	1.5	1.7	1.9	2.2	2.7						
10			.8	1.0	1.1	1.2	1.4		1.8	2.1							
11				1.0	1.1	1.2	1.4										
12					1.1	1.2											
13						1.1											

Standard deviation of excess temperature (°C)

	Segment Number																
Layer	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	21
5	.11	.12	.14	.14	.17	.19	.22	.30	.40	.49	.58	.69	.78	.53	.92	.76	.22
6	.15	.17	.19	.24	.26	.29	.34	.38	.42	.42	.43	.49	.53	.82	.47	.40	.21
7	.18	.18	.19	.24	.25	.26	.30	.32	.33	.33	.36	.48	.58	.78	.39		
8	.22	.21	.21	.25	.25	.25	.28	.29	.31	.34	.40	.51	.59				
9		.24	.23	.25	.25	.26	.27	.28	.30	.34	.41						
10			.25	.27	.26	.26	.26		.29	.33							
11				.28	.27	.26	.26										
12					.28	.27											
13						.27											

Maximum excess temperature (°C)

	Segment Number																
Layer	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	21
5	.7	.8	1.1	1.4	1.5	1.8	2.2	2.6	3.1	3.8	4.8	6.0	7.4	9.8	6.4	4.5	1.8
6	.9	1.0	1.2	1.6	1.6	1.9	2.3	2.7	3.1	3.7	4.7	5.9	7.1	9.2	6.0	3.6	1.3
7	1.1	1.1	1.2	1.7	1.7	1.9	2.3	2.5	2.9	3.5	4.4	5.5	6.8	8.1	5.5		
8	1.3	1.3	1.4	1.7	1.7	1.9	2.1	2.4	2.8	3.3	4.2	4.9	6.3				
9		1.4	1.5	1.7	1.8	1.8	2.0	2.3	2.6	3.5	4.2						
10			1.6	1.8	1.8	1.9	2.0		2.7	3.4							
11				1.8	1.8	1.8	1.9										
12					1.8	1.8											
13						1.8											

Exhibit 15. Maximum response temperatures (C) for a given duration for each year 1955 to 1988 with means and standard deviations for each duration.

	Duration, Days							
Year	1	5	10	20	30	40	60	80
55	31.4	30.9	30.0	28.8	28.3	27.8	26.0	21.3
56	28.9	28.4	28.0	27.7	27.5	27.1	26.2	24.7
57	29.8	29.4	29.0	28.5	28.0	27.5	25.7	23.5
58	29.8	29.0	28.3	26.9	26.2	25.8	24.5	22.7
59	29.2	28.4	28.1	27.3	26.7	26.4	26.0	24.7
60	29.4	29.0	28.8	28.0	27.2	26.7	24.6	22.2
61	29.9	29.6	29.2	28.3	27.3	26.5	25.1	23.1
62	28.3	27.9	27.6	27.1	26.5	25.9	25.2	23.5
63	29.0	28.8	28.6	28.1	27.1	26.3	25.2	24.2
64	29.4	29.0	28.6	28.1	26.9	25.9	24.1	23.1
65	28.4	27.9	27.5	27.0	26.4	26.0	25.3	23.6
66	30.0	29.3	28.9	27.5	26.8	26.4	25.0	21.7
67	27.9	27.4	27.1	26.0	25.5	25.2	24.6	22.7
68	28.4	28.0	27.7	27.3	26.8	26.2	25.1	23.9
69	29.0	28.8	28.6	27.1	26.7	26.5	25.6	20.7
70	27.7	26.9	26.5	26.2	25.9	25.4	24.4	23.1
71	28.3	27.3	26.7	26.2	25.8	25.4	24.7	22.8
72	28.7	28.2	27.6	26.5	26.0	25.2	23.8	23.1
73	27.9	27.7	27.5	27.1	26.7	26.4	25.7	24.7
74	29.2	28.7	28.4	27.6	26.2	25.7	24.2	22.0
75	29.8	29.0	28.7	28.1	27.6	27.3	26.7	22.9
76	27.9	27.6	27.4	26.8	25.9	25.4	24.7	24.0
77	29.9	29.4	28.9	27.8	26.5	26.1	25.1	23.6
78	28.3	27.9	27.8	27.3	26.7	26.3	25.7	23.7
79	29.8	28.5	27.4	26.8	26.3	25.7	24.4	23.2
80	31.4	30.9	30.5	29.4	28.8	28.5	27.3	23.8
81	30.2	29.5	28.7	27.2	26.6	26.1	25.3	24.1
82	28.9	28.6	28.4	27.8	26.8	26.4	24.6	23.0
83	30.4	30.0	29.5	29.1	28.7	28.4	27.6	23.0
84	29.3	28.9	28.7	28.0	27.5	27.2	26.2	25.1
85	28.0	27.8	27.5	27.2	26.9	26.5	25.2	22.7
86	30.9	30.7	30.3	28.8	28.0	27.6	26.2	24.7
87	31.5	30.8	30.2	29.1	28.6	28.1	27.0	25.6
88	30.4	30.1	29.9	29.5	29.1	28.5	27.7	26.3
Mean	29.3	28.8	28.4	27.7	27.0	26.5	25.4	23.4
Stdev	1.05	1.04	1.01	.90	.91	.93	.98	1.15

Exhibit 16. 1-, 5-, 7-, 10-, 20-, and 30-day waterbody response temperatures (C) for 1989, 1990 and 1991. These are the temperatures that hypothetically would have been experienced at the Station intake for the noted durations in the absence of operations at the Clinton Power Station.

year	duration in days that a given temperature is exceeded					
	1	5	7	10	20	30
1989	29.2	28.6	28.0	27.8	27.3	26.9
1990	28.3	27.9	27.8	27.7	27.3	26.8
1991	29.5	29.2	29.1	28.9	28.4	28.0

Exhibit 17. Table of response (intake) temperatures (C) as a function of annual frequency and duration computed from Springfield, Illinois climatological data for 1955 to 1988.

Return Period	Duration, Days					
Years	1	5	7	10	20	30
2	30.1	29.6	29.4	29.1	28.4	27.7
5	31.0	30.5	30.3	30.1	29.1	28.5
10	31.6	31.1	30.9	30.6	29.7	29.0
20	32.2	31.7	31.5	31.2	30.2	29.5
30	32.6	32.0	31.8	31.5	30.5	29.8

~~**Exhibit 18.** Days exceeding 99 F at the discharge flume for Case 1 and Case 2 for normal year, one year in five, one year in ten, one year in twenty and one year in thirty.~~

~~Return period, years~~	~~Case 1~~	~~Case 2~~
~~normal~~	~~60~~	~~63~~
~~5~~	~~70~~	~~74~~
~~10~~	~~78~~	~~>90~~
~~20~~	~~>90~~	~~>90~~
~~30~~	~~>90~~	~~>90~~

See Exhibit 4A.

Exhibit 19. Maximum observed flume discharge temperatures for each of the three study years.

year	max flume temp, C	date	reactor power, %	intake temp, C	condenser temp rise, °C	Station temp rise, °C
1989	40.0	7/11/89	99	28.4	14.0	11.6
1990	37.8	8/28/90	83	28.3	10.7	9.6
1991	39.7	7/19/91	96	29.2	12.2	10.5

See Exhibit 43

Exhibit 20. Mean of the daily average response temperature in the month and year.

year	month 1	2	3	4	5	6	7	8	9	10	11	12	Mean
55	.8	.8	5.5	12.9	19.9	22.0	28.2	28.6	22.9	15.8	5.8	.3	13.6
56	.1	.6	4.8	9.9	18.1	25.6	26.9	26.8	22.1	16.8	8.7	.7	13.4
57	.2	1.1	4.5	9.7	18.8	23.7	27.3	28.3	23.3	15.1	6.1	1.7	13.3
58	.1	.6	2.7	10.4	17.3	22.4	25.6	27.4	23.0	16.6	10.0	.6	13.1
59	.1	.5	4.2	11.1	19.6	24.9	26.4	27.5	23.4	15.4	4.9	1.0	13.2
60	.9	.1	.7	11.5	16.3	22.4	26.9	27.5	25.6	17.1	7.5	1.3	13.2
61	.1	1.6	6.1	8.7	16.0	23.0	26.2	28.4	24.7	15.4	8.1	1.5	13.3
62	.1	.4	2.0	9.9	21.6	24.4	27.1	25.5	22.1	16.9	6.8	1.2	13.2
63	.1	.1	4.5	13.0	17.7	24.3	27.2	26.7	22.3	18.1	9.5	1.2	13.7
64	.6	.3	3.8	10.4	20.2	24.1	27.0	25.2	22.5	13.6	9.8	.4	13.2
65	1.0	1.0	1.2	10.3	20.5	23.9	26.8	25.9	22.4	15.3	9.2	3.4	13.4
66	.9	1.1	4.7	9.4	16.6	22.9	28.2	25.6	21.5	13.3	7.4	1.7	12.8
67	.8	.4	4.0	14.2	15.6	23.1	25.4	25.5	20.9	13.9	5.4	1.1	12.5
68	.4	.9	3.3	11.8	16.3	23.6	26.6	26.4	21.1	15.2	6.6	.9	12.8
69	.1	.3	2.3	11.4	17.6	21.3	27.7	26.4	22.7	15.0	5.6	.5	12.6
70	.1	.4	2.9	10.0	20.4	23.0	25.5	26.0	23.5	15.5	6.9	2.4	13.0
71	.0	1.3	3.7	10.6	15.3	24.2	25.8	24.5	23.5	18.1	9.2	2.8	13.2
72	.5	.3	5.1	10.3	18.5	23.4	25.5	26.0	23.4	14.4	5.7	.3	12.8
73	.8	.9	6.9	10.7	16.6	24.1	26.9	26.4	23.4	18.7	9.3	2.4	13.9
74	.5	1.0	6.5	11.3	17.8	22.3	27.6	25.4	20.9	14.1	9.2	.8	13.1
75	.4	.4	2.2	8.6	19.6	24.3	27.8	27.6	21.8	15.7	9.9	2.2	13.4
76	.1	3.2	8.3	14.0	16.7	23.9	26.8	25.0	21.4	13.6	4.1	.1	13.1
77	.0	1.3	7.2	14.6	21.3	23.5	28.2	25.8	23.4	14.3	9.0	.5	14.1
78	.0	.0	1.4	11.8	16.1	24.2	27.3	26.1	24.8	14.4	8.5	.6	12.9
79	.0	.1	3.4	10.5	17.6	23.3	25.5	27.0	23.7	15.2	8.5	2.0	13.1
80	.6	.1	2.7	10.2	18.4	24.4	29.4	28.5	24.7	16.3	7.2	1.9	13.7
81	.3	1.7	5.9	15.3	16.3	24.2	27.9	25.6	22.1	14.2	9.1	1.5	13.7
82	.0	.6	4.1	10.0	19.7	23.3	27.1	26.5	22.1	15.6	7.9	4.4	13.4
83	.4	1.3	5.3	8.1	16.6	23.7	28.8	28.5	23.4	15.4	8.7	.8	13.4
84	.0	2.3	1.4	8.9	17.5	25.0	26.9	27.8	22.0	16.6	8.3	2.6	13.3
85	.5	.9	6.1	13.5	19.9	23.3	27.2	26.2	22.8	15.4	9.0	.3	13.8
86	.4	.6	4.5	13.9	20.1	25.7	29.2	26.7	22.5	17.1	7.3	.9	14.1
87	.1	.9	5.6	11.6	21.3	26.7	28.1	28.4	23.1	13.0	8.5	2.3	14.1
88	.3	.6	4.6	12.8	19.9	27.1	28.7	28.7	22.5	14.7	6.8	1.4	14.0
89	.7	.4	3.9	11.5	17.4	24.0	27.0	26.9	22.7	15.3	8.0	.6	13.2
90	1.5	3.1	7.4	11.1	17.0	23.0	26.3	26.5	24.1	14.9	10.0	3.3	14.0
91	.0	1.1	6.2	13.9	20.5	27.1	28.5	26.6	23.8	15.3			16.3
Mean	.4	.9	4.3	11.3	18.3	23.9	27.2	26.7	22.9	15.4	7.8	1.4	13.4
Stdev	.4	.7	1.8	1.8	1.8	1.3	1.0	1.1	1.1	1.3	1.6	1.0	.6
Max	1.5	3.2	8.3	15.3	21.6	27.1	29.4	28.7	25.6	18.7	10.0	4.4	16.3
Min	.0	.0	.7	8.1	15.3	21.3	25.4	24.5	20.9	13.0	4.1	.1	12.5

Exhibit 21. April through September mean monthly response temperatures for the normal year, the 1 in 10 year, and the 1 in 30 year.

	April	May	June	July	August	September
normal year	11.3	18.3	23.9	27.2	26.7	22.9
1 year in 10	14.0	20.7	25.9	28.7	28.5	24.7
1 year in 30	15.0	21.5	27.1	29.3	28.7	25.3

Appendix A.

Exhibit D

Probabilistic Hydrothermal Modeling Study of Clinton Lake

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February 1989

Document No. 89-15-R

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1.0 Executive Summary

Clinton Lake has been analyzed and modeled for 1988 realtime plant operational conditions and meteorological conditions. The model has been successfully verified for these conditions and used to determine the longitudinal and vertical distribution of temperatures throughout the lake for two cases of full load operations at different lake operating levels.

The model results have been combined with a statistical analysis of 34 years of meteorological data to determine the temperatures that would occur at certain specified annual frequencies for different daily durations. These results can be used to evaluate the effects of different thermal limitations relative to plant operations and to perform comparative fisheries thermal tolerance analyses.

2.0 Introduction

Hydrothermal modeling studies were conducted on Clinton Lake to predict temperatures throughout the lake at varying meteorological and plant operating conditions. These temperature predictions are used to establish thermal limits on the lake that will ensure the power station can operate as designed without adverse impact on biological conditions in the lake.

This study consisted of temperature predictions by the GLVHT model, verification of the model with 1988 observed temperatures, and a statistical analysis of 34 years of meteorological data to determine the probability of severe meteorological conditions.

Specifically, the hydrothermal modeling studies of Clinton Lake and Clinton Power Station operations are designed to: (a) verify the generalized, longitudinal-vertical and hydrodynamics and transport (GLVHT) model for the summer of 1988 realtime data and operations; (b) perform a statistical analysis of meteorological data for 34 years of record extending from 1955 through 1988; and, (c) to combine the results of these two analyses for case studies of plant operations over the years. The GLVHT modeling for 1988 is discussed in report section 3.0, the statistical analysis is discussed in report section 4.0, and the combined case analyses are discussed in section 5.0

Previous hydrothermal analyses of Clinton Lake were carried out using the LARM (laterally averaged reservoir model) which is a predecessor to the GLVHT model. Different LARM simulations, designated by IPC as LARM 1, LARM 2 and LARM 3, were carried out over the years as input data improved on expected operating lake elevations, powerplant heat rejection rates, and powerplant condenser cooling water flow rates. Results of the previous LARM simulations are presented in Appendix A of this report. The significant differences between the present GLVHT modeling and the previous LARM modeling are discussed in Section 3.0 of this report.

3.0 Description and Verification of the Model

The GLVHT model design, development and examples of past applications are presented in Buchak and Edinger (1984). It is a continuously maintained model that is supported by routines to perform different types of analyses of model output.

The GLVHT model is based on the longitudinal and vertical, laterally averaged equations of momentum, continuity and constituent transport. The formulation includes the vertically varying longitudinal momentum balance, the vertical momentum in the form of the hydrostatic approximation, local continuity, the free-water surface condition based on vertically integrated continuity, and longitudinal and vertical transport of any number of constituents. Constituents that determine density such as temperature and salinity are related to momentum through an equation of state. The vertically varying longitudinal momentum includes local acceleration of horizontal velocity, horizontal and vertical advective momentum transfer, the horizontal pressure gradient, and horizontal and vertical shear stress. Included in the latter are the surface wind stress and the bottom stress due to friction. The horizontal pressure gradient includes the barotropic surface slope and the baroclinic vertical integral of the horizontal density gradient which is the dominant term of density induced convective circulation.

The time-varying solution technique of the model is based on an implicit scheme that results from the simultaneous solution of the horizontal momentum equation and the free-water surface equation of vertically integrated continuity. This technique results in the surface long wave equation that is solved on each time step to give the water surface profiles, from which the vertical pressure distribution can be determined. The horizontal momentum is then computed, followed by internal continuity and then constituent transport. Upwind differencing is used for the advective processes in the momentum and constituent transport balances. Vertical turbulent transfer of momentum and constituents is determined from the vertical shear of horizontal velocity and a density gradient dependent Richardson number function.

Structural differences between the previous LARM model and the GLVHT model are given in Table 4-1 of Buchak and Edinger (1984). Improvements over the previous LARM simulations for Clinton Lake include:

a. The use of realtime operating data as input.

b. The use of a term by term heat budget for evaluating surface heat exchange from hourly meteorological data.

c. The ability to compute excess temperatures throughout the lake due to powerplant operations.

d. The inclusion of lake elevation changes due to natural and forced evaporation.

e. The inclusion of separate flows and heat rejection rates for the condenser cooling water pumping and the service water flows.

3.1 Model Setup and Data Sources

The GLVHT model was set up for the same lake geometry as used in the previous LARM simulations. The longitudinal lake segmentation and numbering is shown in Figure 3-1. The longitudinal segments are each 1518.5 m long. Also shown in Figure 3-1 is the location of the continuous recording Data Sondes used for model verification.

The geometry required in the model is the laterally averaged widths of the lake over the vertical in each longitudinal segment. These widths are shown in Table 3-1. The vertical thickness of the layers is 1.1 m with variable surface layer thickness. The relationship between lake elevation and model layers is given in Table 3-1.

The time series input data required to run the model over realtime periods are the meteorological data of cloud cover, air temperature, dewpoint temperature, windspeed and wind direction; the plant operating data of heat rejection rates, condenser cooling water pumping and service water pumping; and, the hydrological data of tributary surface inflows and temperatures and groundwater inflows and temperature.

The 1988 meteorological data were obtained hourly from the National Climatic Data Center for Springfield, Illinois. The 1988 plant operating data for the verification simulations were provided as daily average values of power factors, condenser pumping rates and service water pumping rates by IPC personnel. The heat rejection rate was established as 6.713 x 10^9 Btu/Hr at 100% power level and assumed to be proportional to the power level. Operational input data for the

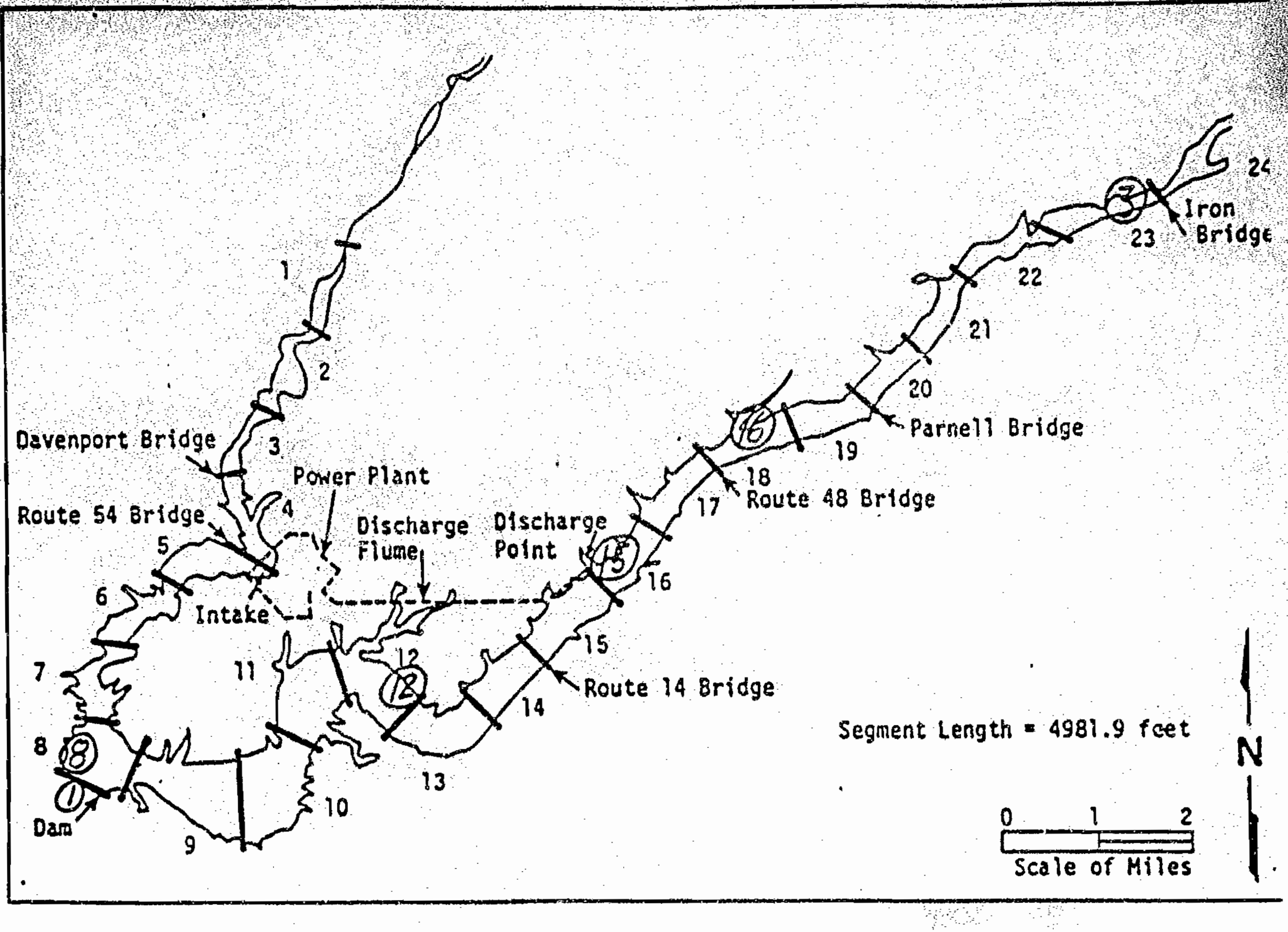

Figure 3-1. Map of Clinton Lake segments with Data Sonde site locations circled (six locations -- Site 3 in segment 23, Site 16 in segment 18, Site 15 in segment 16, Site 12 in segment 12, Site 8 in segment 8, Site 1 downstream of segment 8).

Table 3-1. GLVHT finite difference grid with Clinton Lake widths in meters shown for ea segment and layer. Segment locations are shown in Figure 3-1. Elevations at the top of ea layer are also shown. Normal pool elevation is 210.31 m (690 ft), with the water surfa in layer 5.

Layer	Segment Number 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
2	0.	335.	377.	467.	580.	652.	709.	821.	972.	1074.	1075.	1016.	919.	789.	697.	661.	638.
3	0.	303.	353.	450.	567.	641.	699.	810.	957.	1051.	1043.	977.	883.	761.	672.	628.	591.
4	0.	256.	319.	428.	550.	627.	686.	797.	941.	1028.	1005.	928.	836.	726.	644.	592.	540.
5	0.	151.	234.	367.	511.	597.	660.	773.	913.	985.	932.	828.	733.	640.	564.	490.	401.
6	0.	151.	234.	367.	511.	597.	860.	773.	913.	985.	932.	828.	733.	640.	564.	490.	401.
7	0.	54.	138.	278.	437.	542.	622.	740.	873.	923.	838.	701.	585.	480.	396.	308.	200.
8	0.	24.	81.	188.	331.	457.	574.	708.	826.	854.	747.	584.	449.	338.	256.	184.	100.
9	0.	9.	36.	101.	212.	347.	492.	633.	735.	747.	625.	441.	295.	192.	128.	85.	41.
10	0.	3.	15.	54.	135.	253.	389.	516.	603.	609.	489.	305.	164.	82.	40.	23.	11.
11	0.	0.	8.	31.	85.	176.	298.	416.	486.	475.	358.	192.	78.	27.	0.	0.	0.
12	0.	0.	3.	14.	42.	104.	210.	321.	372.	336.	226.	102.	20.	5.	0.	0.	0.
13	0.	0.	0.	0.	15.	45.	110.	164.	212.	170.	96.	36.	7.	0.	0.	0.	0.
14	0.	0.	0.	0.	3.	11.	31.	59.	69.	47.	20.	5.	0.	0.	0.	0.	0.
15	0.	0.	0.	0.	0.	0.	2.	7.	9.	6.	0.	0.	0.	0.	0.	0.	0.
16	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

Layer	Segment Number 18	19	20	21	22	23	24
1	0.	0.	0.	0.	0.	0.	0.
2	621.	606.	558.	470.	397.	372.	0.
3	565.	548.	500.	413.	341.	316.	0.
4	504.	485.	438.	353.	282.	257.	0.
5	342.	319.	279.	206.	145.	124.	0.
6	342.	319.	279.	206.	145.	124.	0.
7	129.	109.	89.	53.	23.	12.	0
8	45.	31.	25.	13.	4.	0.	0.
9	13.	6.	5.	3.	0.	0.	0.
10	0.	0.	0.	0.	0.	0.	0.
11	0.	0.	0.	0.	0.	0.	0.
12	0.	0.	0.	0.	0.	0.	0.
13	0.	0.	0.	0.	0.	0.	0.
14	0.	0.	0.	0.	0.	0.	0.
15	0.	0.	0.	0.	0.	0.	0.
16	0.	0.	0.	0.	0.	0.	0.

Layer	Thickness m	Elevation m	Area Millions of m2	Cumulative Volume Millions of m3
2	1.1	213.36	22.460	157.371
3	1.1	212.26	21.368	132.843
4	1.1	211.16	20.080	109.140
5	1.1	210.06	16.998	87.052
6	1.1	208.96	16.998	68.354
7	1.1	207.86	12.954	49.656
8	1.1	206.76	10.357	35.407
9	1.1	205.66	7.614	24.014
10	1.1	204.56	5.605	15.419
11	1.1	203.46	3.993	9.254
12	1.1	202.36	2.681	4.861
13	1.1	201.26	1.328	1.912
14	1.1	200.16	.372	.451
15	1.1	199.06	.038	.042

Map References	Segments	Layers
Davenport Bridge	3/4	
Route 54 Bridge	4/5	
Intake	5	7, 8, 9
Dam overflow	8	5
Dam underflow	8	10
Route 14 Bridge	14/15	
Discharge flume	16	
Route 48 Bridge	17/18	
Parnell Bridge	19/20	
Iron Bridge	23/24	

case simulations described in section 5.0 were provided by IPC personnel.

Hydrological surface inflow data were not available for 1988. However, 1988 was an abnormally dry summer that would have produced close to zero inflows. The validity of this assumption is demonstrated by the reproduction of falling lake elevations in the modeling over the summer. Groundwater inflow data for the lake were not available. The lake outflow to lower Salt Creek was assumed constant at 0.14 m^3/s (5 cfs).

3.2 Model Verification for 1988

The summer of 1988 represented the first period of continuous plant operation for which realtime operating data and meteorological data were available for modeling. It also represented a period for which there was complete verification data available for plant intake temperatures, flume discharge temperatures, mixing zone temperatures and at continuous recording Data Sonde stations throughout the lake.

Model verification consists of comparing model output to daily lake elevations and the average daily temperatures at each of the Data Sonde temperature recorders whose locations are shown in Figure 3-1.

Figure 3-2 shows the observed and computed lake levels for June through August 1988 due to natural and forced evaporation as well as downstream releases from the lake. It indicates that the model slightly overestimates lake drawdown by a few centimeters probably due to not including surface and groundwater inflows to the lake. However, the comparison is quite good.

Figure 3-3 shows a comparison of daily computed and observed intake temperatures based on the daily plant operating records. The comparison shows a slight tendency for the model to overestimate intake temperatures during June. This may be attributable to lack of surface and groundwater inflow data.

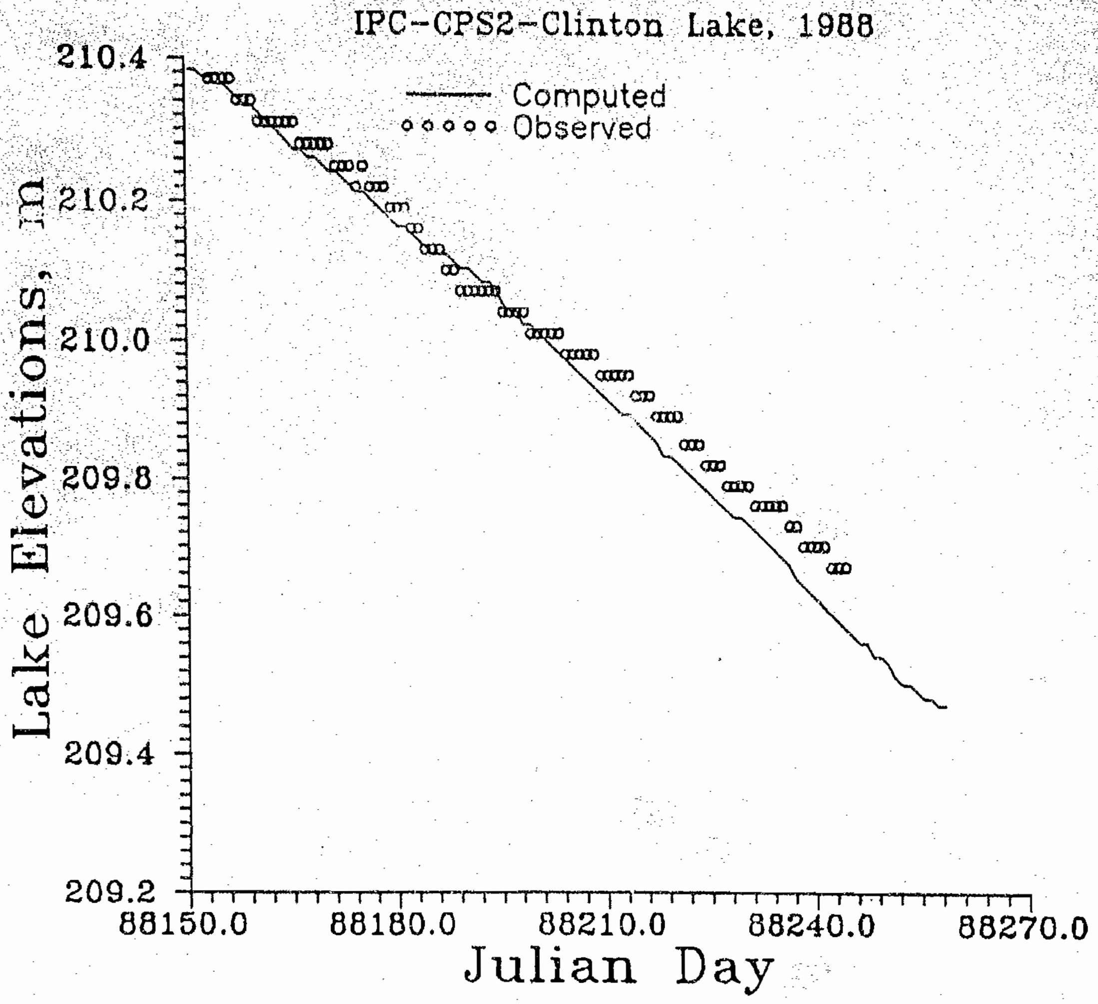

Figure 3-2. Computed and observed lake elevations for 1988 operating conditions.

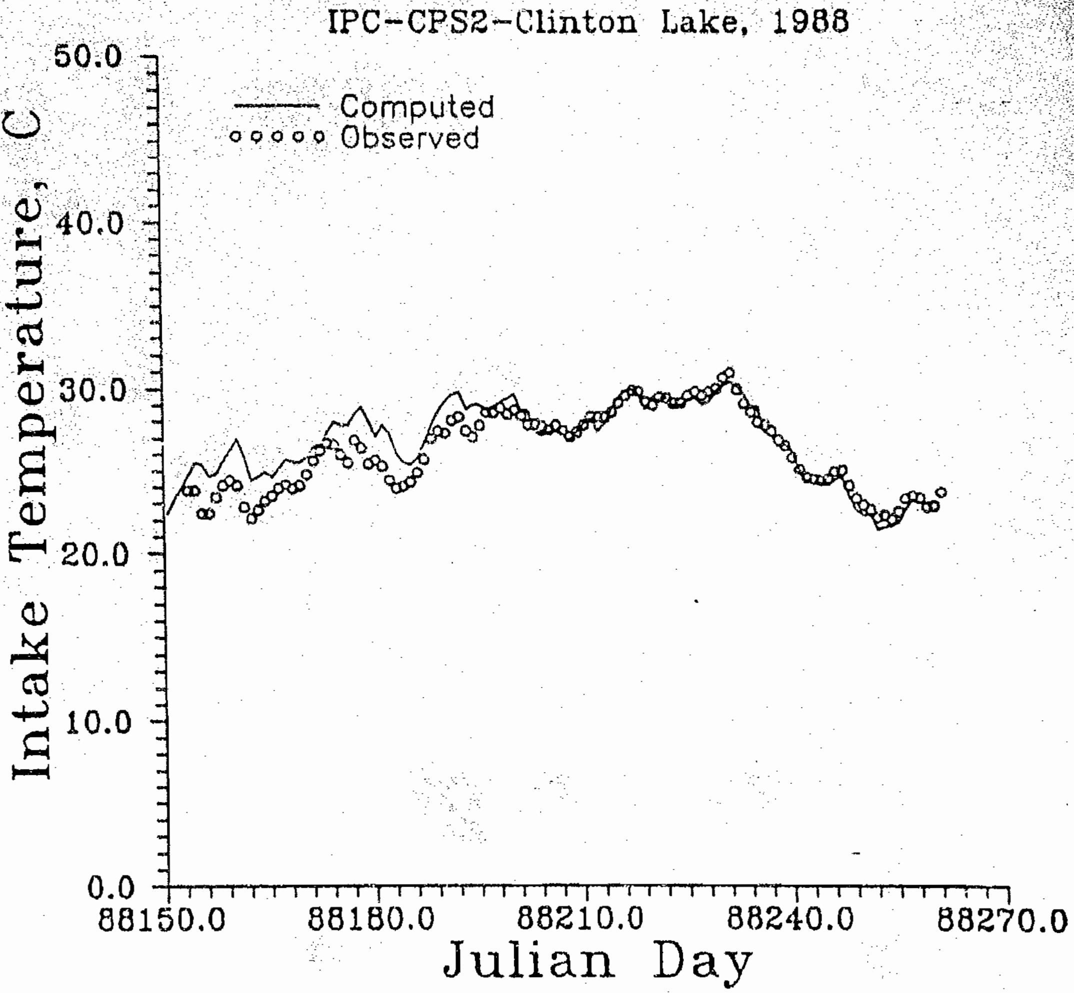

Figure 3-3. Computed and observed intake temperatures for 1988 operating conditions.

Figure 3-4(a) shows a comparison of the daily computed and observed flume temperatures at the second drop structure based on the daily plant operating records. The comparison shows a tendency to overestimate flume temperatures in the early part of the records because of the previously mentioned overestimate of intake temperatures. Figure 3-4(b) shows a comparison of the daily computed and observed difference between flume and intake temperatures, and indicates that the IPC heat loads and pumping rates were accurate.

Figure 3-5(a) shows a comparison of the computed and observed mixing zone temperatures from the Data Sondes placed around the surface of model segment 16. The computed values are taken from the surface cell of model segment 16. The comparison shows that the model at this segment slightly underestimates the spatially averaged temperatures computed from the Data Sondes. Figure 3-5(b) shows a comparison for the difference between mixing zone temperatures and intake temperatures.

Figure 3-6 shows a comparison of the computed and observed outlet temperatures from the lake downstream into Salt Creek. The model overestimates these temperatures as well as the daily temperature amplitudes because of the lack of groundwater inflow data into this deeper portion of the lake.

Figure 3-7 shows a comparison of the computed and observed temperatures at Data Sonde site 3 in the shallow upper end of the Salt Creek arm. These temperatures are highly variable from day to day because of the shallow nature of the arm. However, the comparisons are quite good.

Figure 3-8 shows a comparison of the computed and observed temperatures at Data Sonde site 8 located near the surface of model segment 8 at the dam. The comparisons are quite good.

Figure 3-9 shows a comparison of the computed and observed temperatures at Data Sonde site 12 located on the Salt Creek arm near the surface about half way

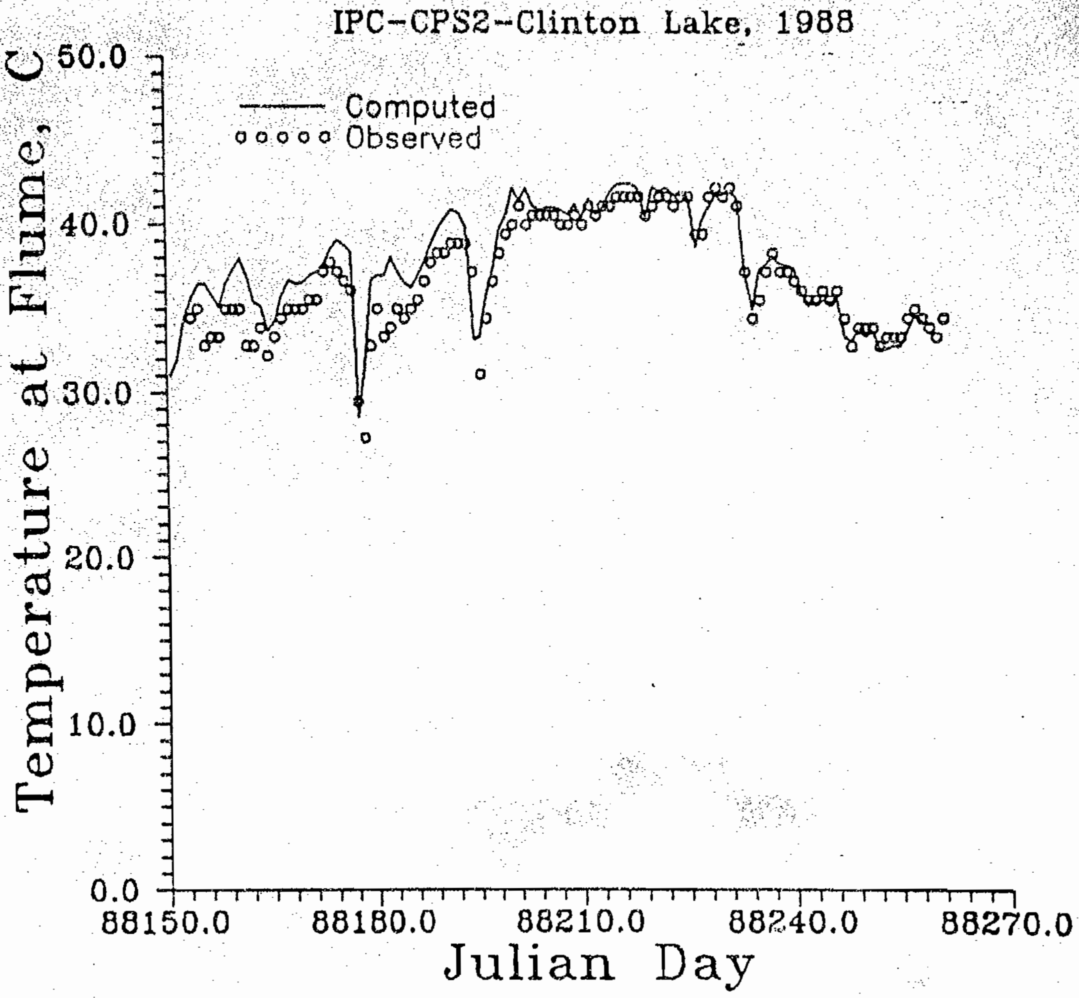

Figure 3-4(a). Computed and observed flume temperatures for 1988 operating conditions.

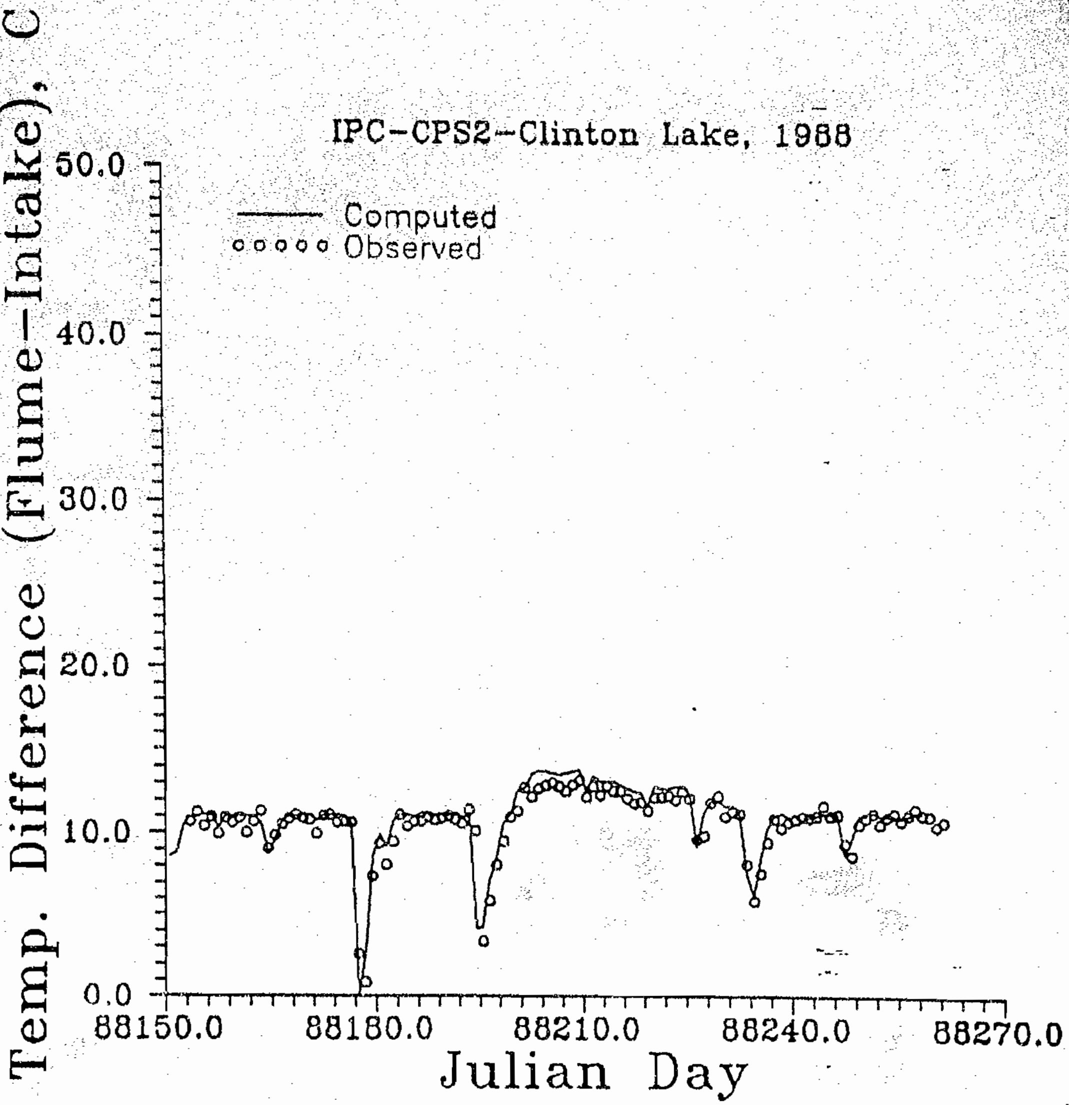

Figure 3-4(b). Computed and observed flume temperature rises for 1988 operating conditions.

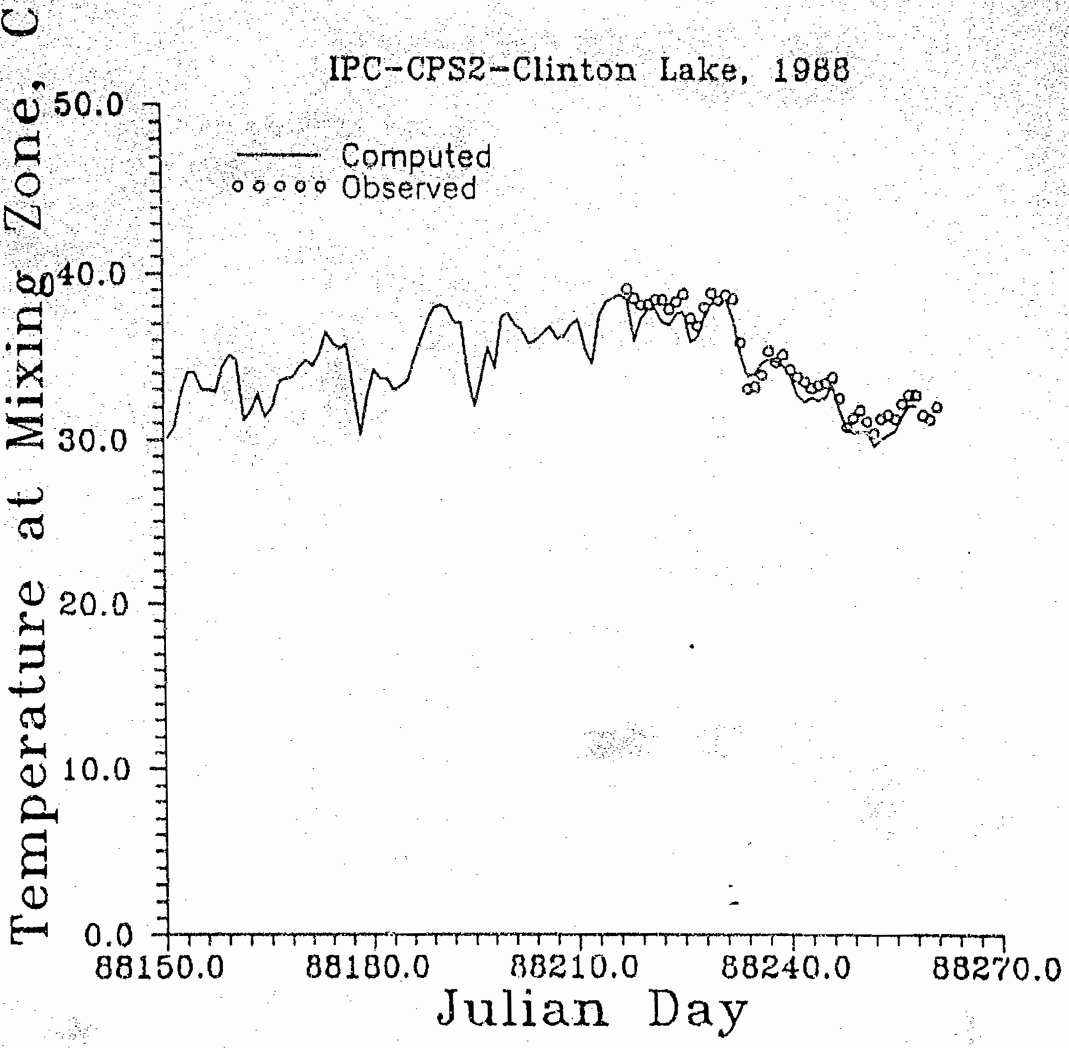

Figure 3-5(a). Computed and observed mixing zone temperatures for 1988 operating conditions.

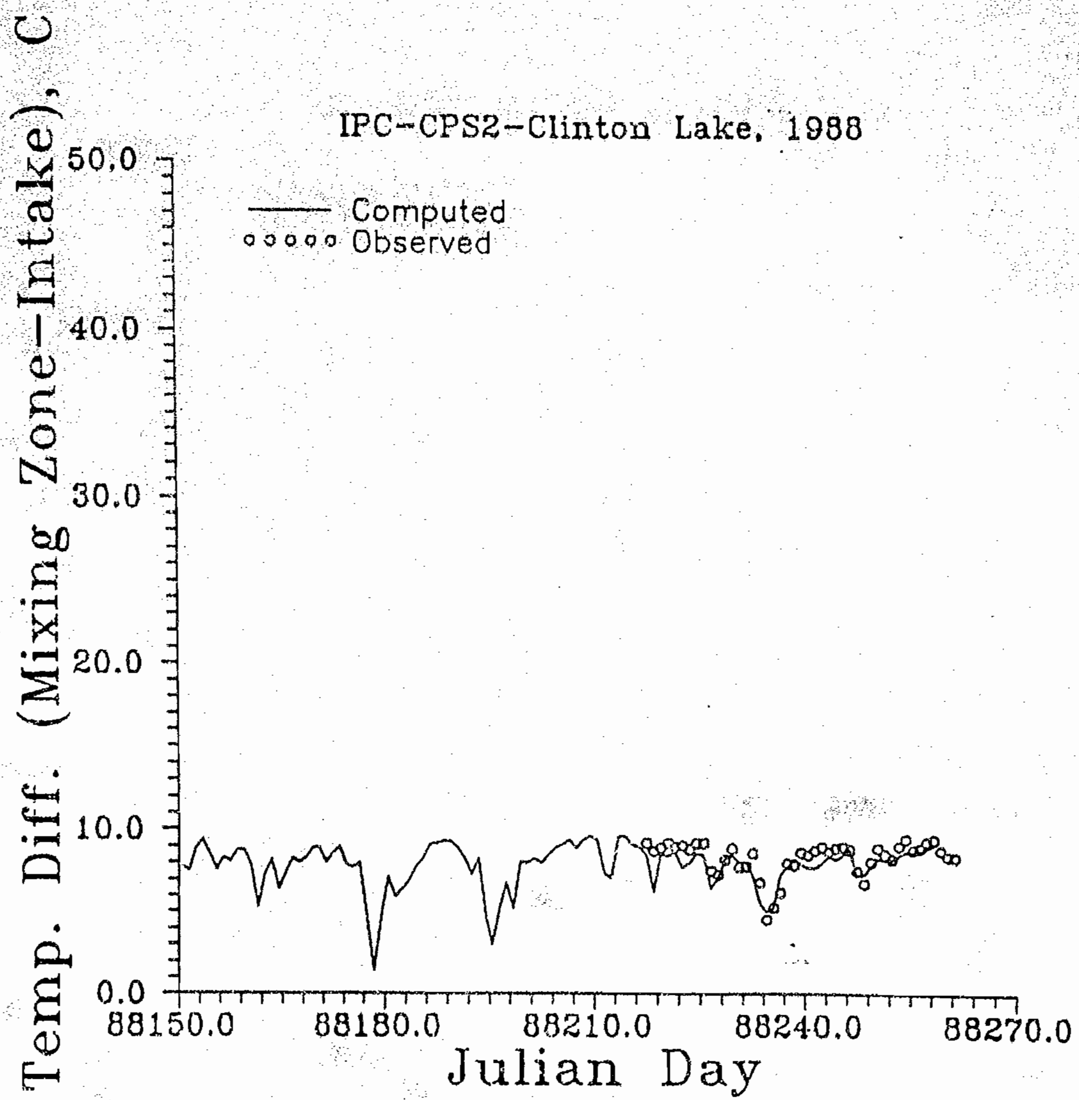

Figure 3-5(b). Computed and observed temperature rises in the mixing zone for 1988 operating conditions.

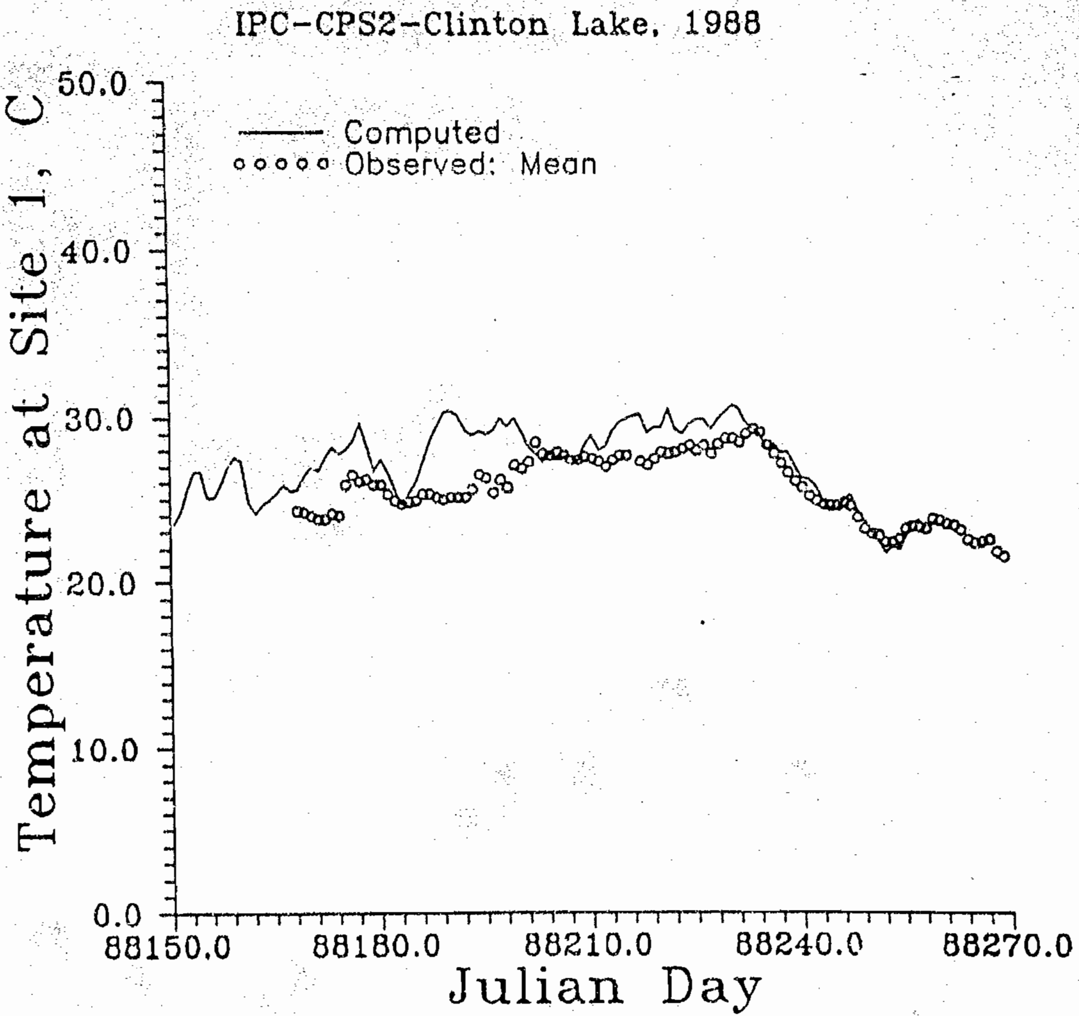

Figure 3-6. Computed and observed Data Sonde Site 1 temperatures for 1988 operating conditions.

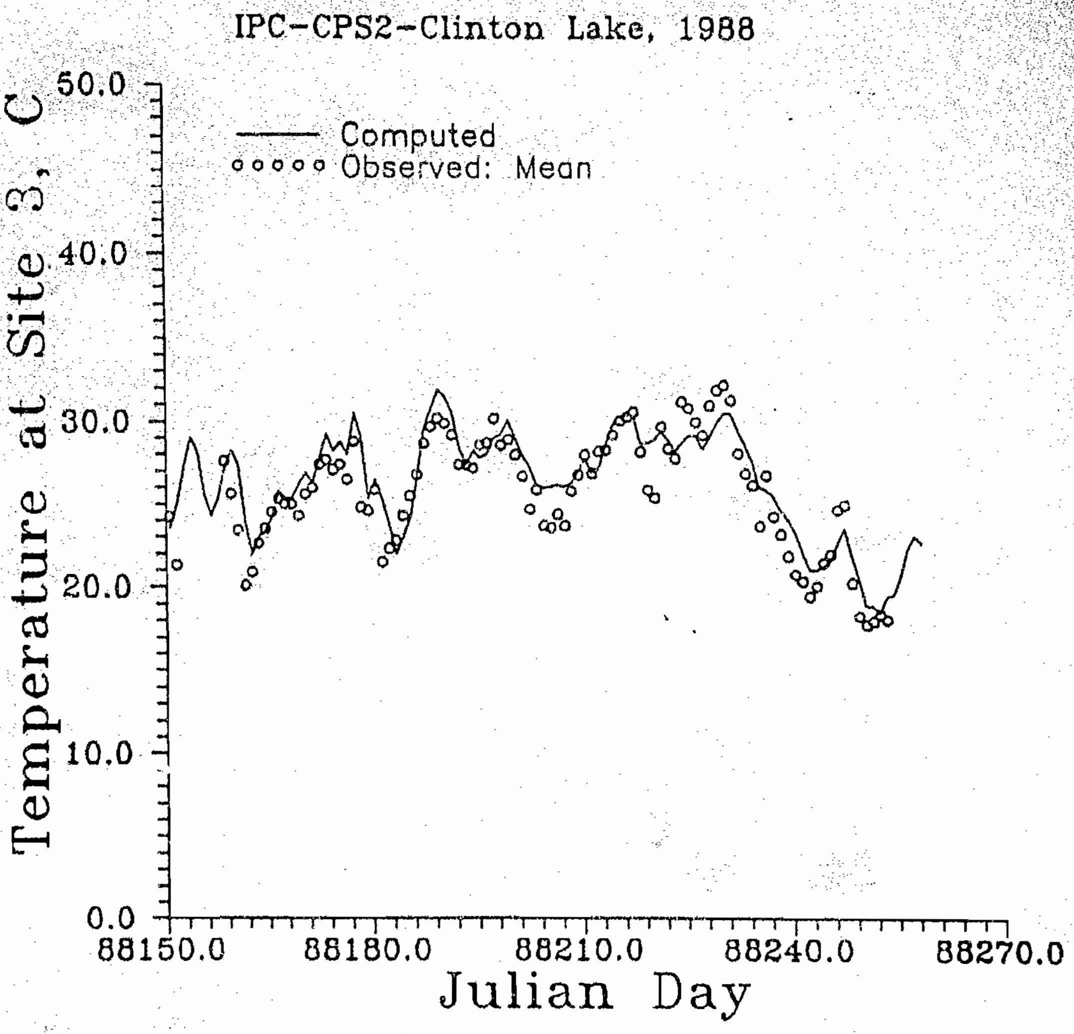

Figure 3-7. Computed and observed Data Sonde Site 3 temperatures for 1988 operating conditions.

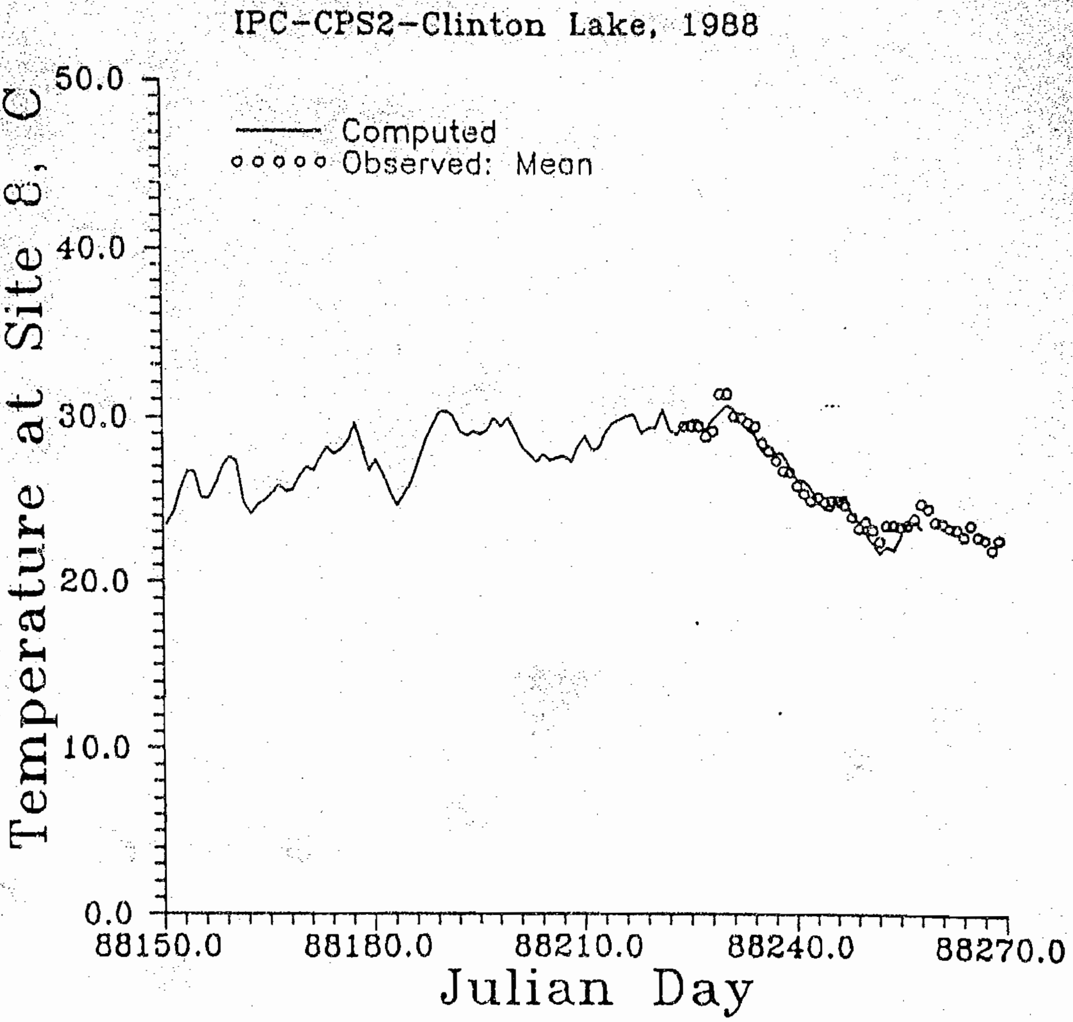

Figure 3-8. Computed and observed Data Sonde Site 8 temperatures for 1988 operating conditions.

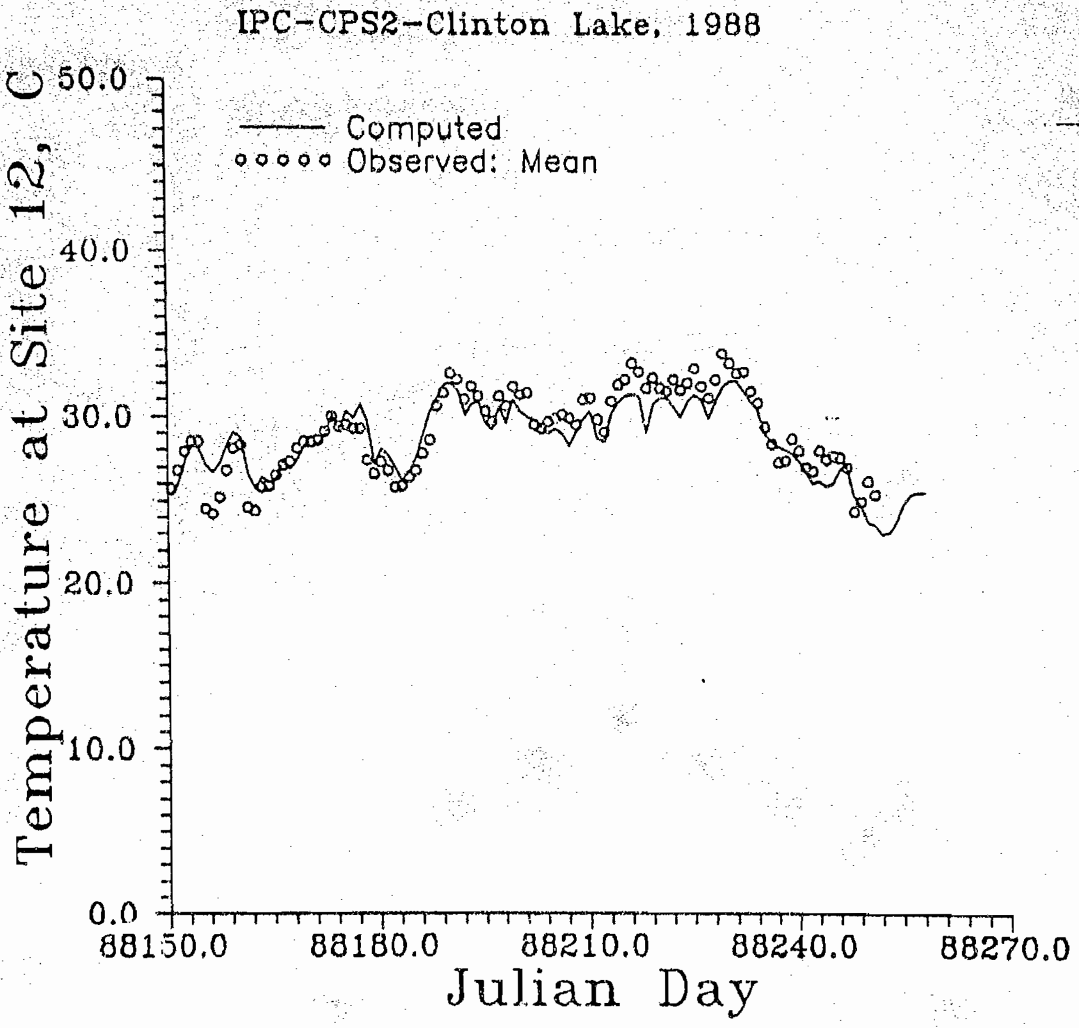

Figure 3-9. Computed and observed Data Sonde Site 12 temperatures for 1988 operating conditions.

between the point of discharge and the dam. It shows that the model slightly underestimates temperatures at site 12 probably due to a residual surface plume extending into the area from the discharge.

Figure 3-10 shows a comparison of the observed temperatures at Data Sonde site 15 located in the end of the discharge canal and the model temperatures for the flume discharge as shown previously in Figure 3-4(a). The observed temperatures at the end of the discharge canal are similar to the observed flume temperatures shown in Figure 3-4(a) indicating that there is insignificant cooling or mixing between the end of the second drop structure and the end of the canal.

Figure 3-11 shows a comparison of the observed and computed temperatures at Data Sonde site 16 in the surface of model segment 18 upstream from the point of discharge on the Salt Creek arm. The comparisons show a slight tendency for the model to overestimate temperatures in early June, as discussed previously, but in general, the comparison is excellent.

Based on the above comparisons, running the model with realtime plant operating data and Springfield meteorological data for 1988 produced good to excellent results.

Adjustments to the model during the verification period were:

a. Slight revisions to the daily plant pumping rates by IPC personnel.

b. Slight corrections on vertical mixing coefficients as indicated by the limited vertical profile temperature data in the vicinity of the mixing zone.

c. An empirical correction between the 108 acre surface layer of model segment 16 and the measured 26 acre mixing zone data.

No adjustments of the meteorological data for transfer between Springfield, Illinois and the lake were found necessary except for anemometer height relative to the lake elevation.

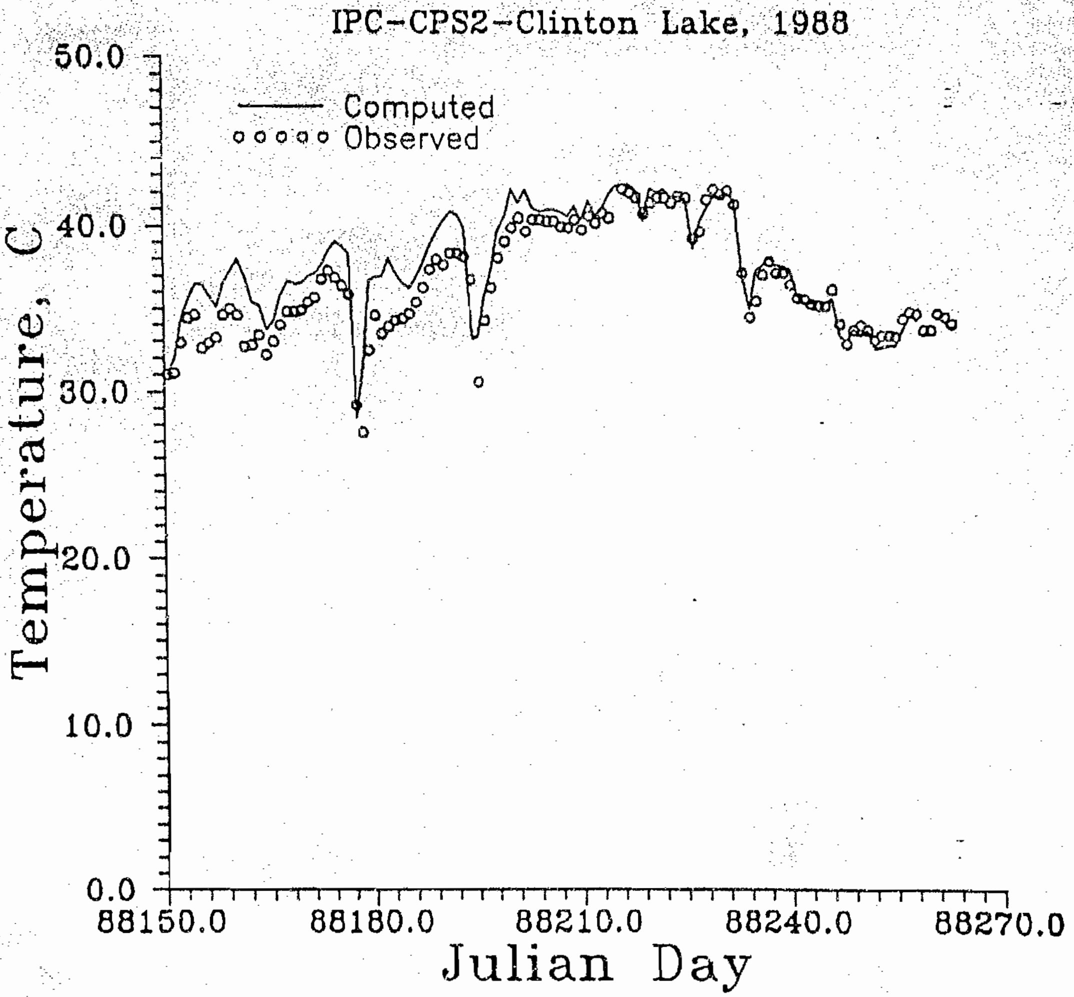

Figure 3-10. Computed discharge flume temperature and observed Data Sonde Site 15 temperature for 1988 operating conditions.

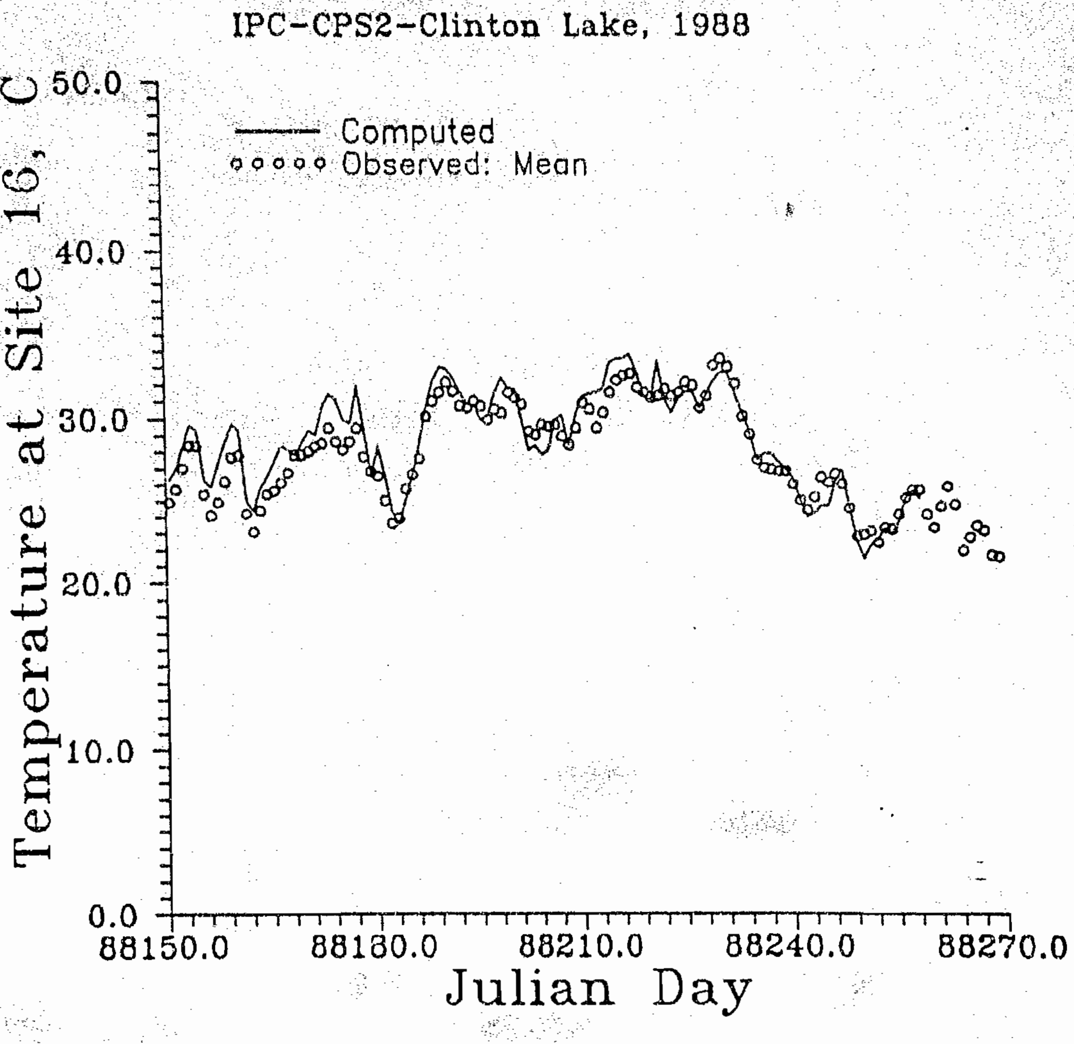

Figure 3-11. Computed and observed Data Sonde Site 16 temperatures for 1988 operating conditions.

3.3 Excess Temperatures for 1988

The GLVHT model enables excess temperatures to be calculated throughout the lake due to the plant operations. The excess temperatures are the temperature rise above ambient temperatures due to the heat source, plant pumping, surface heat dissipation, recirculation, and meteorological conditions (primarily windspeed).

A summary of the summer of 1988 (June through August) excess temperatures as the mean excess temperatures throughout the lake, their standard deviation over the summer due to time-varying plant operations and meteorological conditions, and the maximum value attained at any point in the lake over the summer is shown in Table 3-2.

Mean excess temperatures decay up and down the lake away from the point of discharge due to surface heat dissipation and decrease vertically due to re-entrainment and mixing of cooler water in the lake. The standard deviations demonstrate very little variation in excess temperatures despite the varying plant operations and varying meteorological conditions. Also, the standard deviations decrease up and down the lake and in the vertical along with the mean excess temperatures.

4.0 Meteorological Data Analysis and Statistics

Long term meteorological records were obtained from Springfield, Illinois for June through August from 1955 through 1988. The hourly 1988 records were used in the above GLVHT simulations. The records consisted of hourly, and in some years tri-hourly, data of cloud cover, air temperature, dewpoint temperature, windspeed and wind direction. These lengthy records were converted into hourly waterbody response temperatures which would be the water temperature that would result from meteorological conditions alone without accounting for

Table 3-2. Excess temperature means, standard deviations and maxima by lake segments and elevations for 1988 operating conditions. Layer elevations and landmark locations are shown in Table 3-1.

Mean discharge excess temperature is 9.9 deg C
Standard deviation of the discharge excess temperature is 1.84 deg C

Mean excess temperature (deg C)

	Segment Number																
Layer	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	21
5	.3	.4	.6	.7	.8	1.0	1.2	1.4	1.7	2.2	2.9	3.8	5.1	8.0	4.6	2.5	.3
6	.3	.4	.6	.8	.9	1.0	1.2	1.4	1.7	2.2	3.0	4.0	5.2	6.9	4.3	2.3	.2
7	.3	.4	.6	.8	.9	1.0	1.2	1.5	1.7	2.1	2.8	3.7	4.9	5.8	4.0	2.1	.3
8	.3	.4	.6	.8	.9	1.0	1.2	1.4	1.7	2.0	2.5	3.3	4.4	4.9	3.6	2.0	.3
9	.4	.5	.6	.8	.9	1.0	1.2	1.4	1.6	1.8	2.3	3.0	4.0	4.3	3.4	1.9	.3
10	.4	.5	.6	.8	.9	1.0	1.1	1.3	1.5	1.7	2.0	2.5	3.6	3.9	3.3		
11	.4	.5	.6	.7	.9	1.0	1.1	1.2	1.4	1.6	1.7	2.0					
12	.4	.5	.6	.7	.8	.9	1.0	1.1	1.3	1.4	1.5	1.6					
13			.6	.7	.8	.9	1.0	1.1	1.2	1.3	1.4						
14			.6	.7	.8	.9	1.0	1.0	1.1	1.2							
15					.8	.9	.9	1.0									

Standard deviation of excess temperature (deg C)

	Segment Number																
Layer	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	21
5	.10	.12	.15	.17	.20	.23	.27	.35	.46	.59	.70	.89	1.18	1.41	1.05	.83	.26
6	.13	.15	.19	.24	.27	.30	.36	.40	.46	.52	.57	.70	.89	1.22	.73	.53	.22
7	.16	.17	.20	.25	.27	.29	.33	.36	.39	.43	.48	.61	.79	1.05	.64	.48	.22
8	.18	.19	.21	.25	.27	.28	.32	.34	.36	.40	.46	.58	.75	.90	.57	.49	.23
9	.21	.21	.22	.26	.27	.28	.30	.32	.35	.39	.44	.56	.73	.84	.54	.49	.25
10	.23	.23	.24	.26	.27	.28	.29	.31	.32	.36	.41	.54	.72	.77	.54		
11	.25	.25	.25	.27	.27	.28	.28	.29	.30	.33	.37	.48					
12	.25	.26	.25	.27	.28	.28	.28	.27	.29	.31	.34	.42					
13			.25	.28	.28	.27	.27	.27	.28	.31	.32						
14			.26	.28	.28	.28	.27	.27	.28	.30							
15					.28	.28	.27	.27									

Maximum excess temperature (deg C)

	Segment Number																
Layer	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	21
5	.6	.8	1.0	1.2	1.3	1.5	1.9	2.3	2.7	3.4	4.3	5.5	6.9	9.6	6.5	4.7	1.4
6	.8	.9	1.1	1.4	1.4	1.6	2.0	2.3	2.7	3.3	4.2	5.5	6.6	9.0	5.5	3.5	1.0
7	1.0	1.0	1.1	1.5	1.5	1.6	1.9	2.2	2.5	3.0	3.8	5.0	6.2	7.9	4.9	3.6	1.0
8	1.1	1.1	1.1	1.5	1.5	1.6	1.8	2.1	2.4	2.8	3.6	4.5	5.9	6.6	4.8	4.1	1.1
9	1.2	1.2	1.3	1.5	1.6	1.6	1.8	2.0	2.3	2.7	3.3	4.3	5.3	5.8	4.5	4.2	1.4
10	1.3	1.3	1.4	1.5	1.6	1.6	1.7	1.9	2.1	2.5	3.1	4.0	4.9	5.2	4.4		
11	1.3	1.3	1.4	1.5	1.6	1.6	1.7	1.7	2.0	2.4	3.0	3.5					
12	1.3	1.4	1.4	1.5	1.6	1.6	1.7	1.7	1.9	2.2	2.9	3.3					
13			1.4	1.5	1.6	1.6	1.7	1.7	1.8	2.1	2.7						
14			1.3	1.5	1.6	1.6	1.7	1.7	1.7	1.9							
15					1.6	1.6	1.7	1.7									

inflow hydrology, stratification, or plant operations.

The comparison between the 1988 response temperatures and the computed plant intake temperatures is shown in Figure 4-1. After complete mixing of the lake near the intake has begun the response temperatures are representative of intake temperatures. This relationship holds because, there is only an intake excess temperature (rise due to plant operations) of between 0.5°C and 0.8°C (Table 3-2). That is, the plant has a very small effect on intake temperatures due to recirculation.

The records for each year were subjected to a duration analysis to determine the temperature equalled or exceeded for a specified number of days. The results of the duration analysis for each year are shown in Table 4-1. The 1 day duration (maximum daily average temperature) for 1955 was 31.4 C (88.5 F) and did not recur until after 1978. Based on the previous analyses of the 1955 to 1978 records at Lake Decatur, this temperature was the worst in 24 years of record. However, as Table 4-1 shows, temperatures near or at this value occurred also in 1980 and 1987 making the 31.4 C the worst temperature in 7 to 8 years.

In order to determine the annual return periods of temperatures at each duration, the temperatures within each duration were subjected to a Gumbel extreme value statistical analysis. The Gumbel analysis was tested for this data and found to describe the annual frequency or return period with which the temperatures occur. The Gumbel analysis states that the probability, or annual frequency, of equalling or exceeding a given temperature at a given duration is:

$$P(T)=1-\mathrm{Exp}[-\mathrm{Exp}(-(T-b)/a)]$$

where T is the temperature; $b=Tm+0.45S$ where Tm is the mean temperature in the duration and S is the standard deviation; and, $a=S/1.283$. The mean temperature

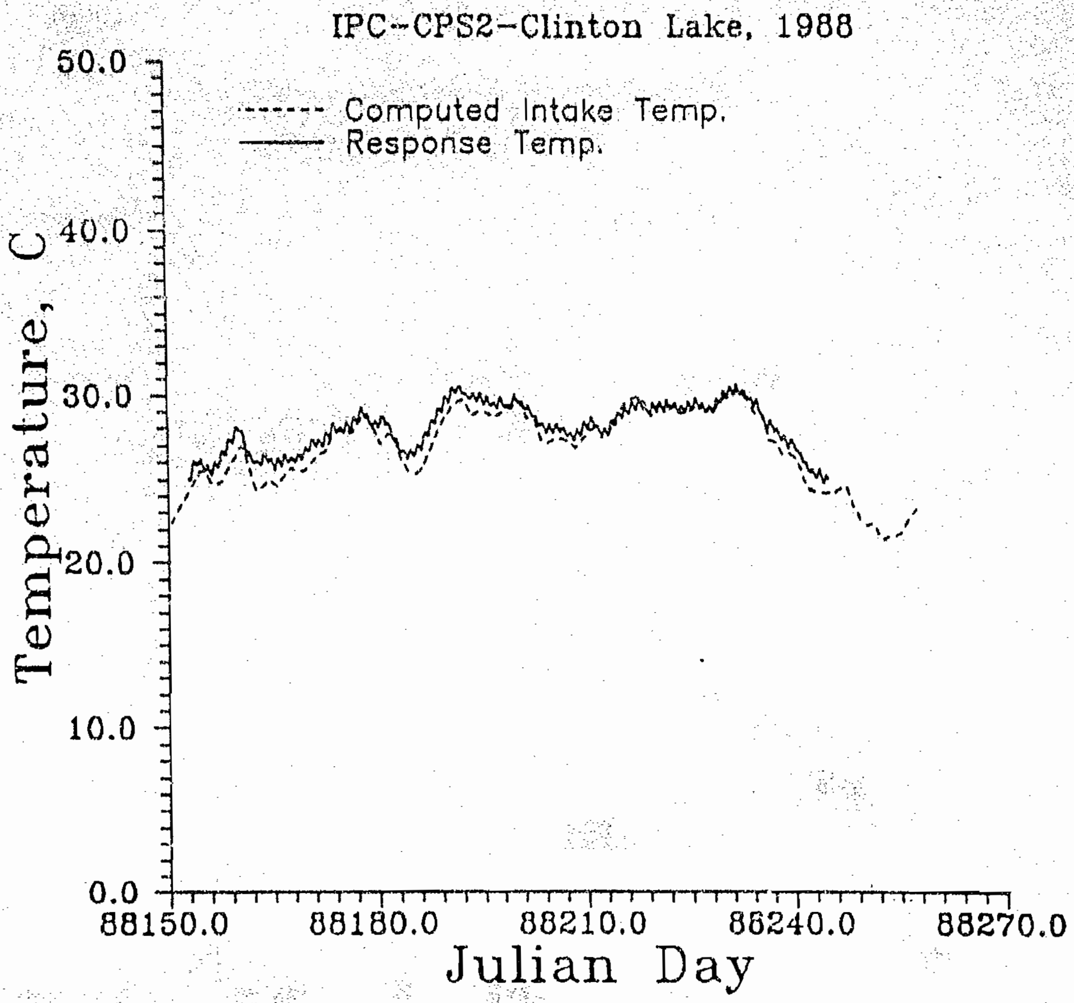

Figure 4-1. Time series of 1988 response temperatures superimposed on 1988 computed intake temperatures.

Table 4-1. Temperatures (C) equalled or exceeded for a given duration for each year 1955 to 1988 with means and standard deviations for each duration.

	Duration, Days							
Years	1	5	10	20	30	40	60	80
55	31.4	30.9	30.0	28.8	28.3	27.8	26.0	21.3
56	28.9	28.4	28.0	27.7	27.5	27.1	26.2	24.7
57	29.8	29.4	29.0	28.5	28.0	27.5	25.7	23.5
58	29.8	29.0	28.3	26.9	26.2	25.8	24.5	22.7
59	29.2	28.4	28.1	27.3	26.7	26.4	26.0	24.7
60	29.4	29.0	28.8	28.0	27.2	26.7	24.6	22.2
61	29.9	29.6	29.2	28.3	27.3	26.5	25.1	23.1
62	28.3	27.9	27.6	27.1	26.5	25.9	25.2	23.5
63	29.0	28.8	28.6	28.1	27.1	26.3	25.2	24.2
64	29.4	29.0	28.6	28.1	26.9	25.9	24.1	23.1
65	28.4	27.9	27.5	27.0	26.4	26.0	25.3	23.6
66	30.0	29.3	28.9	27.5	26.8	26.4	25.0	21.7
67	27.9	27.4	27.1	26.0	25.5	25.2	24.6	22.7
68	28.4	28.0	27.7	27.3	26.8	26.2	25.1	23.9
69	29.0	28.8	28.6	27.1	26.7	26.5	25.6	20.7
70	27.7	26.9	26.5	26.2	25.9	25.4	24.4	23.1
71	28.3	27.3	26.7	26.2	25.8	25.4	24.7	22.8
72	28.7	28.2	27.6	26.5	26.0	25.2	23.8	23.1
73	27.9	27.7	27.5	27.1	26.7	26.4	25.7	24.7
74	29.2	28.7	28.4	27.6	26.2	25.7	24.2	22.0
75	29.8	29.0	28.7	28.1	27.6	27.3	26.7	22.9
76	27.9	27.6	27.4	26.8	25.9	25.4	24.7	24.0
77	29.9	29.4	28.9	27.8	26.5	26.1	25.1	23.6
78	28.3	27.9	27.8	27.3	26.7	26.3	25.7	23.7
79	29.8	28.5	27.4	26.8	26.3	25.7	24.4	23.2
80	31.4	30.9	30.5	29.4	28.8	28.5	27.3	23.8
81	30.2	29.5	28.7	27.2	26.6	26.1	25.3	24.1
82	28.9	28.6	28.4	27.8	26.8	26.4	24.6	23.0
83	30.4	30.0	29.5	29.1	28.7	28.4	27.6	23.0
84	29.3	28.9	28.7	28.0	27.5	27.2	26.2	25.1
85	28.0	27.8	27.5	27.2	26.9	26.5	25.2	22.7
86	30.9	30.7	30.3	28.8	28.0	27.6	26.2	24.7
87	31.5	30.8	30.2	29.1	28.6	28.1	27.0	25.6
88	30.4	30.1	29.9	29.5	29.1	28.5	27.7	26.3
Mean	29.3	28.8	28.4	27.7	27.0	26.5	25.4	23.4
Std. Dev.	1.05	1.04	1.01	.90	.91	.93	.98	1.15

(Tm) and standard deviation (S) for each duration are given in Table 4-1. The return period, in years, is R=1/P(T) from the above equation.

The overall frequency-duration analysis of the records from 1955 to 1988 can be generalized as shown in Table 4-2 to give the response temperature equalled or exceeded for a given return period and duration. In Table 4-2 a given temperature would move diagonally downward for increasing durations and return periods; for example, 31.0 C (87.8 F) is equalled or exceeded for 1 day once in 5 years, for 5 days once in 8 years, for 10 days once in 18 years and so on.

Thus, based on the 1988 modeling and analysis, the response temperatures are representative of intake temperatures as they would have occurred in previous years, and their statistics over 1955 to 1988 are representative of their duration in any year and their return period in years.

5.0 Case Analyses

Two operating cases have been identified for analysis, those being (1) 100 percent power, 100 percent circulating water flow, and the lake starting at normal elevation, and (2) 100 percent power, 100 percent circulating water flow, and the lake starting at 685.5 ft. These cases were evaluated to determine temperature effects in the lake for normal station operations over the extremes of lake level conditions reasonably anticipated. The parameters in each case are as follows:

Case	Plant Load, %	Pumping Rate, cfs	May 31 El., Ft.	
1	100	1410	690.0	(Normal pool)
2	100	1373	685.5	(Drought level pool)

Table 4-2. Table of response (intake) temperatures (C) as a function of annual frequency and duration computed from Springfield, Illinois climatological data for 1955 to 1988.

Return Period Years	Duration, Days					
	1	5	7	10	20	30
2	30.1	29.6	29.4	29.1	28.4	27.7
5	31.0	30.5	30.3	30.1	29.1	28.5
10	31.6	31.1	30.9	30.6	29.7	29.0
20	32.2	31.7	31.5	31.2	30.2	29.5
30	32.6	32.0	31.8	31.5	30.5	29.8

The 100% plant load heat rejection rate is 6.713 x 10^9 Btu/Hr. The service water pumping rate in each case is 87 cfs.

The excess temperatures through the lake and their statistics are given for each case in Table 5-1 and Table 5-2 respectively. The excess temperatures near the discharge are slightly higher for Case 2 than for Case 1 because of the lower starting lake elevation in Case 2. The standard deviations of excess temperature in each case are less than those shown for the 1988 operating conditions because the Case 1 and Case 2 heat rejection rates are constant through the summer and the plant pumping rates vary only slightly with lake level drawdown due to evaporation (Table 3-2). The excess temperatures in Table 5-1 and Table 5-2 can be combined with the intake response temperature statistics in Table 4-2 to give the lake temperatures that would occur for a normal year, one year in ten and one year in thirty at a duration of one day, seven days and thirty days.

The temperature distributions are shown for Case 1 in Table 5-3 for a one day duration at each annual frequency, in Table 5-4 for a seven day duration and in Table 5-5 for a thirty day duration. The temperature distributions are shown for Case 2 in Table 5-6 for a one day duration, in Table 5-7 for a seven day duration and in Table 5-8 for a thirty day duration. In each case, the response temperature, the flume discharge temperature, and the mixing zone temperature in the surface layer of segment 16 is indicated. For Case 1, the one in thirty year one day flume discharge temperature is 43.7 C (110.7 F) and the one in thirty year one day mixing zone temperature is 41.4 C (106.5 F) (Table 5-3). Since the surface water and ground water inflows are unknown for past years, the deeper water temperatures in Table 5-3 through Table 5-8 are over-estimated.

The frequency-duration analysis was used to determine the number of days that a temperature limit of 99 F (37.22 C) would be exceeded for each case at the mixing zone and at the discharge flume for a normal year, one year in ten

Table 5-1. Excess temperature means, standard deviations and maxima by lake segments and elevations for Case 1 conditions (normal lake elevation and 1410 cfs pumping). Layer elevations and landmark locations are shown in Table 3-1.

Discharge excess temperature is 11.1 deg C
Mixing zone excess temperature is 8.8 deg C

Mean excess temperature (deg C)

	Segment Number															
Layer	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	21
5	.4	.5	.8	1.0	1.1	1.3	1.5	1.8	2.1	2.7	3.4	4.5	5.9	8.8	5.1	2.7	.3
6	.4	.5	.8	1.0	1.1	1.2	1.5	1.7	2.1	2.7	3.5	4.6	5.9	7.8	4.8	2.5	.2
7	.4	.6	.8	1.0	1.1	1.3	1.5	1.8	2.1	2.6	3.4	4.4	5.6	6.6	4.5	2.4	.3
8	.4	.6	.8	1.0	1.2	1.3	1.5	1.8	2.0	2.4	3.0	3.9	5.2	5.6	4.1	2.2	.3
9	.4	.6	.8	1.0	1.1	1.3	1.5	1.7	1.9	2.2	2.7	3.5	4.7	5.0	3.8	2.1	.3
10	.5	.6	.8	1.0	1.1	1.2	1.4	1.6	1.8	2.1	2.4	3.1	4.3	4.5	3.8		
11	.5	.6	.8	1.0	1.1	1.2	1.4	1.5	1.7	1.9	2.1	2.4					
12	.5	.6	.8	.9	1.1	1.2	1.3	1.4	1.6	1.7	1.8	2.0					
13			.8	.9	1.0	1.1	1.2	1.3	1.5	1.6	1.7						
14			.8	.9	1.0	1.1	1.2	1.3	1.4	1.5							
15					1.0	1.1	1.2	1.3									

Standard deviation of excess temperature (deg C)

	Segment Number															
Layer	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	21
5	.11	.12	.14	.14	.17	.19	.22	.30	.40	.49	.58	.69	.78	.53	.92	.76	.22
6	.15	.17	.19	.24	.26	.29	.34	.38	.42	.42	.43	.48	.53	.82	.47	.40	.21
7	.18	.18	.19	.24	.25	.26	.30	.32	.33	.33	.36	.48	.58	.78	.39	.37	.22
8	.22	.21	.21	.25	.25	.25	.28	.29	.31	.34	.40	.51	.59	.61	.33	.41	.25
9	.25	.24	.23	.25	.25	.26	.27	.28	.30	.34	.41	.52	.61	.57	.33	.45	.28
10	.28	.27	.25	.27	.26	.26	.26	.27	.29	.33	.39	.54	.66	.53	.31		
11	.30	.29	.27	.28	.27	.26	.26	.26	.28	.32	.38	.51					
12	.31	.30	.28	.29	.28	.27	.25	.25	.27	.31	.35	.45					
13			.28	.29	.28	.27	.25	.24	.27	.31	.33						
14			.28	.30	.29	.27	.25	.25	.27	.31							
15					.29	.27	.26	.26									

Maximum excess temperature (deg C)

	Segment Number															
Layer	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	21
5	.7	.8	1.1	1.4	1.5	1.8	2.2	2.6	3.1	3.8	4.8	6.0	7.4	9.8	6.4	4.5	1.8
6	.9	1.0	1.2	1.6	1.6	1.9	2.3	2.7	3.1	3.7	4.7	5.9	7.1	9.2	6.0	3.6	1.3
7	1.1	1.1	1.2	1.7	1.7	1.9	2.3	2.5	2.9	3.5	4.4	5.5	6.8	8.1	5.5	3.8	1.2
8	1.3	1.3	1.4	1.7	1.7	1.9	2.1	2.4	2.8	3.3	4.2	4.9	6.3	7.0	5.1	4.3	1.2
9	1.4	1.4	1.5	1.7	1.8	1.8	2.0	2.3	2.6	3.5	4.2	4.7	5.9	6.3	4.7	4.4	1.5
10	1.5	1.5	1.6	1.8	1.8	1.9	2.0	2.3	2.7	3.4	4.3	4.7	5.4	5.8	4.7		
11	1.5	1.6	1.6	1.8	1.8	1.8	1.9	2.2	2.6	3.3	4.2	4.6					
12	1.5	1.6	1.8	1.8	1.8	1.8	1.9	2.1	2.6	3.1	4.1	4.6					
13			1.6	1.8	1.8	1.3	1.9	2.0	2.5	2.9	3.7						
14			1.6	1.8	1.8	1.8	1.8	1.8	2.4	2.7							
15					1.8	1.8	1.8	1.8									

Table 5-2. Excess temperature means, standard deviations and maxima by lake segments and elevations for Case 2 conditions (low lake elevation and 1373 cfs pumping). Layer elevations and landmark locations are shown in Table 3-1.

Discharge excess temperature is 11.4 deg C
Mixing zone excess temperature is 10.0 deg C

Mean excess temperature (deg C)

	Segment Number															
Layer	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	21
6	.4	.6	.9	1.1	1.3	1.5	1.8	2.1	2.6	3.2	4.3	5.4	7.0	10.0	5.3	2.4	.1
7	.2	.4	.7	.9	1.0	1.2	1.4	1.8	2.2	2.9	3.9	5.2	6.9	9.2	4.2	1.4	.0
8	.3	.4	.8	1.0	1.1	1.3	1.5	1.9	2.3	3.0	4.0	5.4	7.0	7.9	3.9	1.4	.0
9	.3	.5	.8	1.0	1.1	1.3	1.8	1.8	2.2	2.8	3.7	5.0	6.6	6.6	3.8	1.3	.1
10	.3	.5	.8	1.0	1.1	1.3	1.5	1.8	2.1	2.5	3.3	4.5	6.3	5.8	3.7		
11	.4	.5	.8	1.0	1.1	1.3	1.4	1.7	2.0	2.3	2.9	3.7					
12	.4	.5	.7	1.0	1.1	1.2	1.4	1.6	1.9	2.1	2.5	3.0					
13			.7	1.0	1.1	1.2	1.3	1.5	1.7	1.9	2.1						
14			.8	.9	1.1	1.2	1.3	1.4	1.6	1.7							
15					1.1	1.2	1.3	1.3									

Standard deviation of excess temperature (deg C)

	Segment Number															
Layer	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	21
6	.14	.14	.14	.13	.13	.20	.24	.32	.44	.50	.49	.62	.76	.49	.96	.60	.05
7	.17	.19	.24	.30	.32	.35	.42	.48	.55	.58	.66	.73	.69	.44	.66	.65	.06
8	.20	.23	.26	.31	.32	.33	.38	.41	.45	.44	.45	.48	.51	.51	.55	.64	.08
9	.25	.27	.30	.32	.31	.32	.35	.37	.41	.42	.48	.57	.52	.57	.54	.65	.12
10	.29	.31	.33	.33	.31	.33	.34	.36	.40	.44	.52	.62	.56	.62	.53		
11	.32	.34	.35	.34	.32	.33	.34	.34	.38	.43	.51	.66					
12	.34	.36	.37	.35	.33	.33	.33	.33	.38	.41	.50	.69					
13			37	.38	.34	.33	.33	.32	.35	.39	.44						
14			.37	.37	.34	.32	.31	.30	.34	.38							
15					.34	.32	.31	.31									

Maximum excess temperature (deg C)

	Segment Number															
Layer	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	21
6	.7	.9	1.2	1.5	1.6	1.9	2.3	2.8	3.5	4.3	5.4	6.7	8.4	10.8	6.4	3.7	.2
7	1.0	1.2	1.3	1.7	1.8	2.1	2.4	2.9	3.5	4.3	5.5	7.0	8.5	10.4	5.0	3.1	.4
8	1.3	1.4	1.5	1.8	1.9	2.1	2.5	2.9	3.4	4.1	5.2	6.6	8.3	9.3	5.8	4.2	.7
9	1.5	1.6	1.7	1.9	1.9	2.1	2.4	2.8	3.2	3.8	4.8	6.3	8.2	8.4	5.8	4.7	1.2
10	1.8	1.7	1.8	1.9	1.9	2.1	2.3	2.6	3.0	3.6	4.6	6.1	8.0	7.8	5.6		
11	1.7	1.8	1.8	1.9	2.0	2.0	2.2	2.5	2.8	3.6	4.6	5.5					
12	1.7	1.8	1.9	1.9	2.0	2.0	2.1	2.3	2.6	3.5	4.6	5.3					
13			1.9	1.9	2.0	2.0	2.1	2.2	2.6	3.3	4.4						
14			1.9	1.9	2.0	2.0	2.1	2.1	2.5	3.0							
15					2.0	2.0	2.0	2.0									

Table 5-3. Case 1 temperatures (C) by lake segment and elevations and discharge and mixing zone temperatures for one day duration for (a) normal year; (b) one year in ten; (c) one year in thirty. Layer elevations and landmark locations are shown in Table 3-1.

(a) Normal year

Response temperature is 30.1 C
Discharge temperature is 41.2 C
Mixing zone temperature is 38.9 C

	Segment Number																
Layer	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	21
5	30.5	30.6	30.9	31.1	31.2	31.4	31.6	31.9	32.2	32.8	33.5	34.6	36.0	38.9	35.2	32.8	30.4
6	30.5	30.8	30.9	31.1	31.2	31.3	31.6	31.8	32.2	32.6	33.6	34.7	36.0	37.9	34.9	32.6	30.3
7	30.5	30.7	30.9	31.1	31.2	31.4	31.6	31.9	32.2	32.7	33.5	34.5	35.7	36.7	34.6	32.5	30.4
8	30.5	30.7	30.9	31.1	31.3	31.4	31.6	31.9	32.1	32.5	33.1	34.0	35.3	35.7	34.2	32.3	30.4
9	30.5	30.7	30.9	31.1	31.2	31.4	31.6	31.8	32.0	32.3	32.8	33.6	34.8	35.1	33.9	32.2	30.4
10	30.6	30.7	30.9	31.1	31.2	31.3	31.5	31.7	31.9	32.2	32.5	33.2	34.4	34.6	33.9		
11	30.6	30.7	30.9	31.1	31.2	31.3	31.5	31.6	31.8	32.0	32.2	32.5					
12	30.5	30.7	30.9	31.0	31.2	31.3	31.4	31.5	31.7	31.8	31.9	32.1					
13			30.9	31.0	31.1	31.2	31.3	31.4	31.6	31.7	31.8						
14			30.9	31.0	31.1	31.2	31.3	31.4	31.5	31.6							
15					31.1	31.2	31.3	31.4									

(b) One year in ten

Response temperature is 31.6 C
Discharge temperature is 42.7 C
Mixing zone temperature is 40.4 C

	Segment Number																
Layer	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	21
5	32.0	32.1	32.4	32.6	32.7	32.9	33.1	33.4	33.7	34.3	35.0	36.1	37.5	40.4	36.7	34.3	31.9
6	32.0	32.1	32.4	32.6	32.7	32.8	33.1	33.3	33.7	34.3	35.1	36.2	37.5	39.4	36.4	34.1	31.8
7	32.0	32.2	32.4	32.6	32.7	32.9	33.1	33.4	33.7	34.2	35.0	36.0	37.2	38.2	36.1	34.0	31.9
8	32.0	32.2	32.4	32.6	32.8	32.9	33.1	33.4	33.6	34.0	34.6	35.5	36.8	37.2	35.7	33.8	31.9
9	32.0	32.2	32.4	32.6	32.7	32.9	33.1	33.3	33.5	33.8	34.3	35.1	36.3	36.6	35.4	33.7	31.9
10	32.1	32.2	32.4	32.6	32.7	32.8	33.0	33.2	33.4	33.7	34.0	34.7	35.9	36.1	35.4		
11	32.1	32.2	32.4	32.6	32.7	32.8	33.0	33.1	33.3	33.5	33.7	34.0					
12	32.1	32.2	32.4	32.5	32.7	32.8	32.9	33.0	33.2	33.3	33.4	33.6					
13			32.4	32.5	32.6	32.7	32.8	32.9	33.1	33.2	33.3						
14			32.4	32.5	32.6	32.7	32.8	32.9	33.0	33.1							
15					32.6	32.7	32.8	32.9									

(c) One year in thirty

Reaponse temperature is 32.6 C
Diecharge temperature is 43.7 C
Mixing zone temperature is 41.4 C

	Segment Number																
Layer	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	21
5	33.0	33.1	33.4	33.6	33.7	33.9	34.1	34.4	34.7	35.3	36.0	37.1	38.5	41.4	37.7	35.3	32.9
6	33.0	33.1	33.4	33.6	33.7	33.8	34.1	34.3	34.7	35.3	36.1	37.2	38.5	40.4	37.4	35.1	32.8
7	33.0	33.2	33.4	33.6	33.7	33.9	34.1	34.4	34.7	35.2	36.0	37.0	38.2	39.2	37.1	35.0	32.9
8	33.0	33.2	33.4	33.6	33.8	33.9	34.1	34.4	34.6	35.0	35.6	36.5	37.8	38.2	36.7	34.8	32.9
9	33.0	33.2	33.4	33.6	33.7	33.9	34.1	34.3	34.5	34.8	35.3	36.1	37.3	37.6	36.4	34.7	32.9
10	33.1	33.2	33.4	33.6	33.7	33.8	34.0	34.2	34.4	34.7	35.0	35.7	36.9	37.1	36.4		
11	33.1	33.2	33.4	33.6	33.7	33.8	34.0	34.1	34.3	34.5	34.7	35.0					
12	33.1	33.2	33.4	33.5	33.7	33.8	33.9	34.0	34.2	34.3	34.4	34.6					
13			33.4	33.5	33.6	33.7	33.8	33.9	34.1	34.2	34.3						
14			33.4	33.5	33.6	33.7	33.8	33.9	34.0	34.1							
15					33.6	33.7	33.8	33.9									

Table 5-4. Case 1 temperatures (C) by lake segment and elevations and discharge and mixin zone temperatures for seven day duration for (a) normal year; (b) one year in ten; (c) on year in thirty. Layer elevations and landmark locations are shown in Table 3-1.

(a) Normal year

Response temperature is 29.4 C
Discharge temperature is 40.5 C
Mixing zone temperature is 38.2 C

	Segment Number																
Layer	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	21
5	29.8	29.9	30.2	30.4	30.5	30.7	30.9	31.2	31.5	32.1	32.8	33.9	35.3	38.2	34.5	32.1	29.7
6	29.8	29.9	30.2	30.4	30.5	30.6	30.9	31.1	31.5	32.1	32.9	34.0	35.3	37.2	34.2	31.9	29.6
7	29.8	30.0	30.2	30.4	30.5	30.7	30.9	31.2	31.5	32.0	32.8	33.8	35.0	36.0	33.9	31.8	29.7
8	29.8	30.0	30.2	30.4	30.8	30.7	30.9	31.2	31.4	31.8	32.4	33.3	34.6	35.0	33.5	31.6	29.7
9	29.8	30.0	30.2	30.4	30.5	30.7	30.9	31.1	31.3	31.6	32.1	32.9	34.1	34.4	33.2	31.5	29.7
10	29.9	30.0	30.2	30.4	30.5	30.6	30.8	31.0	31.2	31.5	31.8	32.5	33.7	33.9	33.2		
11	29.9	30.0	30.2	30.4	30.5	30.6	30.8	30.9	31.1	31.3	31.5	31.8					
12	29.9	30.0	30.2	30.3	30.5	30.6	30.7	30.8	31.0	31.1	31.2	31.4					
13			30.2	30.3	30.4	30.5	30.6	30.7	30.9	31.0	31.1						
14			30.2	30.3	30.4	30.5	30.6	30.7	30.8	30.9							
15					30.4	30.5	30.6	30.7									

(b) One year in ten

Response temperature is 30.9 C
Discharge temperature is 42.0 C
Mixing zone temperature is 39.7 C

	Segment Number																
Layer	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	21
5	31.3	31.4	31.7	31.9	32.0	32.2	32.4	32.7	33.0	33.6	34.3	35.4	36.8	39.7	36.0	33.6	31.2
6	31.3	31.4	31.7	31.9	32.0	32.1	32.4	32.6	33.0	33.6	34.4	35.5	36.8	38.7	35.7	33.4	31.1
7	31.3	31.5	31.7	31.9	32.0	32.2	32.4	32.7	33.0	33.5	34.3	35.3	36.5	37.5	35.4	33.3	31.2
8	31.3	31.5	31.7	31.9	32.1	32.2	32.4	32.7	32.9	33.3	33.9	34.8	36.1	36.5	35.0	33.1	31.2
9	31.3	31.5	31.7	31.9	32.0	32.2	32.4	32.6	32.8	33.1	33.6	34.4	35.6	35.9	34.7	33.0	31.2
10	31.4	31.5	31.7	31.9	32.0	32.1	32.3	32.5	32.7	33.0	33.3	34.0	35.2	35.4	34.7		
11	31.4	31.5	31.7	31.9	32.0	32.1	32.3	32.4	32.6	32.8	33.0	33.3					
12	31.4	31.5	31.7	31.8	32.0	32.1	32.2	32.3	32.5	32.6	32.7	32.9					
13			31.7	31.8	31.9	32.0	32.1	32.2	32.4	32.5	32.8						
14			31.7	31.8	31.9	32.0	32.1	32.2	32.3	32.4							
15					31.9	32.0	32.1	32.2									

(c) One year in thirty

Response temperature is 31.8 C
Discharge temperature is 42.9 C
Mixing zone temperature is 40.6 C

	Segment Number																
Layer	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	21
5	32.2	32.3	32.8	32.8	32.9	33.1	33.3	33.6	33.9	34.5	35.2	36.3	37.7	40.6	36.9	34.5	32.1
6	32.2	32.3	32.6	32.8	32.9	33.0	33.3	33.5	33.9	34.5	35.3	36.4	37.7	39.6	36.6	34.3	32.0
7	32.2	32.4	32.6	32.8	32.9	33.1	33.3	33.6	33.9	34.4	35.2	36.2	37.4	38.4	36.3	34.2	32.1
8	32.2	32.4	32.6	32.8	33.0	33.1	33.3	33.6	33.8	34.2	34.8	35.7	37.0	37.4	35.9	34.0	32.1
9	32.2	32.4	32.6	32.8	32.9	33.1	33.3	33.5	33.7	34.0	34.5	35.3	36.5	36.8	35.6	33.9	32.1
10	32.3	32.4	32.6	32.8	32.9	33.0	33.2	33.4	33.6	33.9	34.2	34.9	36.1	36.3	35.6		
11	32.3	32.4	32.6	32.8	32.9	33.0	33.2	33.3	33.5	33.7	33.9	34.2					
12	32.3	32.4	32.6	32.7	32.9	33.0	33.1	33.2	33.4	33.5	33.6	33.8					
13			32.6	32.7	32.8	32.9	33.0	33.1	33.3	33.4	33.5						
14			32.6	32.7	32.8	32.9	33.0	33.1	33.2	33.3							
15					32.8	32.9	33.0	33.1									

Table 5-5. Case 1 temperatures (C) by lake segment and elevations and discharge and mixing zone temperatures for thirty day duration for (a) normal year; (b) one year in ten; (c) one year in thirty. Layer elevations and landmark locations are shown in Table 3-1.

(a) Normal year

Response temperature is 27.7 C
Discharge temperature is 38.8 C
Mixing zone temperature is 36.5 C

	Segment Number																
Layer	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	21
5	28.1	28.2	28.5	28.7	28.8	29.0	29.2	29.5	29.8	30.4	31.1	32.2	33.6	36.5	32.8	30.4	28.0
6	28.1	28.2	28.5	28.7	28.8	28.9	29.2	29.4	29.8	30.4	31.2	32.3	33.6	35.5	32.5	30.2	27.9
7	28.1	28.3	28.5	28.7	28.8	29.0	29.2	29.5	29.8	30.3	31.1	32.1	33.3	34.3	32.2	30.1	28.0
8	28.1	28.3	28.5	28.7	28.9	29.0	29.2	29.5	29.7	30.1	30.7	31.6	32.9	33.3	31.8	29.9	28.0
9	28.1	28.3	28.5	28.7	28.8	29.0	29.2	29.4	29.6	29.9	30.4	31.2	32.4	32.7	31.5	29.8	28.0
10	28.2	28.3	28.5	28.7	28.8	28.9	29.1	29.3	29.5	29.8	30.1	30.8	32.0	32.2	31.5		
11	28.2	28.3	28.5	28.7	28.8	28.9	29.1	29.2	29.4	29.6	29.8	30.1					
12	28.2	28.3	28.5	28.6	28.8	28.9	29.0	29.1	29.3	29.4	29.5	29.7					
13			28.5	28.6	28.7	28.8	28.9	29.0	29.2	29.3	29.4						
14			28.5	28.6	28.7	28.8	28.9	29.0	29.1	29.2							
15					28.7	28.8	28.9	29.0									

(b) One year in ten

Response temperature is 29.0 C
Discharge temperature is 40.1 C
Mixing zone temperature is 37.8 C

	Segment Number																
Layer	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	21
5	29.4	29.5	29.8	30.0	30.1	30.3	30.5	30.8	31.1	31.7	32.4	33.5	34.9	37.8	34.1	31.7	29.3
6	29.4	29.5	29.8	30.0	30.1	30.2	30.5	30.7	31.1	31.7	32.5	33.6	34.9	36.8	33.8	31.5	29.2
7	29.4	29.6	29.8	30.0	30.1	30.3	30.5	30.8	31.1	31.6	32.4	33.4	34.6	35.6	33.5	31.4	29.3
8	29.4	29.6	29.8	30.0	30.2	30.3	30.5	30.8	31.0	31.4	32.0	32.9	34.2	34.6	33.1	31.2	29.3
9	29.4	29.6	29.8	30.0	30.1	30.3	30.5	30.7	30.9	31.2	31.7	32.5	33.7	34.0	32.8	31.1	29.3
10	29.5	29.6	29.8	30.0	30.1	30.2	30.4	30.6	30.8	31.1	31.4	32.1	33.3	33.5	32.8		
11	29.5	29.6	29.8	30.0	30.1	30.2	30.4	30.5	30.7	30.9	31.1	31.4					
12	29.5	29.6	29.8	29.9	30.1	30.2	30.3	30.4	30.6	30.7	30.8	31.0					
13			29.8	29.9	30.0	30.1	30.2	30.3	30.5	30.6	30.7						
14			29.8	29.9	30.0	30.1	30.2	30.3	30.4	30.5							
15					30.0	30.1	30.2	30.3									

(c) One year in thirty

Response temperature is 29.8 C
Discharge temperature is 40.9 C
Mixing zone temperature is 38.6 C

	Segment Number																
Layer	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	21
5	30.2	30.3	30.6	30.8	30.9	31.1	31.3	31.6	31.9	32.5	33.2	34.3	35.7	38.6	34.9	32.5	30.1
6	30.2	30.3	30.6	30.8	30.9	31.0	31.3	31.5	31.9	32.5	33.3	34.4	35.7	37.6	34.6	32.3	30.0
7	30.2	30.4	30.6	30.8	30.9	31.1	31.3	31.6	31.9	32.4	33.2	34.2	35.4	36.4	34.3	32.2	30.1
8	30.2	30.4	30.6	30.8	31.0	31.1	31.3	31.6	31.8	32.2	32.8	33.7	35.0	35.4	33.9	32.0	30.1
9	30.2	30.4	30.6	30.8	30.9	31.1	31.3	31.5	31.7	32.0	32.5	33.3	34.5	34.8	33.6	31.9	30.1
10	30.3	30.4	30.6	30.8	30.9	31.0	31.2	31.4	31.6	31.9	32.2	32.9	34.1	34.3	33.6		
11	30.3	30.4	30.6	30.8	30.9	31.0	31.2	31.3	31.5	31.7	31.9	32.2					
12	30.3	30.4	30.6	30.7	30.9	31.0	31.1	31.2	31.4	31.5	31.6	31.8					
13			30.6	30.7	30.8	30.9	31.0	31.1	31.3	31.4	31.5						
14			30.6	30.7	30.8	30.9	31.0	31.1	31.2	31.3							
15					30.8	30.9	31.0	31.1									

Table 5-6. Case 2 temperatures (C) by lake segment and elevations and discharge and mixing zone temperatures for one day duration for (a) normal year; (b) one year in ten; (c) one year in thirty. Layer elevations and landmark locations are shown in Table 3-1.

(a) Normal year

Response temperature is 30.1 C
Discharge temperature is 41.5 C
Mixing zone temperature is 40.1 C

	Segment Number																
Layer	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	21
6	30.5	30.7	31.0	31.2	31.4	31.6	31.9	32.2	32.7	33.3	34.4	35.5	37.1	40.1	35.4	32.5	30.2
7	30.3	30.5	30.8	31.0	31.1	31.3	31.5	31.9	32.3	33.0	34.0	35.3	37.0	39.3	34.3	31.5	30.1
8	30.4	30.5	30.9	31.1	31.2	31.4	31.8	32.0	32.4	33.1	34.1	35.5	37.1	38.0	34.0	31.5	30.1
9	30.4	30.6	30.9	31.1	31.2	31.4	31.7	31.9	32.3	32.9	33.8	35.1	36.7	36.7	33.7	31.4	30.2
10	30.4	30.6	30.9	31.1	31.2	31.4	31.6	31.9	32.2	32.6	33.4	34.6	36.4	35.9	33.8		
11	30.5	30.6	30.9	31.1	31.2	31.4	31.5	31.8	32.1	32.4	33.0	33.8					
12	30.5	30.6	30.8	31.1	31.2	31.3	31.5	31.7	32.0	32.2	32.6	33.1					
13			30.8	31.1	31.2	31.3	31.4	31.6	31.8	32.0	32.2						
14			30.9	31.0	31.2	31.3	31.4	31.5	31.7	31.8							
15					31.2	31.3	31.4	31.4									

(b) One year in ten

Response temperature is 31.6 C
Discharge temperature is 43.0 C
Mixing zone temperature is 41.6 C

	Segment Number																
Layer	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	21
6	32.0	32.2	32.5	32.7	32.9	33.1	33.4	33.7	34.2	34.8	35.9	37.0	38.6	41.6	36.9	34.0	31.7
7	31.8	32.0	32.3	32.5	32.6	32.8	33.0	33.4	33.8	34.5	35.5	36.8	38.5	40.8	35.8	33.0	31.6
8	31.9	32.0	32.4	32.6	32.7	32.9	33.1	33.5	33.9	34.6	35.6	37.0	38.6	39.5	35.5	33.0	31.6
9	31.9	32.1	32.4	32.6	32.7	32.9	33.2	33.4	33.8	34.4	35.3	36.6	38.2	38.2	35.2	32.9	31.7
10	31.9	32.1	32.4	32.6	32.7	32.9	33.1	33.4	33.7	34.1	34.9	36.1	37.9	37.4	35.3		
11	32.0	32.1	32.4	32.6	32.7	32.9	33.0	33.3	33.6	33.9	34.5	35.3					
12	32.0	32.1	32.3	32.6	32.7	32.8	33.0	33.2	33.5	33.7	34.1	34.6					
13			32.3	32.6	32.7	32.8	32.9	33.1	33.3	33.5	33.7						
14			32.4	32.5	32.7	32.8	32.9	33.0	33.2	33.3							
15					32.7	32.8	32.9	32.9									

(c) One year in thirty

Response temperature is 32.6 C
Discharge temperature is 44.0 C
Mixing zone temperature is 42.6 C

	Segment Number																
Layer	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	21
6	33.0	33.2	33.5	33.7	33.9	34.1	34.4	34.7	35.2	35.8	36.9	38.0	39.6	42.6	37.9	35.0	32.7
7	32.8	33.0	33.3	33.5	33.6	33.8	34.0	34.4	34.8	35.5	36.5	37.8	39.5	41.8	36.8	34.0	32.6
8	32.9	33.0	33.4	33.6	33.7	33.9	34.1	34.5	34.9	35.8	36.6	38.0	39.6	40.5	36.5	34.0	32.6
9	32.9	33.1	33.4	33.6	33.7	33.9	34.2	34.4	34.8	35.4	36.3	37.6	39.2	39.2	36.2	33.9	32.7
10	32.9	33.1	33.4	33.6	33.7	33.9	34.1	34.4	34.7	35.1	35.9	37.1	38.9	38.4	36.3		
11	33.0	33.1	33.4	33.6	33.7	33.9	34.0	34.3	34.6	34.9	35.5	36.3					
12	33.0	33.1	33.3	33.6	33.7	33.8	34.0	34.2	34.5	34.7	35.1	35.6					
13			33.3	33.6	33.7	33.8	33.9	34.1	34.3	34.5	34.7						
14			33.4	33.5	33.7	33.8	33.9	34.0	34.2	34.3							
15					33.7	33.8	33.9	33.9									

Table 5-7. Case 2 temperatures (C) by lake segment and elevations and discharge and mixing zone temperatures for seven day duration for (a) normal year; (b) one year in ten; (c) one year in thirty. Layer elevations and landmark locations are shown in Table 3-1.

(a) Normal year

Response temperature is 29.4 C
Discharge temperature is 40.8 C
Mixing zone temperature is 39.4 C

Layer	Segment Number																
	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	21
6	29.8	30.0	30.3	30.5	30.7	30.9	31.2	31.5	32.0	32.6	33.7	34.8	36.4	39.4	34.7	31.8	29.5
7	29.6	29.8	30.1	30.3	30.4	30.6	30.8	31.2	31.6	32.3	33.3	34.6	36.3	38.6	33.6	30.8	29.4
8	29.7	29.8	30.2	30.4	30.5	30.7	30.9	31.3	31.7	32.4	33.4	34.8	36.4	37.3	33.3	30.8	29.4
9	29.7	29.9	30.2	30.4	30.5	30.7	31.0	31.2	31.6	32.2	33.1	34.4	36.0	36.0	33.0	30.7	29.5
10	29.7	29.9	30.2	30.4	30.5	30.7	30.9	31.2	31.5	31.9	32.7	33.9	35.7	35.2	33.1		
11	29.8	29.9	30.2	30.4	30.5	30.7	30.8	31.1	31.4	31.7	32.3	33.1					
12	29.8	29.9	30.1	30.4	30.5	30.6	30.8	31.0	31.3	31.5	31.9	32.4					
13			30.1	30.4	30.5	30.6	30.7	30.9	31.1	31.3	31.5						
14			30.2	30.3	30.5	30.6	30.7	30.8	31.0	31.1							
15					30.5	30.6	30.7	30.7									

(b) One year in ten

Response temperature is 30.9 C
Discharge temperature is 42.3 C
Mixing zone temperature is 40.9 C

Layer	Segment Number																
	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	[illegible]
6	31.3	31.5	31.8	32.0	32.2	32.4	32.7	33.0	33.5	34.1	35.2	36.3	37.9	40.9	36.2	33.3	31.0
7	31.1	31.3	31.6	31.8	31.9	32.1	32.3	32.7	33.1	33.8	34.8	36.1	37.8	40.1	35.1	32.3	30.9
8	31.2	31.3	31.7	31.9	32.0	32.2	32.4	32.8	33.2	33.9	34.9	36.3	37.9	38.8	34.8	32.3	30.9
9	31.2	31.4	31.7	31.9	32.0	32.2	32.5	32.7	33.1	33.7	34.6	35.9	37.5	37.5	34.5	32.2	31.0
10	31.2	31.4	31.7	31.9	32.0	32.2	32.4	32.7	33.0	33.4	34.2	35.4	37.2	36.7	34.6		
11	31.3	31.4	31.7	31.9	32.0	32.2	32.3	32.6	32.9	33.2	33.8	34.6					
12	31.3	31.4	31.6	31.9	32.0	32.1	32.3	32.5	32.8	33.0	33.4	33.9					
13			31.6	31.9	32.0	32.1	32.2	32.4	32.6	32.8	33.0						
14			31.7	31.8	32.0	32.1	32.2	32.3	32.5	32.6							
15					32.0	32.1	32.2	32.2									

(c) One year in thirty

Response temperature is 31.8 C
Discharge temperature is 43.2 C
Mixing zone temperature is 41.8 C

Layer	Segment Number																
	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	21
6	32.2	32.4	32.7	32.9	33.1	33.3	33.6	33.9	34.4	35.0	36.1	37.2	38.8	41.8	37.1	34.2	31.9
7	32.0	32.2	32.5	32.7	32.8	33.0	33.2	33.6	34.0	34.7	35.7	37.0	38.7	41.0	36.0	33.2	31.8
8	32.1	32.2	32.6	32.8	32.9	33.1	33.3	33.7	34.1	34.8	35.8	37.2	38.8	39.7	35.7	33.2	31.8
9	32.1	32.3	32.6	32.8	32.9	33.1	33.4	33.6	34.0	34.6	35.5	36.8	38.4	38.4	35.4	33.1	31.9
10	32.1	32.3	32.6	32.8	32.9	33.1	33.3	33.6	33.9	34.3	35.1	36.3	38.1	37.6	35.5		
11	32.2	32.3	32.6	32.8	32.9	33 1	33.2	33.5	33.8	34.1	34.7	35.5					
12	32.2	32.3	32.5	32.8	32.9	33.0	33.2	33.4	33.7	33.9	34.3	34.8					
13			32.5	32.8	32.9	33.0	33.1	33.3	33.5	33.7	33.9						
14			32.6	32.7	32.9	33.0	33.1	33.2	33.4	33.5							
15					32.9	33.0	33.1	33.1									

Table 5-8. Case 2 temperatures (C) by lake segment and elevations and discharge and mixi zone temperatures for thirty day duration for (a) normal year; (b) one year in ten; (c) o year in thirty. Layer elevations and landmark locations are shown in Table 3-1.

(a) Normal year

Response temperature is 27.7 C
Discharge temperature is 39.1 C
Mixing zone temperature is 37.7 C

	Segment Number															
Layer	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	21
6	28.1	28.3	28.6	28.8	29.0	29.2	29.5	29.8	30.3	30.9	32.0	33.1	34.7	37.7	33.0	30.1	27.8
7	27.9	28.1	28.4	28.6	28.7	28.9	29.1	29.5	29.9	30.6	31.6	32.9	34.6	36.9	31.9	29.1	27.7
8	28.0	28.1	28.5	28.7	28.8	29.0	29.2	29.6	30.0	30.7	31.7	33.1	34.7	35.6	31.6	29.1	27.7
9	28.0	28.2	28.5	28.7	28.8	29.0	29.3	29.5	29.9	30.5	31.4	32.7	34.3	34.3	31.3	29.0	27.8
10	28.0	28.2	28.5	28.7	28.8	29.0	29.2	29.5	29.8	30.2	31.0	32.2	34.0	33.5	31.4		
11	28.1	28.2	28.5	28.7	28.8	29.0	29.1	29.4	29.7	30.0	30.6	31.4					
12	28.1	28.2	28.4	28.7	28.8	28.9	29.1	29.3	29.6	29.8	30.2	30.7					
13			28.4	28.7	28.8	28.9	29.0	29.2	29.4	29.6	29.8						
14			28.5	28.6	28.8	28.9	29.0	29.1	29.3	29.4							
15					28.8	28.9	29.0	29.0									

(b) One year in ten

Response temperature is 29.0 C
Discharge temperature is 40.4 C
Mixing zone temperature is 39.0 C

	Segment Number															
Layer	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	21
6	29.4	29.6	29.9	30.1	30.3	30.5	30.8	31.1	31.6	32.2	33.3	34.4	36.0	39.0	34.3	31.4	29.1
7	29.2	29.4	29.7	29.9	30.0	30.2	30.4	30.8	31.2	31.9	32.9	34.2	35.9	38.2	33.2	30.4	29.0
8	29.3	29.4	29.8	30.0	30.1	30.3	30.5	30.9	31.3	32.0	33.0	34.4	36.0	36.9	32.9	30.4	29.0
9	29.3	29.5	29.8	30.0	30.1	30.3	30.6	30.8	31.2	31.8	32.7	34.0	35.6	35.6	32.6	30.3	29.1
10	29.3	29.5	29.8	30.0	30.1	30.3	30.5	30.6	31.1	31.5	32.3	33.5	35.3	34.8	32.7		
11	29.4	29.5	29.8	30.0	30.1	30.3	30.4	30.7	31.0	31.3	31.9	32.7					
12	29.4	29.5	29.7	30.0	30.1	30.2	30.4	30.6	30.9	31.1	31.5	32.0					
13			29.7	30.0	30.1	30.2	30.3	30.5	30.7	30.9	31.1						
14			29.8	29.9	30.1	30.2	30.3	30.4	30.6	30.7							
15					30.1	30.2	30.3	30.3									

(c) One year in thirty

Response temperature is 29.8 C
Discharge temperature is 41.2 C
Mixing zone temperature is 39.8 C

	Segment Number															
Layer	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	21
6	30.2	30.4	30.7	30.9	31.1	31.3	31.6	31.9	32.4	33.0	34.1	35.2	36.8	39.8	35.1	32.2	29.9
7	30.0	30.2	30.5	30.7	30.8	31.0	31.2	31.6	32.0	32.7	33.7	35.0	36.7	39.0	34.0	31.2	29.8
8	30.1	30.2	30.6	30.8	30.9	31.1	31.3	31.7	32.1	32.8	33.8	35.2	36.8	37.7	33.7	31.2	29.8
9	30.1	30.3	30.6	30.8	30.9	31.1	31.4	31.6	32.0	32.6	33.5	34.8	36.4	36.4	33.4	31.1	29.9
10	30.1	30.3	30.6	30.8	30.9	31.1	31.3	31.6	31.9	32.3	33.1	34.3	36.1	35.6	33.5		
11	30.2	30.3	30.6	30.8	30.9	31.1	31.2	31.5	31.8	32.1	32.7	33.5					
12	30.2	30.3	30.5	30.8	30.9	31.0	31.2	31.4	31.7	31.9	32.3	32.8					
13			30.5	30.8	30.9	31.0	31.1	31.3	31.5	31.7	31.9						
14			30.6	30.7	30.9	31.0	31.1	31.2	31.4	31.5							
15					30.9	31.0	31.1	31.1									

and one year in thirty. The results of this analysis are given in Table 5-9. The table shows that for Case 1 the 99 F limit is exceeded in the discharge flume for more than 90 days one year in thirty and is exceeded in the mixing zone for 60 days one year in thirty.

6.0 Sensitivity Analyses

Sensitivity analyses were performed for different plant loads, plant pumping rates and lake elevations to determine the change in mixing zone temperatures to each of these parameters. The results of the sensitivity analyses are as follows:

a. For heat rejection rate, the temperatures in the mixing zone decrease by 0.80 °C (1.44°F) for each 10% decrease in plant load.

b. For pumping rates, the temperatures in the mixing zone increase by 0.23 °C (0.41°F) for each 100 cfs decrease in pumping rate.

c. For lake elevations, the temperatures in the mixing zone increase by 0.24 °C (0.43°F) for each foot decrease in May 31 lake starting elevation.

These sensitivity values can be used to estimate changes in mixing zone conditions for small changes in the above parameters.

7.0 Conclusions

The GLVHT model has been successfully verified for 1988 realtime operating conditions. It has been used to compute excess temperature distributions for continuous 100% full load operations for two different initial lake elevations.

The results of the GLVHT analysis have been combined with the results of a statistical analysis of 34 years of meteorological records to produce lake temperatures that would occur at certain specified annual frequencies over different daily durations. These results can be used to judge the significance of different temperature limitations and to perform comparative fisheries thermal

Table 5-9. Days exceeding 99 F at the discharge flume and at the mixing zone for Case 1 and Case 2 for normal year, one year in five, one year in ten, one year in twenty and one year in thirty.

Days exceeding temperature limits

Return period, years	Mixing zone Days exceeding 37.22 C Case 1	 Case 2	Discharge flume Days exceeding 37.22 C Case 1	 Case 2
normal	19	39	60	63
5	31	55	70	74
10	43	64	78	>90
20	54	72	>90	>90
30	60	76	>90	>90

tolerance studies.

Additional effort is required to further verify the modeling results, to develop realtime operating rules to meet thermal limits, and to relate temperature distributions in the lake to future fisheries studies. For verification, the 1988 results show that the model is satisfactorily related to plant realtime operating conditions and the Springfield, Illinois meteorological data, but further work is required to characterize the stratification in the deeper segments of the lake due to surface and groundwater inflows. Development of realtime operating rules relative to thermal limits requires determining the monitoring and operational procedures to be followed over realtime to meet the thermal limits. The fisheries evaluations requires a comparison of absolute temperatures with excess temperatures at different locations in the lake to separate plant operating effects from natural temperature variations due to meteorological conditions.

References

Buchak, E. M. and J. E. Edinger. 1984. Generalized, Longitudinal-Vertical Hydrodynamics and Transport: Development, Programming and Applications. Prepared for U.S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, Mississippi. Contract No. DACW39-84-M-1636. Prepared by J. E. Edinger Associates, Inc., Wayne, PA. Document No. 84-18-R. June.

Appendix A

Previous Hydrothermal Analyses of Clinton Lake
for
Clinton Power Station Unit 1 Operations

Hydrothermal Analyses of Clinton Lake for Clinton Power Station Unit 1 Operations

Prepared for

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Environmental Affairs Department

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Document No. 88-60-R

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Modeling and analysis of the hydrothermal characteristics of Clinton Lake in response to Clinton Power Station (CPS) operations have been conducted on four occasions since 1979 for different station heat loads, flume discharge flow rates and lake elevations under 1955 meteorological conditions. The first simulations were made using the LARM (Laterally Averaged Reservoir Model) and were reported in IPC (1980). In 1981 two additional simulations were made, one using the LARM model and reported in Buchak (1981), and the other by NRC using the MITemp model and reported in NRC (1981). The fourth simulations are summarized in this report.

Station and lake operating conditions used for each simulation and simulation results are summarized in Table 1. The different major operating characteristics used in the simulations were station heat rejection, flume discharge rate, and lake elevations. Simulations based on the daily meteorological conditions for 1955 were used because previous analyses in IPC (1980) and Buchak (1981) showed this record produced the highest ambient lake temperatures during the summer months in 26 years of meteorological record.

The 1980 simulations shown in Table 1 and reported in IPC (1980) served as the basis of the previous Illinois Power Company (IPC) request for thermal limitations on Clinton Lake. Comparison of the 1981 LARM simulations and the 1981 NRC MITemp simulations for nearly identical station and lake conditions shows that independent modeling efforts give nearly identical results with the 1981 LARM simulations. Modeling using LARM is therefore considered reliable.

The LARM Model

The LARM Model is a state of the art model for long, narrow lakes like Clinton with complex flows as induced by the station operations. The LARM Model used in this and past simulations is described in detail in Section 5 of IPC (1980) which is attached as Appendix A. Briefly, the LARM Model is a time-varying hydrodynamic and heat transport model that computes the time-varying longitudinal and vertical temperatures throughout Clinton Lake. The model input includes daily meteorological data of (shortwave solar radiation, air temperature, dew point temperature, wind speed) and station operating data (heat loads, discharge flume flows rates, discharge temperatures). The hydrodynamics of the model computes time-varying longitudinal and vertical velocities in response to inflows, wind shear, and buoyancy effects of the flume discharge. The heat transport includes solar radiation, back radiation, evaporation and conduction at the water surface as well as station heat loads. Evaporative water loss and its resulting lake level change is not included in the LARM simulations.

The longitudinal segmentation of Clinton Lake for the LARM application is shown in Figure 1 and described in detail in Section 6 of IPC (1980) which is also attached as Appendix A. The longitudinal resolution is 4981.9 feet and the vertical resolution in each segment is 3.6 feet. The station intake withdraws water from segment 5. The overflow service spillway and submerged outlet works are located in segment 8. The station discharge to the lake is into the surface layer of segment 16. The station discharge flume runs from the station to model segment 16.

The LARM simulations for 1980, 1981 and 1988 were conducted using 1955 average daily meteorological data from Springfield, Illinois, a reconstructed

Salt Creek inflow temperature and flow record, and station data provided by IPC personnel. Using average daily meteorological data from off-site does not allow detailed representation of onsite diurnal lake water temperature variations. Similarly, average daily station heat rejections rates do not allow accurate representation of diurnal temperatures at the discharge flume. Consequently, predicted maximum daily or maximum average daily temperatures may be in error by about ± 1.5 °F.

1988 LARM Simulation Results

The present 1988 LARM simulations were performed for the station and lake operating conditions given in Table 1 using the average daily off-site Springfield, Illinois 1955 meteorological data. The LARM setup for the 1988 simulations was the same as described in Section 5 of the attached Appendix A. The major improvements in the 1988 simulations were more accurate representation of the discharge flume flow rates and the station heat rejection rate.

The LARM model version for Clinton Lake was first exercised for the 1980 simulation conditions to assure that it reproduced the previous results using more recent computer hardware and compilers. When the reproduction was determined to be successful, the revised discharge flume flow rates and heat loads were then inserted into the validated code and simulations were performed to determine the spacial temperature fields and statistics for the highest one day, highest seven day and highest thirty day average temperatures. These data were similar to results presented in Appendix A for the 1980 station operating conditions.

Results of the 1988 simulations are presented in the attached tables as follows:

Table 2 gives the ambient temperature field for the day of highest ambient temperature at the intake which is 31.9 C (89.5 F) at the 5.4 foot depth on 1 August 1955.

Table 3 gives ambient temperature statistics at selected locations for July 1955.

Table 4 gives ambient temperature statistics at selected locations for August 1955.

Table 5 gives the temperature field at selected lake locations for simulated station operating conditions for the day of highest flume discharge temperature which is 1 August 1955. On that date the temperature of the lake discharge to Salt Creek is predicted to be 32.8 C (91.1 F) and the flume discharge temperature to be 44.3 C (111.7 F).

Table 6 gives the July 1955 temperature statistics for simulated station operating conditions at different locations throughout the lake.

Table 7 gives the August 1955 temperature statistics for simulated station operations at different locations throughout the lake.

Table 8 gives the September 1955 temperature statistics for simulated station operations at different locations throughout the lake.

Longitudinal and vertical profiles of the one day, seven day and thirty day moving average maximum temperatures for July, August, and September are given in Table 9, Table 10, and Table 11. The moving averages are computed through each month beginning on the first day of the month and using the previous values in the record. The period spanned by the respective moving averages is indicated in each Table.

Table 9 gives the July 1955 temperature fields for simulated station operations for the highest one day average temperature, the highest seven day average temperature and the highest thirty day average temperature. In the discharge flume, the July 1955 highest one day temperature is 44.3 C (111.7 F), the highest seven day temperature is 42.9 C (109.2 F), and the highest thirty day temperature is 41.0 C (105.8 F). Within the lake, the highest one day temperature is in Segment 16 with a surface temperature of 42.4 C (108.3 F) and a bottom temperature of 38.0 C (100.4 F). The July 1955 seven day surface temperature in discharge segment 16 is 40.9 C (105.6 F) and the bottom temperature is 36.3 C (97.4 F). The July 1955 thirty day surface temperature in discharge segment 16 is 38.8 C (101.8 F) and the bottom temperature is 34.0 C (93.2 F).

Table 10 gives the August 1955 temperature fields for simulated station operations for the highest one day average temperature, the highest seven day average temperature and the highest thirty day average temperature. In the discharge flume, the August 1955 highest one day temperature is 44.4 C (111.7 F), the highest seven day temperature is 43.9 C (111.2 F) and the highest thirty day temperature is 41.8 C (107.2 F). Within the lake, the highest one day temperature is in Segment 16 with a surface temperature of 42.7 C (108.9 F) and a bottom temperature of 38.0 C (100.4 F). The August 1955 seven day surface temperature in discharge segment 16 is 42.1 C (107.8 F) and the bottom temperature is 37.5 C (99.5 F). The August 1955 thirty day surface temperature in segment 16 is 39.6 C (103.3 F) and the bottom temperature is 34.8 C (93.2 F).

Table 11 gives the September 1955 temperature fields for simulated station operations for the highest one day average temperature, the highest seven day average temperature and the highest thirty day average temperature. In the discharge flume, the September 1955 highest one day temperature is 37.9 C (100.2 F), the highest seven day temperature is 38.6 C (101.8 F), and the highest thirty day temperature is 40.2 C (104.4 F). Within the lake, the highest one day temperature is in Segment 16 with a surface temperature of 36.3 C (97.3 F) and a bottom temperature of 30.6 C (87.1 F). The September 1955 seven day surface temperature in discharge segment 16 is 36.3 C (97.3 F) and the bottom temperature is 31.8 C (89.2 F). The September 1955 thirty day surface temperature in discharge segment 16 is 37.9 C (100.2 F) and the bottom temperature is 33.0 C (91.4 F).

The September 1955 results in Table 11 show that the seven day and thirty day moving average values occurred on September 1 thereby incorporating the previous six and twenty-nine days of August respectively. Since the end of August into September represents a decreasing trend in temperatures, the thirty day moving average temperature for September is actually higher than the seven day average as indicated in Table 11.

Accuracy of LARM Model Results

The LARM model was exercised for 1978 meteorological conditions in the 1980 simulations for computation of ambient temperatures. The computed ambient temperatures were compared to temperature observed by IPC on the lake during 1978. These results are reported in IPC (1980) Figure 6-1 and show the computed average daily temperatures are generally within 1.0 °F to 1.5°F of the instantaneously measured temperature profiles throughout the lake over five surveys. The notable exception in that comparison was the 27 September 1978 results which was attributed to uncertain meteorological data inputed to the model for the period.

More recent detailed statistical analysis of model results versus field observations have been made for a number of hydrothermal simulations for various versions of LARM and GLVHT where reliable meteorological data existed (Edinger and Buchak, 1987). These comparisons show that for monthly surveys summarized over 6 month periods at numerous profile stations, the mean error of the model results ranged from 0.11 °C (0.2 °F) to 0.37 °C (0.67 °F), and the standard error of these mean errors ranged from 0.17 °C (0.31 °F) to 0.74 °C (1.33 °F). These results indicate that LARM and its later versions accurately reproduces observed temperatures given reliable meteorological data.

LARM Model Sensitivity

Given the 1955 meteorological data, Clinton Lake simulation results are most sensitive to the station heat rejection rate, the discharge flume flow rate and the lake elevation. There are sufficient simulation results in Table 1 to determine the sensitivity of the maximum daily discharge temperature to each of these parameters relative to the 1988 simulation conditions.

The station heat load determines the extent to which the flume discharge temperature is elevated above the maximum ambient water temperature of 31.6 C (88.8 F). The temperature elevation will be 3.39 °F per $1.0\text{x}10^{9}$ Btu/Hr of heat rejection for a discharge flume flow rate of 1387 cfs at a lake level 685.5 ft.

Sensitivity to discharge flume flow rate is determined from the increase in temperature across the condenser at a heat rejection rate of $6.71\text{x}10^{9}$

Btu/Hr, and represents a temperature increase of 1.3 °F for each 100 cfs decrease in flow below 1387 cfs.

The lake elevation affects both the lake volume for heat storage and the lake surface area for surface heat dissipation. Sensitivity to lake level can be determined by comparing modeling results at two different lake levels. For each foot increase in lake level above elevation 685.5 ft the maximum daily discharge flume temperature will decrease approximately 0.2 °F.

Sensitivity of the days exceeding 99 F to the maximum daily flume discharge temperature can be determined by comparing the 1981 and 1988 LARM results. This shows an increase of 6 days per 1 °F increase in maximum daily flume discharge temperatures.

The above sensitivity parameters can be used to determine the reduction in heat load required to lower the 111.7 F maximum daily discharge flume temperature to the current 108.3 F. A reduction in discharge temperatures of 3.3 °F would be required which at a sensitivity of 3.39 °F above ambient per 10^9 Btu/Hr of heat rejection would correspond to a reduction in the heat load of 0.97×10^9 Btu/Hr. This represents a load reduction on the station of about 15% based on 1955 conditions.

Modeling During Variance Period

The planned hydrothermal studies for Clinton Lake (Davis, 1988) during the summer of 1988 through 1990 will use the most recent version of LARM called GLVHT (Generalized, Longitudinal-Vertical Hydrodynamics and Transport) described in Buchak and Edinger (1984). Model input will include hourly on-site meteorological data and actual operating station heat rejection data. The GLVHT uses hourly meteorological data; includes evaporative water loss;

realistically simulates branching of North Fork Creek to Salt Creek at the dam; accurately represents the bridge flow constrictions in the reservoir; and provides more detailed representation of the various combinations and locations of station cooling water discharges and flow returns.

In addition to utilizing GLVHT for the 1988 through 1990 studies, the on-site meteorological data will allow re-calibrating the long term Springfield, Illinois meteorological record to the site. This recalibration will enable an accurate ambient temperature-duration days-annual frequency analysis to be performed and provide a more accurate basis for characterizing flume discharge temperatures with respect to natural variations.

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Table 1 Summary of Plant and Lake Operating Conditions and Maximum Daily Discharge Temperature Statistics for Different Hydrothermal Simulations on Clinton Lake using 1955 Meteorological Data

Year Model	1980(1) LARM	1980(1) LARM	1981(2) LARM	1981(3) MITEMP	1988(4) LARM
Percent Load, %	92	100	100	100	100
Heat Load, 10^9 Btu/Hr	5.94	6.4	6.41	6.61	6.71
Pumping Rate, cfs	1447	1447	1400	1400	1387
Lake Elevation, ft	690	690	685.5	685.5	685.5
Daily Maximum Flume Temperature, F	106.7	108.3	111.2	110.4	111.7
Days Exceeding 99 F	44	55	66	60	69

(1) IPC (1980)
(2) Buchak (1981)
(3) NRC (1981)
(4) Edinger and Buchak (1988) and this report

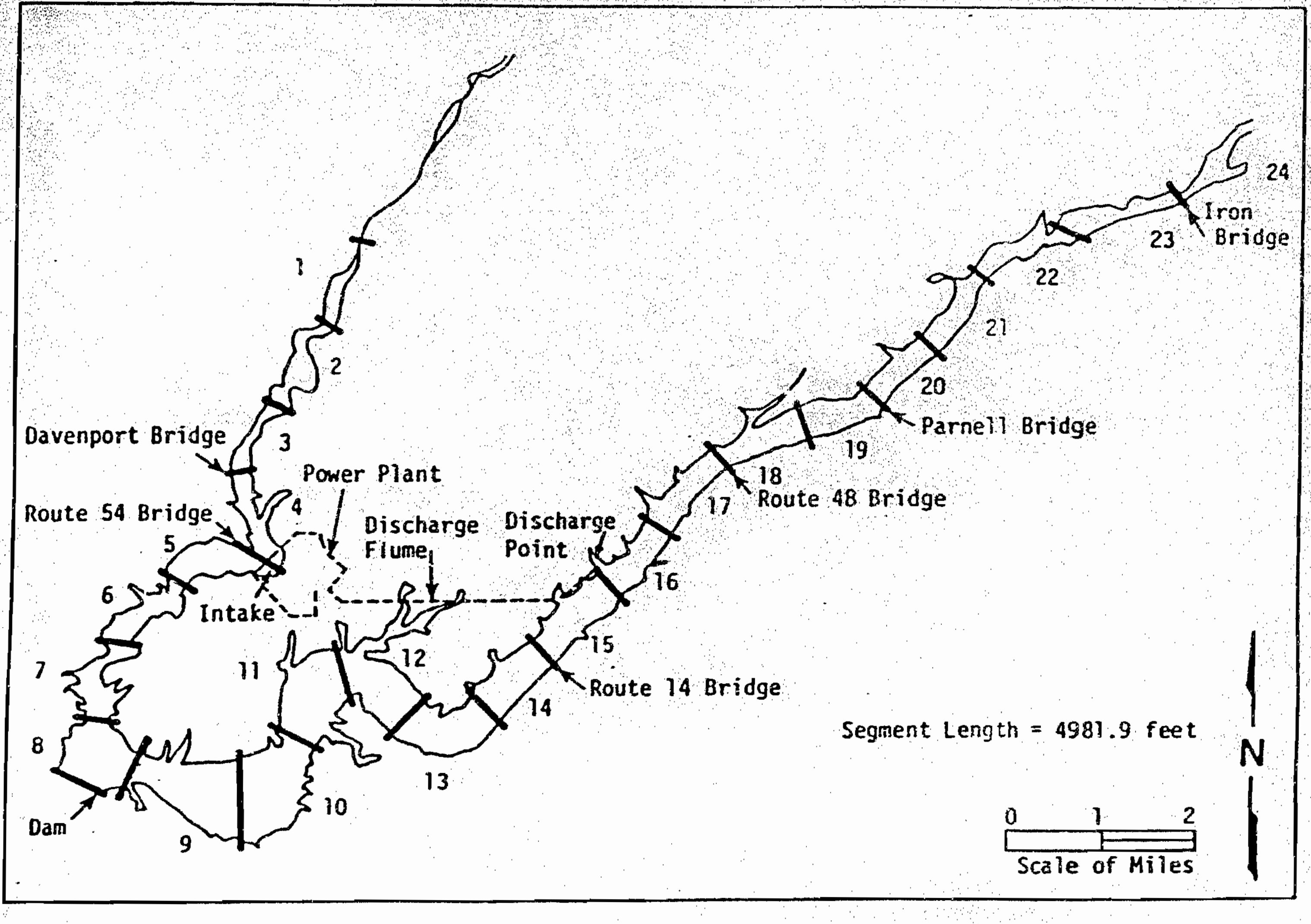


Figure 1 Longitudinal Segmentation of Clinton Lake for LARM Application

Table 2 Boundary Conditions and Ambient Temperature Field for August 1, 1955 (Julian Day 213).

Boundary Conditions

Salt Creek Inflow Rate (m3 s-1): .1
Salt Creek Inflow Temperature (C): 21.9

North Fork Inflow Rate (m3 s-1): .1
North Fork Inflow Temperature (C): 21.9

Discharge Flume Flow Rate (m3 s-1): .0
Discharge Flume Temperature (C): 31.6

Submerged Lake Outlet Works Flow Rate (m3 s-1): .1
Submerged Lake Outlet Works Temperature (C): 31.1

Overflow Service Spillway Flow Rate (m3 s-1): .0
Overflow Service Spillway Temperature (C): 32.3

Intake Flow Rate (m3 s-1): .0
Intake Flow Temperature (C): 31.6

Salt Creek Outflow Temperature (C): 31.1

Temperature Field (C)

Depth	Segment Number																
Ft	2	4	5	6	8	10	11	12	13	14	15	16	17	18	19	20	22
1.8	32.8	32.6	32.3	32.4	32.3	31.9	31.9	32.2	32.1	32.1	32.7	32.9	33.0	33.2	33.2	33.2	33.3
5.4	32.4	32.2	31.9	32.1	32.0	31.4	31.4	31.8	31.5	31.4	32.2	32.5	32.8	33.0	33.1	33.1	33.3
9.0	31.5	31.8	31.6	31.7	31.8	31.1	30.9	31.2	31.1	31.0	31.8	32.2	32.3	32.9	33.0	33.1	33.2
12.6	31.4	31.5	31.3	31.4	31.5	30.9	30.6	30.7	30.6	30.7	31.8	32.0	32.3	32.9	33.0	33.1	.0
16.2	31.3	31.1	31.0	31.0	31.1	30.6	30.4	30.3	30.3	30.4	31.8	31.9	32.2	.0	.0	.0	.0
19.8	.0	30.7	30.8	30.7	30.6	30.4	30.1	30.0	30.0	30.2	.0	.0	.0	.0	.0	.0	.0
23.4	.0	30.5	30.5	30.4	30.2	30.1	29.9	29.9	29.9	30.0	.0	.0	.0	.0	.0	.0	.0
27.0	.0	.0	30.4	30.2	30.0	29.9	29.8	29.8	29.8	.0	.0	.0	.0	.0	.0	.0	.0
30.6	.0	.0	30.2	30.1	29.3	29.6	29.7	29.7	.0	.0	.0	.0	.0	.0	.0	.0	.0
34.2	.0	.0	.0	.0	29.8	29.8	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

Note: Identified depths are relative to a lake elevation of 685.5 feet above mean sea level.

Legend

Map References	Segment Numbers
Davenport Bridge	3/4
Route 54 Bridge	4/5
Intake	5
Dam	8
Route 14 Bridge	14/15
Discharge	16
Route 48 Bridge	17/18
Parnell Bridge	19/20
Iron Bridge	23/24

Table 3 Ambient Temperature Statistics at Selected Locations, July 1955

Days Indicated Temperature is Equalled or Exceeded	Temperature, C						
	Intake Segment 5	Overflow Service Spillway Segment 8	Submerged Lake Outlet Works Segment 8	Discharge Surface Segment 16	Discharge Bottom Segment 16	Route 48 Bridge Surface Segment 17/18	Discharge Flume
31	25.7	25.3	25.2	26.1	25.6	26.4	25.7
30	25.9	25.7	25.6	26.3	26.3	26.5	25.9
29	26.7	27.0	25.9	28.0	26.6	27.9	26.7
28	27.6	27.1	26.6	28.0	27.9	28.0	27.6
27	27.7	27.3	26.7	28.0	28.0	28.1	27.7
26	27.7	27.6	26.8	28.1	28.0	28.2	27.7
25	28.0	27.7	26.9	28.2	28.1	28.3	28.0
24	28.1	27.8	27.4	28.4	28.1	28.5	28.1
23	28.1	28.2	27.8	28.5	28.1	28.6	28.1
22	28.2	28.2	27.9	28.5	28.2	28.7	28.2
21	28.2	28.3	28.2	28.5	28.2	28.8	28.2
20	28.3	28.4	28.3	28.7	28.3	28.9	28.3
19	28.3	28.5	28.3	28.8	28.3	29.0	28.3
18	28.4	28.6	28.3	28.8	28.3	29.0	28.4
17	28.4	28.7	28.5	28.9	28.3	29.1	28.4
16	28.4	28.8	28.5	29.0	28.3	29.2	28.4
15	28.5	28.8	28.6	29.3	28.5	29.4	28.5
14	28.5	29.0	28.7	29.3	28.6	29.5	28.5
13	28.5	29.2	28.8	29.4	28.6	29.5	28.5
12	28.6	29.3	28.9	29.4	28.6	29.6	28.6
11	28.7	29.4	29.0	29.6	28.7	29.6	28.7
10	29.2	29.6	29.1	30.1	29.0	30.1	29.2
9	29.7	29.7	29.1	30.3	29.6	30.5	29.7
8	30.1	30.0	29.4	30.4	29.7	30.5	30.1
7	30.2	30.6	29.5	30.5	29.8	30.7	30.2
6	30.5	30.7	29.5	31.3	30.1	31.7	30.5
5	30.7	30.9	29.6	31.6	30.1	31.7	30.7
4	30.7	31.5	29.6	31.6	30.4	31.9	30.7
3	31.0	31.6	29.8	32.6	30.8	32.9	31.0
2	31.3	31.8	30.0	32.6	31.2	33.0	31.3
1	31.6	32.5	31.0	33.2	32.1	33.5	31.6

Table 4 Ambiant Temperature Statistics at Selected Locations, August 1955

	Temperature, C						
Days Indicated Temperature is Equalled or Exceeded	Intake Segment 5	Overflow Service Spillway Segment 8	Submerged Lake Outlet Works Segment 8	Discharge Surface Segment 16	Discharge Bottom Segment 16	Route 48 Bridge Surface Segment 17/18	Discharge Flume
31	25.4	26.1	26.3	24.4	24.4	23.7	25.4
30	26.6	26.9	27.0	25.5	25.5	25.0	26.6
29	26.7	27.2	27.1	26.3	25.5	26.0	26.7
28	26.9	27.3	27.1	26.3	25.7	26.1	26.9
27	27.0	27.3	27.2	26.5	26.0	26.2	27.0
26	27.1	27.4	27.2	26.6	26.3	26.3	27.1
25	27.2	27.6	27.4	26.6	26.3	26.3	27.2
24	27.2	27.6	27.4	27.0	26.6	26.8	27.2
23	27.3	27.6	27.4	27.0	26.7	26.8	27.3
22	27.3	27.6	27.4	27.2	27.0	26.9	27.3
21	27.3	27.7	27.4	27.2	27.0	26.9	27.3
20	27.5	27.7	27.6	27.4	27.1	27.0	27.5
19	27.6	27.8	27.6	27.4	27.2	27.2	27.6
18	27.7	28.0	27.7	27.6	27.2	27.3	27.7
17	27.8	28.1	27.7	27.7	27.3	27.4	27.8
16	28.0	28.3	27.8	27.8	27.3	27.5	28.0
15	28.1	28.4	27.9	27.8	27.5	27.7	28.1
14	28.2	28.6	27.9	27.9	27.6	27.7	28.2
13	28.3	28.7	28.0	27.9	27.6	27.8	28.3
12	28.4	28.7	28.3	28.2	27.7	28.0	28.4
11	28.4	28.8	28.7	28.6	27.8	28.5	28.4
10	28.6	28.9	28.7	28.6	28.3	28.9	28.6
9	28.9	29.0	28.8	28.9	28.6	28.9	28.9
8	29.1	29.5	29.1	29.5	28.7	29.1	29.1
7	29.4	29.7	29.6	29.7	28.9	29.9	29.4
6	30.1	30.3	30.4	29.7	29.6	29.9	30.1
5	30.8	30.8	30.9	30.5	30.5	30.2	30.8
4	31.4	31.2	31.0	31.5	31.6	31.5	31.4
3	31.5	32.3	31.1	32.9	31.9	33.2	31.5
2	31.6	32.7	31.1	32.9	31.9	33.3	31.6
1	31.7	32.7	31.2	33.1	32.0	33.4	31.7

Table 5 Boundary Conditions and Temperature Field under Current Heat Load (6.713×10^9 Btu/hr, 1387.5 cfs) for August 1, 1955 (Julian Day 213).

Boundary Conditions

Salt Creek Inflow Rate ($m^3 s^{-1}$): .1
Salt Creek Inflow Temperature (C): 21.9

North Fork Inflow Rate ($m^3 s^{-1}$): .1
North Fork Inflow Temperature (C): 21.9

Discharge Flume Flow Rate ($m^3 s^{-1}$): 39.3
Discharge Flume Temperature (C): 44.3

Submerged Lake Outlet Works Flow Rate ($m^3 s^{-1}$): .1
Submerged Lake Outlet Works Temperature (C): 32.8

Overflow Service Spillway Flow Rate ($m^3 s^{-1}$): .0
Overflow Service Spillway Temperature (C): 33.6

Intake Flow Rate ($m^3 s^{-1}$): 39.3
Intake Flow Temperature (C): 32.9

Salt Creek Outflow Temperature (C): 32.8

Temperature Field (C)

Depth	Segment Number																
Ft	2	4	5	6	8	10	11	12	13	14	15	16	17	18	19	20	22
1.8	33.0	33.1	33.3	33.2	33.6	34.2	34.8	35.8	36.8	38.3	40.2	42.5	39.0	36.0	34.1	33.4	33.3
5.4	32.7	32.8	33.3	33.2	33.4	33.7	34.1	35.0	35.6	36.8	39.3	40.5	38.4	35.8	34.1	33.4	33.3
9.0	32.0	32.4	32.9	33.0	33.2	33.0	33.2	33.6	33.8	34.2	37.7	36.8	37.8	35.5	34.1	33.4	33.2
12.6	31.9	32.0	32.4	32.9	33.1	32.8	32.5	32.6	32.7	32.9	37.7	38.2	37.8	35.1	34.1	33.4	.0
16.2	31.9	31.6	32.4	32.6	32.8	32.3	32.1	32.0	32.0	32.1	37.7	38.0	37.8	.0	.0	.0	.0
19.8	.0	31.1	32.2	32.3	32.4	31.9	31.7	31.6	31.6	31.7	.0	.0	.0	.0	.0	.0	.0
23.4	.0	30.9	32.0	32.0	31.9	31.8	31.4	31.4	31.4	31.5	.0	.0	.0	.0	.0	.0	.0
27.0	.0	.0	31.8	31.8	31.8	31.4	31.3	31.2	31.2	.0	.0	.0	.0	.0	.0	.0	.0
30.6	.0	.0	31.7	31.6	31.4	31.3	31.2	31.2	.0	.0	.0	.0	.0	.0	.0	.0	.0
34.2	.0	.0	.0	.0	31.3	31.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

Note: Identified depths are relative to a lake elevation of 685.5 feet above mean sea level.

Legend

Map References	Segment Numbers
Davenport Bridge	3/4
Route 54 Bridge	4/5
Intake	5
Dam	8
Route 14 Bridge	14/15
Discharge	16
Route 48 Bridge	17/18
Parnell Bridge	19/20
Iron Bridge	23/24

Table 6 Temperature Statistics under Current Heat Load (6.713 x 10^9 Btu/hr, 1387.5 cfs) at Selected Locations, July 1955

Days Indicated Temperature is Equalled or Exceeded	Temperature, C						
	Intake Segment 5	Overflow Service Spillway Segment 8	Submerged Lake Outlet Works Segment 8	Discharge Surface Segment 16	Discharge Bottom Segment 16	Route 48 Bridge Surface Segment 17/18	Discharge Flume
31	26.7	26.7	26.5	33.5	30.3	29.1	37.0
30	26.8	26.8	26.7	33.9	30.5	30.1	37.9
29	27.6	27.9	26.9	35.8	31.0	30.2	38.7
28	28.0	28.1	27.6	36.3	31.3	30.3	39.3
27	28.2	28.4	27.6	36.3	31.5	30.5	39.4
26	28.3	28.5	27.8	36.7	32.0	30.7	39.5
25	28.4	28.6	28.0	37.3	32.1	31.0	39.5
24	28.8	28.8	28.3	37.3	32.5	31.1	39.6
23	29.0	29.5	28.8	37.3	32.6	31.2	39.9
22	29.0	29.5	28.8	37.5	32.9	31.3	40.1
21	29.0	29.5	29.5	37.8	33.2	31.6	40.1
20	29.1	29.6	29.5	37.9	33.4	31.7	40.1
19	29.1	29.7	29.6	38.0	33.5	31.8	40.2
18	29.2	29.8	29.8	38.3	33.6	31.8	40.3
17	29.3	29.9	29.8	38.4	33.6	32.4	40.4
16	29.4	30.1	29.8	38.4	33.7	32.5	40.6
15	29.4	30.2	29.9	38.7	33.7	32.6	40.6
14	29.4	30.2	30.1	38.8	33.9	32.7	40.6
13	29.5	30.5	30.3	38.8	34.0	32.8	40.7
12	29.7	30.7	30.4	39.0	34.1	33.0	41.1
11	30.2	30.9	30.5	39.0	34.2	33.1	41.4
10	30.4	31.0	30.6	39.4	34.6	33.1	41.7
9	30.9	31.1	30.7	39.8	35.0	33.7	41.8
8	30.9	31.2	30.8	39.9	35.2	33.9	42.1
7	31.0	32.0	30.8	40.1	35.5	33.9	42.2
6	31.3	32.2	30.8	40.7	35.6	34.9	42.4
5	31.4	32.3	30.9	40.7	36.1	34.9	42.9
4	32.1	32.9	31.1	41.1	36.2	35.2	42.9
3	32.1	33.1	31.2	41.8	36.2	36.1	43.5
2	32.6	33.2	31.6	41.9	37.3	36.5	43.7
1	32.9	33.7	32.5	42.3	37.9	36.9	44.3

Table 7 Temperature Statistics under Current Heat Load (6.713 x 10^9 Btu/hr, 1387. cfs) at Selected Locations, August 1955

Days Indicated Temperature is Equalled or Exceeded	Temperature, C						
	Intake Segment 5	Overflow Service Spillway Segment 8	Submerged Lake Outlet Works Segment 8	Discharge Surface Segment 16	Discharge Bottom Segment 16	Route 48 Bridge Surface Segment 17/18	Discharge Flume
31	26.4	27.5	27.7	33.7	30.3	26.6	37.7
30	27.8	28.3	28.4	35.6	30.5	27.0	38.0
29	27.8	28.6	28.6	36.0	30.9	27.8	39.0
28	28.1	28.8	28.6	36.5	31.0	27.9	39.4
27	28.3	28.9	28.8	37.0	31.7	28.1	39.5
26	28.3	29.1	28.9	37.1	31.8	28.1	39.5
25	28.4	29.1	29.0	37.1	32.0	28.9	39.6
24	28.5	29.2	29.1	37.1	32.3	29.0	39.6
23	28.6	29.2	29.2	37.3	32.4	29.0	39.8
22	28.7	29.3	29.3	37.5	32.5	29.0	39.8
21	28.7	29.6	29.3	37.6	32.5	29.3	39.8
20	28.9	29.7	29.7	37.8	32.5	30.2	40.0
19	28.9	29.7	29.7	37.9	32.6	30.4	40.0
18	29.0	29.7	29.7	38.0	32.6	30.8	40.2
17	29.0	29.8	29.7	38.0	32.8	30.9	40.2
16	29.1	29.9	29.8	38.1	32.9	30.9	40.3
15	29.2	30.0	29.8	38.2	33.0	31.5	40.4
14	29.3	30.0	29.8	38.3	33.1	31.6	40.5
13	29.3	30.2	29.8	38.4	33.4	31.6	40.5
12	29.3	30.3	29.8	38.6	33.7	31.7	40.6
11	29.6	30.5	29.9	38.7	34.0	31.9	40.7
10	30.0	30.5	30.0	38.8	34.1	32.0	40.7
9	30.0	30.6	30.1	39.0	34.7	33.3	40.9
8	30.2	30.8	30.1	39.1	34.9	33.5	41.3
7	30.8	31.5	30.7	39.6	35.1	33.6	41.4
6	31.1	31.7	31.6	39.8	35.4	34.6	41.5
5	31.8	32.1	32.2	40.1	36.4	34.6	42.4
4	32.6	32.8	32.8	40.9	37.7	35.5	43.1
3	32.9	33.6	32.9	42.5	37.9	36.0	44.0
2	33.0	33.9	32.9	42.7	38.0	36.1	44.3
1	33.2	34.0	33.0	42.8	38.1	36.2	44.3

Table 8 Temperature Statistics under Current Heat Load (6.713 x 109 Btu/hr, 1387.5 cfs) at Selected Locations, September 1955

	Temperature, C						
Days Indicated Temperature is Equalled or Exceeded	Intake Segment 5	Overflow Service Spillway Segment 8	Submerged Lake Outlet Works Segment 8	Discharge Surface Segment 16	Discharge Bottom Segmont 16	Route 48 Bridge Surface Segment 17/18	Discharge Flume
30	21.5	22.0	22.0	28.8	23.9	19.3	32.3
29	21.6	22.3	22.0	29.4	24.7	20.3	32.7
28	21.8	22.5	22.2	29.4	25.8	22.0	33.0
27	22.1	22.6	22.4	30.0	25.9	23.9	33.2
26	22.1	22.7	22.7	30.4	26.0	24.1	33.2
25	22.2	22.8	22.8	30.6	26.3	24.1	33.4
24	22.8	23.1	23.0	31.2	27.2	24.2	33.4
23	23.0	23.3	23.1	31.2	27.5	24.7	33.6
22	23.0	23.3	23.2	31.7	27.5	24.7	33.9
21	23.1	23.4	23.3	31.8	27.6	25.4	34.2
20	23.2	23.5	23.4	31.9	28.1	25.5	34.4
19	23.5	23.9	23.6	32.3	28.4	25.6	34.6
18	23.6	24.0	23.8	32.7	28.5	25.6	34.7
17	23.6	24.1	23.9	32.8	28.7	25.8	34.7
16	23.7	24.1	24.0	32.9	28.8	25.8	34.8
15	23.7	24.3	24.2	33.0	28.8	26.2	34.8
14	23.9	24.4	24.3	33.1	28.9	26.4	34.9
13	23.9	24.5	24.6	33.3	29.0	26.7	35.2
12	24.0	24.7	24.9	33.3	29.0	26.8	35.5
11	25.0	25.5	25.6	33.5	29.4	27.3	35.9
10	25.5	26.0	26.0	33.6	29.5	27.6	36.1
9	25.7	26.6	26.6	33.7	29.8	27.6	36.3
8	25.8	26.6	26.7	35.1	29.9	27.9	37.1
7	26.1	26.7	26.7	35.5	30.1	28.0	37.3
6	26.2	26.9	26.9	35.6	30.3	28.0	37.5
5	26.2	27.0	26.9	35.7	30.3	28.1	37.6
4	26.3	27.1	26.9	35.8	30.5	28.6	37.6
3	26.5	27.3	27.0	35.9	30.6	28.7	37.6
2	26.5	27.3	27.0	36.4	30.7	28.9	37.7
1	26.6	27.4	27.3	36.6	31.0	29.5	37.8

Table 9 Highest One-, Seven- and Thirty-day Average Temperature for July 1955 under Current Heat Load (6.713 x 109 Btu/hr, 1387.5 cfs).

Highest One-day Average Temperature (July 31) -- Comparable Discharge Plume Temperature is 44.3 C

Temperature Field (C)

Depth Ft	Segment Number 2	4	5	6	8	10	11	12	13	14	15	16	17	18	19	20	22
1.8	32.9	33.0	33.3	33.2	33.4	33.9	34.4	35.5	36.4	37.8	39.8	42.4	38.9	36.0	34.2	33.4	33.2
5.4	32.6	32.7	33.3	33.1	33.2	33.5	34.0	34.9	35.4	36.6	39.2	40.4	38.3	35.9	34.2	33.4	33.2
9.0	31.9	32.4	33.0	33.1	33.1	32.8	33.1	33.8	33.9	34.2	37.9	38.8	37.8	35.5	34.2	33.4	33.2
12.6	31.8	31.9	32.5	32.9	32.9	32.4	32.3	32.6	32.8	32.9	37.9	38.2	37.8	35.1	34.2	33.4	.0
15.2	31.7	31.4	32.4	32.7	32.6	32.0	31.8	31.9	32.0	32.1	37.8	38.0	37.8	.0	.0	.0	.0
19.8	.0	30.9	32.1	32.3	32.2	31.7	31.5	31.5	31.5	31.7	.0	.0	.0	.0	.0	.0	.0
23.4	.0	30.7	31.8	32.0	31.8	31.4	31.3	31.2	31.3	31.4	.0	.0	.0	.0	.0	.0	.0
27.0	.0	.0	31.7	31.7	31.4	31.2	31.1	31.1	31.1	.0	.0	.0	.0	.0	.0	.0	.0
30.8	.0	.0	31.6	31.5	31.3	31.1	31.1	31.1	.0	.0	.0	.0	.0	.0	.0	.0	.0
34.2	.0	.0	.0	.0	31.2	31.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

Highest Seven-day Average Temperature (July 25 to July 31) -- Comparable Discharge Plume Temperature is 42.9 C

Temperature Field (C)

Depth Ft	Segment Number 2	4	5	6	8	10	11	12	13	14	15	16	17	18	19	20	22
1.8	31.7	31.9	32.3	32.2	32.3	32.8	33.3	34.3	35.1	36.3	38.2	40.9	37.9	35.1	33.2	32.3	31.9
5.4	31.3	31.4	32.1	32.0	32.0	32.4	33.0	34.0	34.7	35.9	37.9	39.2	37.0	34.5	32.8	32.1	31.7
9.0	30.5	31.0	31.8	31.8	31.7	32.0	32.5	33.4	33.6	34.4	37.1	37.3	36.3	33.7	32.5	31.8	31.6
12.6	30.4	30.6	31.3	31.6	31.5	31.6	31.9	32.5	32.6	33.0	36.6	36.5	36.2	33.1	32.5	31.6	.0
16.2	30.2	30.4	31.2	31.4	31.3	31.3	31.5	31.8	31.9	32.1	36.4	36.3	36.1	.0	.0	.0	.0
19.8	.0	30.1	31.0	31.2	31.1	31.1	31.2	31.3	31.4	31.6	.0	.0	.0	.0	.0	.0	.0
23.4	.0	30.0	30.9	31.0	31.0	30.9	31.0	31.1	31.1	31.3	.0	.0	.0	.0	.0	.0	.0
27.0	.0	.0	30.9	30.9	30.9	30.8	30.9	30.9	31.0	.0	.0	.0	.0	.0	.0	.0	.0
30.6	.0	.0	30.8	30.8	30.8	30.8	30.8	30.9	.0	.0	.0	.0	.0	.0	.0	.0	.0
34.2	.0	.0	.0	.0	30.8	30.8	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

Highest Thirty-day Average Temperature (July 2 to July 31) -- Comparable Discharge Plume Temperature is 41.0 C

Temperature Field (C)

Depth Ft	Segment Number 2	4	5	6	8	10	11	12	13	14	15	16	17	18	19	20	22
1.8	29.8	29.9	30.2	30.2	30.4	30.8	31.3	32.1	33.0	34.2	36.1	38.8	35.4	32.8	31.2	30.4	30.0
5.4	29.4	29.5	30.1	30.1	30.2	30.5	31.0	31.7	32.4	33.8	35.6	36.9	34.6	32.3	30.9	30.3	29.8
9.0	28.8	29.2	29.9	29.9	30.1	30.2	30.6	31.2	31.5	32.3	34.5	35.0	34.0	31.7	30.7	30.1	29.7
12.6	28.7	28.9	29.7	29.9	29.9	29.9	30.2	30.7	30.8	31.1	34.1	34.3	34.0	31.3	30.6	29.9	.0
16.2	28.5	28.6	29.6	29.7	29.8	29.7	29.9	30.2	30.3	30.5	33.9	34.0	33.9	.0	.0	.0	.0
19.8	.0	28.4	29.5	29.6	29.7	29.5	29.7	29.9	30.0	30.1	.0	.0	.0	.0	.0	.0	.0
23.4	.0	28.3	29.4	29.5	29.5	29.4	29.5	29.7	29.8	29.9	.0	.0	.0	.0	.0	.0	.0
27.0	.0	.0	29.4	29.4	29.4	29.3	29.4	29.5	29.6	.0	.0	.0	.0	.0	.0	.0	.0
30.6	.0	.0	29.3	29.4	29.4	29.3	29.3	29.5	.0	.0	.0	.0	.0	.0	.0	.0	.0
34.2	.0	.0	.0	.0	29.3	29.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

Note: Identified depths are relative to a lake elevation of 685.5 feet above mean sea level.

Table 10 Highest One-, Seven- and Thirty-day Average Temperature for August 1955 under Current Heat Load (6.713 x 109 Btu/hr, 1387.5 cfs).

Highest One-day Average Temperature (August 2) -- Comparable Discharge Flume Temperature is 44.4 C

Temperature Field (C)

Depth									Segment Number								
Ft	2	4	5	6	8	10	11	12	13	14	15	16	17	18	19	20	22
1.8	33.2	33.3	33.5	33.5	34.0	34.8	35.4	36.3	37.4	38.8	40.5	42.7	39.2	36.2	34.3	33.6	33.5
5.4	33.0	33.0	33.5	33.4	33.9	34.4	34.8	35.8	36.4	37.6	39.7	40.8	38.5	35.9	34.3	33.6	33.5
9.0	32.3	32.7	33.2	33.2	33.6	33.8	33.9	34.2	34.5	34.9	38.2	38.9	37.9	35.4	34.2	33.6	33.5
12.6	32.2	32.4	32.5	33.0	33.3	33.3	33.2	33.2	33.3	33.4	37.9	38.2	37.9	35.0	34.2	33.5	.0
16.2	32.1	32.0	32.5	32.8	33.0	32.8	32.7	32.6	32.5	32.6	37.8	38.0	37.9	.0	.0	.0	.0
19.8	.0	31.7	32.3	32.5	32.6	32.4	32.3	32.2	32.1	32.2	.0	.0	.0	.0	.0	.0	.0
23.4	.0	31.5	32.2	32.3	32.3	32.1	32.0	31.9	31.9	31.9	.0	.0	.0	.0	.0	.0	.0
27.0	.0	.0	32.1	32.1	32.0	31.9	31.8	31.7	31.7	.0	.0	.0	.0	.0	.0	.0	.0
30.6	.0	.0	32.0	32.0	31.9	31.8	31.7	31.7	.0	.0	.0	.0	.0	.0	.0	.0	.0
34.2	.0	.0	.0	.0	31.8	31.7	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

Highest Seven-day Average Temperature (July 28 to August 3) -- Comparable Discharge Flume Temperature is 43.9 C

Temperature Field (C)

Depth									Segment Number								
Ft	2	4	5	6	8	10	11	12	13	14	15	16	17	18	19	20	22
1.8	32.8	32.9	33.2	33.2	33.4	33.9	34.5	35.5	36.4	37.7	39.5	42.1	39.0	36.2	34.2	33.4	33.1
5.4	32.4	32.5	33.2	33.0	33.1	33.5	34.1	35.0	35.6	36.9	39.0	40.3	38.2	35.7	34.1	33.2	33.0
9.0	31.7	32.1	32.8	32.8	32.9	32.9	33.3	34.0	34.2	34.8	37.9	38.4	37.5	35.1	33.9	33.1	32.9
12.6	31.5	31.7	32.2	32.6	32.6	32.5	32.6	33.0	33.1	33.4	37.5	37.7	37.4	34.6	33.9	32.9	.0
16.2	31.4	31.3	32.1	32.4	32.3	32.1	32.1	32.3	32.3	32.5	37.4	37.5	37.4	.0	.0	.0	.0
19.2	.0	31.0	31.9	32.1	32.0	31.8	31.8	31.9	31.8	31.9	.0	.0	.0	.0	.0	.0	.0
23.4	.0	30.8	31.7	31.6	31.7	31.5	31.5	31.8	31.6	31.7	.0	.0	.0	.0	.0	.0	.0
27.0	.0	.0	31.6	31.7	31.5	31.4	31.3	31.4	31.4	.0	.0	.0	.0	.0	.0	.0	.0
30.6	.0	.0	31.6	31.5	31.4	31.3	31.3	31.3	.0	.0	.0	.0	.0	.0	.0	.0	.0
34.2	.0	.0	.0	.0	31.3	31.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

Highest Thirty-day Average Temperature (July 12 to August 10) -- Comparable Discharge Flume Temperature is 41.8 C

Temperature Field (C)

Depth									Segment Number								
Ft	2	4	5	6	8	10	11	12	13	14	15	16	17	18	19	20	22
1.8	30.1	30.5	31.0	31.1	31.4	31.8	32.2	33.0	33.9	35.2	36.9	39.6	35.9	33.0	31.3	30.8	30.1
5.4	29.8	30.2	30.9	31.0	31.3	31.8	32.0	32.8	33.4	34.5	36.4	37.8	35.2	32.5	31.1	30.4	30.0
9.0	29.3	29.9	30.8	30.9	31.1	31.3	31.6	32.1	32.5	33.2	35.3	35.7	34.8	32.0	31.0	30.3	29.9
12.6	29.2	29.7	30.6	30.8	31.0	31.1	31.3	31.6	31.9	32.3	35.0	35.0	34.5	31.7	31.0	30.2	.0
16.2	29.2	29.5	30.5	30.7	30.9	30.9	31.0	31.2	31.4	31.7	34.9	34.8	34.5	.0	.0	.0	.0
19.8	.0	29.4	30.4	30.6	30.7	30.7	30.6	31.0	31.1	31.4	.0	.0	.0	.0	.0	.0	.0
23.4	.0	29.3	30.4	30.5	30.6	30.6	30.7	30.8	30.9	31.1	.0	.0	.0	.0	.0	.0	.0
27.0	.0	.0	30.3	30.4	30.5	30.5	30.6	30.7	30.8	.0	.0	.0	.0	.0	.0	.0	.0
30.6	.0	.0	30.3	30.4	30.5	30.5	30.5	30.6	.0	.0	.0	.0	.0	.0	.0	.0	.0
34.2	.0	.0	.0	.0	30.4	30.5	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

Note: Identified depths are relative to a lake elevation of 685.5 feet above mean sea level.

Table 11 Highest One-, Seven- and Thirty-day Average Temperature for September 1955 under Current Heat Load (6.713 x 109 Btu/hr, 1387.5 cfs).

Highest One-day Average Temperature (September 6) -- Comparable Discharge Flume Temperature is 37.9 C

Temperature Field (C)

Depth	Segment Number																
Ft	2	4	5	6	8	10	11	12	13	14	15	16	17	18	19	20	22
1.8	25.2	25.8	26.6	26.8	27.2	28.1	28.7	29.4	30.6	32.0	33.8	36.3	32.6	28.9	26.4	25.3	25.0
5.4	24.9	25.5	26.5	26.7	27.2	28.1	28.6	29.3	30.4	31.6	33.2	34.4	31.4	28.1	26.0	25.1	24.8
9.0	24.6	25.3	26.4	26.7	27.2	27.9	28.3	28.6	29.3	30.0	32.1	31.8	30.4	27.2	25.8	24.9	24.7
12.6	24.6	25.0	26.3	26.6	27.1	27.6	27.8	27.9	28.3	28.7	31.5	30.9	30.3	26.6	25.7	24.9	.0
16.2	24.6	24.8	26.3	26.6	27.0	27.4	27.4	27.5	27.7	28.0	31.1	30.6	30.3	.0	.0	.0	.0
19.8	.0	24.7	26.3	26.5	26.9	27.1	27.2	27.2	27.3	27.5	.0	.0	.0	.0	.0	.0	.0
23.4	.0	24.6	26.3	26.4	26.7	27.0	27.0	27.1	27.2	27.3	.0	.0	.0	.0	.0	.0	.0
27.0	.0	.0	26.3	26.4	26.6	26.9	26.9	27.0	27.1	.0	.0	.0	.0	.0	.0	.0	.0
30.6	.0	.0	26.2	26.3	26.6	26.8	26.9	27.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
34.2	.0	.0	.0	.0	26.6	26.8	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

Highest Seven-day Average Temperature (August 26 to September 1) -- Comparable Discharge Flume Temperature is 38.6 C

Temperature Field (C)

Depth	Segment Number																
Ft	2	4	5	6	8	10	11	12	13	14	15	16	17	18	19	20	22
1.8	25.7	26.7	27.7	28.0	28.4	28.5	28.9	29.5	30.2	31.4	33.2	36.3	33.0	29.9	27.7	26.6	25.4
5.4	25.7	26.6	27.7	28.0	28.4	28.6	28.9	29.5	30.3	31.4	33.0	34.5	32.1	29.2	27.5	26.5	25.4
9.0	25.6	26.6	27.7	28.0	28.4	28.6	28.9	29.5	30.1	31.0	32.5	32.7	31.4	28.5	27.3	26.4	25.4
12.6	25.5	26.5	27.7	28.0	28.5	28.6	28.9	29.5	29.9	30.4	32.2	32.0	31.4	28.1	27.3	26.3	.0
16.2	25.5	26.4	27.7	28.0	28.5	28.6	28.9	29.4	29.6	30.0	32.1	31.8	31.4	.0	.0	.0	.0
19.8	.0	26.4	27.7	28.0	28.5	28.6	28.9	29.3	29.5	29.8	.0	.0	.0	.0	.0	.0	.0
23.4	.0	26.4	27.7	28.0	28.5	28.6	28.9	29.2	29.4	29.6	.0	.0	.0	.0	.0	.0	.0
27.0	.0	.0	27.7	28.0	28.5	28.6	28.8	29.2	29.3	.0	.0	.0	.0	.0	.0	.0	.0
30.6	.0	.0	27.7	28.0	28.5	28.6	28.6	29.1	.0	.0	.0	.0	.0	.0	.0	.0	.0
34.2	.0	.0	.0	.0	28.5	28.6	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

Highest Thirty-day Average Temperature (August 3 to September 1) -- Comparable Discharge Flume Temperature is 40.2 C

Temperature Field (C)

Depth	Segment Number																
Ft	2	4	5	6	8	10	11	12	13	14	15	16	17	18	19	20	22
1.8	27.5	28.4	29.2	29.4	29.8	30.3	30.7	31.3	32.3	33.5	35.2	37.9	33.9	30.6	28.8	27.9	27.3
5.4	27.4	28.2	29.2	29.4	29.8	30.2	30.6	31.2	32.0	33.0	34.7	35.9	33.1	30.1	28.7	27.8	27.2
9.0	27.2	28.0	29.1	29.4	29.8	30.1	30.4	30.9	31.4	32.2	33.8	34.0	32.6	29.6	28.5	27.7	27.2
12.6	27.1	27.8	29.1	29.3	29.7	30.0	30.2	30.6	30.9	31.4	33.6	33.3	32.5	29.3	28.5	27.6	.0
16.2	27.1	27.7	29.1	29.3	29.6	29.9	30.1	30.4	30.6	30.9	33.4	33.0	32.5	.0	.0	.0	.0
19.8	.0	27.6	29.0	29.3	29.6	29.8	30.0	30.2	30.4	30.6	.0	.0	.0	.0	.0	.0	.0
23.4	.0	27.6	29.0	29.2	29.5	29.7	29.8	30.1	30.2	30.4	.0	.0	.0	.0	.0	.0	.0
27.0	.0	.0	29.0	29.2	29.5	29.6	29.8	30.0	30.1	.0	.0	.0	.0	.0	.0	.0	.0
30.6	.0	.0	29.0	29.2	29.4	29.6	29.7	29.9	.0	.0	.0	.0	.0	.0	.0	.0	.0
34.2	.0	.0	.0	.0	29.4	29.6	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

Note: Identified depths are relative to a lake elevation of 685.5 feet above mean sea level.

Appendix A

Thermal Demonstration
Pursuant To
Illinois Pollution Control Board
Rules and Regulations
Chapter 3, Rule 203 (i) (10)

Section 5 Hydrothermal Model

Section 6 Results

Illinois Power Company

Clinton Power Station

Unit 1

July 1980

SECTION 5.0
HYDROTHERMAL MODEL OF CLINTON LAKE

The natural circulation in a long, narrow, relatively deep impoundment like Clinton Lake is controlled by inflows and outflows, wind driven circulation, vertical stratification and thermal convection (due to differential heating and cooling between more rapidly heated and cooler shallow waters and the deeper portions of the lake). For summertime low flow conditions, wind driven circulation tends to dominate. With the plant in operation, the lake circulation will be modified by: (1) the plant pumping from the discharge to the intake, and (2) additional thermal convection due to the warmer discharge over the surface and attendant sinking of cooler water to the deeper portions of the lake and movement back toward the discharge as a density underflow. The hydrodynamics and temperature structure of Clinton Lake is essentially two dimensional in the longitudinal and vertical directions, with limited lateral variability.

5.1 THE LARM MODEL

The hydrodynamic and temperature distribution analysis of Clinton Lake requires a model that represents the longitudinal and vertical equations of fluid motion, continuity and heat transport and that incorporates a coupling of buoyancy between the temperature distribution and the equations of motion as well as surface wind forces. The Laterally Averaged Reservoir Model (LARM) has been developed for the analysis and prediction of two dimensional (longitudinal and vertical) hydrodynamics and temperature structure using time varying inflow, outflow and meteorological data.(1,2)

LARM represents an advancement in the state-of-the-art of impoundment and cooling lake analysis and prediction. It was originally developed for the Ohio River Division of the U.S. Army Corps of Engineers and has received extensive testing and verfication by application to Sutton Lake, West Virginia, Center Hill Reservoir, Tennessee and compared to laboratory flume tests at the Waterways Experiment Station in Vicksburg, Mississippi. The LARM model has also been applied to the study of chlorine transport in a stratified cooling lake, safe shutdown impoundment analysis and multiple thermal discharges on a stratified run of river impoundment.

Development of the LARM hydrodynamics and transport code has three basic steps including: (1) integration of the three-dimensional equations of fluid motion and transport to the laterally averaged form; (2) manipulation of the laterally averaged equations to arrive at the solution technique; and (3) development of the numerical finite difference form of the equations for computer coding. The first step of forming the laterally averaged transport relationships has been presented in Reference 2. The remaining two steps are described below.

5.1.1 THE LATERALLY AVERAGED RELATIONSHIPS

The laterally averaged equations of fluid motion and transport are the horizontal momentum balance:

$$\frac{\partial UB}{\partial t} + \frac{\partial UUB}{\partial x} + \frac{\partial WUB}{\partial z} = -\frac{1}{\rho}\frac{\partial BP}{\partial x} + \frac{\partial}{\partial x}(BAx\partial U/\partial x) + \frac{\partial\partial\tau x}{\partial x}, \qquad (5.1)$$

and the vertical equation of motion as reduced to the hydrostatic approximation:

$$\frac{\partial P}{\partial z} = \rho g\ . \qquad (5.2)$$

The equation of fluid continuity is:

$$\frac{\partial UB}{\partial x} + \frac{\partial WB}{\partial z} = qB\ . \qquad (5.3)$$

The equation of heat transport is:

$$\frac{\partial BT}{\partial t} + \frac{\partial UBT}{\partial x} + \frac{\partial WBT}{\partial z} - \frac{\partial}{\partial x}(BDx\partial T/\partial x) - \frac{\partial}{\partial z}(BDz\partial T/\partial z) = HnB/\rho Cp\ . \qquad (5.4)$$

The equation of state relating density and temperature is:

$$\rho = \rho_t(T) \quad . \tag{5.5}$$

In the above equations,

x = Horizontal dimension
z = Vertical dimension
t = time
U = The laterally averaged horizontal velocity component
W = The laterally averaged vertical velocity component
B = Waterbody width as a function of x and z
P = Fluid pressure
ρ = Fluid density
ρ_t = Temperature dependent fluid density
Ax = Horizontal momentum dispersion coefficient
τx = Vertically distributed horizontal shear
g = Vertical gravitational acceleration
q = Lateral inflow and outflows per unit volume
T = Temperature
Hn = Net heat additions or losses per unit volume
Cp = Specific heat of water.

Equations 5.1 to 5.5 constitute five equations in x, z and t to be solved for the five unknowns of U, W, P, T and ρ.

For a free water surface located at $z = \zeta(x,t)$ and a fixed bottom located at $z = h(x)$, the free water surface is related to the above relationships (Equations 5.1-5.5) by vertically integrating continuity in Equation 5.3 to give

$$B_\zeta \frac{\partial \zeta}{\partial t} = \frac{\partial}{\partial z} \int_\zeta^h UB\, dz - \int_\zeta^h qB dz \tag{5.6}$$

where $B\zeta$ is evaluated at $z=\zeta$ and where $W_\zeta = \partial\zeta/\partial t$. In Equation 5.6 the vertical integral of $\partial UB/\partial x$ has been expanded by Liebnitz' rule to give the gradient of the vertical integral of the horizontal velocity, and the terms $UB\partial h/Mx$, $UBMz/Mx$ and Wh cancel by application of kinematic boundary conditions.

5.1.2 THE FINITE DIFFERENCE RELATIONSHIPS

The irregular boundaries of a real waterbody, the irregular form of the time-varying boundary data and the complexity of the interrelationships between the five transport equations require that finite difference forms of the equations be evaluated for a numerical solution. The order of equation solution, at each time step, is (1) evaluate the water elevation as a function of x from Equation 5.6, (2) use these results to evaluate the horizontal pressure gradient and evaluate the horizontal velocity component from Equation 5.1, and (3) evaluate the vertical velocity component by integrating Equation 5.3 vertically upward from the bottom. The horizontal and vertical velocity components are used to determine the temperature distribution and hence the density distribution, which in turn enters the horizontal momentum and the surface elevation equations through the horizontal pressure gradient.

The differencing scheme chosen for the equations is a space-staggered orientation of the variables shown in Figure 5-1. The state variables of pressure, P, temperature, T, and density, ρ, are defined at one set of points and U and W velocity components are defined at the intermediate horizontal and vertical points, respectively. The space-staggered grid allows the horizontal pressure gradient for computing $U_{i,k}$ to be determined directly from the computed values of $P_{i,k}$ and $P_{i+1,k}$ with no spatial averaging. The finite difference velocity components $U_{i,k}$ and $W_{i,k}$ are defined as averages over Wz and Wx, respectively. Transport of heat and other constituents is defined by the location of the $U_{i,k}$ and $W_{i,k}$ velocity components.

Numerical evaluation of the integrals and development of the finite difference z equation requires establishing the grid notation for the overall waterbody. As shown in Figure 5-2, the longitudinal and vertical profile of the waterbody

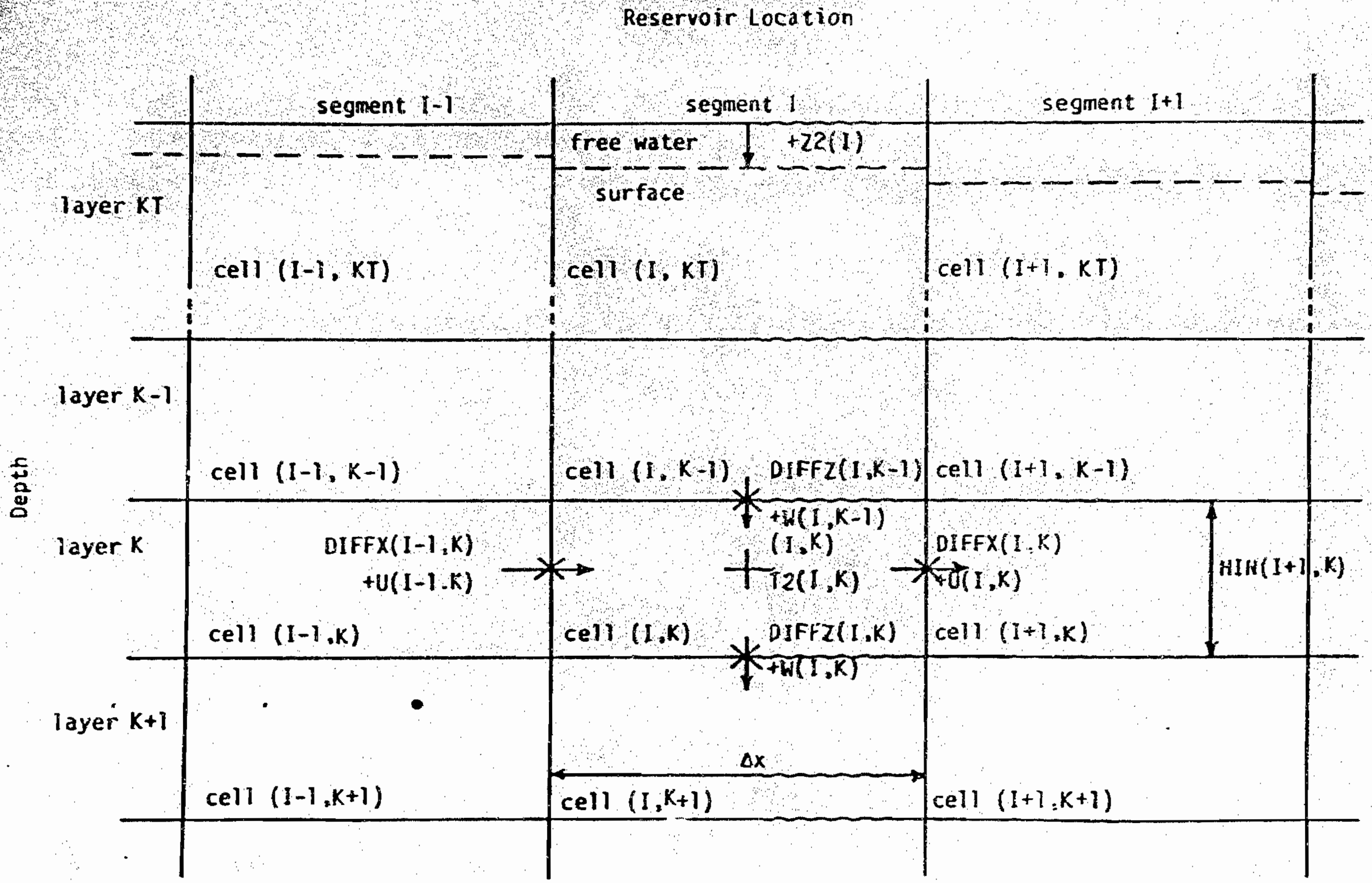


Figure 5-1. Relative Location and Sign Convention for Determination of Major Variables by Cells in LARM.

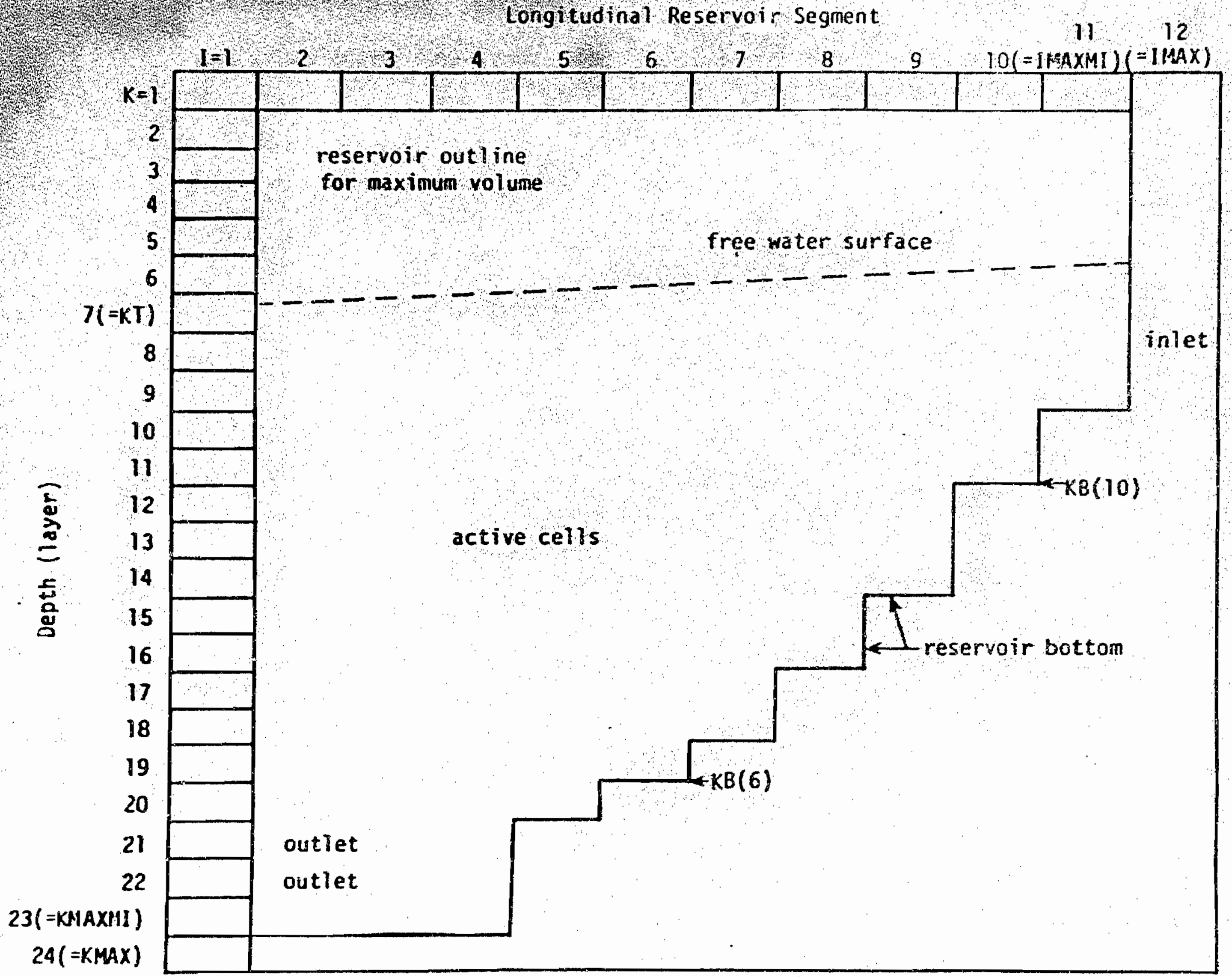


Figure 5-2. Representative Reservoir Grid and Cell Nomenclature for LARM.

is divided into a set of Δx and Δz cells each with a lateral width of B(i,k). The top active layer is identified as KT and the bottom of each column is KB which is a function of I.

5.1.3 NUMERICAL CONSTITUENT TRANSPORT, T and ρ

Once U and W are known for the $t+\Delta t$ time step, the temperature distribution can be computed from Equation 5.4. An "upwind" differencing scheme is used for the advection terms, $\partial UBT/\partial x$ and $\partial WBT/\partial z$, to maintain numerical stability. The temperature equation is solved spatially implicitly line by line for the reservoir grid depicted in Figure 5-2.

Heating and cooling due to meteorological conditions is described by surface heat exchange and attenuation of short wave solar radiation through the water column. The net rate of surface heat exchange for the top cell is:

$$Hn = (Hs + Ha - Hsr - Har) - (Hbr + He + Hc) , \qquad (5.7)$$

where:

Hn = Net rate of surface heat exchange
Hs = Short wave solar radiation
Ha = Long wave atmospheric radiation
Hsr = Short wave radiation reflection
Har = Atmospheric radiation reflection
Hbr = Long wave back radiation from the water surface
He = Evaporative heat loss
Hc = Conduction between air and water.

The net rate of surface heat exchange is evaluated in terms of the coefficient of surface heat exchange, K_s, and the equilibrium temperature, E,(3) to give:

$$Hn = -K_s (Ts - E) , \qquad (5.8)$$

where Ts is the water surface temperature. The coefficient of surface heat exchange and the equilibrium temperature are computed from meteorological data of short wave solar radiation (Hs), air temperature (Ta), dew point temperature (Td), and scalar wind speed (Ws).

Short wave solar radiation penetrates the water surface and is attenuated through the water column as:

$$Hs(z) = Hs(1 - b)\,Exp\,(-az)\,, \qquad (5.9)$$

where b is the fraction absorption in the surface layer, a is the radiation attenuation coefficient, and z is the depth below the water surface. The short wave solar radiation, Hs, is either measured directly with a pyroheliometer or computed from latitude, solar angle and cloud cover information.

5.2 MODEL SET-UP

Model set-up requires specifying detailed reservoir geometry as lateral widths at each depth at each cross-section, the location and operation of inflows and outflows to and from the lake, and boundary conditions at internal barriers in the lake.

Model geometry was determined from reservoir cross-sections derived from a reservoir topographic map.(4) Cross-sectional data was placed in the GEDA program developed by the Hydrologic Engineering Center U.S. Army Corps of Engineers.(5) The GEDA program allows interpolating the cross-sectional data to uniformly spaced model cross-sections and determining the reservoir widths in each layer of the cross-sections.

Computational cells required division of Clinton Lake into longitudinal segments, shown in Figure 5-3. Longitudinal spacing of computational cells was determined from inspection of a planar map such that the plant discharge and intake were positioned near the centers of cells and that the internal barrier bridges were near the ends of the cells. A longitudinal grid spacing of

TABLE 5-1

CLINTON LAKE SCHEMATIZATION FOR LARM; CELL WIDTHS IN FEET SHOWN ON LONGITUDINAL-VERTICAL VIEW NORTHEAST FROM THE DAM

	I=1	I=2	I=3	I=4	I=5	I=6	I=7	I=8	I=9	I=10	I=11	I=12
K=1												
K=2		1098	1236	1531	1902	2139	2327	2694	3188	3523	3527	3333
K=3		994	1159	1476	1860	2104	2294	2658	3139	3450	3422	3207
K=4		840	1048	1403	1806	2057	2251	2616	3089	3372	3297	3045
K=5*		621	878	1286	1729	1998	2198	2566	3033	3285	3147	2840
K=6		368	650	1122	1620	1921	2134	2504	2960	3175	2968	2593
K=7		178	454	913	1434	1780	2040	2428	2863	3029	2751	2299
K=8		79	265	618	1987	1499	1883	2322	2710	2803	2450	1916
K=9		29	118	331	696	1137	1615	2078	2412	2405	2050	1447
K=10		11	50	176	444	830	1276	1692	1979	1999	1605	1000
K=11			26	101	278	576	976	1364	1596	1560	1175	631
K=12			11	45	137	341	691	1055	1221	1102	741	334
K=13					48	148	360	604	695	559	315	117
K=14					10	36	103	195	226	156	64	16
K=15							10	23	30	19		
K=16												

	I=13	I=14	I=15	I=16	I=17	I=18	I=19	I=20	I=21	I=22	I=23	I=24
K=1												
K=2	3015	2589	2288	2170	2094	2037	1987	1831	1542	1303	1220	
K=3	2897	2496	2250	2061	1939	1853	1797	1642	1356	1120	1037	
K=4	2744	2384	2113	1943	1771	1653	1590	1438	1157	925	844	
K=5*	2542	2230	1983	1769	1521	1354	1282	1138	870	650	572	
K=6	2271	1969	1717	1447	1112	889	812	696	480	302	239	
K=7	1919	1577	1299	1011	656	424	357	292	173	75	40	
K=8	1474	1110	841	604	328	148	103	83	44	13		
K=9	967	631	419	280	136	43	21	17	9			
K=10	538	269	131	75	35							
K=11	256	89										
K=12	95	20										
K=13	24											
K=14												
K=15												
K=16												

---

* K5 is the elevation of 690 ft. M.S.L. which is the design pool elevation.

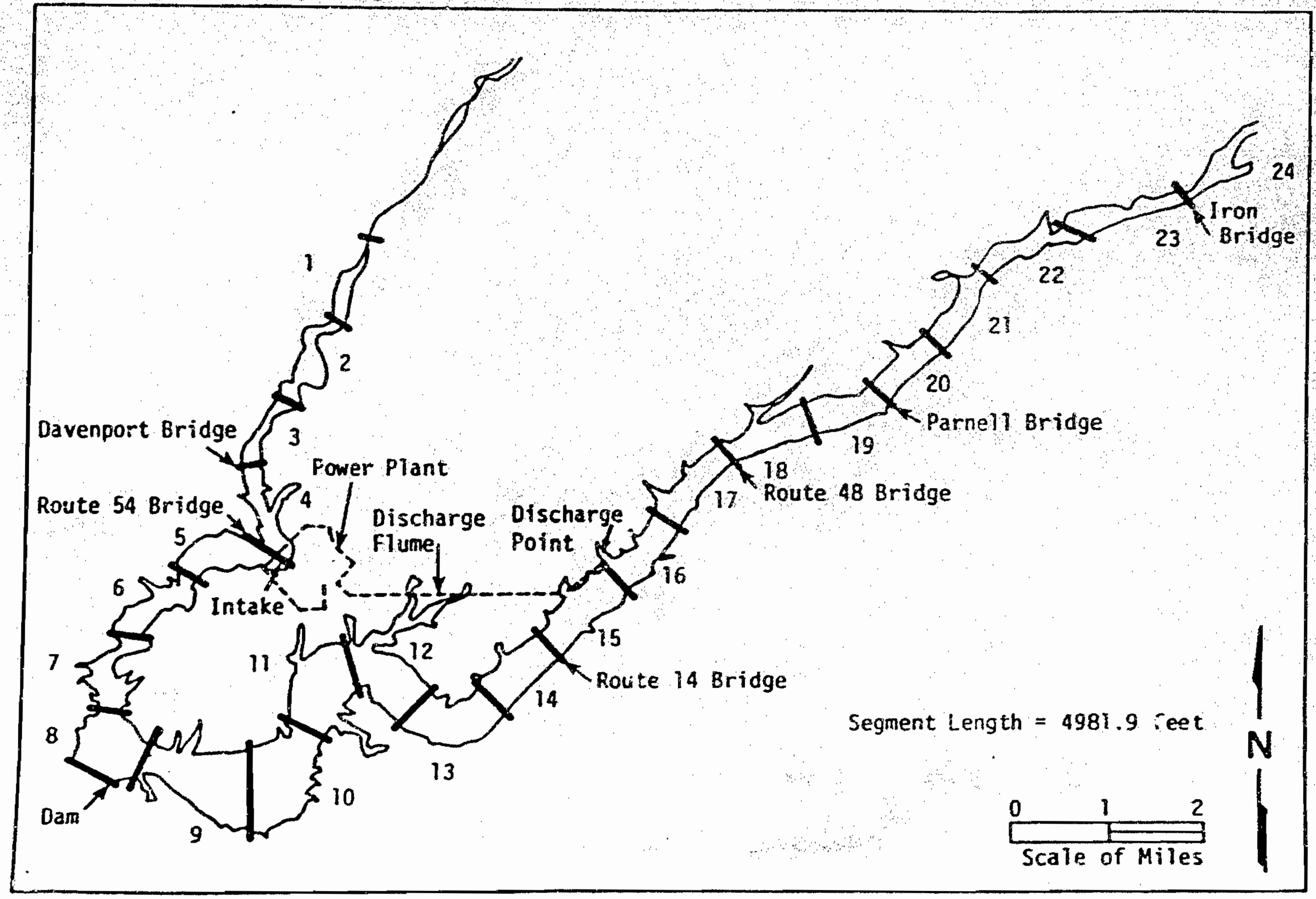


Figure 5-3. Longitudinal Segmentation of Clinton Lake for LARM Application

Wx = 1518.5 meters (4981.9 feet) satisfied these constraints. The depth of each cell was chosen to be Δz = 1.1 meters (3.6 feet) for vertical detail. The lake longitudinal and vertical profile was resolved into a grid 22 cells long (at the maximum water surface) by a maximum of 14 cells deep (from the maximum flood level water surface to the bottom). The widths of each cell, shown as a longitudinal (extending down the North Fork arm and up the Salt Creek arm) and vertical profile of the lake determined using GEDA are given in Table 5-1.

The model set up for Clinton Lake also requires specifying the hydraulic conditions of the tributary inflows, the submerged lake outlet structure, the spillway, the plant intake structure, the plant discharge structure, and at the barrier bridges. These are described in the following sections.

5.2.1 TRIBUTARY INFLOWS

The North Fork tributary inflow entered the model computational grid at Cell I=2, K=6 and the Salt Creek inflow entered at Cell I=23, K=6 (Table 5-1). Both of these inflows were assumed to enter the model at a fixed depth below the lake operating surface elevation. Since the upper reaches of both arms are separated by internal barriers, i.e., bridge causeways, from the main lake, any convective circulation due to the inflows being warmer or cooler than the lake temperature at which they enter was confined to the longitudinal cells between the inflow and the first barrier. Normally during the summer months inflow temperatures were less than the lake surface temperature and the inflows entered at a low level density inflow as specified in the model.

5.2.2 SUBMERGED LAKE OUTLET WORKS

The submerged lake outlet works at the dam is shown in Figure 5-4. It is used to maintain a minimum downstream release of five cfs. With a single 12-inch gate open, discharge is 5 cfs at an elevation of 687 ft. MSL and increases with surface elevation to 10 cfs at a pool elevation of 690 ft. MSL. In the model set-up the low flow withdrawal structure is assumed to withdraw from cell I=8, K=10.

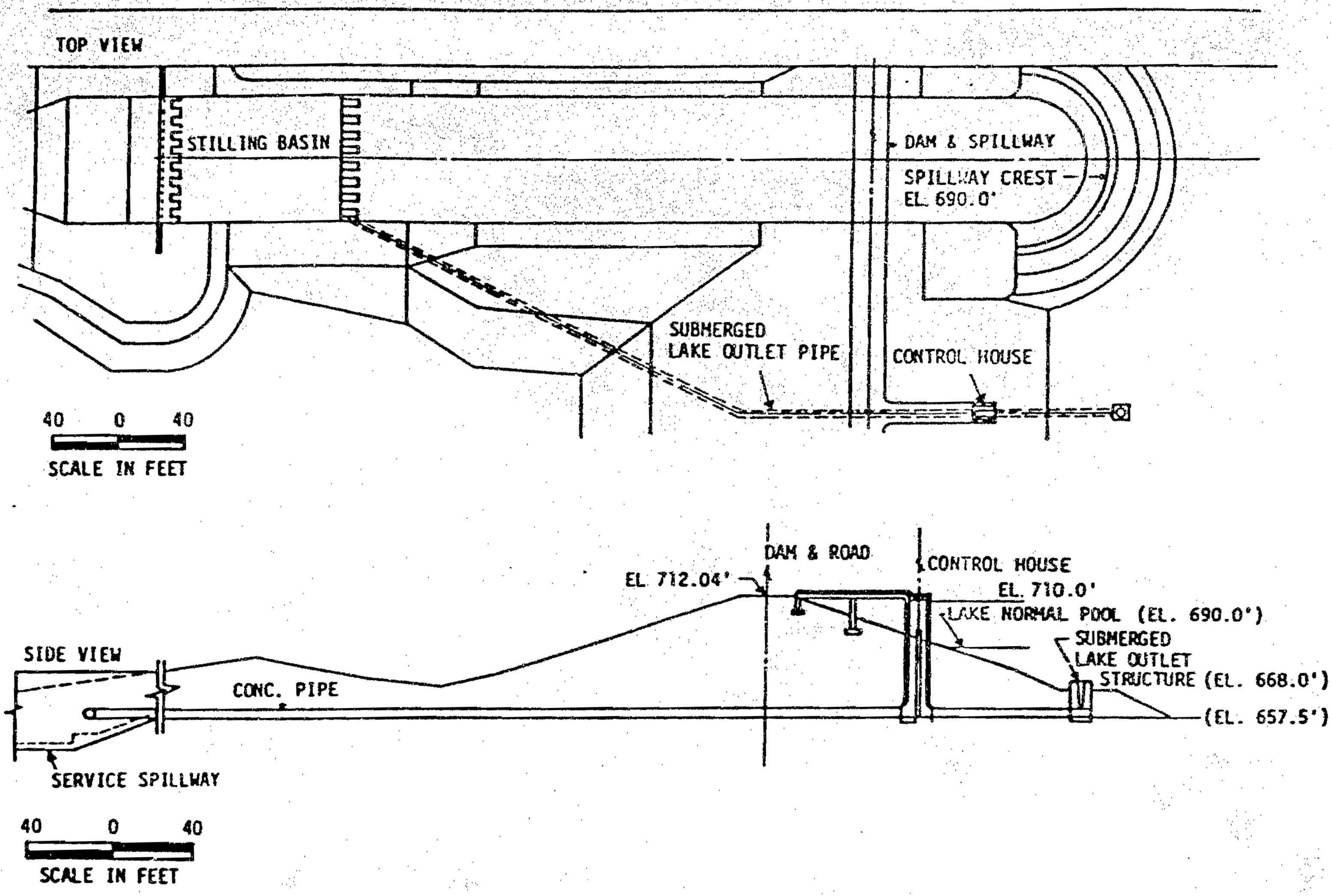


Figure 5-4. Clinton Lake Outlet Works

SECTION 6.0
RESULTS OF HYDROTHERMAL MODEL

The hydrodynamic and temperature regimes are computed for the 1978 year of meteorological data under the following conditions: (1) no heat load to determine the distribution of ambient temperature, (2) with one unit operation at both 92 and 100 percent load (3) with two unit operation at 92 percent load with the effluent temperature constrained to 35.6°C (96°F), i.e., the existing effluent limitation to Clinton Lake. The 1978 results are use to verify and validate the application of LARM to Clinton Lake and represen the fourth worst summer in 26 years. The 1955 year of data are computed fo the same conditions and represent the worst summer in 26 years. The power plant cooling water heat rejection is taken at 92 percent of the full load value to be compatible with the conditions in a previous study conducted fo IPC.(1)

6.1 1978 PREDICTIONS

Results of the 1978 computations are given in Appendices B.1 to B.4 for the four cases of ambient temperature, unconstrained one unit operation at 92 and 100 percent load and constrained two unit operations during the two warmest weeks of the summer. The ambient temperature predictions can be cor pared to the monthly lake temperature measurements made during 1978. A preliminary examination of the 1978 temperature data indicated a groundwater inflow was taking place in the deeper portions of the lake near segment 8 of the lake profile given in Table 5-1. A groundwater source is incorporated in the model for the bottom cell of this section for the 1978 computations.

6.1.1 AMBIENT TEMPERATURES AND VERIFICATION

Comparisons of the monthly temperature measurements at three stations throughout the lake to the computed temperatures for 1978 with no heat load are presented in Figure 6-1.(2) The measurements are for 1 meter depth inte vals while the predictions begin approximately 0.5 meters under the surface and are for 1.1 meter increments below that depth and must be interpolated between the observations for comparison.

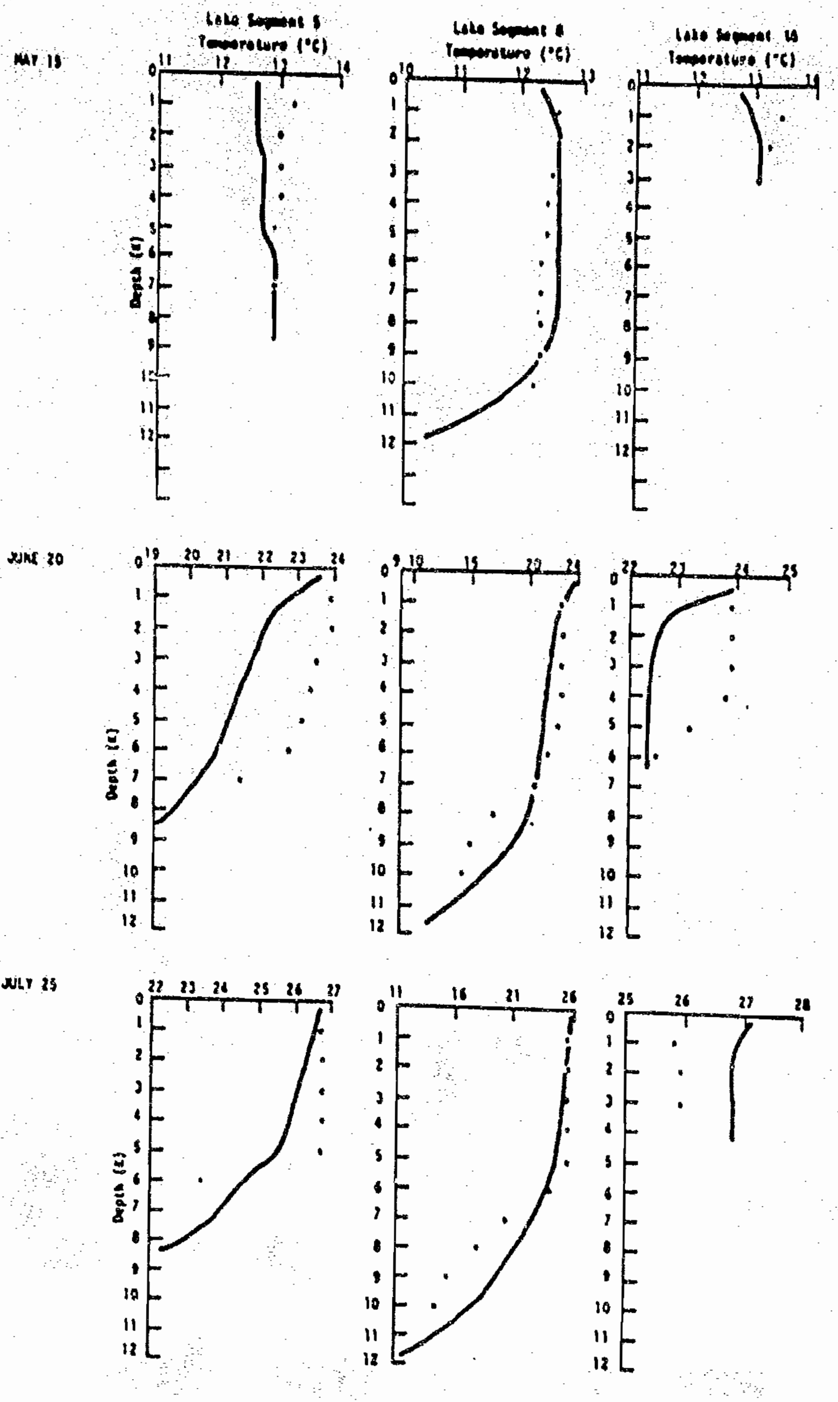


Figure 6-1. Verification of LARM (line) with Measured Field Data (dots) from Clinton Lake during 1978

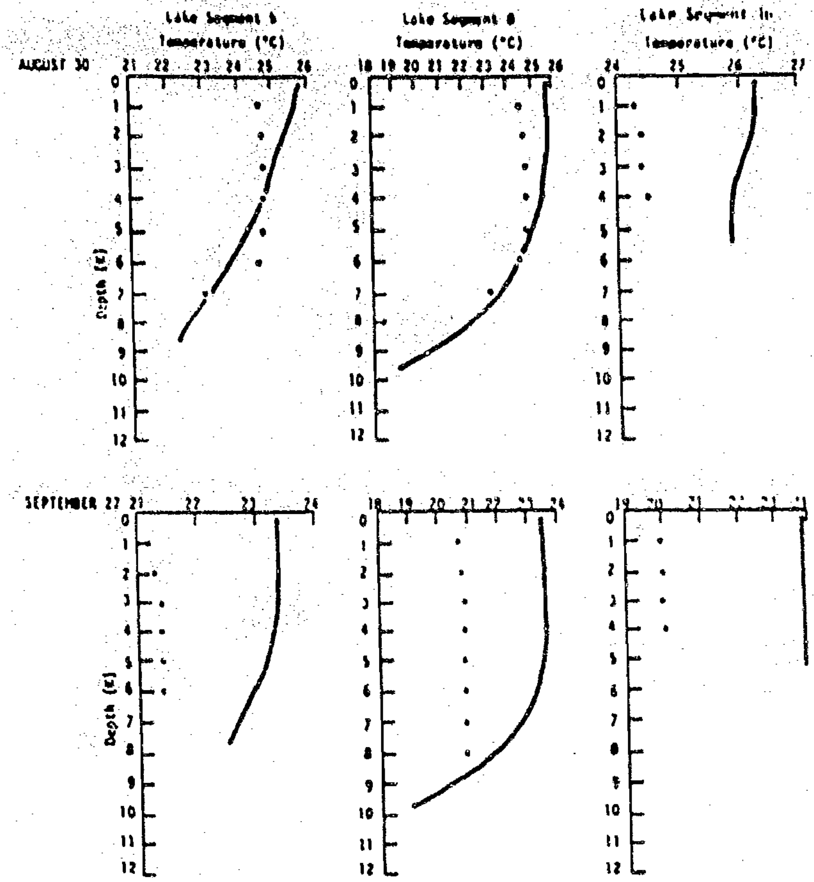


Figure 6-1. (Continued)

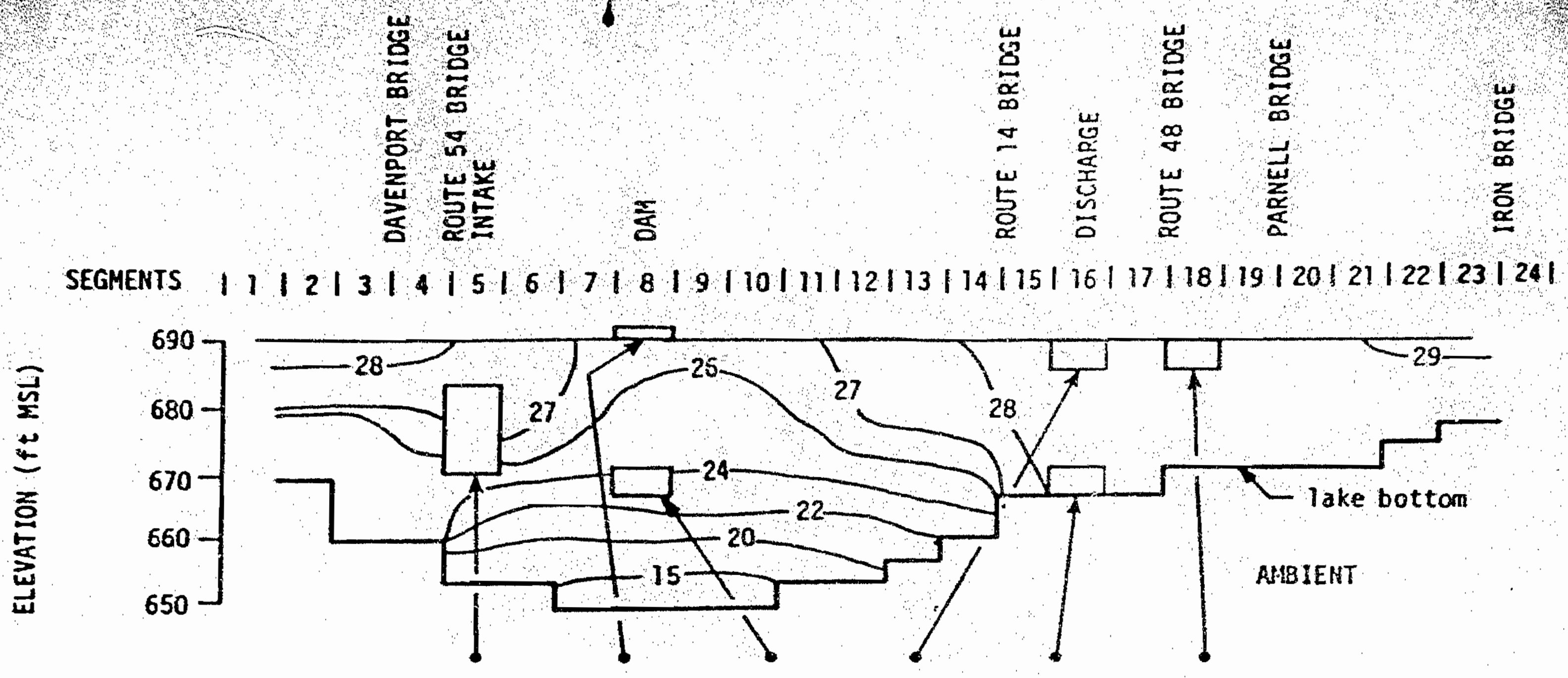
Comparisons for the deepwater segment (8) are quite good until the September 27, 1978 survey when predicted temperatures tend to be conservative, i.e., 2.5C° to 3C° (4.5 to 5.4F°) higher than measured temperatures. Examination of the 1978 meteorological data, Appendix A.1, indicates that the observed offsite short wave solar radiation for the period of September 23 to 26, 1978 is high relative to the observed on-site air temperatures, and this can account for the higher predicted temperatures.

Comparisons for the shallower segments (5 and 16) are not as good as the deep water segment. Model prediction for segment 5 at the upper portion of North Fork and segment 16 at the upper portion of Salt Creek appear to underestimate temperatures in early summer and overestimate temperatures in late summer. These discrepancies may be due to groundwater sources in the upper portion of each segment not considered in the model. Overall LARM appears to be well suited to simulate the thermal response of Clinton Lake.

Computed maximum lake temperatures occur on day 204 when the shallow water upper arm surface temperatures reach 28.5°C (83.3°F) to 29.1°C (84.4°F) and the deeper stations near the dam have surface temperatures ranging from 26.5°C (79.7°F) to 26.6°C (79.9°F). The shallower upper arms warm faster, as expected, but wind mixing and thermal convection would tend to diminish longitudinal surface temperature gradients. Internal barriers (bridge causeways and submerged road beds) tend to prevent surface mixing between the upper arm and deeper stations.

Computed ambient temperatures for the warmest day (Julian day 204) are shown in Figure 6-2 in the longitudinal and vertical directions. Also listed are the summary statistics for July. As can be seen in Figure 6-2, median temperatures in July were a maximum of 2.6C° (4.7F°) lower than the maximum daily values on day 204.

The lake circulation as indicated by the vertical profiles of the horizontal velocity component (U) is dominated by the wind driven surface currents.



ZEROTH PERCENTILE	23.30	24.90	22.00	25.60	24.90	26.00
FIFTH PERCENTILE	23.48	25.02	22.00	25.60	24.96	26.06
TENTH PERCENTILE	23.70	25.12	22.08	26.32	25.10	26.58
TWENTIETH PERCENTILE	24.10	25.34	22.70	26.54	25.10	26.94
THIRTIETH PERCENTILE	24.30	25.56	22.90	26.86	25.20	27.16
FORTIETH PERCENTILE	24.40	25.96	23.30	27.00	25.46	27.36
MEDIAN	24.50	26.10	23.40	27.20	25.60	27.40
SIXTIETH PERCENTILE	25.00	26.42	23.52	27.40	25.94	27.64
SEVENTIETH PERCENTILE	25.24	26.60	23.80	27.44	26.84	27.90
EIGHTIETH PERCENTILE	25.86	26.76	24.02	27.60	26.96	28.20
NINETIETH PERCENTILE	26.28	27.00	24.20	27.98	27.40	28.50
NINETY-FIFTH PERCENTILE	27.00	27.14	24.36	28.34	27.78	28.64
HUNDREDTH PERCENTILE	27.30	27.20	24.60	28.40	28.20	28.70
MEAN	24.87	26.10	23.34	27.12	25.98	27.51
STANDARD DEVIATION	0.98	0.68	0.70	0.67	0.94	0.69

Figure 6-2. Graphic Presentation of Longitudinal and Vertical Ambient Temperatures (°C) of Clinton Lake on July 23 (Julian Day 204), 1978 and Tabulated Summary Statistics for July 1978.

The vector wind direction and resulting wind shear, given in the Appendix B.1 Tables, causes a water surface slope up the arms for southerly winds and toward the dam for northerly winds with a surface current following the wind direction. The wind-induced surface slope results in a return bottom flow opposite in direction to the surface flow. This cellular circulation due to the wind is interrupted by the bottom barriers and the different orientation of successive lake sections to the wind direction.

6.1.2 1978 WITH HEAT LOADS

The temperature and flow distributions resulting from the heat loads and circulation imposed by 1 unit and 2 unit operations are given in Appendices B.2 through B.4. Examination of the day to day circulation patterns generally show a surface flow due to discharge buoyancy. The surface flows return toward the deeper portions of the lake and the discharge region as a density flow that resemble a two cell circulation. Discharge buoyancy induced velocities and wind induced velocities are additive resulting in complex and dynamic flow patterns in Clinton Lake.

General circulation due to the discharge is a result of the cooling and sinking of the discharge water at the extremities of the lake near the intake and near the Route 48 bridge. The cooler underflow is mixed upward into the moving surface layer and decreases the surface temperature through mixing as well as surface heat dissipation. The underflow from the dam toward the discharge region generally reaches the discharge for one unit operation resulting in substantial stratification near the discharge. For constrained two unit operation the flow from the discharge region is generally down the lake and stratification is less intense than for 1 unit operation. The bottom water at the discharge for two unit operation is provided from the return circulation upstream of the discharge.

Wind mixing from day to day is sometimes strong enough to break up the density induced circulation due to the discharge. The wind mixing is important in maintaining deeper layer water quality since without it the underflow returning toward the discharge has little opportunity for surface reaeration.

Maximum surface temperatures for both 1 unit and 2 unit constrained operation occurs on day 204. The detailed temperature distribution for 1 unit operations at 92 and 100 percent load on day 204 is given in Figure 6-3. The 1 unit operation for this day at 92 percent load results in a discharge flume temperature of 37.4°C (99.3°F) and a mixed temperature at the surface of 36.1°C (97.0°F). Stratification at the discharge results in a maximum bottom water temperature of 32.4°C (90.3°F). At 100 percent load, the discharge flume temperature is 38.2°C (100.8°F), the mixed temperature of the lake surface at the point of discharge is 36.7°C (98.1°F) and the maximum bottom lake temperature at the point of discharge is 32.8°C (91.0°F). There is little difference in the two profiles between 92 and 100 percent load factors.

Monthly summaries of temperature under Unit 1 operation at 92 percent load are presented in Figures 6-4, 6-5, 6-6, 6-7 for June, July, August and September, respectively. A temperature difference is noted at the discharge cell as surface temperatures are typically 4C° (7.2F°) higher than those at the bottom of the discharge cell, a depth of 6 meters. That large difference decreases toward the dam as temperature differences from surface to near bottom vary from 1.5C° (2.7F°) to 2C° (3.6F°). The internal barrier resulting from the Route 48 Bridge may be affecting the surface temperatures upstream of the Route 48 Bridge. Surface temperatures appear low when considering that the two stations are separated by 3100 meters and the Route 48 Bridge is downwind of the dominant southwesterly winds.

Salt Creek temperatures downstream of the dam were investigated to determine if an exceedence of the 32.2°C (90°F) water quality standard had occurred; and if it did, whether the exceedance was greater than 1.7C° (3F°) for 1.0 percent of the time. Maximum downstream temperatures of Salt Creek were 28.2°C (82.8°F), 30.4°C (86.7°F) and 30.5°C (86.9°F) under 1978 no-heat load, one unit unconstrained at 92 percent load and one unit unconstrained at 100 percent load, respectively. These values are below the 32.2°C (90°F) water quality standard.

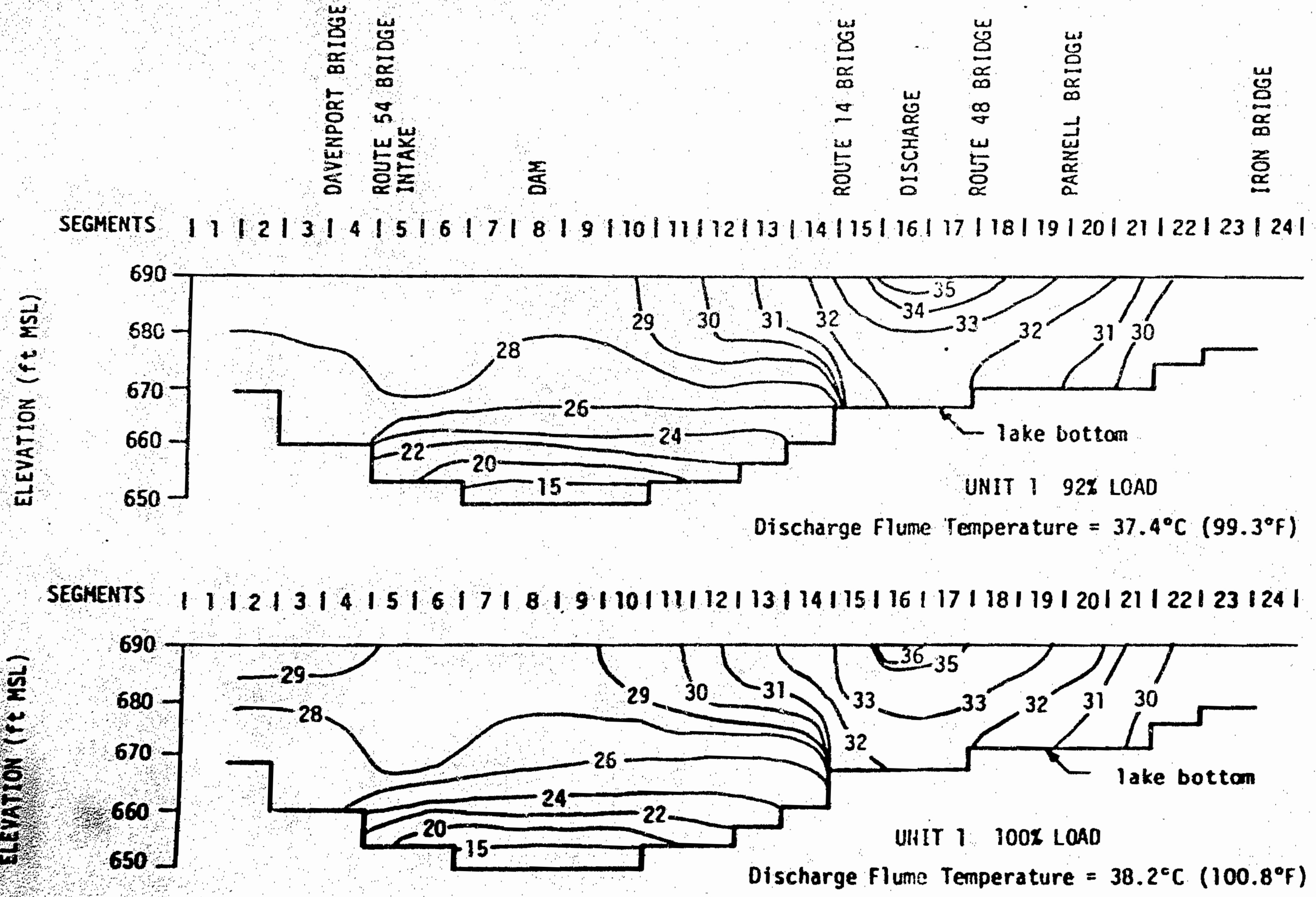
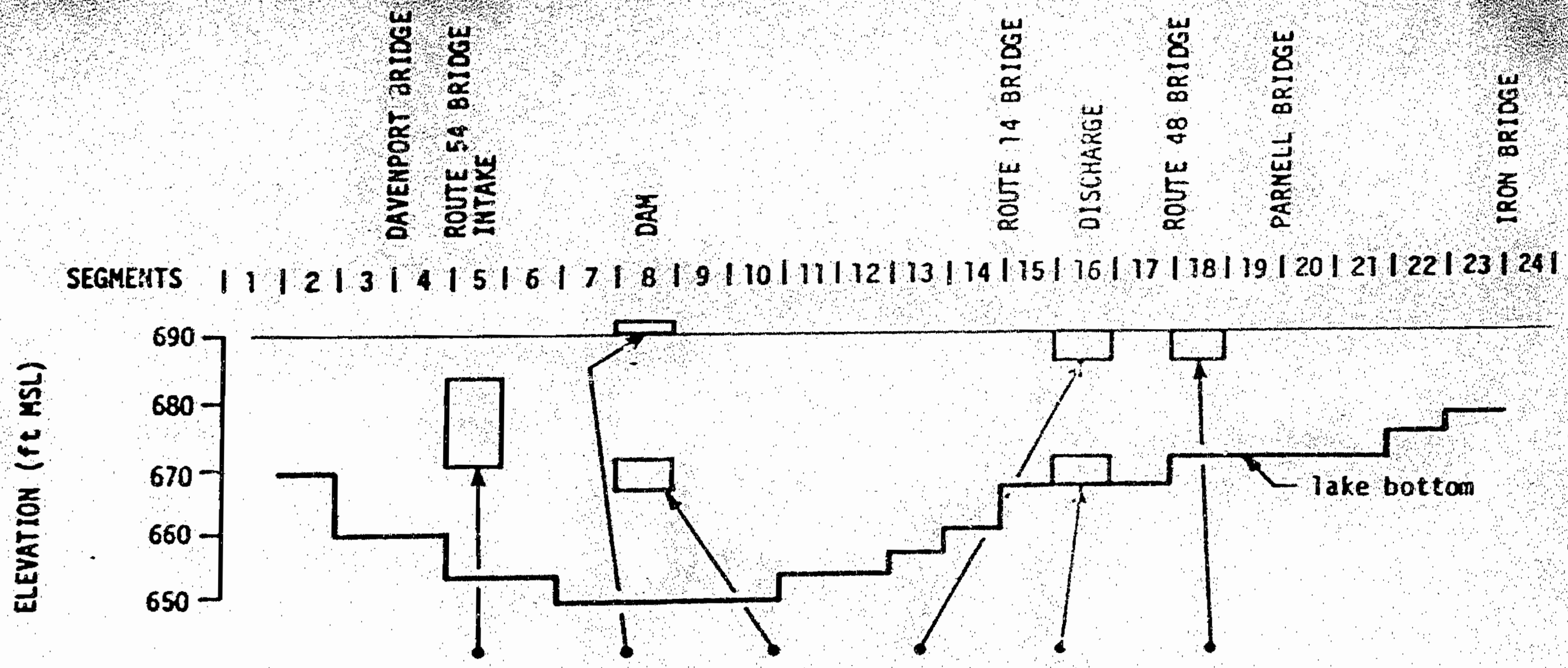
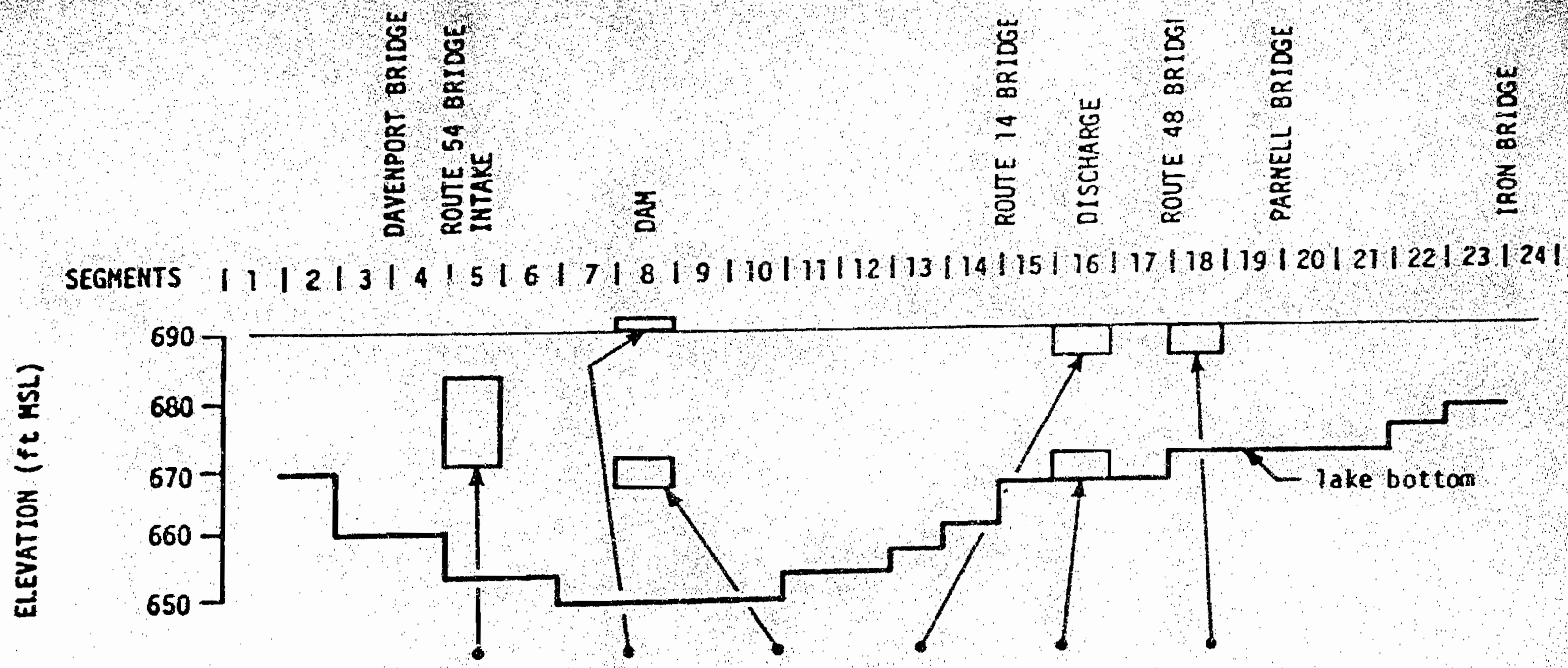


Figure 6-3. Longitudinal and Vertical Temperatures (°C) of Clinton Lake on July 23 [illegible] Under Unit 1 Operation at 92 and 100 Percent Load.



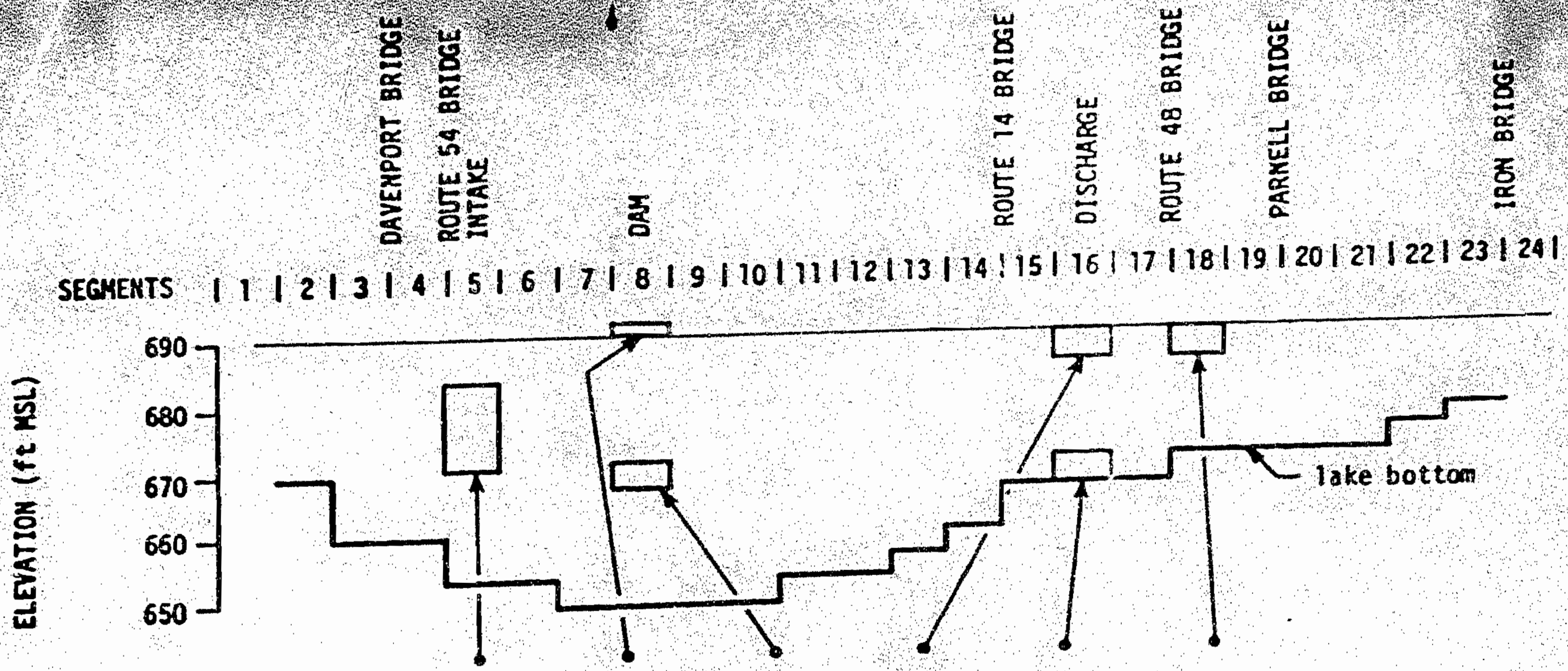
ZEROTH PERCENTILE	21.20	21.80	19.80	29.00	25.40	26.20
FIFTH PERCENTILE	21.48	21.86	19.86	29.00	25.62	26.26
TENTH PERCENTILE	22.13	22.03	20.53	29.12	25.81	26.71
TWENTIETH PERCENTILE	22.40	22.58	21.36	29.84	26.20	27.00
THIRTIETH PERCENTILE	22.93	23.13	21.73	30.20	26.40	27.43
FORTIETH PERCENTILE	23.10	23.38	22.38	30.40	26.44	27.90
MEDIAN	23.30	23.55	22.80	30.55	26.75	28.20
SIXTIETH PERCENTILE	23.50	24.20	22.90	30.96	27.06	28.30
SEVENTIETH PERCENTILE	23.70	25.11	23.07	31.54	27.40	28.70
EIGHTIETH PERCENTILE	25.04	26.18	23.40	32.92	27.70	29.86
NINETIETH PERCENTILE	25.89	27.11	23.79	33.69	28.35	31.00
NINETY-FIFTH PERCENTILE	26.10	28.44	24.25	34.00	28.64	31.44
HUNDREDTH PERCENTILE	26.10	28.60	24.30	34.00	28.80	31.60
MEAN	23.58	24.26	22.42	31.05	26.91	28.37
STANDARD DEVIATION	1.33	1.87	1.20	1.52	0.86	1.49

Figure 6-4. Summary Statistics of Temperatures (°C) of Clinton Lake during June 1978 Under Unit 1 Operation at 92 Percent Load.



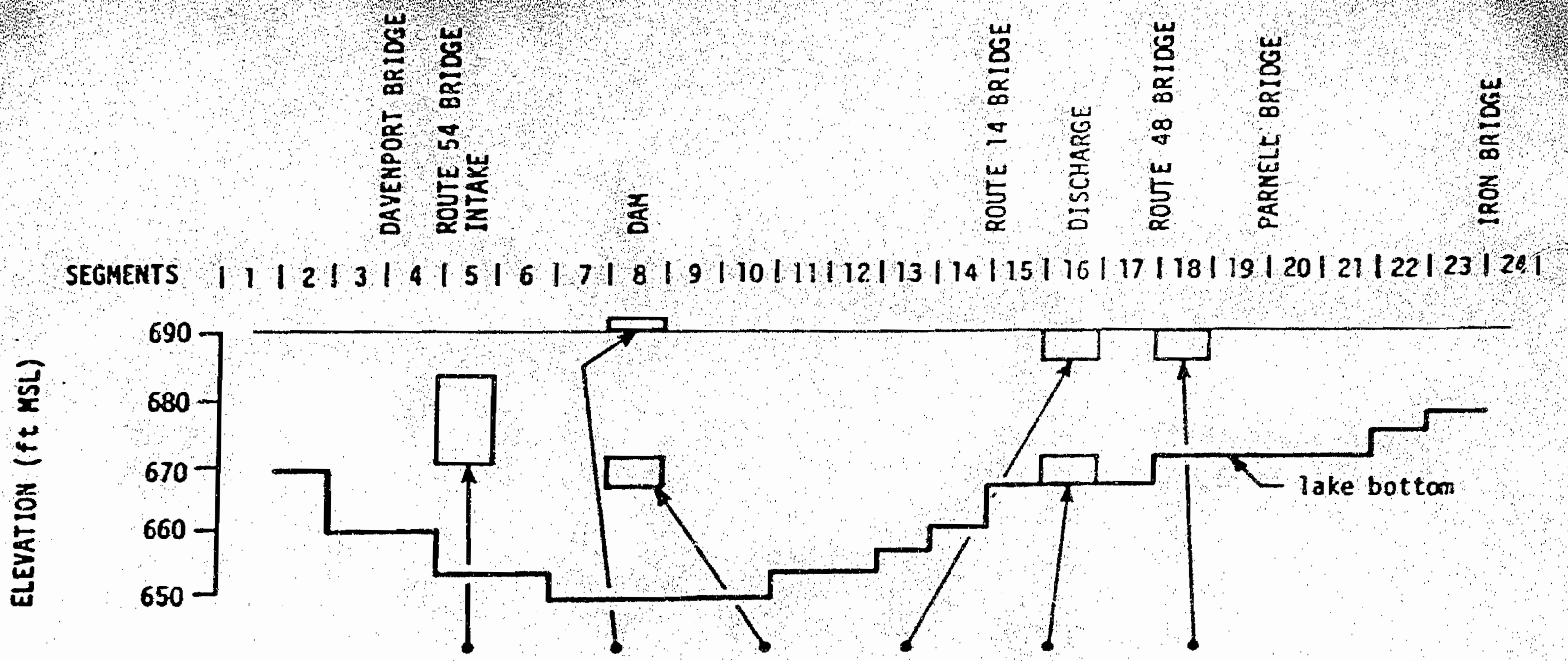
ZEROTH PERCENTILE	26.10	27.20	24.70	32.90	27.90	28.70
FIFTH PERCENTILE	26.22	27.26	24.70	33.02	28.02	28.76
TENTH PERCENTILE	26.70	27.40	24.88	33.26	28.24	29.22
TWENTIETH PERCENTILE	26.80	27.50	25.50	33.62	28.54	29.48
THIRTIETH PERCENTILE	26.90	27.76	25.60	34.20	28.66	30.46
FORTIETH PERCENTILE	27.08	28.08	26.20	34.40	28.78	30.60
MEDIAN	27.30	28.30	26.20	34.60	28.90	30.90
SIXTIETH PERCENTILE	27.40	28.52	26.32	34.70	29.46	31.24
SEVENTIETH PERCENTILE	27.50	28.74	26.44	34.80	30.38	31.68
EIGHTIETH PERCENTILE	27.82	28.86	26.60	35.06	30.30	32.06
NINETIETH PERCENTILE	28.30	29.30	26.90	35.64	31.44	33.46
NINETH-FIFTH PERCENTILE	28.84	29.34	27.10	36.12	31.98	34.04
HUNDREDTH PERCENTILE	28.90	29.40	27.10	36.30	32.40	34.10
MEAN	27.32	28.29	26.10	34.50	29.53	31.02
STANDARD DEVIATION	0.66	0.68	0.28	0.82	1.23	1.42

Figure 6-5. Summary Statistics of Temperatures (°C) of Clinton Lake During July 1978 Under Unit 1 Operation at 92 Percent Load.



ZEROTH PERCENTILE	26.60	27.10	26.00	33.60	28.70	29.30
FIFTH PERCENTILE	26.66	27.16	26.06	33.84	28.76	29.30
TENTH PERCENTILE	26.99	27.24	26.10	34.10	29.10	29.74
TWENTIETH PERCENTILE	27.10	27.64	26.20	34.34	29.20	30.54
THIRTIETH PERCENTILE	27.20	27.76	26.36	34.46	29.30	30.76
FORTIETH PERCENTILE	27.40	28.10	26.40	34.70	29.48	31.00
MEDIAN	27.70	28.20	26.50	34.90	29.60	31.30
SIXTIETH PERCENTILE	27.80	28.30	26.60	35.00	29.72	31.72
SEVENTIETH PERCENTILE	27.80	28.60	26.70	35.10	30.14	31.94
EIGHTIETH PERCENTILE	27.96	28.90	26.80	35.32	30.50	32.06
NINETIETH PERCENTILE	28.44	29.30	26.80	35.48	31.40	32.68
NINETY-FIFTH PERCENTILE	28.98	30.30	27.04	35.60	31.68	33.02
HUNDREDTH PERCENTILE	29.40	30.60	27.10	36.10	31.80	33.20
MEAN	27.62	28.28	26.51	34.82	29.85	31.29
STANDARD DEVIATION	0.59	0.79	0.28	0.55	0.85	1.00

Figure 6-6. Summary Statistics of Temperatures (°C) of Clinton Lake During August 1978 Under Unit 1 Operation at 92 Percent Load.



ZEROTH PERCENTILE	24.50	25.10	24.70	31.20	27.20	27.10
FIFTH PERCENTILE	24.56	25.10	24.81	31.31	27.20	27.10
TENTH PERCENTILE	24.82	25.31	24.92	31.81	27.30	27.24
TWENTIETH PERCENTILE	25.10	25.92	25.42	32.16	28.16	28.04
THIRTIETH PERCENTILE	26.17	26.45	25.89	33.10	29.13	29.30
FORTIETH PERCENTILE	27.04	27.04	26.20	34.00	29.50	30.78
MEDIAN	27.25	27.45	26.30	34.20	30.15	31.40
SIXTIETH PERCENTILE	27.40	27.90	26.46	34.66	30.26	31.66
SEVENTIETH PERCENTILE	27.77	28.24	26.50	35.07	30.90	32.14
EIGHTIETH PERCENTILE	28.00	28.58	26.58	35.18	31.10	32.64
NINETIETH PERCENTILE	28.29	28.90	26.60	35.78	31.95	32.90
NINETY-FIFTH PERCENTILE	28.63	29.55	26.85	35.95	32.15	33.14
HUNDREDTH PERCENTILE	28.90	29.60	26.90	36.00	32.20	33.30
MEAN	26.86	27.33	26.09	33.98	29.82	30.67
STANDARD DEVIATION	1.31	1.32	0.62	1.45	1.54	2.05

Figure 6-7. Summary Statistics of Temperatures (°C) of Clinton Lake During September 1978 Under Unit 1 Operation at 92 Percent Load.

Figure 6-8 presents two unit operation at 92 percent load with temperature constraints. Constrained operation results in a discharge temperature to the lake of 35.6°C (96.0°F), a mixed temperature at the lake surface at the point of discharge of 35.1°C (95.2°F) and a maximum bottom lake temperature at the point of discharge of 32.8°C (91.0°F) on day 204.

A comparison of one unit unconstrained operation at 92 percent load (Figure 6-3) to two unit operation constrained (Figure 6-8) reveals the average temperature of the lake is higher in the latter case. The only exception is at the immediate point of discharge where the unconstrained discharge temperature is 1.8C° (3.2F°) above the constrained value. Longitudinal and vertical temperatures in Clinton Lake are lower under unconstrained operation of one unit versus constrained operation of two units for the vast majority of the lake.

A validation of the temperature results with heat loads and a comparative estimate of discharge mixing is provided by comparing the LARM predictions with a simpler plug flow heat balance. Temperature as a function of cooling lake surface area is given in the plug flow balance by the relationship:

$$T(A) = (\Delta Tp \ Exp\ (-kA/Q)\ /\ (1-Exp\ (-kAp/Q))) + Tamb \qquad (6.1)$$

where ΔTp is the plant condenser temperature rise, Ap is the lake surface area between the discharge and intake, T(A) is the temperature of the lake at A and Tamb is the ambient temperature of the lake before any heat additions.$^{(3)}$ Figure 6-9 gives the ambient and 1 unit LARM surface temperatures for day 204 as a function of distance (LARM Stations) along the lake. Simpl plugflow temperatures from Equation 6.1 are also given on Figure 6-9.

Figure 6-9 shows that the plugflow temperatures result in about the same intake temperatures as for the LARM results. However, due to the return density flow and mixing in the vicinity of the discharge, the LARM results give lower surface temperatures than the simple plugflow computations and results in a substantial reduction in surface area at the higher temperature

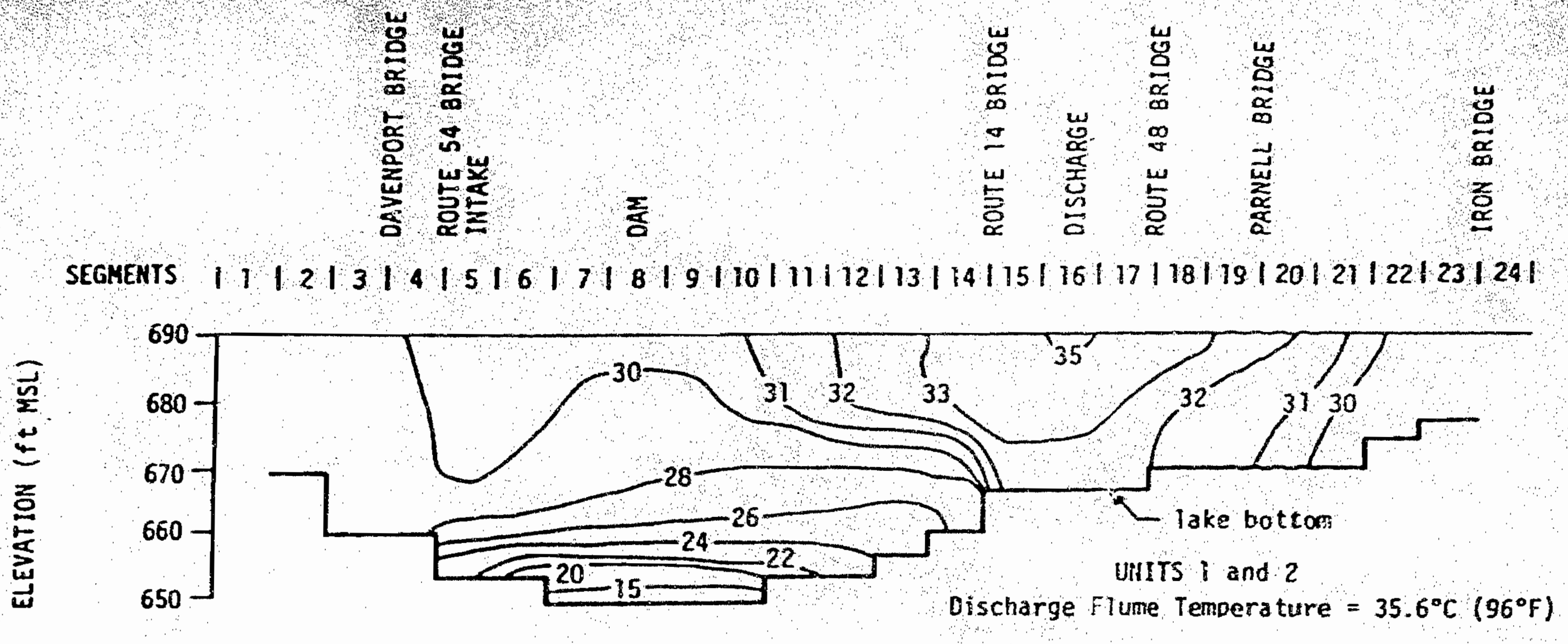


Figure 6-8. Longitudinal and Vertical Temperatures (°C) of Clinton Lake on July 23 (Julian Day 204), 1978 Under Units 1 and 2 Operation at 92 Percent Load and Discharge Temperature Constrained to Less Than or Equal to 35.6°C (96°F).

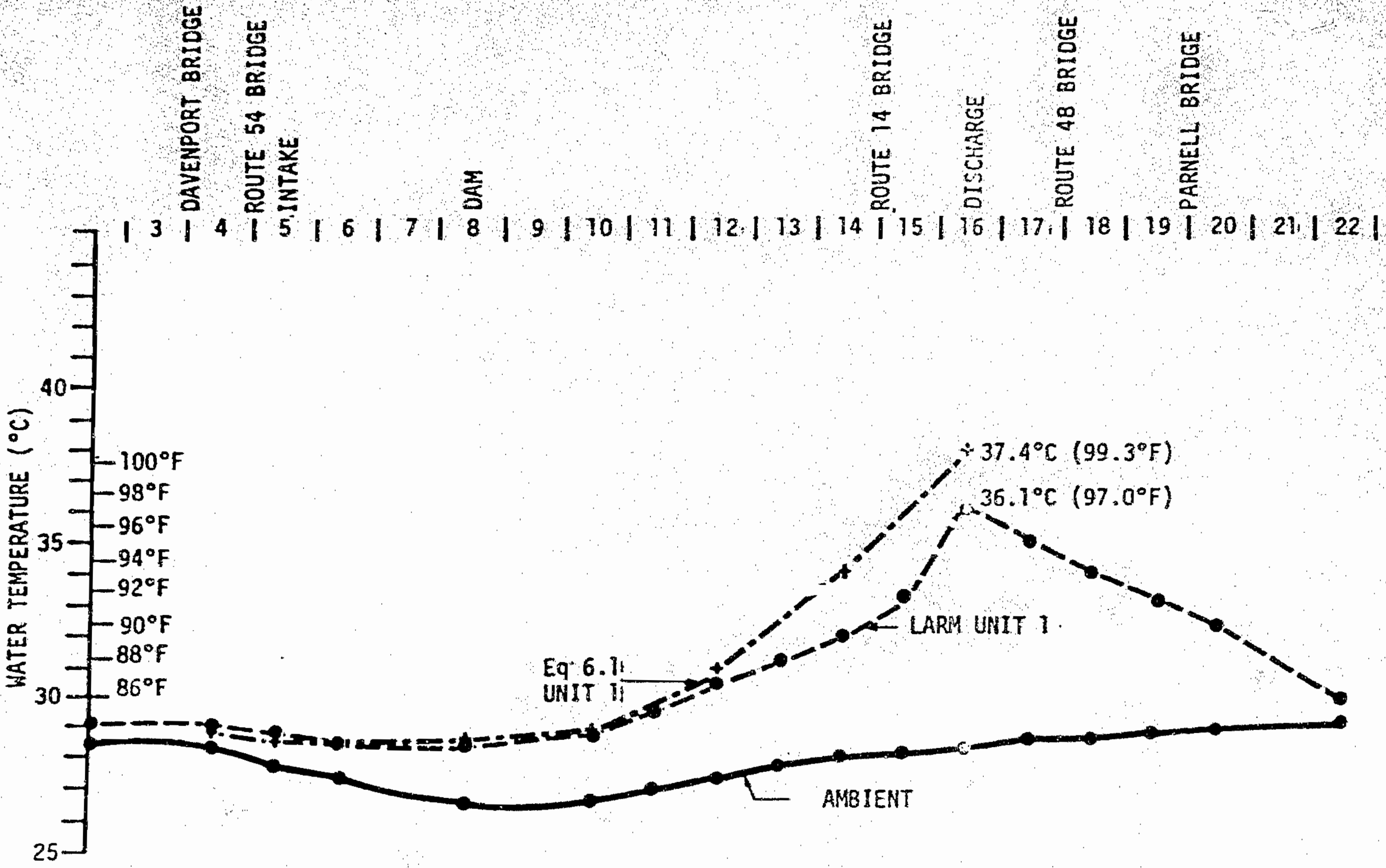


Figure 6-9. Longitudinal Profiles of Surface Temperatures (°C) for July 23 (Julian Day 204), 1978 Under Ambient Conditions, and Unit 1 Operation at 92 Percent Load.

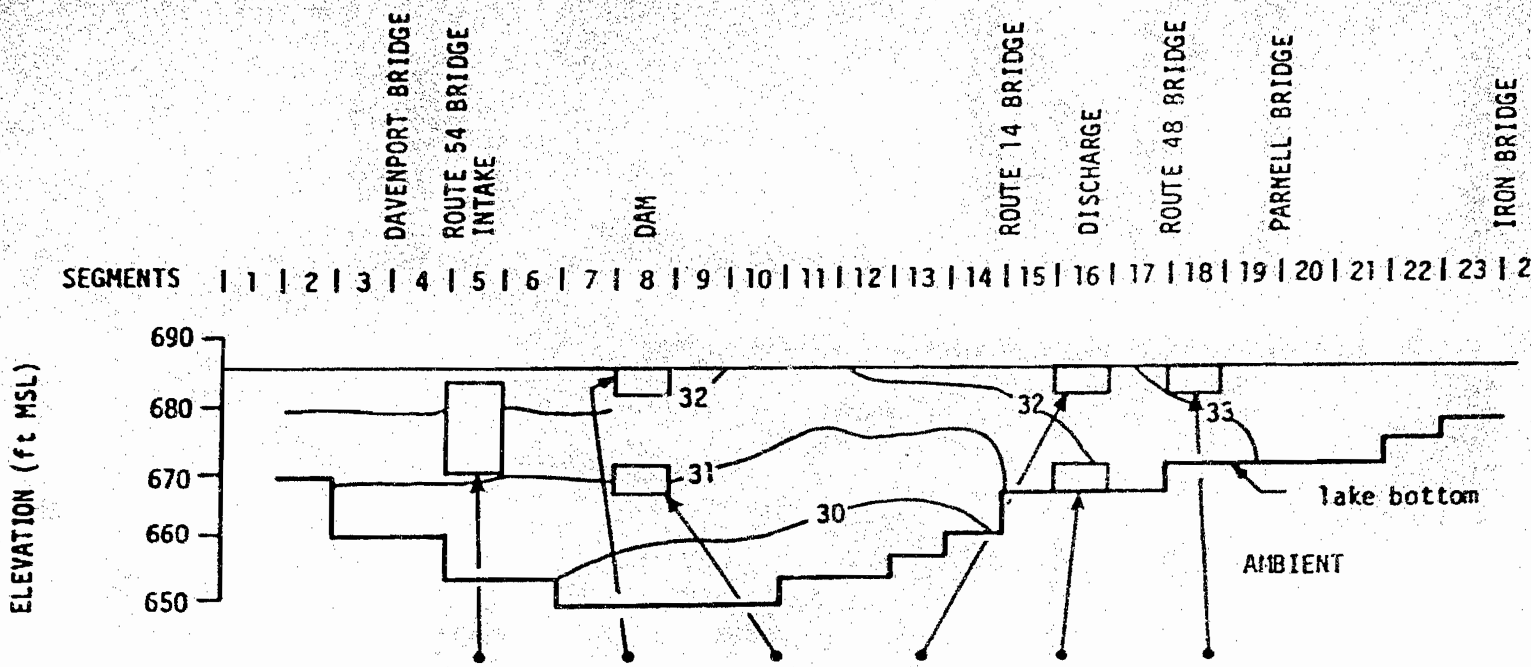
6.2 1955 PREDICTIONS

Results for the 1955 computations are given in Appendices C.1 to C.4 during the two warmest weeks of the summer for the following conditions: (1) no heat load to determine the distribution of ambient temperature, (2) one unit operation at both 92 and 100 percent load and (3) two unit operation at 92 percent load constrained to a maximum discharge temperature of 96°F. The 1955 LARM results for two unit constrained operation are compared to the previous results given in IPC.(1) Another comparison to be made is between the temperature distributions resulting from one unit unconstrained operation to the temperature distributions resulting from two unit constrained operations.

Meteorological data for 1955 is given in Appendix A.2. It shows the equilibrium temperatures of surface heat exchange reaching a maximum of 90.1°F to 94.7°F for days 208 and 214. In the year 1978 for comparison, Appendix A.1, the equilibrium temperatures reached a maximum of 81.3°F to 89.8°F over the period of day 221 to day 226. Thus, the potential for atmospheric heating is much greater in 1955 than in 1978.

The 1955 LARM simulations are carried out for dry weather low lake level conditions. The North Fork and Salt Creek flows are set at 2.5 cfs each to just balance the minimum flow release of 5 cfs at the low level outflow structure. The lake level is set at the 1 in 20 year level of 685.5 feet.(4) Groundwater inflow into the deeper portions of the lake is ignored, resulting in higher calculated lake temperatures than would have occurred.

The ambient temperature and flow distributions for the 1955 conditions show 1955 ambient lake temperatures above 30°C (86°F) for day 210 to day 216. The maximum surface temperature is 33.3°C (92.0°F) on day 213, with temperature distribution as shown in Figure 6-10. There are 1955 ambient temperatures above 32.2°C (90°F) for day 210 to day 213. In contrast, the maximum ambient temperature for 1978, Appendix B.1, was 29.1°C (84.4°F) on day 204. Stratification of the deeper portions of the lake is much less in 1955 than in 1978 because the 1955 model does not allow for groundwater inflow and for higher wind speeds which occurred in 1955.



ZEROTH PERCENTILE	25.30	26.20	26.30	24.40	24.50	23.80
FIFTH PERCENTILE	26.14	26.56	26.72	25.12	25.10	24.52
TENTH PERCENTILE	26.84	27.14	27.12	26.30	25.62	26.02
TWENTIETH PERCENTILE	27.20	27.38	27.28	26.60	26.40	26.30
THIRTIETH PERCENTILE	27.30	27.60	27.46	27.12	26.88	26.86
FORTIETH PERCENTILE	27.70	27.70	27.60	27.40	27.18	27.16
MEDIAN	28.10	28.20	27.70	27.80	27.40	27.50
SIXTIETH PERCENTILE	28.32	28.62	28.14	28.04	27.62	27.84
SEVENTIETH PERCENTILE	28.62	28.94	28.74	28.78	28.42	28.90
EIGHTIETH PERCENTILE	29.76	30.06	30.12	29.70	29.32	29.90
NINETIETH PERCENTILE	31.48	32.08	31.08	32.54	31.84	32.86
NINETY-FIFTH PERCENTILE	31.60	32.64	31.18	32.98	31.94	33.34
HUNDREDTH PERCENTILE	31.60	32.70	31.30	33.10	32.00	33.40
MEAN	28.37	28.70	28.40	28.27	27.88	28.12
STANDARD DEVIATION	1.60	1.70	1.45	2.11	1.97	2.33

Figure 6-10. Graphic Presentation of Longitudinal and Vertical Ambient Temperatures (°C) of Clinton Lake on August 1 (Julian Day 213), 1955 and Tabulated Summary Statistics for August 1955.

6.2.1 1955 WITH HEAT LOADS

The plant discharge is presently permitted for two unit operation with a maximum discharge temperature of 35.6°C (96°F). It is of interest to compare lake temperature profiles with one unit in operation to the profiles of two unit operation for the extreme 1955 meteorological and low flow conditions. Since stratification and circulation are important considerations, particularly in the vicinity of the discharge, the comparison is based on the LARM results.

Maximum surface temperatures for both 1 unit unconstrained and 2 unit constrained operation occurs on day 213. The detailed temperature distribution for 1 unit operation at 92 percent and 100 percent load on day 213 is given in Figure 6-11. One unit operation for this day at 92 percent load results in a discharge flume temperature of 41.5°C (106.7°F), a mixed temperature of the lake surface at the point of discharge of 40.3°C (104.5°F) and a bottom lake temperature at the point of discharge of 36.9°C (98.4°F). Stratification at the discharge results in the 3.4C° (6.1F°) temperature difference from surface to bottom. At 100 percent load, the discharge flume temperature is 42.4°C (108.3°F), the mixed temperature of the lake surface at the point of discharge is 41.0°C (105.8°F) and the maximum bottom temperature at the point of discharge is 37.3°C (99.1°F). There is little difference in the two profiles between 92 and 100 percent load factors.

Salt Creek temperatures downstream of the dam were investigated to determine if an exceedence of the 32.2°C (90°F) water quality standard had occurred and if it did, whether the exceedance was greater than 1.7C° (3F°) for 1.0 percent of the time. Maximum downstream temperatures of Salt Creek were 31.3°C (88.3°F), 32.7°C (90.9°F) and 32.9°C (91.2°F) under 1955 no-heat load, one unit unconstrained at 92 percent load and one unit unconstrained at 100 percent load, respectively. Maximum Salt Creek temperatures are in excess of the 32.2°C (90°F) standard, but are less than 1.7C° (3F°) above it. Percentage of time above 32.2°C (90°F) was found to be 1.2 percent and 1.6 percent, respectively for both operational modes.

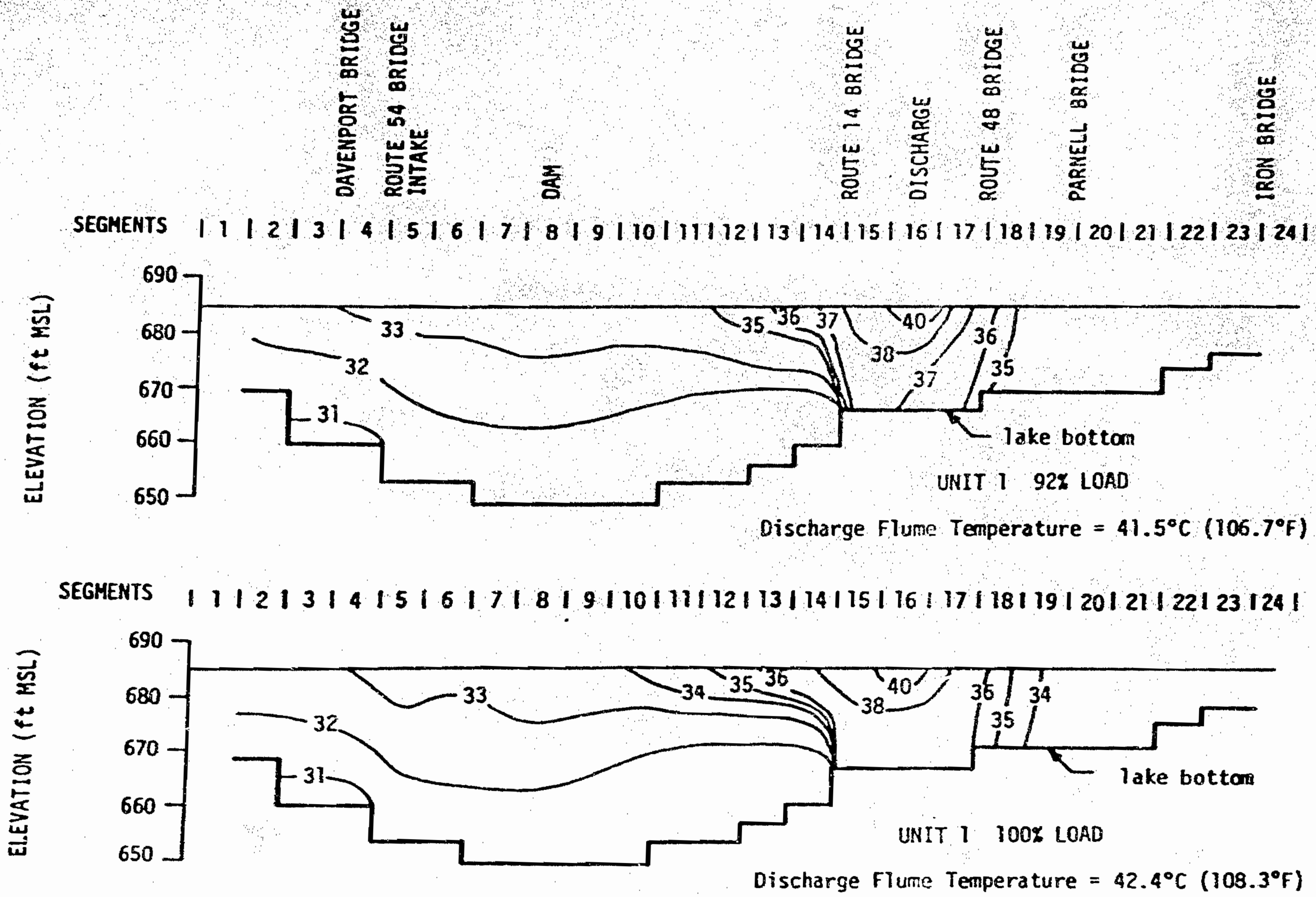


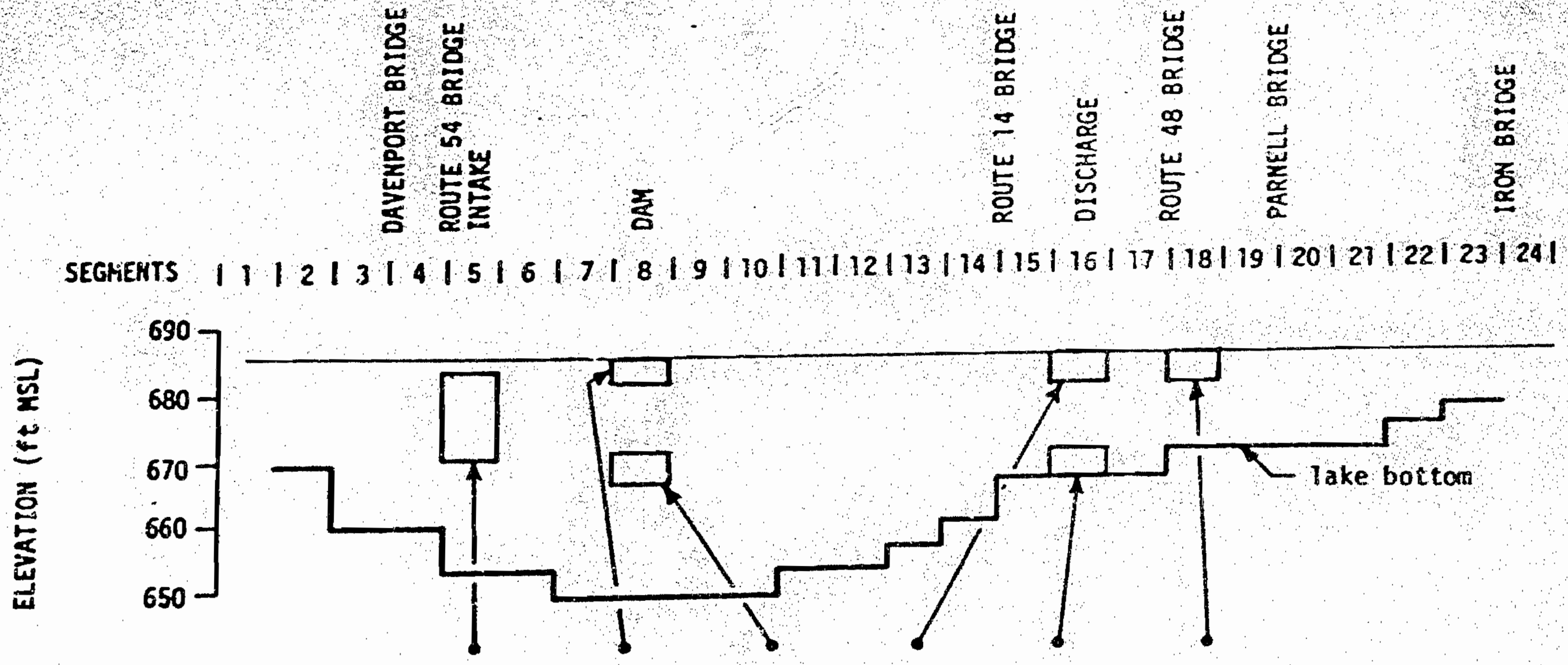
Figure 6-11. Longitudinal and Vertical Temperatures (°C) of Clinton Lake on August 1 (Julian Day 213) 1955 Under Unit 1 Operation at 92 and 100 Percent Load.

Monthly summaries of temperature under Unit 1 operation at 92 percent load are presented in Figures 6-12, 6-13, 6-14 and 6-15 for June, July, August and September, respectively. A temperature difference is noted at the discharge cell as surface temperatures are typically 3.6C° (6.5F°) higher than those at the bottom of the discharge cell, a depth of 5 meters. That large difference decreases toward the dam as surface and near bottom temperatures vary by less than 1C° (1.8F°).

Figure 6-16 presents two unit operation with the 35.6°C (96°F) temperature constraint. Constrained operation results in a discharge temperature of 35.6°C (96.0°F), a mixed surface temperature at the point of discharge of 35.5°C (95.9°F) and a maximum bottom lake temperature at the point of discharge of 35.0°C (95.0°F).

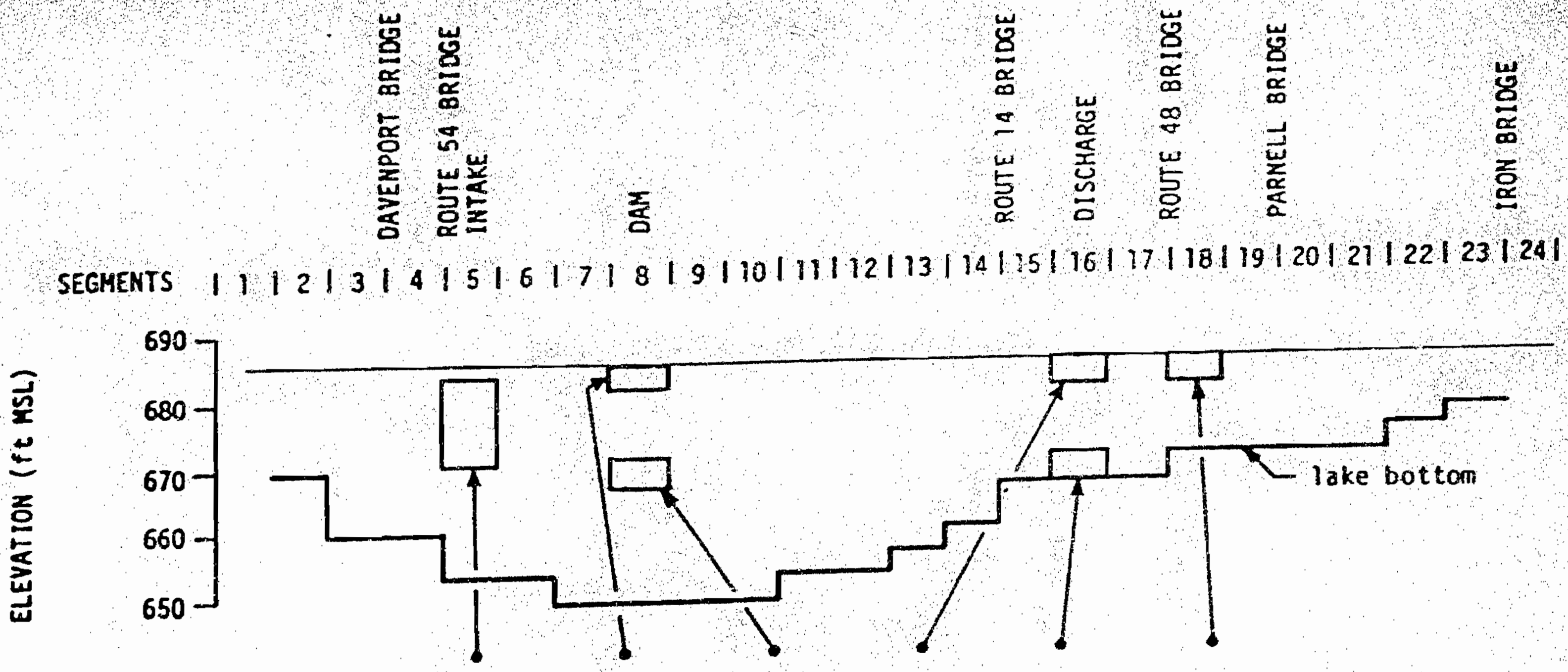
The magnitude of overall lake heating can be determined by comparing the intake temperatures for these cases. The 1955 one unit unconstrained operation at 92 and 100 percent load, Appendices C.2 and C.3, results in a maximum intake temperature of 32.7°C (90.0°F) on day 213, and is above 32.2°C (90°F) only from day 210 to day 216, a value that can be approached in the summer under natural conditions. The two unit 96°F constrained discharge operation, Appendix C.4, results in a maximum intake temperature of 33.3°C (91.9°F) on day 213, and is above 32.2°C (90°F) from day 204 to day 216. Thus, one unit unconstrained operation results in a slightly lower intake temperature and a shorter duration of intake temperatures above 32.2°C (90°F) than that resulting from two unit constrained operation.

Another comparison of overall lake heating is the total number of days with temperatures exceeding 32.2°C (90°F) anywhwere in the lake. One unit unconstrained operation has lake temperatures above 32.2°C (90°F) from day 180 to day 240 in 1955 or a duration of 60 days. Two unit constrained operation results in lake temperatures above 32.2°C (90°F) from day 171 to day 264 or for 93 days. Thus one unit operation results in one-third fewer days with lake temperatures above 32.2°C (90°F) for 1955.



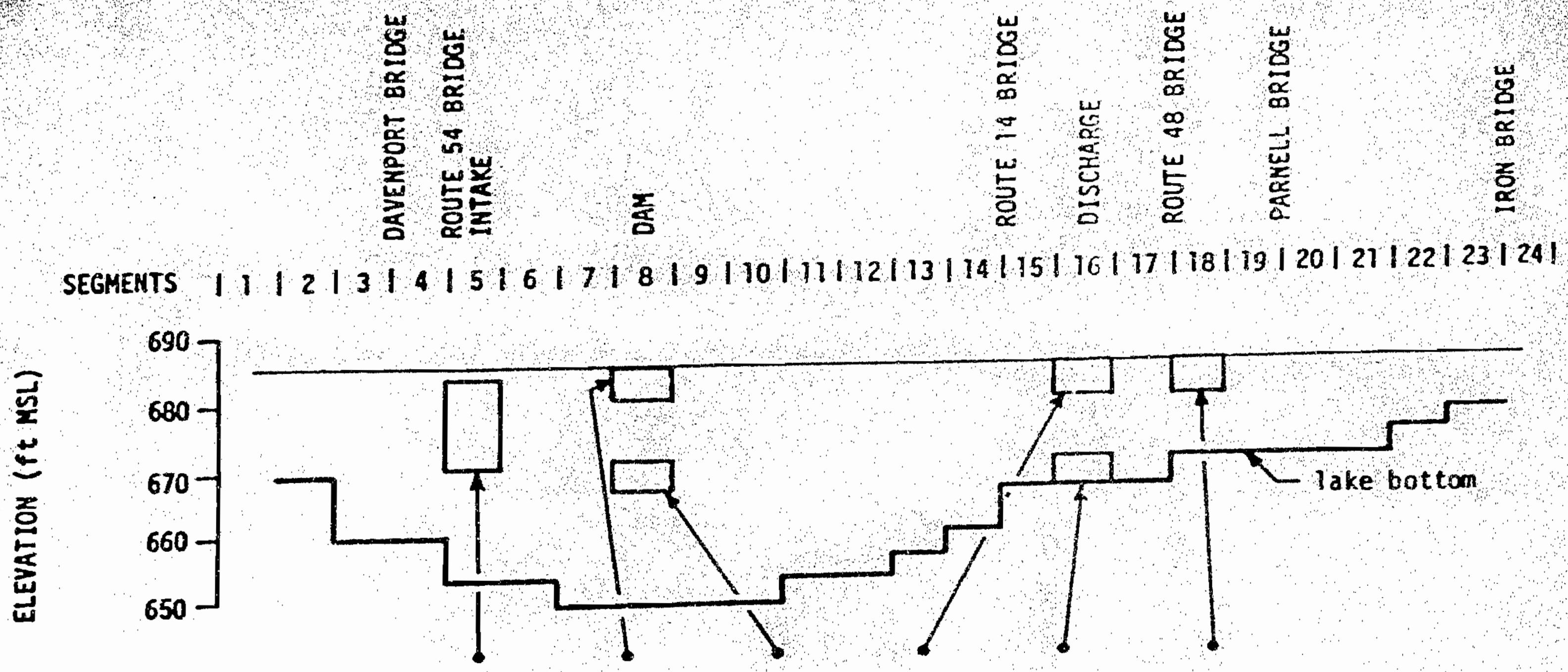
ZEROTH PERCENTILE	19.00	19.60	19.50	25.40	20.70	17.50
FIFTH PERCENTILE	19.17	19.60	19.61	25.46	21.20	18.16
TENTH PERCENTILE	19.61	20.03	20.30	26.07	21.79	20.25
TWENTIETH PERCENTILE	20.90	21.46	20.64	27.04	23.34	22.50
THIRTIETH PERCENTILE	21.30	21.83	21.43	28.25	24.30	23.28
FORTIETH PERCENTILE	21.54	22.24	21.78	29.00	25.18	24.32
MEDIAN	22.50	22.50	22.10	29.50	26.05	25.85
SIXTIETH PERCENTILE	23.14	24.16	22.36	31.32	27.06	26.40
SEVENTIETH PERCENTILE	24.30	24.92	23.20	31.97	28.97	27.04
EIGHTIETH PERCENTILE	24.60	25.48	24.74	32.42	29.30	27.96
NINETIETH PERCENTILE	25.83	26.36	26.10	32.97	29.49	28.38
NINETY-FIFTH PERCENTILE	26.04	27.15	26.34	33.33	29.64	28.74
HUNDREDTH PERCENTILE	26.20	27.20	26.50	33.60	29.80	28.90
MEAN	22.58	23.25	22.56	29.80	26.16	24.93
STANDARD DEVIATION	2.10	2.23	2.02	2.51	2.82	3.11

Figure 6-12 Summary Statistics of Temperatures (°C) of Clinton Lake During June 1955 Under Unit 1



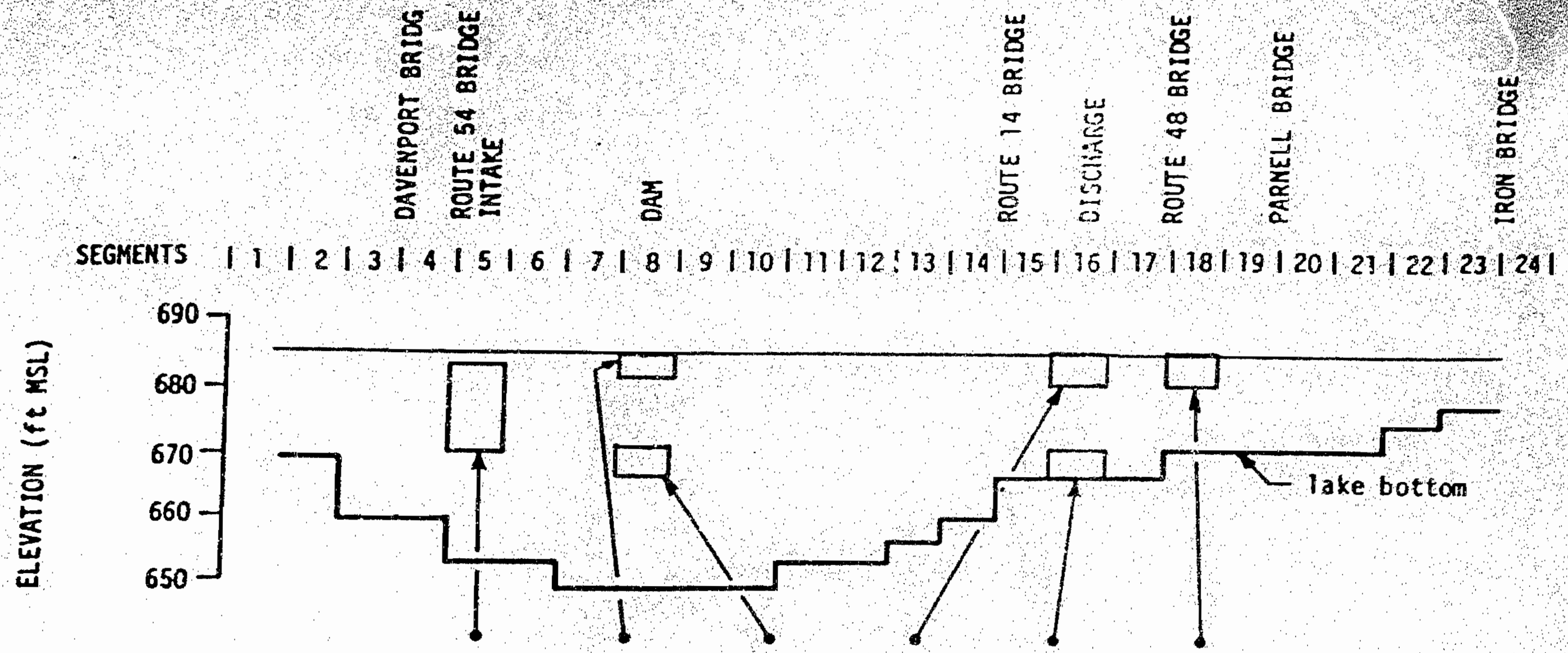
ZEROTH PERCENTILE	26.50	26.50	26.30	31.60	29.40	29.00
FIFTH PERCENTILE	26.56	26.62	26.42	31.78	29.52	29.24
TENTH PERCENTILE	27.58	27.82	26.84	34.20	30.28	29.56
TWENTIETH PERCENTILE	28.24	28.34	27.74	35.02	31.42	30.12
THIRTIETH PERCENTILE	28.90	29.30	28.66	35.40	31.88	30.66
FORTIETH PERCENTILE	29.08	29.40	29.40	35.98	32.50	30.96
MEDIAN	29.20	29.60	29.70	36.40	32.60	31.70
SIXTIETH PERCENTILE	29.34	30.26	29.90	36.74	33.04	31.94
SEVENTIETH PERCENTILE	30.46	30.74	30.50	37.62	33.74	32.40
EIGHTIETH PERCENTILE	30.94	31.80	30.56	38.26	34.44	33.66
NINETIETH PERCENTILE	31.98	32.84	30.90	39.56	35.18	35.02
NINETY-FIFTH PERCENTILE	32.52	33.14	31.72	39.86	36.44	35.66
HUNDREDTH PERCENTILE	32.70	33.50	32.20	40.10	36.80	35.90
MEAN	29.53	29.97	29.38	36.45	32.85	31.83
STANDARD DEVIATION	1.56	1.78	1.51	2.03	1.78	1.84

Figure 6-13. Summary Statistics of Temperatures (°C) of Clinton Lake During July 1955 Under Unit 1 Operation at 92 Percent Load.



ZEROTH PERCENTILE	26.30	27.50	27.70	31.80	29.10	26.50
FIFTH PERCENTILE	27.08	27.86	28.00	32.94	29.40	26.68
TENTH PERCENTILE	27.76	28.26	28.30	34.26	29.62	26.94
TWENTIETH PERCENTILE	28.20	28.74	28.70	34.90	30.88	28.10
THIRTIETH PERCENTILE	28.46	28.90	28.90	35.36	31.36	28.56
FORTIETH PERCENTILE	28.70	29.38	29.30	35.66	31.50	29.44
MEDIAN	29.00	29.50	29.40	35.80	31.80	30.40
SIXTIETH PERCENTILE	29.30	29.82	29.60	36.32	32.42	30.70
SEVENTIETH PERCENTILE	29.74	30.28	29.74	36.70	33.30	31.56
EIGHTIETH PERCENTILE	30.74	31.30	31.18	37.66	34.20	33.18
NINETIETH PERCENTILE	32.64	33.22	32.58	40.00	36.82	34.92
NINETY-FIFTH PERCENTILE	32.82	33.70	32.64	40.54	37.04	35.14
HUNDREDTH PERCENTILE	33.00	33.10	32.70	40.60	37.10	35.20
MEAN	29.40	29.98	29.76	36.25	32.49	30.41
STANDARD DEVIATION	1.64	1.63	1.43	1.92	1.78	2.61

Figure 6-14. Summary Statistics of Temperatures (°C) of Clinton Lake During August 1955 Under Unit 1 Operation at 92 Percent Load.



ZEROTH PERCENTILE	21.30	21.80	21.80	26.90	22.80	19.10
FIFTH PERCENTILE	21.47	21.86	21.80	26.96	23.35	19.65
TENTH PERCENTILE	21.72	22.11	22.00	27.64	24.18	21.95
TWENTIETH PERCENTILE	22.38	22.66	22.62	28.76	25.40	23.54
THIRTIETH PERCENTILE	22.93	23.10	23.03	29.49	26.43	24.26
FORTIETH PERCENTILE	23.40	23.74	23.48	30.38	27.00	24.62
MEDIAN	23.50	23.95	23.85	30.75	27.65	25.20
SIXTIETH PERCENTILE	23.90	24.36	24.58	31.10	27.80	25.76
SEVENTIETH PERCENTILE	25.48	25.98	26.12	31.47	28.37	26.71
EIGHTIETH PERCENTILE	26.10	26.58	26.50	33.46	29.06	27.00
NINETIETH PERCENTILE	26.29	26.79	26.70	33.79	29.20	27.67
NINETY-FIFTH PERCENTILE	26.39	27.04	26.98	34.10	29.58	27.88
HUNDREDTH PERCENTILE	26.50	27.20	27.20	34.10	29.80	28.10
MEAN	23.96	24.37	24.32	30.78	27.21	25.07
STANDARD DEVIATION	1.66	1.74	1.79	2.14	1.81	2.16

Figure 6-15. Summary Statistics of Temperatures (°C) of Clinton Lake During September 1955 Under Unit 1 Operation at 92 Percent Load.

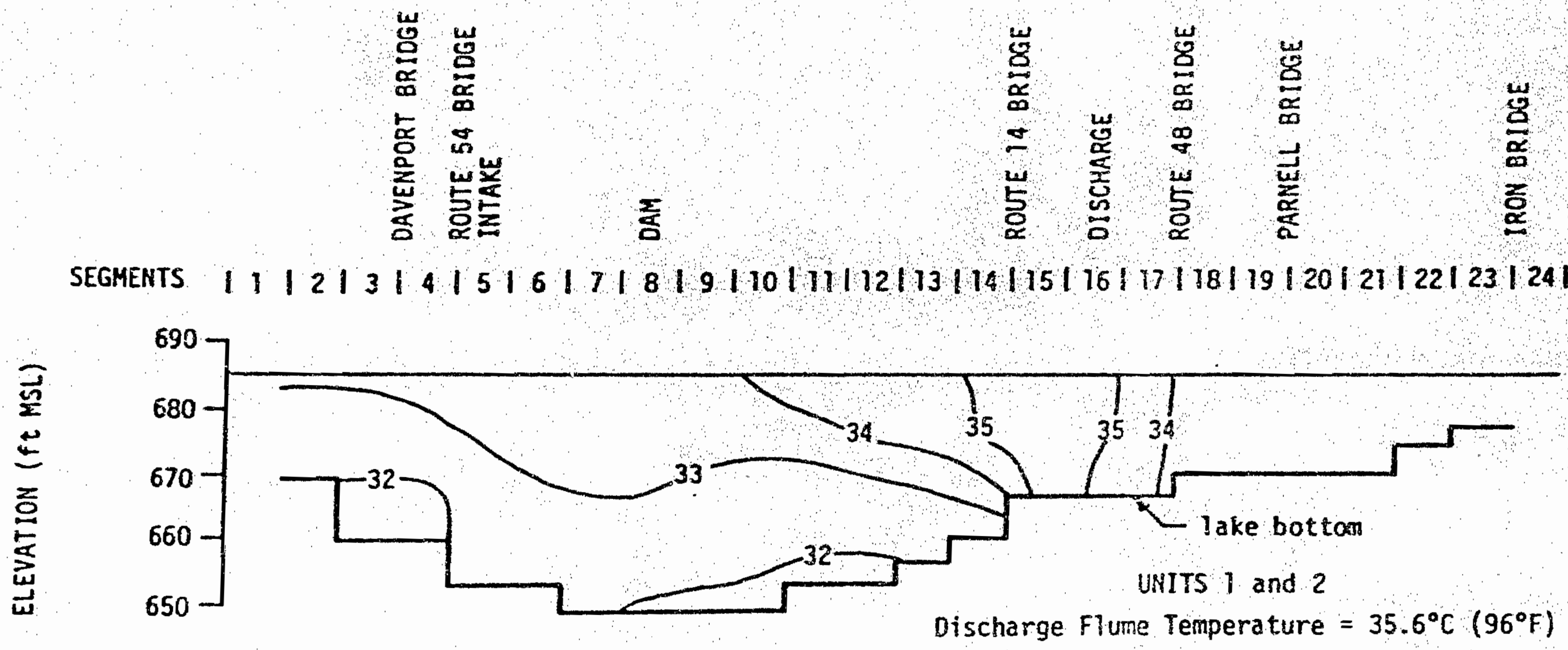


Figure 6-16. Longitudinal and Vertical Temperatures (°C) of Clinton Lake on August 1 (Julian Day 213), 1955 under Units 1 and 2 Operation at 92 Percent Load and Discharge Temperature Constrained to Less than or Equal to 35.6°C (96°F).

The extent of lake stratification for the two cases can be compared for the detailed temperatures on day 213 in the vicinity of the discharge. For this day, one unit unconstrained operation at 92 percent load (Figure 6-11) has a maximum surface temperature of 40.3°C (104.5°F) and bottom temperature of 36.9°C (98.4°F). Two unit constrained operation (Figure 6-16) has a maximum surface temperature of 35.5°C (95.9°F) and bottom temperature of 35.0°C (95.0°F) and is less stratified than one unit operation. Thus, although the one unit unconstrained operation results in surface temperatures greater than 35.6°C (96°F) on the worst day in 1955, it results in a discharge region bottom temperature only 1.9C° (3.4F°) higher than two unit constrained operations.

One unit unconstrained operation has surface temperatures greater than 35°C (95°F) in the discharge region from day 186 to day 240 and has bottom temperatures greater than 35°C (95°F) from day 210 to day 216. Two unit constrained operation has surface temperatures above 35°C (95°F) in the discharge region from day 186 to day 246 and has bottom temperatures greater than 35°C (95°F) on day 213. Thus, the persistance of surface temperatures above 35°C (95°F) is greater for two unit constrained operation than one unit unconstrained operation. The reverse appears for the bottom temperatures.

In the deeper portions of the lake, at segment 8, one unit unconstrained operation results in a surface temperature of 33.4°C (92°F) and a bottom temperature of 31.1°C (89.6°F). Two unit constrained operations result in a surface temperature of 33.7°C (92.7°F) and bottom temperature of 32.0°C (89.6°F). Thus one unit unconstrained operation results in slightly lower temperatures in the deeper portions of the lake than two unit constrained operation.

A comparison of one unit unconstrained operation at 92 percent load (Figure 6-11) to two unit operation constrained (Figure 6-16) reveals the average temperature of the lake is higher in the latter case. The only exception is at the immediate vicinity of discharge where the unconstrained discharge temperature is greater than the constrained value. Longitudinal and vertical temperatures in Clinton Lake are lower under unconstrained operation of one unit versus constrained operation of two units for the majority of the lake.

6.2.2 COMPARISON TO PREVIOUS RESULTS

The previous Clinton Lake temperature study was based on a simple plugflow cooling lake model with no detailed hydrodynamics.(1) Simulations were reported for the year 1955 two unit case with the plant discharge temperature constrained to a maximum of 35.6°C (96°F). Results are given in Table 5.6 of Reference 1 as acres above 32.2°C (90°F) for the 1955 two unit constrained case.

The LARM two unit constrained discharge results for 1955 are given in Appendix C.4. The surface area above 32.2°C (90°F) for the LARM simulations, along with a summary of the previous results, are given in Table 6-1. The previous results show temperatures above 32.2°C (90°F) beginning on day 161 (June 10, 1955, Table 5.6(1)) and continuing through day 243. The LARM results show surface temperatures above 32.2°C (90°F) beginning ten days later on day 171 and extending through day 255. LARM bottom temperatures are above 32.2°C (90°F) from day 186 to day 219.

The LARM results in Table 6-1 show the whole lake surface temperature above 32.2°C (90°F) for day 210 to day 213. As indicated previously, the LARM 1955 ambient temperatures for these days are also above 32.2°C (90°F). Results from the previous study show the maximum area through the period of day 210 to day 216 approaching the full area of the lake.

Areas through the period of days 189 to 198, days 219 to 228, and days 234 to 243 are smaller for the LARM simulation than for the previous simulation. Examination of these periods in Appendix C.4 show the effects of wind mixing and wind shear in containing these areas to the discharge region. The LARM areas are less than the results of the previous study on 17 days out of 24 days of comparisons.

6.3 COMPARISON TO THERMAL EFFLUENT LIMITATIONS

Results of the 1978 and 1955 simulations have been discussed in Sections 6.1 and 6.2, respectively. Longitudinal and vertical temperatures of Clinton

TABLE 6-1

CALCULATED AREAS OF CLINTON LAKE GREATER THAN 90°F UNDER TWO UNIT CONSTRAINED OPERATION IN 1955

Julian Day	LARM Area (Acres)	Previous Study (Acres)
171	391	658
174	288	903
177	406	658
180	479	780
183	179	--
186	943	800
189	985	1052
192	1014	1178
195	1002	1178
198	755	1178
201	1692	1178
204	3795	1555
207	1072	1555
210	3814	1935
213	3814	2690
216	3322	3050
219	281	1920
222	873	981
225	404	981
228	817	981
231	1984	1360
234	1040	1548
237	745	1548
240	688	981
243	216	603
246	470	--
249	457	--
252	387	--
255	148	--

Lake were presented for one unit unconstrained operation at 92 and 100 percent loadings and two unit constrained operation at 92 percent loading with a 35.6°C (96°F) effluent limitation. An analysis of lake temperatures indicated one unit unconstrained operation at 92 percent loading yields slightly higher temperatures near the discharge in Clinton Lake than the constrained two unit operation in 1978. Similar comparisons in 1955 indicated temperatures near the discharge were slightly higher under one unit unconstrained versus two unit constrained operation.

As discussed in Section 2.2 and summarized in Table 2-1, recent IPCB decisions relative to cooling lakes have yielded effluent limitations which contain a maximum temperature and an excursion temperature with an allowable exceedence frequency. For example, the Kincaid Station which uses Lake Sangchris for cooling has an effluent limitation which states that the discharge temperature cannot exceed 43.9°C (111°F) and that the discharge temperature can exceed 37.2°C (99°F) no more than 7 percent of any 12-month period. That limitation was derived from a time series analysis of 1974 and 1975 condenser discharge data and supported by a detailed biological field program. A review of 1974 and 1975 temperatures at Decatur Lake indicates 1974 ranked 18 out of 27 in mean monthly temperature, while 1975 ranked 5 of 26 in mean monthly temperature.

Maximum temperatures listed at Decatur Lake were 27.8°C (82.o°F) in 1974 and 1975. If 27.8°C (82.0°F) is used as a reference temperature, then the excursion temperature of 37.2°C (99°F) and its exceedence probability of 7 percent can be compared to limitations at other locations.

An analysis of the discharge temperatures from the simulations at Clinton Lake was made to determine the maximum temperatures and the exceedence frequencies at 37.2°C (99.0°F). Results of that analysis are listed in Table 6-2. Operation at 92 percent load of Unit 1 yielded maximum discharge temperatures of 37.8°C (100.0°F) in 1978 and 41.6°C (106.9°F) in 1955. These values are within the maximum effluent limitations listed in Table 2-1. Operation at 92 percent load of Unit 1 yielded annual exceedence frequencies of the 37.2°C (99.0°F) discharge temperature of 2.2 percent in 1978 and 11.9 percent in 1955.

TABLE 6-2

MAXIMUM DISCHARGE TEMPERATURES AND EXCURSION TEMPERATURES AND THEIR ASSOCIATED FREQUENCIES AT CLINTON LAKE

Year	Operational Mode	Maximum Discharge Temperature (°C (°F))	Frequency (Percent) Above 37.2°C (99°F)				
			June	July	August	September	Annual*
1978	1 Unit 92% Load	37.8 (100.0)	0.0	10.8	8.2	7.5	2.2
1978	1 Unit 100% Load	38.7 (101.7)	0.0	34.4	59.0	39.3	11.2
1955	1 Unit 92% Load	41.6 (106.9)	0.0	74.2	66.0	0.0	11.9
1955	1 Unit 100% Load	42.4 (108.3)	0.0	88.1	90.3	0.0	15.1

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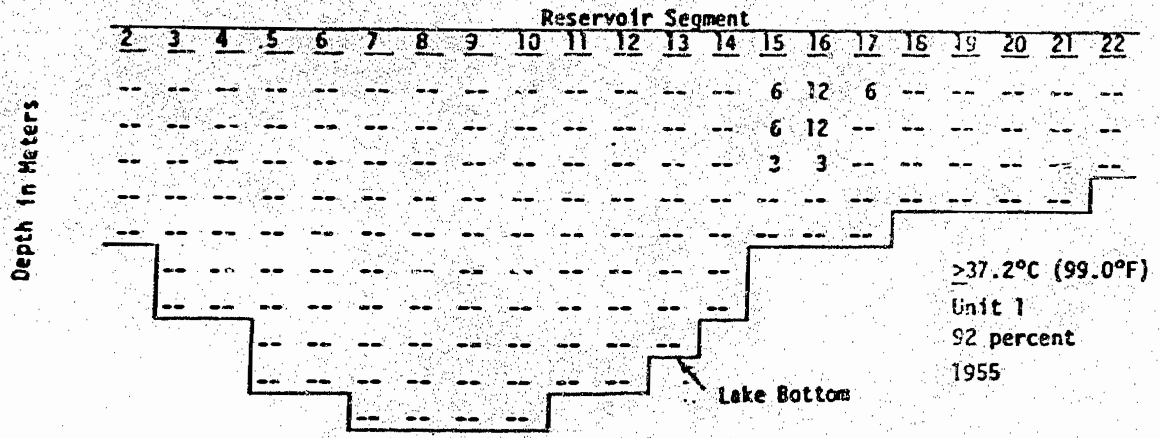
* Based on 365.25 days per year.

While the 37.2°C (99.0°F) limitation may be exceeded by 2.2 percent in 1978 and 11.9 percent in 1955, the extent and duration of temperature in the lake above 37.2°C (99.0°F) have not been discussed.

While the earlier discussions are related to temperatures at the discharge flume, the duration of selected temperatures within Clinton Lake would yield a more meaningful measure for comparison to use criteria. Days in excess of 37.2°C (99.0°F) are presented for 1955 in Figure 6-17. While the discharge temperature exceeded 37.2°C (99.0°F) approximately 2.2 percent of the time under Unit 1 operation at 92 percent load in 1978, no cell in Clinton Lake experienced a daily exceedence of that temperature. In fact, the 11.9 percent exceedence of 37.2°C (99.0°F) in 1955 under Unit 1 operation at 92 percent load resulted in a maximum of 12 days experiencing temperatures in excess of 37.2°C (99.0°F) and then only in the top 2.2 meters at Segment 16.

Additional data are presented at a temperature of 36.7°C (98.0°F) in Figures 6-18 and 6-19. As seen in these figures, as the temperature is lowered from 37.2°C to 36.7°C, the areas experiencing those temperatures increase. Similar data are presented for 35.6°C (96.0°F) which corresponds to the present effluent limitation at the point of discharge. These data are presented in Figures 6-20 and 6-21.

Water Quality Standards in Illinois (Section 203 i 4) indicate the maximum summer water temperatures released to Salt Creek should not exceed 32.2°C (90°F) for more than 1 percent of the time and by no more than 1.7C° (3F°). As noted earlier, modeled releases in 1978 for one unit operation never exceeded 32.2°C (90°F). However, the modeled releases to Salt Creek in 1955 resulted in temperatures that exceed 32.2°C (90°F) for 1.6 percent of the year for 1 unit operation. The maximum discharge temperatures 92.1°F and 91.9°F for 100 and 92 percent load respectively were within the allowable limit, i.e., 93°F. However, the 1.6 percent exceedence of the 90°F limit is slightly above the allowable exceedence of 1 percent. It should be reiterated that the 1955 conditions which were assumed include several conservative assumptions and represent the worst case scenario.



Reservoir Segment

2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
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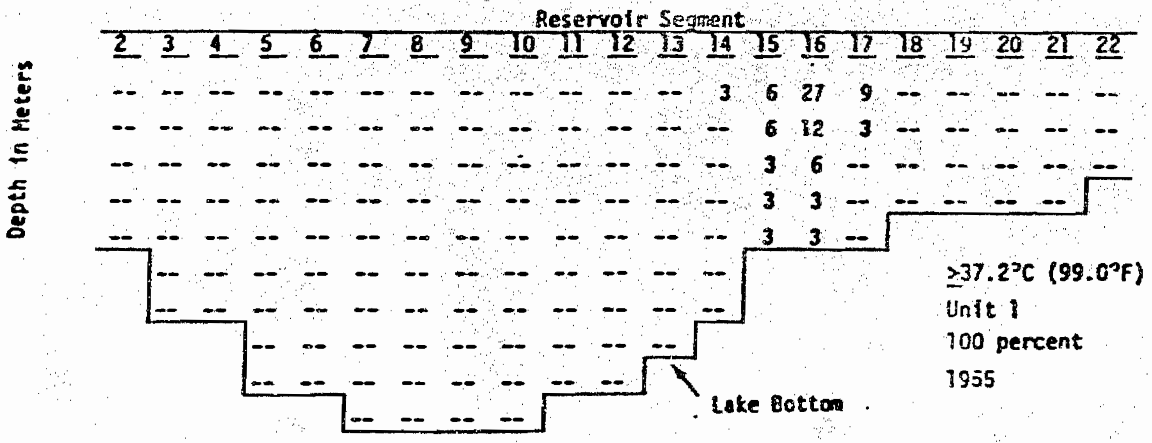
≥37.2°C (99.0°F)
Unit 1
92 percent
1955



Reservoir Segment

2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
--	--	--	--	--	--	--	--	--	--	--	--	3	6	27	9	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	6	12	3	--	--	--	--	--
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					--	--	--	--												

≥37.2°C (99.0°F)
Unit 1
100 percent
1955

Figure 6-17. Number of Days At or Above 37.2°C (99.0°F) in Clinton Lake Under Unit 1 Operation in 1955

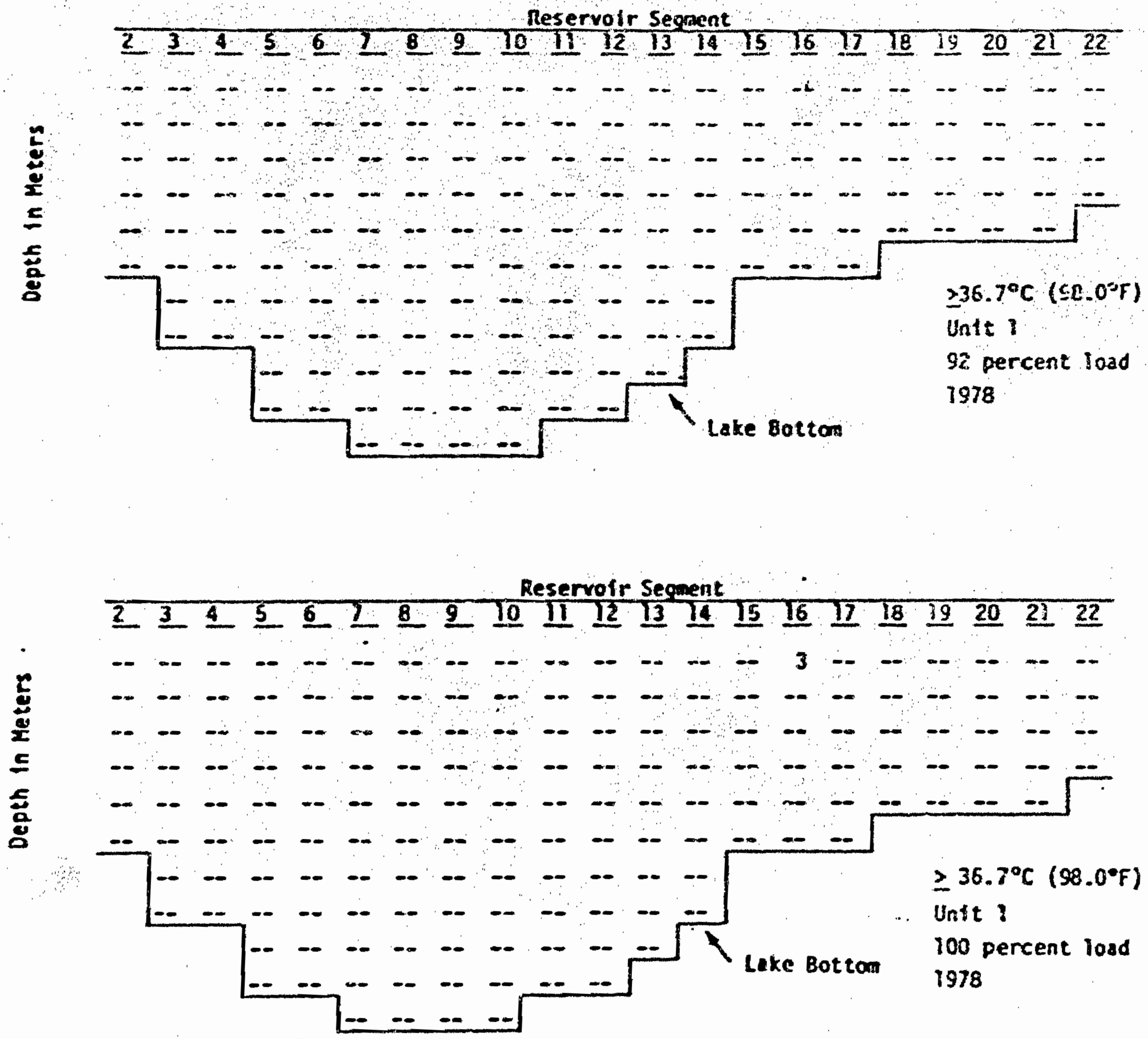
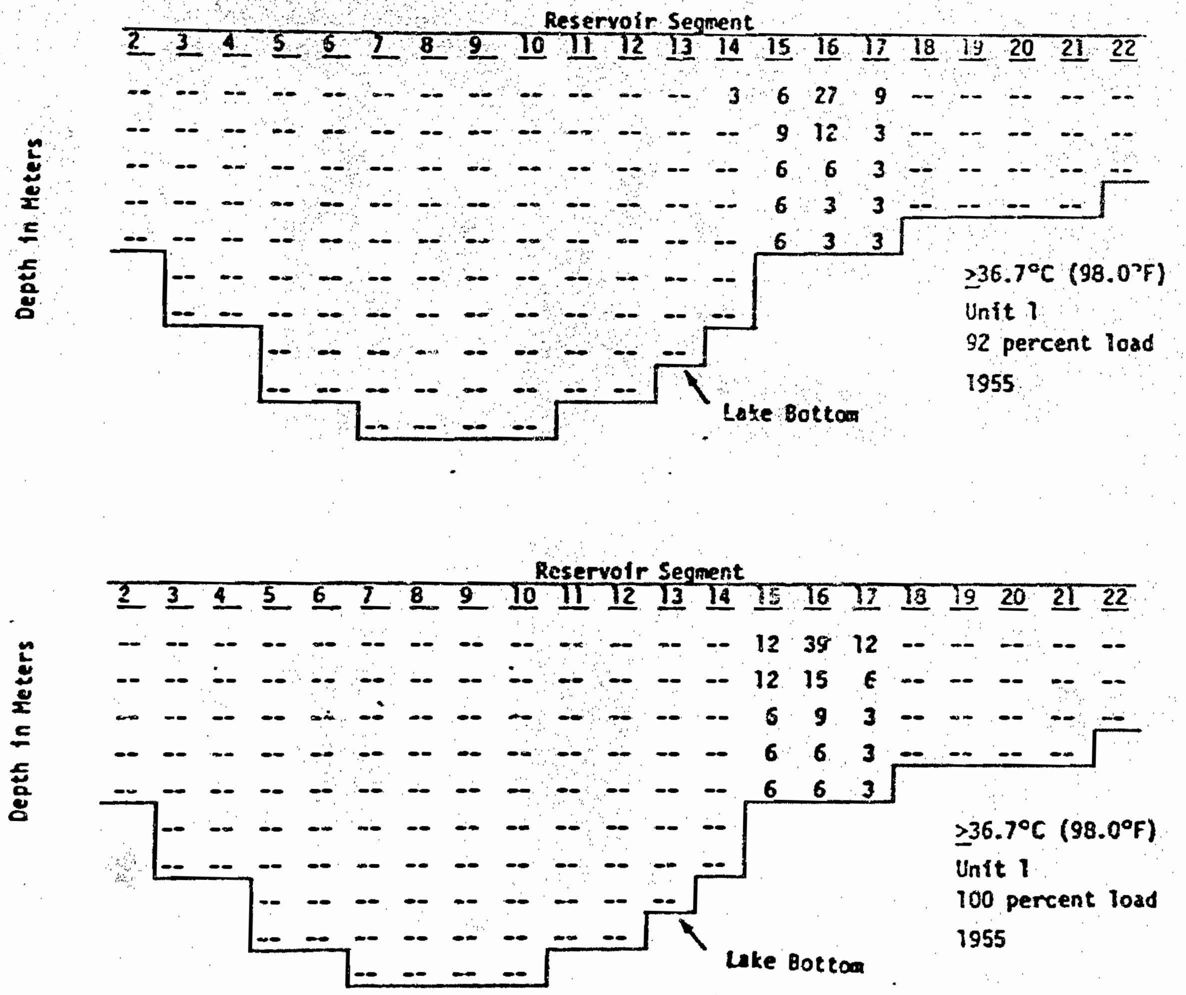


Figure 6-18. Number of Days At or Above 36.7°C (98.0°F) in Clinton Lake Under Unit 1 Operation in 1978



2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
--	--	--	--	--	--	--	--	--	--	--	--	3	6	27	9	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	9	12	3	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	6	6	3	--	--	--	--	--
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					--	--	--	--												

≥36.7°C (98.0°F)
Unit 1
92 percent load
1955

2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
--	--	--	--	--	--	--	--	--	--	--	--	--	12	39	12	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	12	15	6	--	--	--	--	--
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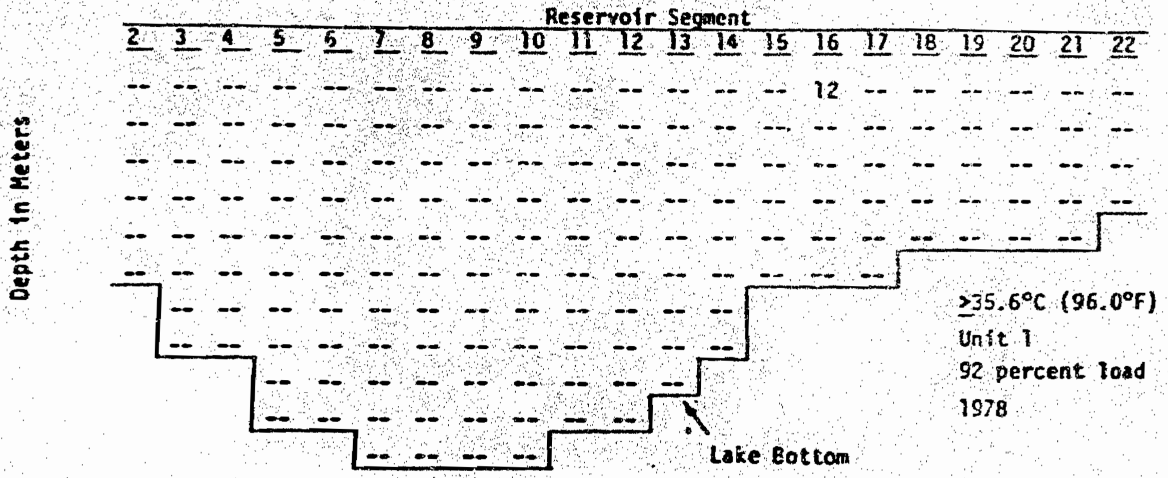
≥36.7°C (98.0°F)
Unit 1
100 percent load
1955

Figure 6-19. Number of Days At or Above 36.7°C (98.0°F) in Clinton Lake Under Unit 1 Operation in 1955



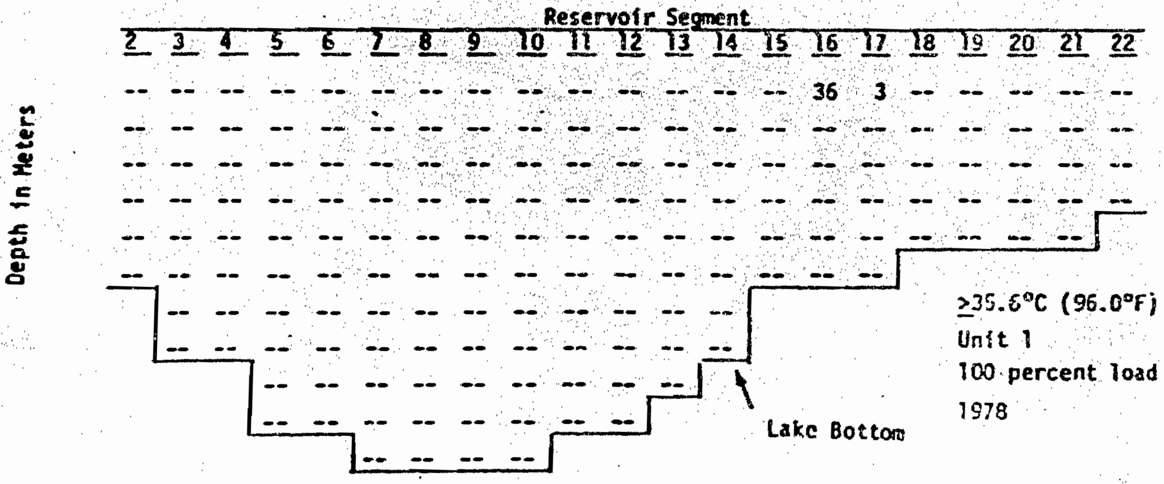
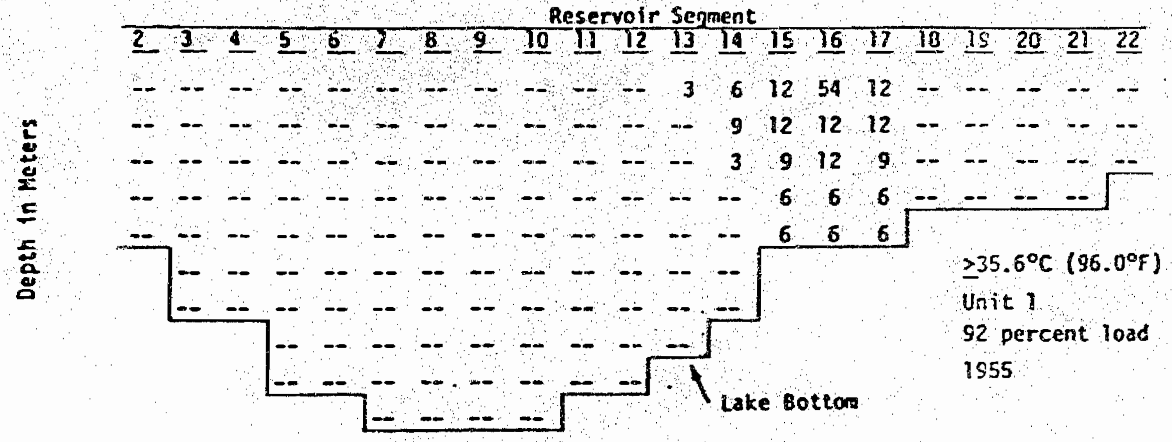


Figure G-20. Number of Days At or Above 35.6°C (96.0°F) in Clinton Lake Under Unit 1 Operation in 1978



2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
--	--	--	--	--	--	--	--	--	--	--	3	6	12	54	12	--	--	--	--	--
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--	--	--	--	--	--	--	--	--	--	--	--	--	6	6	6					
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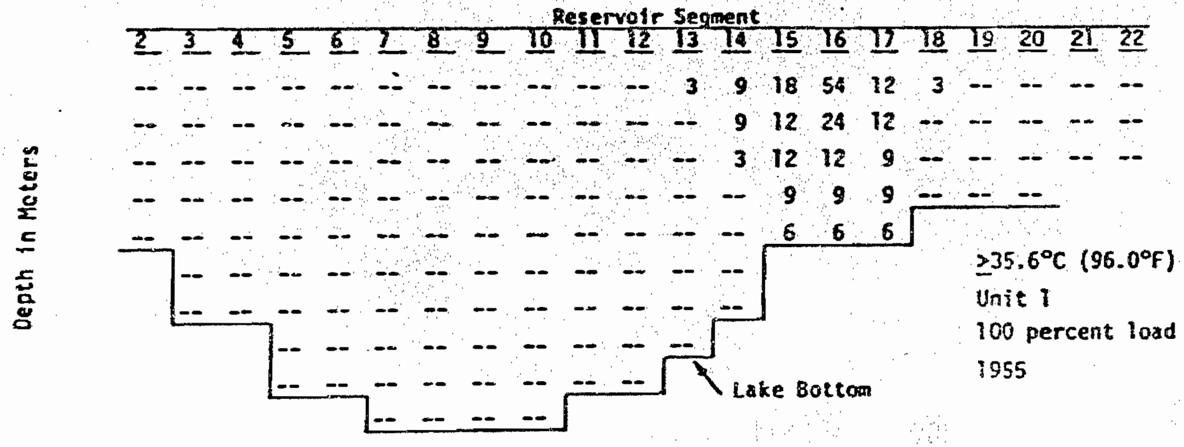
					--	--	--	--												

>35.6°C (96.0°F)
Unit 1
92 percent load
1955



2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
--	--	--	--	--	--	--	--	--	--	--	3	9	18	54	12	3	--	--	--	--
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--	--	--	--	--	--	--	--	--	--	--	--	3	12	12	9	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	9	9	9	--	--	--		
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					--	--	--	--												

>35.6°C (96.0°F)
Unit 1
100 percent load
1955

Figure 6-21. Number of Days At or Above 35.6°C (96.0°F) in Clinton Lake Under Unit 1 Operation in 1955

5

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6

BIOLOGICAL EVALUATION OF PREDICTED THERMAL DISCHARGES IN CLINTON LAKE

Prepared for:

ILLINOIS POWER COMPANY
Clinton, Illinois

Prepared by:

ENVIRONMENTAL SCIENCE AND ENGINEERING, INC.
St. Louis, Missouri

ESE No. 88-821

May 1988

EXECUTIVE SUMMARY

Illinois Power Company submitted a petition in 1980 to the Illinois Pollution Control Board (IPCB) for site specific thermal limits for Clinton Power Station (CPS) discharges to Clinton Lake. The submittal included lake temperatures predicted by the Laterally Averaged Reservoir Model (LARM) and a biological assessment of these temperatures under worst case conditions. These studies predicted CPS could operate at full power with acceptable biological impacts. Based on these studies the IPCB established site specific thermal limits which were anticipated to allow full power operation.

Flume discharge temperatures in the summer of 1987 were higher than expected during power ascention testing. LARM was rerun with actual operating data from the test period. The resultant discharge temperatures exceeded the permitted limits at simulations for full power under worst case meteorological conditions. This report predicts the biological effects of the 1988 LARM simulation on the fish community in Clinton Lake and compares these predictions with those in the 1980 study. Consistency was maintained between this and the 1980 study by using the USEPA protocol for assessment of thermal effects and the same year (1955) for worst case meteorological conditions.

The predicted flume discharge temperature for the warmest single day of the worst case summer was 111.7°F (42.3°C). The comparable temperature in the 1980 study was 108.3°F (42.4°C) and was the basis for the present maximum temperature limit. Heat is quickly dissipated throughout the lake and plant intake temperatures are only 1°C (1.8°F) above ambient temperatures.

The USEPA protocol for evaluation of thermal effects was used to assess the potential impacts of worst case conditions on adult survival, growth and spawning, and embryo survival of six Representative Important Fish Species (RIS). The RIS included gizzard shad, common carp, channel catfish, bluegill, largemouth bass, and white crappie. Temperature criteria for each species were updated for this study with current literature and compared to the preferred habitat available under modeled conditions. For some species the updated temperature criteria resulted in less impact than predicted by the 1980 study.

Predicted impacts for this study and a comparison to the 1980 study are as follows:

Gizzard shad - Impacts on reproduction, growth, and survival were minimal and similar to the 1980 study.

Common carp - Impacts on growth, survival, and reproduction were minimal. Impacts on growth and survival substantially improved over the 1980 study.

Channel catfish - Impacts were minimal on survival and growth; reproduction would be limited in midsummer. Growth improved over the 1980 study.

Bluegill - Impacts on reproduction, growth, and survival were minimal. Growth and survival improved over the 1980 study.

Largemouth bass - Impacts on growth and survival were minimal; reproduction was below optimal. Growth and survival improved over the 1980 study.

White crappie - Impacts on reproduction were substantial. Impacts on crappie survival were severe and indicated this species may be eliminated in either study with or without thermal discharges. If crappie were not eliminated, growth would improve substantially over the 1980 study.

The evaluated conditions using the most up-to-date information indicated little difference to the RIS from that predicted in 1980. The predicted impacts are intentionally conservative as they are based on USEPA protocol, which by their very nature are conservative. Also beneficial impacts of thermal discharges (e.g. increased growth, earlier spawning, etc.) are not used in the USEPA protocol nor were they used in this biological assessment. In the unlikely event white crappie are lost during worst case conditions, they could be restocked using Illinois Power's fish rearing ponds.

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1.0 INTRODUCTION

1.1 BACKGROUND AND PURPOSE

Illinois Power Company (IP) owns and operates Clinton Power Station which is a steam-electric (nuclear) power generating facility located in DeWitt County, Illinois. The station uses a once-through condenser cooling system drawing water from Clinton Lake, a manmade reservoir constructed by Illinois Power to function as the cooling water source for the Clinton Station. The station consists of one 933 net MWe unit which began commercial operation in 1987.

In 1980, Illinois Power submitted a predictive thermal demonstration to the Illinois Pollution Control Board (IPCB) and obtained site-specific thermal limits for the Clinton Power Station discharges to Clinton Lake. This demonstration was based upon a thermal model and interpretation of the biological impacts of the predicted temperatures. The demonstration predicted the Clinton Power Station could operate at full power with acceptable biological impacts. Based on the demonstration, the IPCB established site-specific thermal limits which were anticipated to allow full power operation under worst case conditions.

Flume discharge temperatures were higher than expected during power ascension testing in the summer of 1987. The Laterally Averaged Reservoir Model (LARM) was rerun with actual operating data from the test period. The resultant discharge temperatures exceeded the permitted limits at simulations for full power under worst case meteorological conditions. The purpose of this report is to assess the effects of temperatures predicted by the 1988 LARM simulation on the Clinton Lake fish community and to compare these effects to those in the 1980 demonstration.

1.2 EXISTING COOLING LAKE LIMITS

The thermal effluent limitation established for the Clinton Power Station in 1980 requires that water discharged to Clinton Lake:

1. not exceed 42.2°C (108°F) at any time; and

2. not exceed 37.2°C (99°F) for more than 12 percent of the hours within a moving 12-month period.

Since IP's acceptance of the thermal limitation in 1980, several Illinois power stations using similar cooling lakes have been granted alternate effluent limitations which are higher than those granted Clinton Power Station, based on more recent data. These power stations and their respective thermal limitations are compared to Clinton Power Station in Table 1-1.

Effluent limitations in Table 1-1 were developed from applicant data submitted to IPCB. The data typically consisted of descriptions of temporal variations in discharge temperature and varying degrees of biological field information. Each cooling lake, including Clinton, had been in existence for several years and recreational activities, where appropriate, had developed. Field study information was available from agencies such as the Illinois Department of Conservation and from utility-sponsored field programs.

Studies performed at a number of cooling lakes have generally concluded that thermal discharges have had no detrimental effects on fish or other aquatic organisms. Moreover, studies conducted at Lakes Sangchris, Coffeen, Baldwin, and Newton in Illinois have suggested that several beneficial effects may be attributed to the thermal increases. For example, exceptional largemouth bass fisheries have developed in some of these lakes, perhaps as a result of early intitiation of spawning and greater annual growth during a prolonged growing season. Similar effects have been noted for a variety of species in other cooling impoundments as well. Several other species besides largemouth bass, such as channel catfish, also appear to flourish in these cooling lakes, although others, such as the white crappie have exhibited difficulty in sustaining a self maintaining population.

Approval by IPCB of thermal limitations indicated in Table 1-1 of up to a maximum of 112°F, including allowance of a potentially large short-term

Table 1-1. Listing of Site-Specific Thermal Effluent Limitations Applicable to Power Stations in Illinois Using Cooling Lakes

Power Station	Cooling Lake	Maximum Limitation	Exceedance Frequency	Average Limitation	Exceedance Frequency
Clinton	Clinton	108.3°F (daily average) (limitation granted on 5/28/81)	None	99°F (daily average)	Not to be exceeded more than 12 percent of the days in a year
Kincaid	Sangchris	111°F (instantaneous) (limitation granted on 10/13/77)	None	90°F (hourly)	Not more than 7 percent of the hours in a year
Coffeen	Coffeen	112°F (hourly) (limitation granted on 3/22/82)	No more than 3 percent of the hours from June through September	105°F (monthly)	None; applicable to months from June through September
		94°F (hourly) (limitation granted on 3/22/82)	No more than 2 percent of the hours from October through May	89°F (monthly)	None; applicable to months from October through May
Newton	Newton	111°F (daily average) (limitation granted on 8/21/80)	None	102°F (monthly)	None
Lakeside	Springfield	109°F (hourly) (limitation granted on 9/21/78)	None	99°F (hourly)	Not more than 5 percent of the hours in a year
Dallman	Springfield	109°F (hourly) (limitation granted on 9/21/78)	None	99°F (hourly)	Not more than 8 percent of the hours in a year

Source: Illinois Power, 1988.

exclusion area, indicates that water uses were judged sufficiently protected. These limitations also apparently allow certain habitat in the cooling lakes to exceed aquatic life criteria but for defined short time periods.

1.3 STUDY APPROACH

The analysis of aquatic biological impacts under worst case unconstrained discharge temperatures from one unit operation was undertaken in a similar manner to the 1980 Thermal Demonstration. This technique was undertaken to maintain continuity between the two studies and enable the results of the two studies to be compared. The analysis was conducted by evaluating the refined hydrothermal model of Clinton Lake (established under worst case 1955 meteorological conditions) and applying the model data to a biological assessment of the fish community in Clinton Lake. The evaluation was essentially a predictive evaluation utilizing literature derived aquatic life thermal criteria in conjunction with habitat delineations.

2.0 CLINTON LAKE AND POWER STATION

2.1 CLIMATE

Clinton Lake is located in central Illinois on rather level topography surrounded by gently rolling terrain. A statistical analysis of meteorological data shows changeable weather and wide ranges in annual temperatures quite typical of continental climates. Winters are cold and summers are warm with short periods of fluctuating temperature, humidity, cloudiness, and wind direction.

Large-scale storm activity occurs primarily during the winter and spring with moderate to heavy ice storms migrating across the area once every 5 years on average. A more destructive and intense storm common to the area is the funnel-shaped tornado. Most tornado activity occurs in the spring.

Meteorological data obtained from a 5-year (1972-1977) Clinton Power Station monitoring program and National Weather Service recording stations in Peoria and Clinton adequately describe the climate at Clinton Lake. Relevant climatological data are presented in Table 2-1.

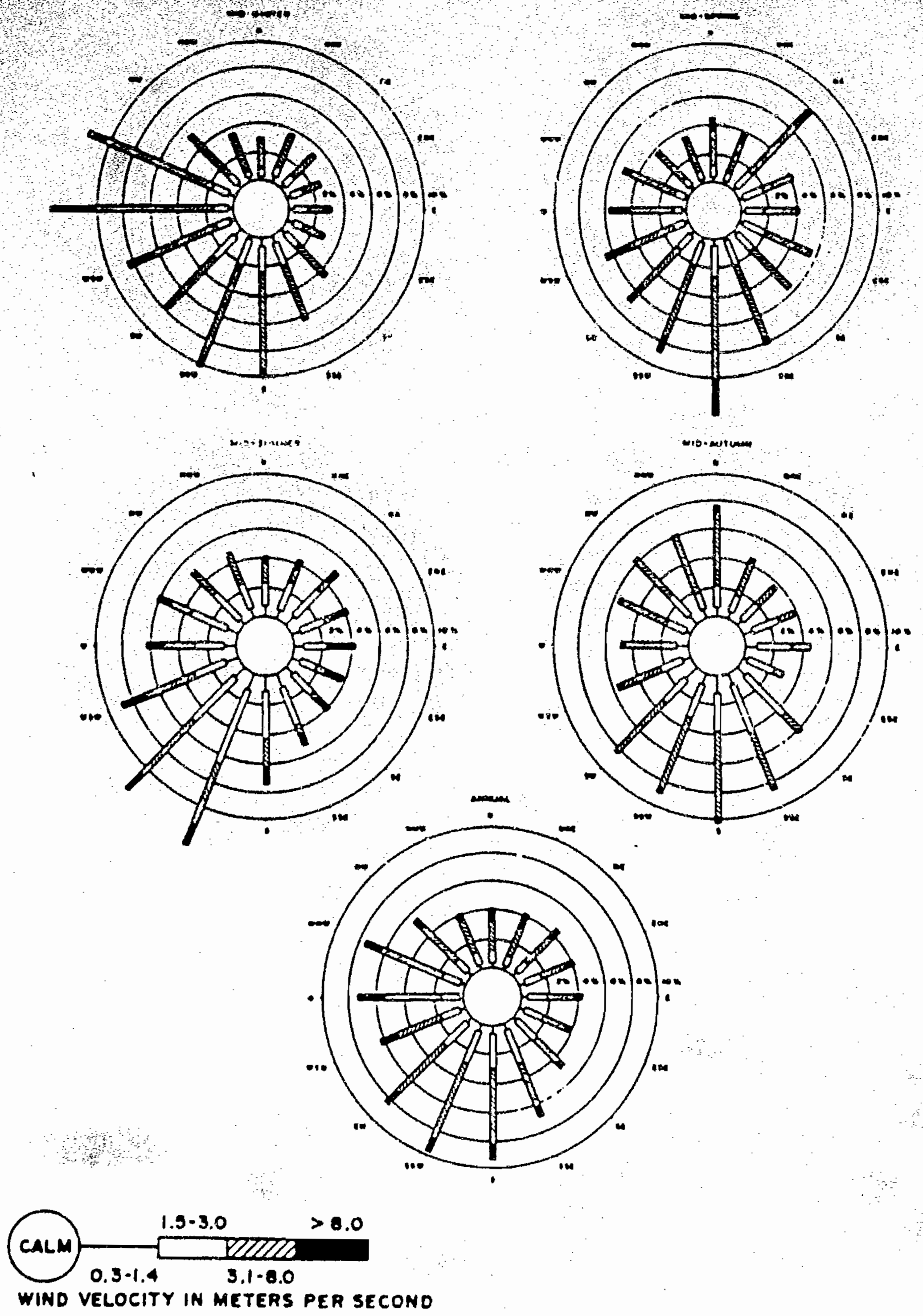
Mean monthly temperatures illustrate the area's wide annual variation in temperature. Extremes over the 5-year record ranged from 95.4°F in July to -19.8°F in January. Precipitation annually averages about 37 inches and is distributed uniformly in the fall, winter and spring with March and June being the wettest months. Summer precipitation consists of brief, scattered showers that produce uneven distributions. November through March constitutes the snowfall season, but offers little contribution to the annual precipitation total.

Mid-seasonal and annual wind roses for Clinton Lake are presented in Figure 2-1 and provides the distribution of wind speed and direction from the period April 13, 1972 through April 31, 1977. Except for the mid-winter case when surface air flow is westerly, the prevailing wind across Clinton Lake originates between the south and southwest sectors at an average speed of

Table 2-1. Climatological Data for Central Illinois, 1950-1975

Parameter		Peoria	Clinton
Temperature (°F)			
Annual Average		50.8	50.9
Maximum		60.5	59.0
Minimum		41.1	42.8
Relative Humidity (%)			
Annual Average at	0000 hours	78	--
	0600 hours	83	--
	1200 hours	62	--
	1800 hours	65	--
Wind			
Annual Average Speed (mps)		4.6	4.1
Prevailing Direction		South	South-Southwest
Fastest Mile:	Speed (sustained)	75	--
	Direction	Northwest	--
	Date	July 1953	--
Precipitation (inches)			
Annual Average		35.06	37.70
Monthly Maximum		(09/61) 13.09	--
24-Hour Maximum		(04/50) 5.06	2.72
Snow (inches)			
Annual Average		23.5	19.0
Monthly Maximum		(12/73) 18.9	--
24-Hour Maximum		(12/73) 10.2	--
Mean Annual Number of Days			
Precipitation ≥0.01 inch		112	--
Snow ≥ 1.0 inch		8	--
Thunderstorms		49	--
Heavy Fog, Visibility ≤ 1/4 mile		21	--
Maximum Temperature ≥90°F		17	19
Minimum Temperature ≤0°F		11	8

Source: U.S. Department of Commerce, 1975.



SOURCE: EIA, 1980

Figure 2-1
PERCENT FREQUENCY OF WIND SPEED AND DIRECTION (WIND ROSES) FOR CLINTON, ILLINOIS (1972-1977)

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4.1 meters per second. It should be noted that the orientation of Clinton Lake is such that the dominant winds from the south and southwest move directly along the centerlines of the North Fork and Salt Creek.

A comparison of the 5-year (1972-1977) and 1955 wind speed data is listed in Table 2-2. Average wind speeds for the mid-summer periods during 1972-1977 and 1955 were 3.9 and 3.7 meters per second, respectively.

Heat input to central Illinois occurs through short-wave solar radiation and long-wave atmospheric radiation. Long-term records compiled by the Illinois State Water Survey indicate the median daily value of short-wave solar radiation in central Illinois is 2,025 Btu/ft^2 during mid-summer. Median daily values in mid-winter are approximately 690 Btu/ft^2.

2.2 CLINTON LAKE

2.2.1 Location and Description

Clinton Lake is located in DeWitt County in central Illinois. This manmade reservoir was constructed by Illinois Power to serve as a cooling water source for the Clinton Power Station. Clinton Lake was formed during 1977/1978 by the impoundment of Salt Creek below the confluence with its North Fork. By mid-May 1978, the two arms of the lake had reached its designed pool elevation of 690 feet mean sea level (690 feet msl).

Clinton Lake was formed by constructing an earth dam across Salt Creek approximately 1,200 feet downstream of its confluence with North Fork and 3300 feet upstream of Illinois State Route 10 (Figure 2-2). Location of the dam is 4 miles east of Clinton. The Salt Creek and North Fork fingers of the U-shaped lake extend 14 miles and 8 miles, respectively, upstream from the dam. The average width of the lake is 1,970 feet (0.37 mile) at a normal pool. Drainage area of the lake is 296 square miles (mi^2). Surface area of the lake is 4,895 acres (7.65 mi^2 or 2.6 percent of the drainage area) and the storage capacity is 74,200 acre-feet at a normal pool elevation of 690 feet (Figure 2-3). Average lake depth is 15.6 feet, while maximum lake

Table 2-2. Comparison of Wind Speed Data (Springfield, Illinois) for the Mid-Summer Periods During 1972-1977 and 1955

Direction	Compass (Degrees)	Occurrence (percent)		Average Speed (m/sec)	
		1972-77	1955*	1972-77	1955*
North	360.0	4.2	1.7	3.3	4.0
North-Northeast	22.5	4.4	3.3	3.6	3.4
Northeast	45.0	5.1	13.3	3.5	3.0
East-Northeast	67.5	4.3	10.0	4.1	4.1
East	90.0	4.4	10.0	4.1	2.7
East-Southeast	112.5	4.1	1.7	3.4	2.5
Southeast	135.0	4.2	1.7	3.3	3.8
South-Southwest	157.5	5.3	1.7	3.4	4.0
South	180.0	7.4	25.0	3.6	3.8
South-Southwest	202.5	12.6	20.0	3.8	3.8
Southwest	225.0	12.1	5.0	4.4	2.5
West-Southwest	247.5	9.1	0.0	4.8	0.0
West	270.0	6.5	3.3	4.4	4.6
West-Northwest	292.5	6.1	1.7	3.8	7.4
Northwest	315.0	5.2	3.3	3.5	2.7
North-Northwest	337.5	5.0	1.7	3.5	4.9

* Source: U.S. Department of Commerce, 1955.

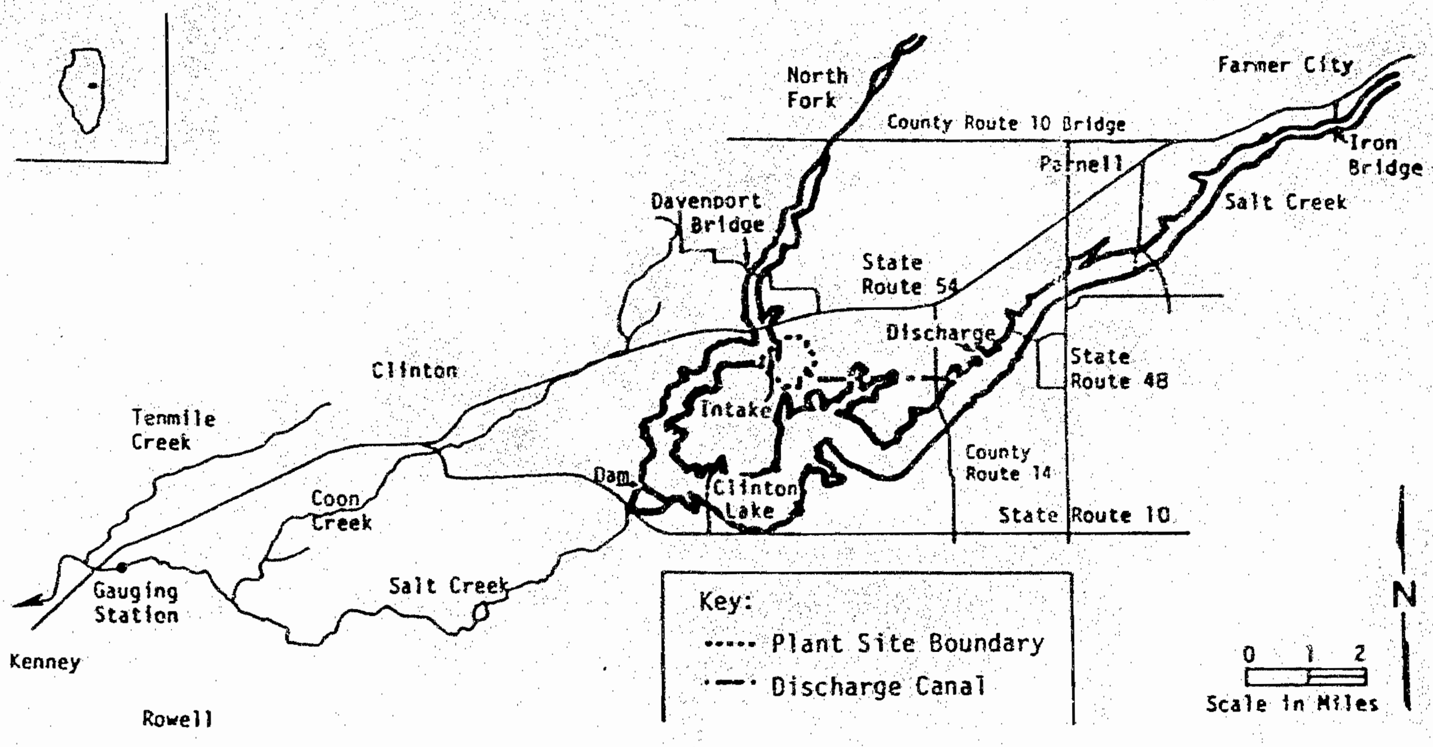

Figure 2-2
CLINTON LAKE, ILLINOIS STUDY AREA

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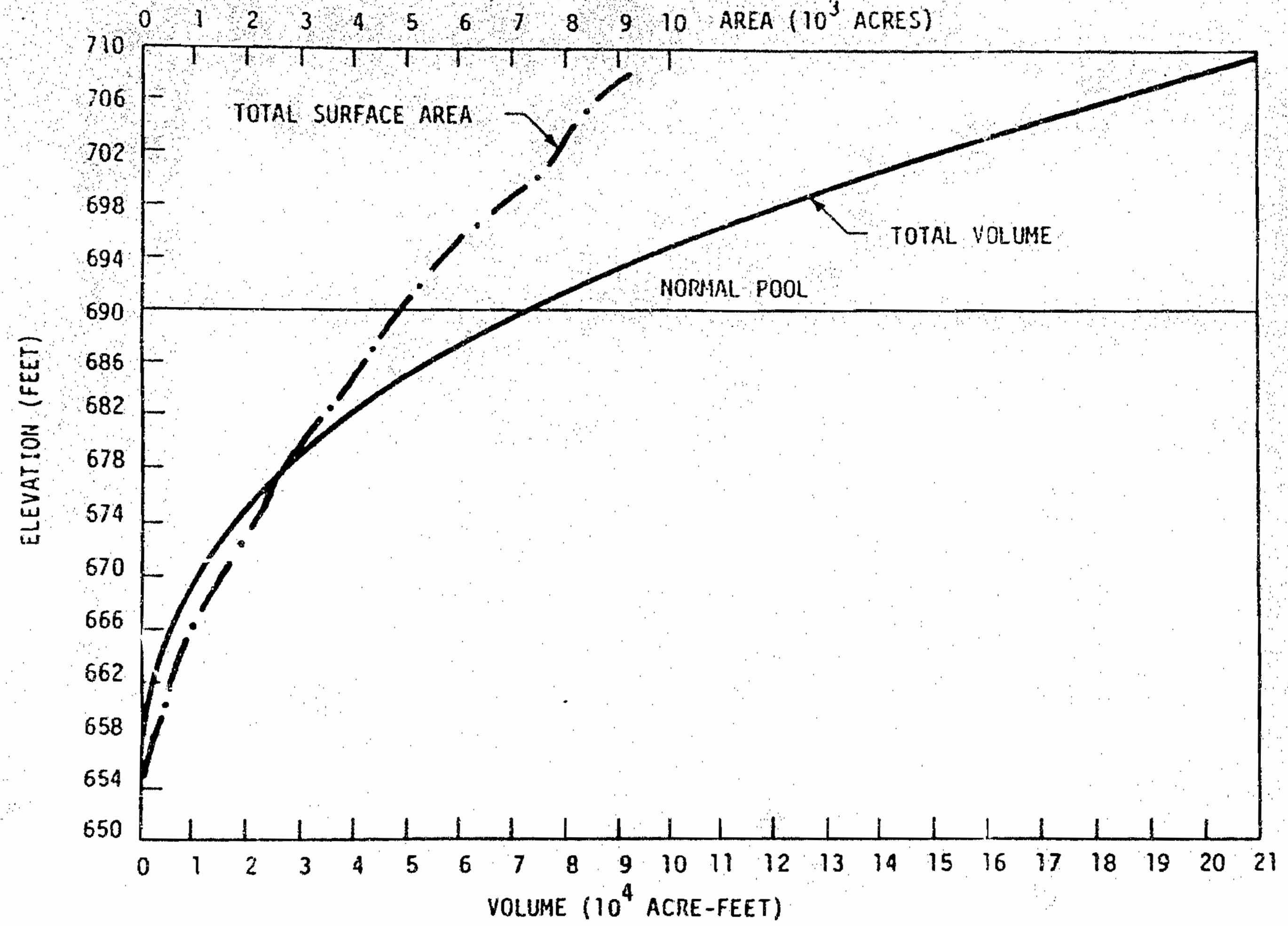

Figure 2-3
AREA (ACRES) AND CAPACITY (ACRE-FEET) FOR CLINTON LAKE AT DIFFERENT LAKE ELEVATIONS

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depth approaches 40 feet near the dam. Inflows to the lake occur as a direct response to precipitation on its drainage area and through ground water discharges.

Headwaters of the lake are above County Route 10 Bridge on the North Fork and Iron Bridge at Farmer City on the Salt Creek. Location of the station and major highway bridges across the lake are shown in Figure 2-2.

Other impoundments located in the central Illinois area include Lake Sangchris, Coffeen Lake, Lake Springfield, Lake Decatur, and Lake Shelbyville (Figure 2-4). Lake Sangchris, Coffeen Lake, and Lake Springfield serve as cooling lakes.

2.2.2 Thermal Conditions

Water temperatures at various locations in Clinton Lake have been routinely measured since 1978 as part of the ongoing environmental monitoring program conducted by Illinois Power. From 1978 through 1986 the Clinton Power Station was under construction; consequently, the lake during this time period did not receive any thermal loading and exhibited ambient condition. Operational testing of the Clinton Power Station began in 1987, resulting in sporadic production of thermal discharges above ambient conditions.

Figure 2-5 illustrates temperature conditions at fisheries monitoring Station 2 (near the discharge outfall) for recent years (1985-1987). These data indicate that typical ambient temperatures in 1985 and 1986 reached approximately 26°C in July. Operational testing in 1987 resulted in periodic temperatures above 30°C near the discharge outfall documenting the above ambient nature of the discharge water. These data also reflect the rapid return to ambient conditions when testing was not being conducted. This is particularly evident during the month of July.

The model year (1955) utilized in this demonstration was selected to represent worst case meterological condtions. In addition to 1955 being the hottest year from 1953 through 1978, it also was defined as the

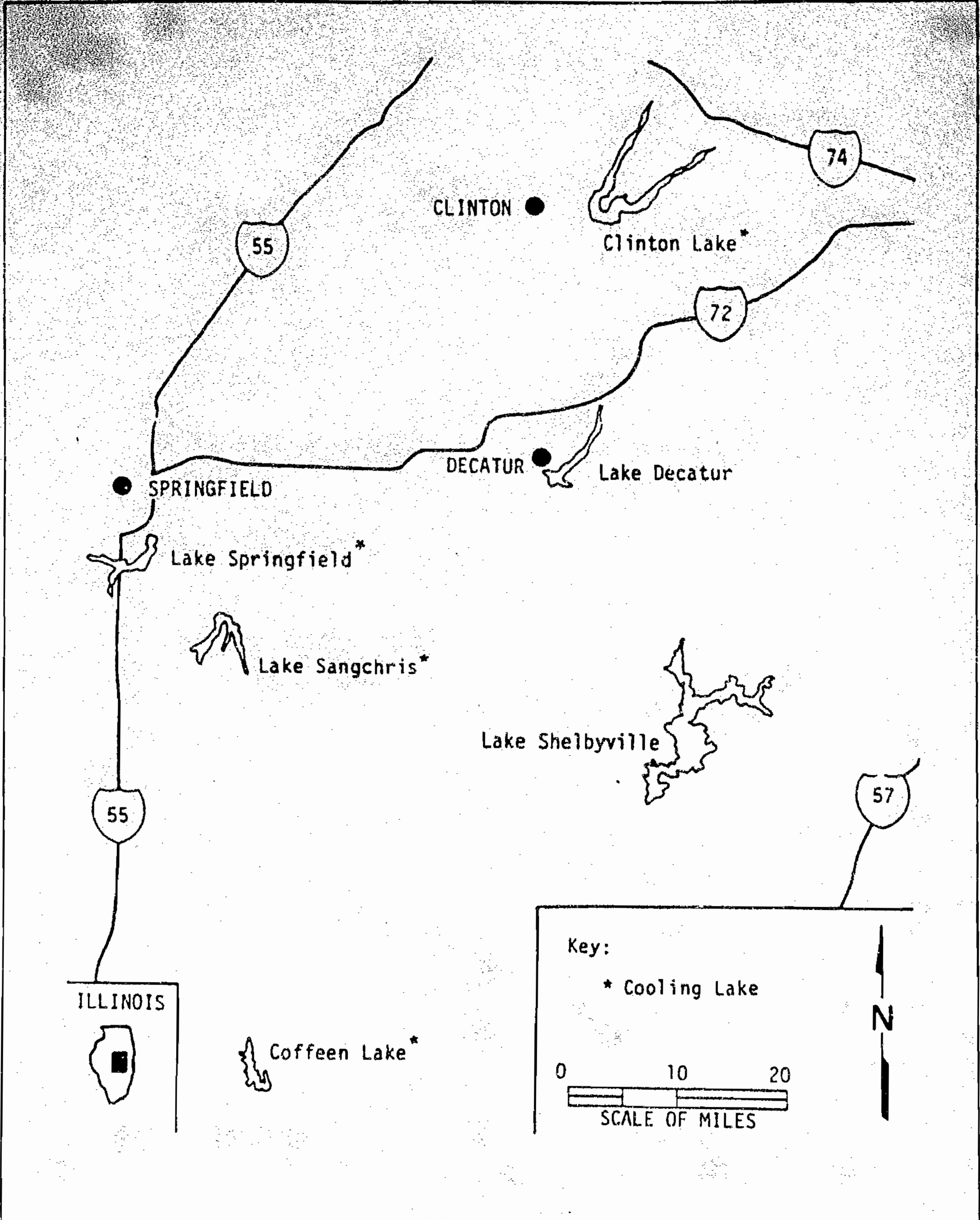

Figure 2-4
IMPOUNDMENTS AND MAJOR CITIES LOCATED IN THE CENTRAL ILLINOIS REGION

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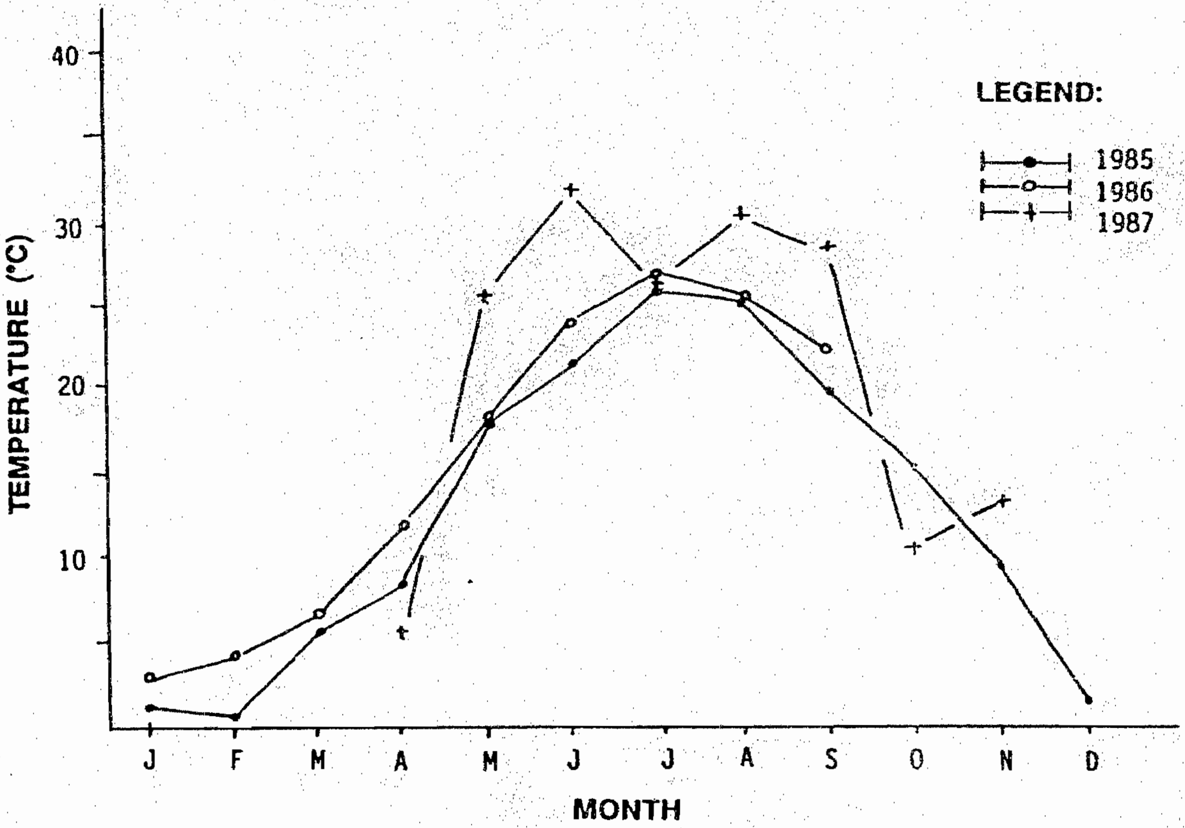

Figure 2-5
TEMPERATURE AT 1-METER DEPTHS AT CLINTON LAKE FISHERIES SAMPLING STATION 2 (DISCHARGE) FOR AMBIENT 1985 AND 1986 AND OPERATIONAL TESTING YEAR 1987

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once-in-50 year drought. These conditions result in a reservoir pool elevation 4.5 feet lower than the normal pool elevation and increased ambient water temperature above 32.0°C near the surface throughout much of the lake during the hottest day of the year (early August). These ambient conditions represent a 6 to 7°C increase over the ambient conditions documented in 1985 and 1986.

2.2.3 Dissolved Oxygen

Atmospheric oxygen and dissolved oxygen normally approach equilibrium at the air-water interface of a body of water and, in general, approach saturation concentrations in the water. As noted for lakes or reservoirs in the Midwest, dissolved oxygen concentrations in the deeper portions of a lake or reservoir will not be at saturation during the summer. Values of dissolved oxygen can decrease during the summer in the deeper water to levels that will not support most aquatic life. This decrease is the result of oxidation of organic bottom sediments and water column demands. Effective vertical migration of oxygen-rich surface water to the bottom is blocked by natural, vertical gradients in temperature during the summer.

Dissolved oxygen has been sampled in Clinton Lake since 1978 at various locations throughout the lake on a monthly basis. Data for 1986 at the monitoring station near the dam are presented in Table 2-3 at 1-meter depth intervals. Corresponding values of temperatures are also presented for comparison. Collected data from 1978 through 1986 indicate that distinct vertical stratification does not typically occur in Clinton Lake except for the deepwater area near the dam.

2.2.4 Inflow to the Lake

A U.S. Geological Survey gaging station is located at Rowell, Illinois approximately 12 miles downstream of the Clinton Dam (Figure 2-2). At this station, Salt Creek has a drainage area of 335 square miles. Records at this station are continuous from October 1942 to present. A summary of the data is presented in Table 2-4 in the form of annual means. The annual average runoff from the Salt Creek drainage area was 9.54 inches from 1943 through

Table 2-3. Dissolved Oxygen and Temperature Data from 1986 Monthly Sampling Program at Clinton Lake Near the Dam (Site 8)

Depth (meters)	Dissolved Oxygen (mg/l)					Temperature (°C)				
	May	June	July	Aug	Sept	May	June	July	Aug.	Sept
1	10.6	10.8	7.0	5.1	8.9	16.2	23.4	26.4	25.0	21.4
2	10.9	11.3	7.1	4.8	8.9	16.0	23.3	26.4	25.0	21.4
3	10.1	11.4	7.3	4.7	8.7	16.0	23.3	26.3	25.0	21.3
4	10.2	10.6	6.4	4.7	7.8	15.9	23.2	26.3	25.0	21.2
5	10.1	10.4	5.8	4.8	7.5	15.9	22.8	26.1	25.0	21.2
6	10.6	9.8	5.1	4.8	7.8	15.9	22.7	26.0	25.0	21.1
7	9.8	8.7	3.8	4.6	4.5	15.9	22.6	25.4	25.0	20.7
8	9.8	2.1	1.9	4.6	4.2	15.8	20.6	25.3	24.9	20.5
9	9.8	0.7	1.5	4.6	3.8	15.8	20.0	24.7	24.9	20.4
10	9.6	0.4	0.8	3.0	3.0	15.8	19.7	22.2	24.5	20.4

Source: Illinois Power Company, 1988.

Table 2-4. Annual Runoff from Salt Creek at Rowell, Illinois from 1943 through 1978

Year	Runoff (inches)	Comparison to Mean Annual (percent)	Rank
1943	17.03	179	33
1944	9.61	101	22
1945	4.99	52	5
1946	13.10	137	31
1947	11.15	117	24
1948	8.68	91	19
1949	7.58	80	15
1950	18.53	194	34
1951	12.89	135	30
1952	12.37	130	29
1953	5.60	59	6
1954	1.45	15	1
1955*	3.49	37	3
1956	4.91	52	4
1957	11.27	118	25
1958	10.22	107	23
1959	7.38	77	13
1960	8.15	86	18
1961	8.96	94	20
1962	11.96	125	27
1963	3.20	34	2
1964	6.61	69	10
1965	7.50	79	14
1966	6.37	67	9
1967	6.61	69	10
1968	21.04	221	36
1969	8.07	85	17
1970	12.25	129	28
1971	5.68	60	7
1972	9.33	98	21
1973	19.22	202	35
1974	15.94	167	32
1975	11.72	123	26
1976	7.95	83	16
1977	5.76	60	8
1978	6.97	73	12

* Test year used in present temperature simulation of Clinton Lake.

Source: U.S.Geological Survey, 1978.

1978. Runoff for 1955 was found to be below the annual mean with a value of 37 percent of the long-term annual mean. A monthly distribution of the mean runoff from 1943 through 1978 is listed in Table 2-5.

A gauge was placed at Iron Bridge on Salt Creek below Farmer City to monitor the local inflow to the Salt Creek branch of Clinton Lake (Figure 2-2). Data obtained in 1978 were compared to corresponding data at Rowell to develop empirical relationships between the gages.

For flows at Rowell in excess of 175 cfs, the following relationship was found:

$$Q_I = 0.56\ Q_R$$

where Q_I is the flow in cfs at Iron Bridge and Q_R is the flow at Rowell in cfs.

For flows at Rowell less than 175 cfs and greater than 12 cfs, the following relationship was found:

$$Q_I = 0.427\ Q_R - 4.81$$

For flows at Rowell less than 12 cfs, the following relationship was found:

$$Q_I = 0.2 \text{ cfs}$$

It would appear that as the flow at Rowell decreases, the percent contribution of surface runoff by Salt Creek above Iron Bridge decreases. On a drainage area ratio basis, flows at Iron Bridge should approximate 4.5 cfs when flows of 12 cfs are measured at Rowell. However, the gage registered only 0.2 cfs. The difference, in a large part, is likely due to ground water discharge occurring between Iron Bridge and Rowell.

2.3 CLINTON POWER STATION

The Clinton Power Station is a nuclear generating facility consisting of one 933 MW steam turbine generator powered by General Electric Boiling Water Reactor. Construction of the Clinton Power Station was completed in 1986 and low power testing and commercial operations commenced in 1987.

Table 2-5. Mean Monthly Runoff for Salt Creek at the Rowell Gauge from 1943 through 1978

Month	Mean Runoff	
	Inches	Cubic Feet Per Second
January	0.91	266
February	1.02	324
March	1.27	368
April	1.65	495
May	1.44	418
June	1.05	315
July	0.54	158
August	0.32	92
September	0.15	44
October	0.25	74
November	0.32	97
December	0.62	181
TOTAL	9.54	--
ANNUAL	--	235

Source: U.S. Geological Survey, 1978.

The Clinton Power Station is designed to operate in the following manner. At a full load of 933 net MWe, the once-through cooling system must dissipate 6.713×10^9 Btu/hr for one-unit operation. A total cooling water flow of 1387.5 cfs (at 685.5 feet msl) is taken from and returned to Clinton Lake via the once-through system under three-pump operation. The multi-pressure condenser used at Clinton Power Station is served by three 189,567 gpm pumps and at 100 percent load is designed for a cooling water temperature rise of 22.7° (12.6C°).

Circulating water is withdrawn from the North Fork branch of Clinton lake, passes through the condenser, flows through a 3.1-mile discharge flume and is discharged to the Salt Creek branch of the lake (Figure 2-6). The intake (Figure 2-7) is designed to withdraw water from a depth of 7 to 20 feet below the normal pool elevation of 690 feet msl. Two drop structures are placed in the 3.1-mile discharge flume to dissipate hydraulic energy and discourage fish migration into the discharge. The discharge flume is trapezoidal in design and has a surface area of 77.81 acres.

Total residence time of the cooling water is 4.5 hours, of which 4.4 hours is in the discharge flume.

Hydrothermal simulations in this study will use a 100 percent load for comparison to previous results and will represent a higher average loading than actually projected by Illinois Power, thus presenting a degree of conservatism in thermal projections.

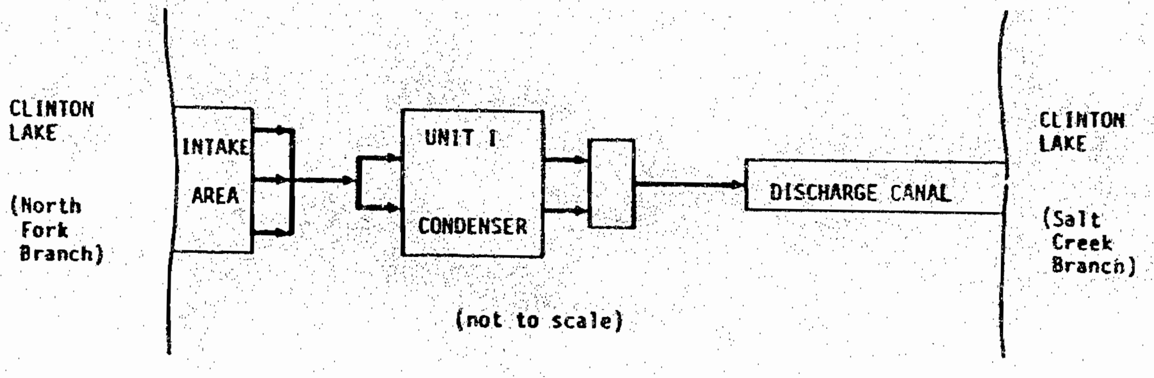

Figure 2-6
CIRCULATING WATER SYSTEM OF CLINTON POWER STATION: SCHEMATIC DIAGRAM OF WATER FLOW

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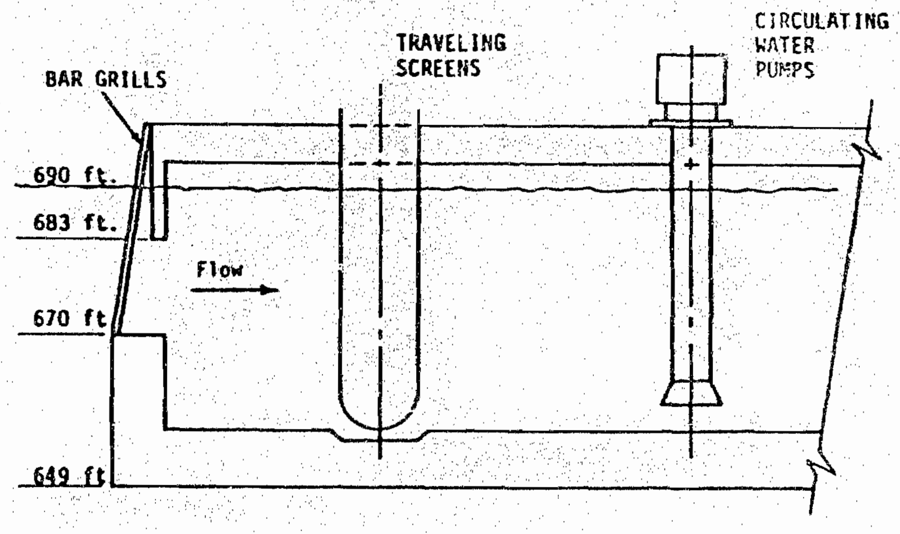

Figure 2-7
CIRCULATING WATER SYSTEM OF CLINTON POWER STATION: DETAIL OF WATER INTAKE STRUCTURE, SIDE VIEW

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3.0 HYDROTHERMAL MODEL OF CLINTON LAKE

The natural circulation in a long, narrow, relatively deep impoundment like Clinton Lake is controlled by inflows and outflows, wind driven circulation, vertical stratification and thermal convection (due to differential heating and cooling between more rapidly heated and cooler shallow waters and the deeper portions of the lake). For summertime low flow conditions, wind driven circulation tends to dominate. With the plant in operation, the lake circulation will be modified by: (1) the plant pumping from the discharge to the intake, and (2) additional thermal convection over the lake surface due to the warmer discharge and the attendant sinking of cooler water to the deeper portions of the lake followed by cool water movement back toward the discharge as a density underflow. The hydrodynamics and temperature structure of Clinton Lake is essentially two dimensional in the longitudinal and vertical directions, with limited lateral variability.

3.1 LATERALLY AVERAGED RESERVOIR MODEL (LARM)

The hydrodynamic and temperature distribution analysis of Clinton Lake requires a model that represents the longitudinal and vertical equations of fluid motion, continuity and heat transport, and that incorporates a coupling of buoyancy between the temperature distribution and the equations of motion as well as surface wind forces. The Laterally Averaged Reservoir Model (LARM) has been developed for the analysis and prediction of two dimensional (longitudinal and vertical) hydrodynamics and temperature structure using time varying inflow, outflow and meteorological data.

LARM was originally developed for the Ohio River Division of the U.S. Army Corps of Engineers and has received extensive testing and verification by application to Sutton Lake, West Virginia; Center Hill Reservoir, Tennessee; and compared to laboratory flume tests at the Waterways Experiment Station in Vicksburg, Mississippi. LARM has also been applied to the study of chlorine transport in a stratified cooling lake, safe shutdown impoundment analysis, and multiple thermal discharges on a stratified run of river impoundment.

LARM was also employed in the 1980 Thermal Demonstration for Clinton Power Station.

Development of the LARM hydrodynamics and transport code has three basic steps including: (1) integration of the three-dimensional equations of fluid motion and transport to the laterally averaged form; (2) manipulation of the laterally averaged equations to arrive at the solution technique; and (3) development of the numerical finite difference form of the equations for computer coding. Detailed explanations of those modeling steps are described in Edinger et al. (1988).

3.2 MODEL SET UP

Model set up requires specifying detailed reservoir geometry as lateral widths at each depth at each cross section, the location and operation of inflows and outflows to and from the lake, and boundary conditions at internal barriers in the lake.

Model geometry was determined from reservoir cross sections derived from a reservoir topographic map. Cross-sectional data was placed in the GEDA program developed by the Hydrologic Engineering Center U.S. Army Corps of Engineers. The GEDA program allows interpolating the cross-sectional data to uniformly spaced model cross-sections and determining the reservoir widths in each layer of the cross-sections.

Computational cells required division of Clinton Lake into longitudinal segments (Figure 3-1). Longitudinal spacing of computational cells was determined from inspection of a planar map such that the plant discharge and intake were positioned near the centers of cells and that the internal barrier bridges were near the ends of the cells. A longitudinal grid spacing of Wx=1,518.5 meters (4,981.9 feet) satisfied these constraints. The depth of each cell was chosen to be Delta z=1.1 meters (3.6 feet) for vertical detail. The lake longitudinal and vertical profile was resolved into a grid 22 cells long (at the maximum water surface) by a maximum of 14 cells deep (from the maximum flood level water surface to the bottom).

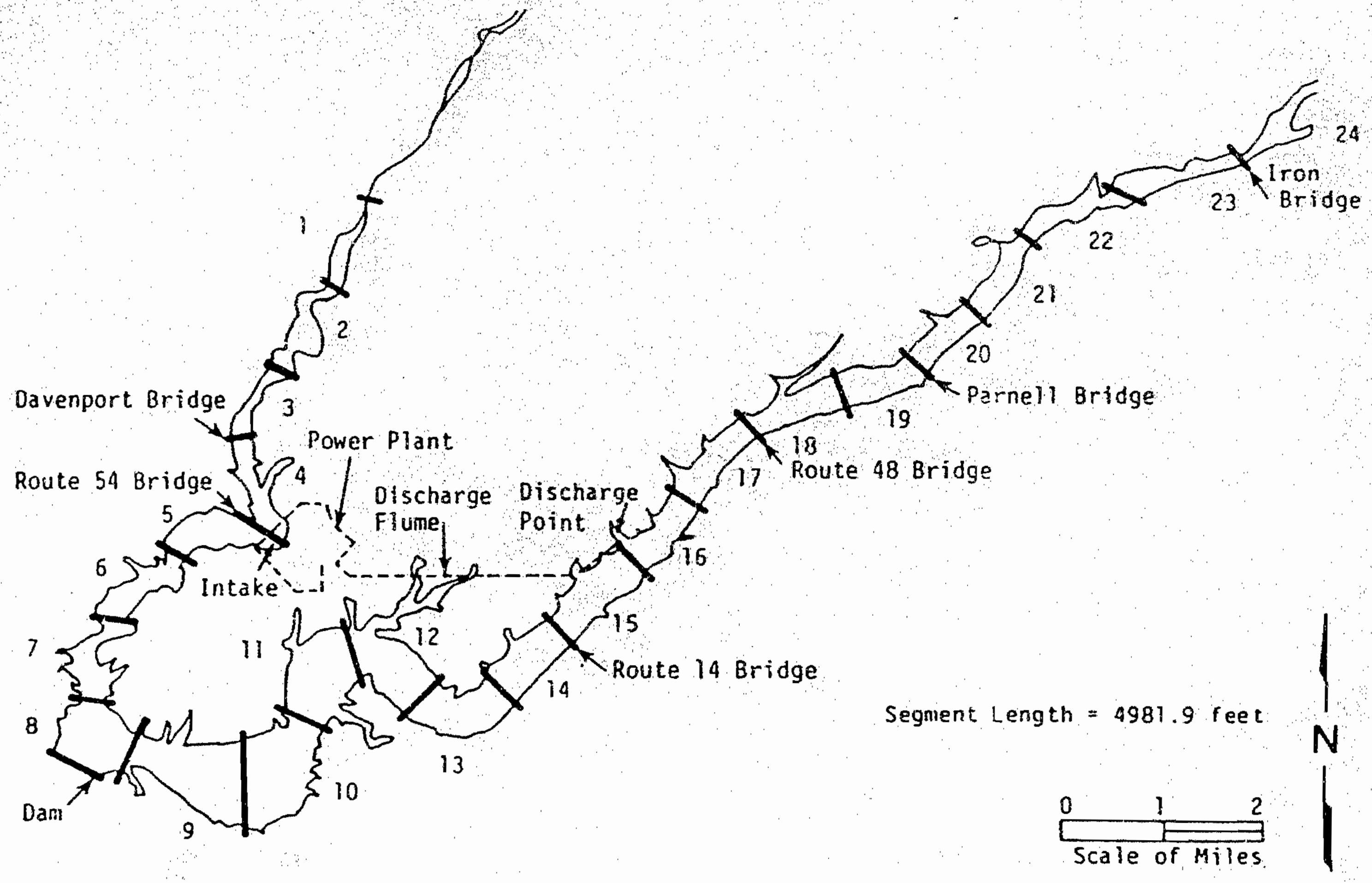

Figure 3-1
LONGITUDINAL SEGMENTATION OF CLINTON LAKE FOR LARM APPLICATION

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3.3 MODEL INPUT

The hydrodynamics and temperature regimes are computed for the 1955 meteorological data. This year has previously been identified as an extreme year for cooling lake operations.

Meteorological data for 1955 was taken from the NOAA Climatological Records for Springfield, Illinois. Measured short wave solar radiation was unavailable for this period and was estimated from cloud cover observations.

Tributary inflow data was also unavailable for 1955. Since 1955 was being simulated as an extreme dry year, the lake level was set at the extreme low level of 685.5 feet with no flow over the spillway. The inflow into each arm was set at a constant low flow value just sufficient to meet the minimum downstream release from the low level outlet. Ground water inflow was disregarded in this analysis. A heat rejection rate of 6.713 Btu/hr and a circulating water flow of 1,387.5 cfs were utilized to represent one unit, three pump operation.

Model input and output utilizing 1955 conditions was undertaken principally for 100 percent load. Single warmest day, warmest seven consecutive days, and 30-day averages were determined monthly from April through October. Ambient (warmest single day in May and August as well as warmest 7 days in May) scenarios were also derived for comparison.

The hydrodynamic and temperature regimes were computed for the 1955 year of meteorological data at 100 percent load and under no heat load to determine the distribution of ambient temperature. The 1955 year meteorological conditions represent probably the worst summer in 50 years and therefore are used in the model to simulate worst case conditions. Tabulation of the model output for 1955 ambient conditions is provided by EIA (1980) and Edinger (1988).

The 1955 LARM simulations were carried out for dry weather and low lake level conditions. The North Fork and Salt Creek flows were set at 2.5 cfs each to balance the minimum flow release of 5 cfs at the low level outflow structure. The lake level was set at 685.5 feet, approximately 5 feet below normal pool elevation. Ground water inflow into the deeper portions of the lake was ignored, resulting in higher calculated lake temperatures than would have occurred.

4.0 RESULTS OF HYDROTHERMAL MODEL

4.1 AMBIENT CONDITIONS

The ambient temperature and flow distributions for the 1955 conditions indicated 1955 ambient lake temperatures above 30°C (86°F) for day 210 to day 216. The maximum surface temperature was 33.3°C (92.0°F) on day 213, with temperature distribution as shown in Figure 4-1. Ambient temperatures exceeded 32.2°C (90°F) from day 210 to day 213. Stratification of the deeper protions of the lake was not significant under 1955 conditions because the 1955 model does not allow for ground water inflow but does allow for high wind speeds.

4.2 MODEL OUTPUT UNDER HEAT LOAD

Maximum surface temperatures for unconstrained operation (100 percent load) occurs on day 213. The detailed temperature distribution within Clinton Lake under these conditions is given in Figure 4-2. Three-pump operation for this day at 100 percent load results in a discharge flume temperature of 44.4°C. A mixed temperature of the lake surface at the point of discharge of 42.7°C. Temperature isotherms (plotted to the nearest whole number) as shown in Figure 4-2 indicates that the majority of Clinton Lake consists of temperatures less than 35°C whereas temperatures less than 33°C are restricted to areas deeper than 10 feet.

The warmest 7-day and 30-day average temperatures reflect much lower temperatures than do single warmest day temperatures under 1955 conditions (Figure 4-3). For example, the mixed temperature of the lake in the immediate vicinity of the discharge is less than 41.0°C during the warmest 7-day period and is less than 39.0°C during the warmest 30-day period. In addition, the majority of the lake has temperatures lower than 33.0°C during the warmest 7-day period while the majority of the lake has temperatures lower than 31.0°C during the warmest 30-day period.

Comparison of the model output under three-pump operation was also made with ambient temperature conditions (Figure 4-1). These results are expressed

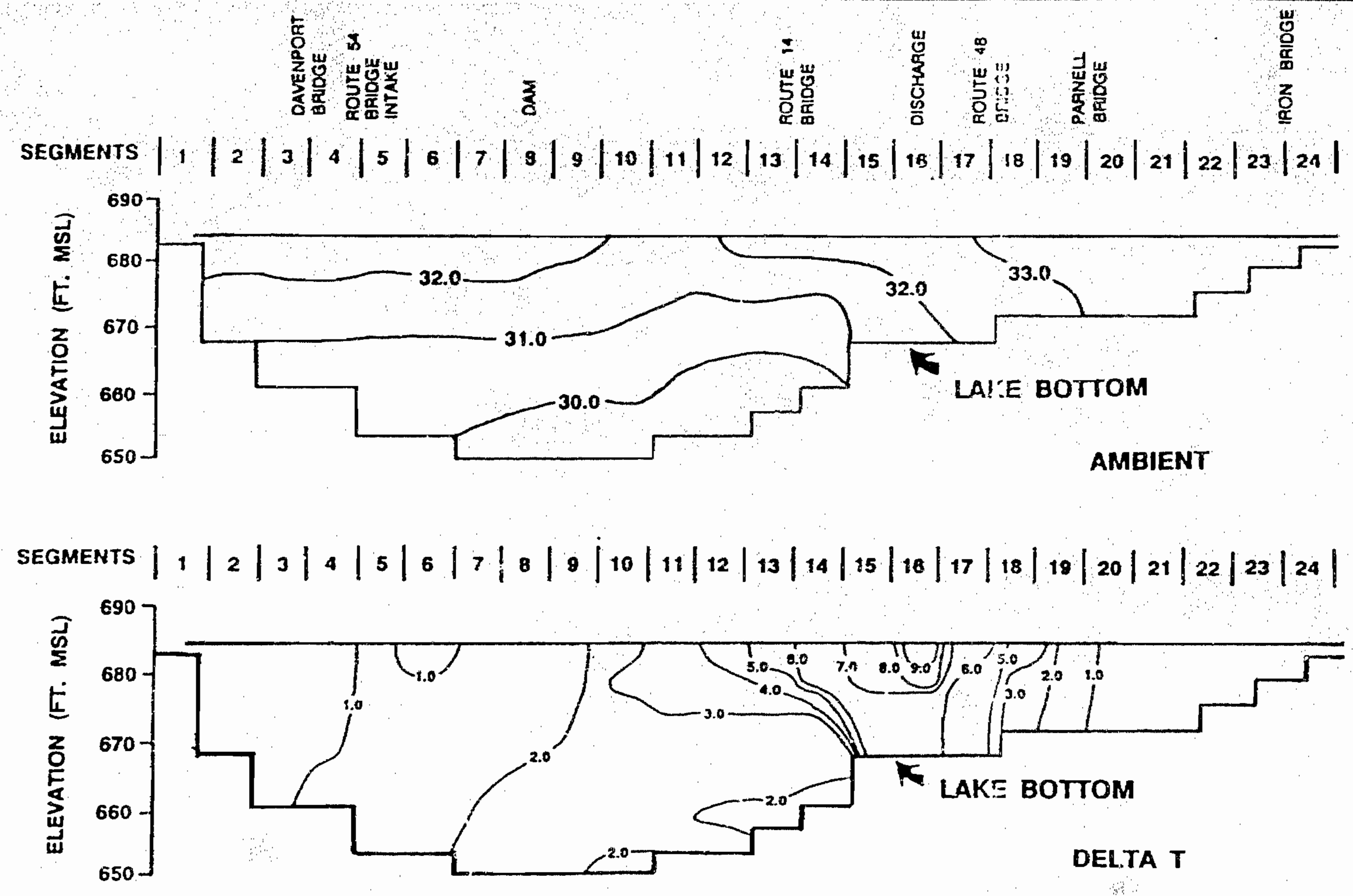

Figure 4-1
AMBIENT AND DELTA T (WARMEST SINGLE DAY TEMPERATURES VERSUS AMBIENT TEMPERATURES) IN CLINTON LAKE UNDER 1955 METEOROLOGICAL CONDITIONS

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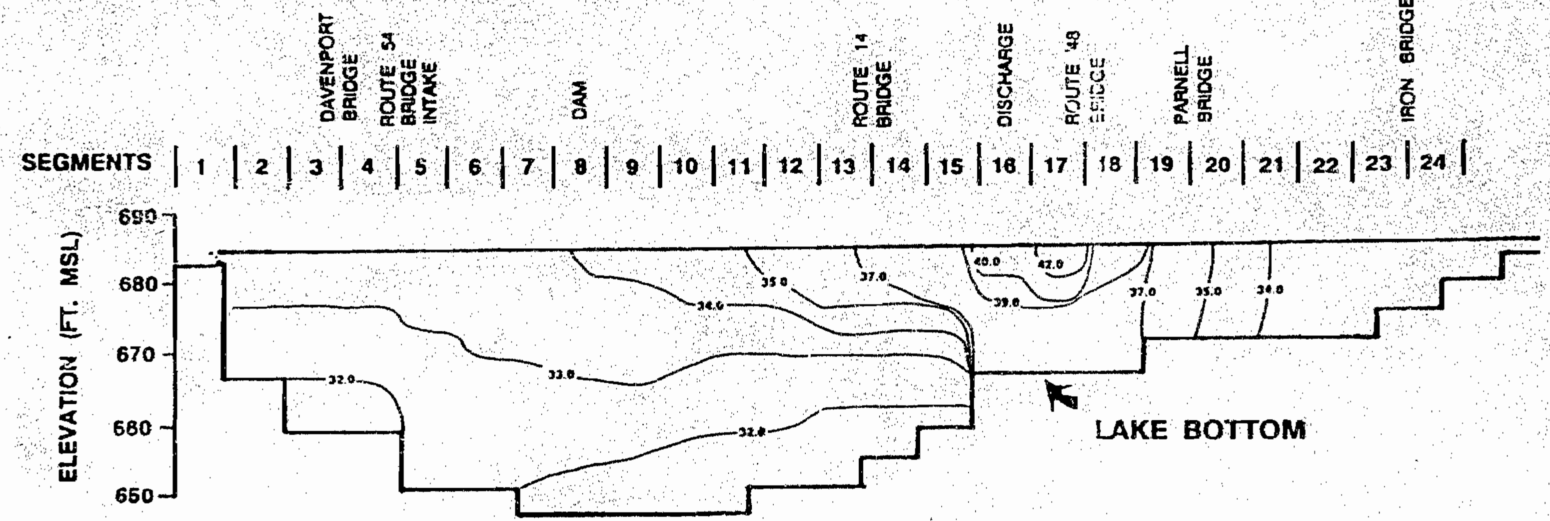

Figure 4-2
HIGHEST 1-DAY AVERAGE WATER TEMPERATURES IN CLINTON LAKE FOR AUGUST 1955 UNDER 100% LOAD

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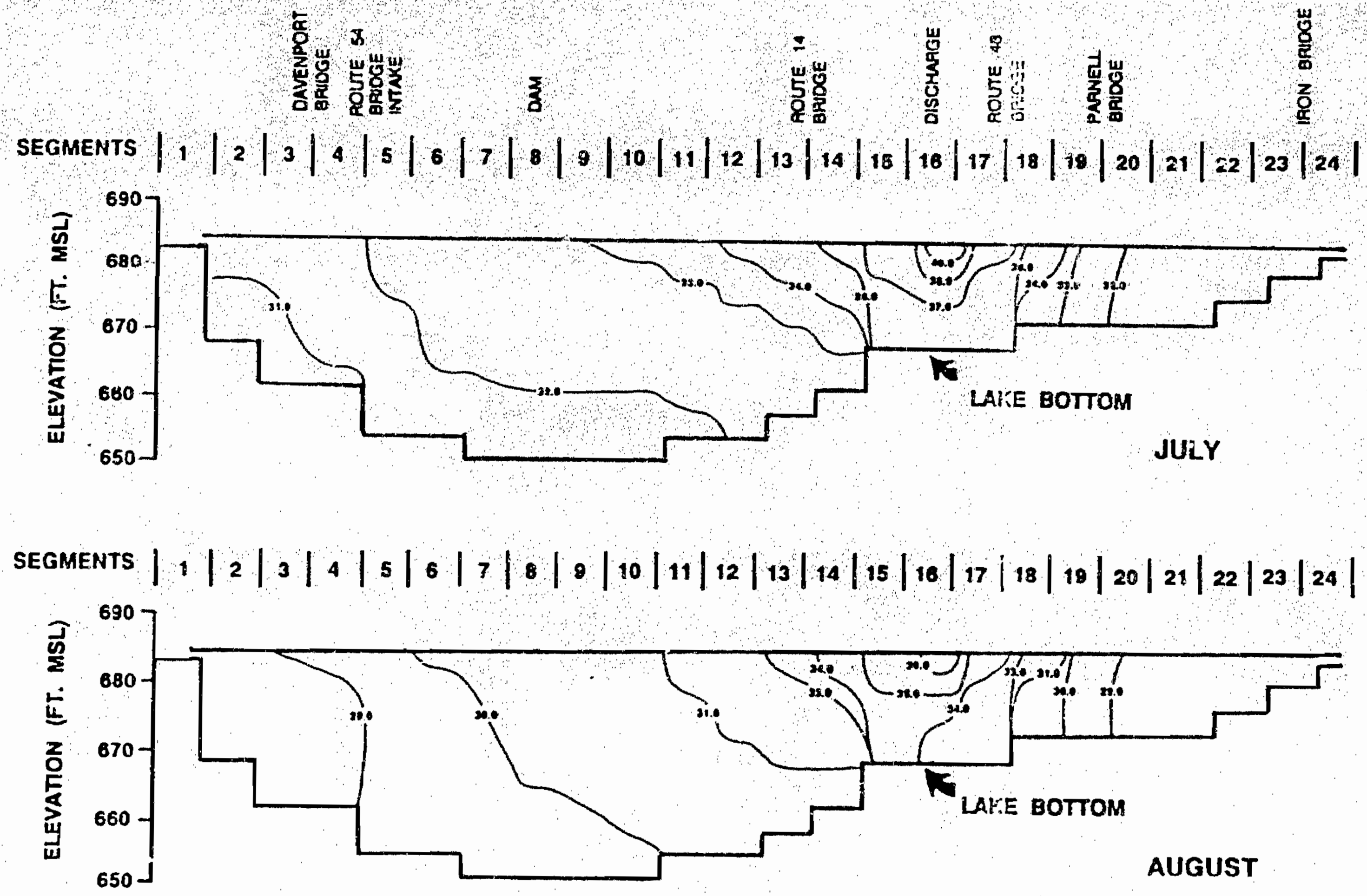

Figure 4-3
HIGHEST 7-DAY AVERAGE WATER TEMPERATURE FOR JULY 1955 AND 30-DAY WATER TEMPERATURE FOR AUGUST 1955 IN CLINTON LAKE UNDER ONE UNIT OPERATION AT 100% LOAD

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as change in temperature °C (i.e., Delta T). Delta T isotherm values range from 1.0°C in the upper ends of each arm to 9.0°C in the vicinity of the discharge (Cell 16). Cells 1 to 11 and 18 to 24 all had Delta T values less than 4.0°C while Cells 1 to 9 and 19 to 24 had Delta T values predominantly less than 2.0°C.

Graphical results of monthly single warmest day, warmest 7 consecutive days, and mean 30-day temperatures are presented in Appendix A.

5.0 ICHTHYOFAUNAL IMPACT ASSESSMENT

5.1 HISTORIC AND EXISTING FISHERY

Illinois Power has conducted the Clinton Lake Environmental Monitoring Program since lake impoundment in 1978, through 1987 to provide preoperational and operational data pertaining to the lake biota (IP, 1987). A major aspect of this program was the collection of fisheries data on a quarterly basis at established locations in the lake. A variety of collection techniques were employed throughout the annual studies with electrofishing producing the majority of the collected fishes.

These annual studies indicated that the Clinton Lake fish community was dominated by gizzard shad, common carp, bluegill, white crappie, largemouth bass, tiger muskellunge, and bigmouth buffalo. Populations of three experimental species (hybrid striped bass, walleye, and tiger muskellunge) are maintained exclusively by stocking. Supplemental stockings of largemouth bass fingerlings also contribute to existing populations.

Species occurrence and catch-per-unit-effort generally stabilized as the lake matured. The seasonal abundance of fishes was typically greatest in summer while biomass was greatest in spring. Seasonal abundance and biomass, however, were lowest in winter. Fish communities were most similar at midlake; transitional areas were similar to each other and one stream-like lake site was an outlier, particularly as the lake aged.

Growth, condition, and population structure of the major species were generally similar to or better than commonly reported in the literature. Predator fish commonly fed on gizzard shad with little diet differences between the main lake or upper ends. All fish were relatively free of external parasites or abnormalities.

The white crappie population was dominated by strong year classes (1978 and 1979) followed by much weaker classes (1980, 1981 and 1982) followed by stronger classes (1983, 1984 and 1985). Cyclic abundances of crappie are quite common (Siefert, 1968). Growth and condition of crappie was generally good to excellent. Population structure was adequate to provide good fishing for the next couple of years especially in 1987 and 1988 (IP, personal communication). Adult crappie fed on small shad while small crappie fed on zooplankton.

The largemouth bass population was dominated by the initial (1978) year class while succeeding year classes were weaker. Condition and population structure were generally good and growth was slightly below average. Rather low abundance of bass was attributed to low spawning success and recruitment. Abundance increased in 1985 and 1986 due to improved natural reproduction and possibly supplemental stockings.

The bluegill population was dominated by small, slow growing fish in somewhat low condition. Some bluegill were large enough to harvest in 1985 and 1986. Bluegill fed on insects, algae, and fish eggs.

The walleye population was characterized by good to excellent growth and condition. Population structure was highly variable depending on survival of fry stockings. Increased fingerling stockings and continued fry stockings should improve the population structure and the fishery. Successful year classes in 1983 and 1984 produced good fishing in 1986 and 1987, and probably should continue in 1988.

Growth and condition of hybrid striped bass equalled that of populations in other Illinois reservoirs. Year class strength varied with the availability of fish for stocking. Fingerling stockings produced strong year classes when available.

The population of tiger muskellunge was dominated by the initial year class (1978) with excellent growth for all year classes. Some year classes were absent due to lack of fish for stocking and other year classes were weak. Continued stockings of the experimental species (i.e., hybrid striped bass, walleye, and tiger muskellunge) may continue to provide additional angling opportunities.

A stunted common carp population was indicated by slow growth, limited recruitment, declining condition, abundance and biomass, and a population structure dominated by only two year classes.

Gizzard shad produced strong year classes each year. The population structure was composed of several year classes, 70 percent of which were young-of-the-year. Shad grew relatively slowly (about 100 mm by age 1) and contributed to the good growth and condition of the predator fishes.

To help meet management goals a fish refuge (prohibition of fishing and trespassing) will be established near the heated water discharge area during winter months. This should prevent overharvest of fishes congregated in warmer waters (Glass and Maughan, 1985; McNurney and Dreier, 1981). Length and creel limits will be proposed to help ensure a balanced population, to capitalize on increased growth in a cooling lake (Tranquilli _et al_., 1981; Sule, 1981; Heidinger and Lewis, 1986), and to more effectively utilize stocked experimental fishes. Onsite fish rearing ponds will continue to produce fish to nonvulnerable sizes. These and other management strategies will be continually refined to meet the overall objectives for the Clinton Lake fish population.

5.2 SPORT FISHERY

The existing sport fishery and the management of the sport fishery are important aspects in the overall management of the Clinton Lake. Fish management strategies will continue to be implemented to meet the goals established in cooperation with the Illinois Department of Conservation. General goals include protection of the resource to promote self-sustaining and healthy populations of important game species, and stocking of experimental fishes to determine their responses to thermal influences, to utilize abundant forage fishes, and to enhance angling opportunities.

Creel collection data collected at Clinton Lake indicate that 16 sport species have been caught by anglers in recent years (Table 5-1). White crappie, bluegill, black bullhead, black crappie, largemouth bass, channel catfish and common carp are among the most common species creeled from Clinton Lake.

The number of fish creeled by anglers increased steadily in recent years which is in part related to increased fishing pressure as well as the abundance of these species in the reservoir. The abundance of sport fishes harvested at Clinton Lake is further reflected in the catch-per-effort associated with fishing in Clinton Lake compared to other lakes in Illinois (Table 5-2).

The popularity of fishing throughout Illinois and at Clinton Lake in particular is evidenced by the high fishing pressure associated with Clinton Lake and other cooling reservoir in Illinois compared to non-cooling reservoirs (Table 5-3).

As indicated earlier in this section, white crappie is the predominant species creeled by anglers at Clinton Lake. This species accounts for 94 percent of the fishes collected by anglers in recent years. White crappie is a popular sport fish throughout the midwest and in recent years the white crappie harvest at Clinton Lake has exceeded that at most other lakes in Illinois (Table 5-4)

In general Clinton Lake supports a thriving sport fishery that services heavy fishing pressure and to date produces above average harvest rates for many sport fishes. This suggests that to date, fisheries management objectives in the lake have been successful.

5.3 FISHERIES ASSOCIATIONS--PREOPERATIONAL VS. 1987 (OPERATIONAL TESTING)

Fish sampling via electrofishing undertaken by Illinois Power biologists on a quarterly basis since 1978 resulted in an extensive database pertaining to species abundance throughout the reservoir. Collected data indicate that

Table 5-1. Estimated Annual Harvest of Fishes Caught by Boat Anglers, Clinton Lake, Illinois, 1982-1986

Species	1982	1983	1984	1985	1986	Total	%
Tiger muskellunge	40	49	0	168	107	464	*
Common carp	1,384	899	518	849	1,550	5,200	--
Bigmouth buffalo	0	0	12	0	0	12	--
Black bullhead	1,924	1,782	482	1,920	8,416	14,524	1
Yellow bullhead	327	85	30	80	0	522	--
Channel catfish	613	786	469	749	3,029	5,646	--
Flathead catfish	17	0	0	0	0	17	--
Hybrid striped bass	175	25	156	249	673	1,278	--
Lepomis sp.	0	0	0	0	234	234	--
Green sunfish	101	849	502	385	239	2,076	--
Bluegill	4,437	1,704	1,503	5,794	11,828	25,266	2
Hybrid sunfish	6	0	32	0	0	38	--
Smallmouth bass	0	0	0	0	28	28	--
Largemouth bass	2,366	1,553	261	1,403	408	5,991	--
White crappie	24,323	129,509	177,553	354,524	495,311	1,181,220	94
Black crappie	135	1,259	819	2,420	3,670	8,303	1
Walleye	1,099	702	142	142	1,512	3,597	--
Freshwater drum	166	79	20	115	74	454	--
TOTAL	37,213	139,281	182,499	368,798	527,079	1,254,870	

* Less than 1 percent.

Source: Illinois Power, in press.

Table 5-2. Catch-Per-Unit-Effort (CPE) and Number of Fishes Per Hectare Harvested for Several Illinois Lakes

	Year(s)	CPE (Fish/hour)	Number/ hectare	Reference
Clinton Lake*	1982	0.16	19	Illinois Power, in press
Clinton Lake*	1983	0.59	70	
Clinton Lake*	1984	0.84	92	
Clinton Lake*	1985	1.47	186	
Clinton Lake*	1986	1.23	266	
Clinton Lake*	1982-1986	0.92	127	
Newton	1987	0.75	127	Bruce, 1988
Rend	1979	1.06	--	Heidinger <u>et al</u>., 1984
Springfield	1979-1982	0.50	50	Heidinger <u>et al</u>., 1984
Coffeen	1987	0.42	59	IDOC, 1988
Sangchris	1987	0.44	95	IDOC, 1987
Sangchris	1984	0.38	50	IDOC, 1987
Sangchris	1973-1975	0.41	89	McNurney and Dreier, 198777
Lake Shelbyville	1987	0.41	45	IDOC, 1988
Baldwin Lake	1979	0.57	54	IDOC, 1988
Carlyle Reservoir	1967-1968	1.06	19	IDOC, 1988
Heidecke Lake	1981-1985	0.21	40	IDOC, 1988
National Average		0.85	63	Jenkins and Morais, 1971

* Boat angler only.

Source: Illinois Power, in press.

Table 5-3. Mean Annual Fishing Pressure on Several Reservoirs in Illinois and Surrounding States

Reservoir, State	Hours/hectare	Reference
Clinton Lake, IL*	172	This report
Lake Springfield, IL	100	Heidinger _et_ _al_., 1984
Sangchris Lake, IL*	167	McNurney and Frakes, 1979
Sangchris Lake, IL*	216	IDOC, 1988
Sangchris Lake, IL*	132	IDOC, 1988
Newton Lake, IL*	211	Bruce, 1988
Coffeen Lake, IL*	142	IDOC, 1988
Baldwin Lake, IL*	94	IDOC, 1988
Heidecke Lake, IL*	189	IDOC, 1988
Carlyle Reservoir, IL	18	IDOC, 1988
Lake Shelbyville, IL	110	IDOC, 1988
Rend Lake, IL	40	Heidinger _et_ _al_., 1984
Sinclair, GA	133	Baker, 1983
Cherokee, TN	60	Baker, 1983
Dale Hollow, TN	36	Baker, 1983
West Point Reservoir, GA	7	Malvestuto _et_ _al_., 1983
Cutfoot Sioux, MN	140	Osborn and Schupp, 1985
Selected reservoirs, NC, SC	8-191 (range)	Baker

* Lake principally designed as a cooling reservoir.

Source: Illinois Power, in press.

Table 5-4. Number Per Hectare and Pounds Per Acre of White Crappie Harvested from Several Illinois Reservoirs

Lake	Year	#/ha*	lbs+/acre	Reference
Clinton Lake, IL	1982	12	2.0	Illinois Power, in press
	1983	65	9.7	
	1984	90	11.9	
	1985	179	25.3	
	1986	250	37.2	
Lake Springfield, IL	1979	6	0.7	Heidinger _et_ _al_., 1984
	1980	32	3.4	Heidinger _et_ _al_., 1984
	1981	25	3.5	Heidinger _et_ _al_., 1984
	1982	5	0.1	Heidinger _et_ _al_., 1984
Coffeen Lake, IL	1987	99	1.4	IDOC, 1988
Sangchris, IL	1984	17	1.1	IDOC, 1988
Sangchris, IL	1987	2	1.2	IDOC, 1988
Newton Lake, IL	1987	230	21.3	Bruce, 1988
Lake Shelbyville, IL	1987	20	3.5	IDOC, 1988
Rend Lake, IL	1979	8	1.2	Heidinger _et_ _al_., 1984
	1980	6	0.6	Heidinger _et_ _al_., 1984
	1981	10	1.1	Heidinger _et_ _al_., 1984
	1982	11	1.2	Heidinger _et_ _al_., 1984

* Hectare.
\+ Pounds.

Source: ESE, 1988.

through 1986 gizzard shad, common carp, bluegill, white crappie, largemouth bass, and green sunfish have numerically dominated the collection. In general, with the exception of largemouth bass, annual collections throughout the reservoir as a whole were similar among pre-operational summary study years. Largemouth bass, however were generally most abundant in 1978 and 1979, stabilizing in abundance beginning in 1980 (Table 5-5).

In 1987 when operational testing began and variable thermal discharges into the lake occurred a variety of lake-wide changes in fish abundance were documented. Total catch rates increased in 1987 as compared to previous study years. In particular the catch rate of gizzard shad increased dramatically. Bluegill, largemouth bass, and white crappie capture rates also increased substantially from previous years. Conversely, common carp catch rates declined (Table 5-5).

Catch rates in Clinton Lake associated with operational testing and the existence of a thermal discharge in 1987 can be evaluated by examining the fish data collected at Station 2 [the sampling station where the plant discharge enters the lake (Figure 5-1)] during the summer these data indicate that capture rates for gizzard shad, green sunfish, bluegill, largemouth bass, white crappie and freshwater drum were higher in 1987 than in most preoperational summer study periods. Conversely, common carp catch rates were lower in 1987 compared to most prior study years (Table 5-6). It is unlikely that this general lakewide increase in abundance was directly related to operational testing of the plant. During testing variable increases in water temperature were documented above ambient levels. However, at the time of sampling in 1987 the increased heat load appears to have been minimal.

A comparison of capture rates at six sampling locations during the summer of 1987 indicates that green sunfish and freshwater drum were most abundant at Station 2 (Table 5-7). The abundance in the Station 2 collection is apparently associated with water flow in/near the discharge canal as these species prefer flowing water. The catch rates of other common species such

Table 5-5. Annual and 9-Year Summary of Number-Per-Hour of Fishes Collected by Electrofishing at Clinton Lake During Ambient 1978-1986 and Operational Testing (1987) Years

Taxa	1978*	1979+	1980+	1981	1982	1983	1984	1985	1986	1978-1986 Average	1987
Gizzard shad	97	115	169	263	336	366	331	352	322	261	577
Threadfin shad	3	12	3	1	1	**	0	0	0	2	0
Grass pickerel	18	2	**	0	**	**	**	**	**	2	0
Tiger muskellunge	3	10	4	2	2	1	**	1	2	3	1
Common carp	75	104	130	129	126	110	83	83	81	102	52
Golden shiner	3	2	2	**	**	**	**	**	**	1	**
Striped shiner	3	**	0	0	0	0	0	0	0	**	0
Red shiner	3	5	4	2	2	1	2	3	1	3	1
Sand shiner	0	0	0	**	0	0	0	0	0	**	0
Redfin shiner	3	11	**	**	0	**	0	0	0	2	0
Steelcolor shiner	4	4	0	**	0	**	0	0	0	1	0
Notropis sp.	0	0	0	0	0	0	0	**	0	**	0
Suckermouth minnow	0	**	0	0	0	0	0	0	0	**	0
Bluntnose minnow	**	**	**	0	0	**	0	0	0	**	0
Fathead minnow	0	0	**	0	0	0	0	0	0	**	0
Creek chub	2	0	0	**	0	0	0	0	0	**	0
Quillback	2	6	13	8	11	6	8	5	5	7	8
Highfin carpsucker	0	0	**	0	0	0	**	0	0	**	0
White sucker	4	2	1	0	**	**	**	**	**	1	0
Northern hog sucker	2	**	0	0	0	0	0	0	0	**	0
Smallmouth buffalo	0	0	**	0	0	0	0	0	0	**	0
Bigmouth buffalo	4	7	17	6	8	6	3	2	1	6	2
Spotted sucker	0	**	**	**	**	1	0	**	**	**	**
Silver redhorse	0	1	4	2	3	2	1	1	**	2	1
Golden redhorse	10	12	10	5	4	2	1	1	1	5	1
Shorthead redhorse	1	3	7	7	9	5	4	3	2	5	3
Black bullhead	6	3	10	7	8	7	4	2	3	6	1
Yellow bullhead	1	1	1	1	1	1	1	1	1	1	**
Channel catfish	**	1	**	**	**	**	1	1	1	**	**
Stonecat	0	**	0	0	0	0	0	0	0	**	0
Flathead catfish	0	**	**	**	**	**	**	**	**	**	**
Blackstripe topminnow	**	**	**	**	**	0	**	**	**	**	0
Hybrid striped bass	**	1	1	**	**	1	2	1	1	1	1
White bass	0	0	0	0	**	0	0	0	0	**	0
Rock bass	1	**	**	**	0	**	**	0	0	**	0
Green sunfish	50	39	17	9	12	11	9	13	12	19	19
Bluegill	24	50	62	33	38	39	37	42	44	41	63
Longear sunfish	0	**	0	0	**	0	0	0	0	**	0
Redear sunfish	5	1	**	0	0	0	0	0	0	1	0
Lepomis hybrid	1	1	1	**	1	**	**	**	1	1	1
Smallmouth bass	3	2	1	**	**	**	**	**	**	1	**
Largemouth bass	89	46	28	20	20	14	12	15	20	29	31
White crappie	1	10	26	13	31	55	56	52	37	31	64
Black crappie	**	**	2	**	1	1	2	1	1	1	1
Pomoxis sp.	0	0	0	0	0	0	0	**	0	**	0
Blackside darter	**	0	0	0	0	**	0	0	0	**	0
Slenderhead darter	0	0	0	0	0	0	0	0	**	**	0
Walleye	6	8	16	7	4	1	1	1	2	5	4
Freshwater	0	**	1	1	3	4	7	11	6	4	9
Total species	34	39	36	32	31	33	29	30	29	33	25
Annual average	440	464	529	518	619	635	567	592	544	545	839

* Summer and fall quarters.
\+ Spring, summer, and fall quarters.
** Less than 0.5 per hour.

Source: Illinois Power, 1988.

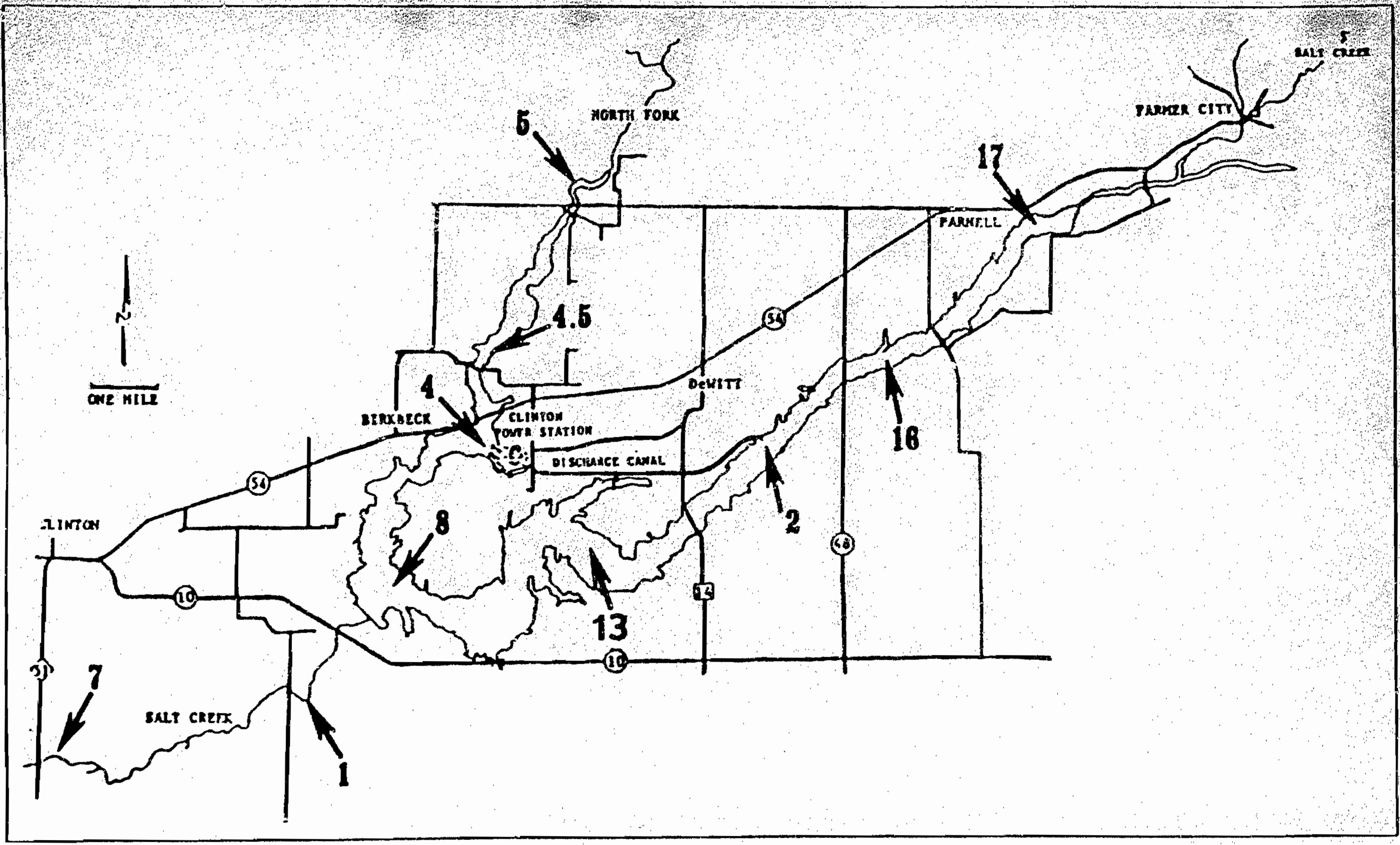

Figure 5-1
FISH SAMPLING SITES USED DURING THE ENVIRONMENTAL MONITORING PROGRAM, CLINTON LAKE, SALT CREEK, AND NORTH FORK, NEAR CLINTON, ILLINOIS, 1978-1986

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Table 5-6. Annual and 9-Year Summary of Number-Per-Hour of Fishes Collected by Electrofishing at Station 2 During Ambient Summer (1978-1986) and Operational Testing (1987) Clinton Lake, Illinois

Taxa	1978	1979	1980	1981	1982	1983	1984	1985	1986	1978-1986 Average	1987
Gizzard shad	164	293	354	343	681	517	1,589	1,637	490	665	1,286
Threadfin shad	9	84	44	7	6	5	0	0	0	17	0
Grass pickerel	23	0	0	0	0	0	0	0	0	2	0
Tiger muskellunge	8	9	16	2	3	0	0	5	3	5	1
Common carp	43	52	180	73	58	39	68	33	14	62	21
Golden shiner	2	8	0	0	0	0	0	1	0	1	0
Striped shiner	1	0	0	0	0	0	0	0	0	*	0
Red shiner	8	1	6	2	1	0	0	0	0	2	1
Redfin shiner	4	0	0	0	0	0	0	0	0	*	0
Quillback	1	5	5	0	1	3	5	3	0	2	1
White sucker	2	0	1	0	0	0	0	0	0	*	0
Bigmouth buffalo	10	3	20	14	19	4	7	1	0	6	0
Silver redhorse	0	2	4	0	0	1	0	1	0	1	1
Golden redhorse	4	14	24	1	4	2	1	0	4	6	0
Shorthead redhorse	1	3	16	5	13	6	6	6	0	6	2
Black bullhead	7	0	13	0	3	1	3	1	1	3	0
Yellow bullhead	0	0	2	0	0	0	1	1	0	*	0
Channel catfish	0	2	0	0	0	1	2	4	0	1	1
Flathead catfish	0	1	0	0	0	0	0	2	0	*	1
Hybrid striped bass	3	5	0	0	0	1	9	11	1	3	3
Rock bass	0	0	1	0	0	0	0	0	0	*	0
Green sunfish	35	17	9	2	1	1	5	5	27	11	75
Bluegill	49	57	85	22	29	28	34	55	20	42	72
Longear sunfish	1	0	0	0	0	0	0	0	0	*	0
Readear sunfish	5	1	0	0	0	0	0	0	0	1	0
Lepomis hybrid	1	1	0	0	1	0	0	1	3	1	3
Smallmouth bass	2	0	0	0	0	0	0	0	0	*	0
Largemouth bass	110	52	29	23	42	33	23	10	33	39	63
White crappie	0	5	3	1	33	27	85	36	48	26	75
Black crappie	0	0	2	0	0	0	4	0	1	1	3
Pomoxis sp.	0	0	0	0	0	0	0	1	0	*	0
Walleye	6	7	16	1	4	3	1	9	3	6	2
Freshwater drum	0	0	3	10	37	13	83	97	37	31	122
Total species	499	622	817	506	936	685	1,926	1,920	605	946	1,733
Temperature (°C)	21	--	26.6	28.4	28.4	27.8	28.5	24.6	29.3	--	29.4

* Less than 0.5 per hour.

Source: Illinois Power, 1988.

Table 5-7. Summary of Electrofishing Catch-Per-Effort (# per hour) at Clinton Lake in 1987 (August) Under Operational Testing Conditions

Species	Sampling Stations					
	4.5	4	8	13	2	16
Gizzard shad	938	1,017	1,033	1,174	1,286	3,060
Tiger muskie	0	0	0	2	1	1
Common carp	50	28	28	17	21	31
Red shiner	0	0	0	2	1	3
Quillback	1	3	0	7	1	9
Bigmouth buffalo	0	0	0	0	0	3
Silver redhorse	1	2	0	0	1	0
Golden redhorse	1	0	1	1	0	1
Shorthead redhorse	11	3	2	3	2	8
Yellow bullhead	2	0	0	2	0	0
Channel catfish	2	0	1	0	1	5
Flathead catfish	2	0	0	0	1	1
Hybrid striper	0	4	0	0	3	0
Green sunfish	5	9	8	9	75	6
Bluegill	85	61	54	49	72	65
Hybrid sunfish	1	0	1	1	3	1
Smallmouth bass	0	0	1	1	0	0
Largemouth bass	45	56	55	51	63	31
White crappie	95	113	2	14	75	120
Black crappie	0	0	2	0	3	0
Walleye	0	24	2	14	2	1
Freshwater drum	8	6	8	16	122	6
Total	1,246	1,326	1,198	1,363	1,733	3,353
Temp (°C)	28.5	26.1	27.9	28.0	29.4	29.6

Source: Illinois Power, in press.

as white crappie, largemouth bass and bluegill were as high or higher at Station 2 than at other sampling locations, suggesting that the sporadic increases in water temperature in the summer (associated with operational testing) did not have a negative influence on the fishery in the areas receiving limited heated effluent.

5.4 SELECTION OF REPRESENTATIVE IMPORTANT SPECIES

Detailed evaluation of the potential effects of the Clinton Power Station's thermal discharge on the ichthyofaunal of Clinton Lake are presented in the following pages for representative important fish species (RIS) in the reservoir which include:

- Gizzard shad,
- Common carp,
- Channel catfish,
- Bluegill,
- Largemouth bass, and
- White crappie.

The species were selected due to their abundance in Clinton Lake, their use as important species in the 1980 Thermal Demonstration and their importance in the reservoir either as a sport species or forage species. These species cumulatively can be considered representative of the range of potential reaction to the thermal loading of Clinton Lake and are important to the maintenance of a balanced fish community. Two species (black crappie and black bullhead) used in the 1980 demonstration were not evaluated in this demonstration. These species were not considered representative of the Clinton Lake fish community. In addition, their temperature tolerances are similar to other RIS selected for evaluation in this demonstration. Consequently, these species were not selected for evaluation.

5.5 ASSESSMENT CRITERIA

5.5.1 Temperature Criteria

Four temperature criteria were used in assessing thermal effects on survival, growth and reproduction of populations of RIS species. Absolute definition of temperature requirements is not available for any fish species (although there is considerable data on some). Indeed, many species exhibit differential thermal tolerance limits depending on acclimation temperatures (Pitt et al., 1956; Cherry et al., 1975; Cheetham et al., 1975). However, the U.S. Environmental Protection Agency (USEPA) has outlined a protocol, summarized below, defining the effects of temperature on various life stages that should be considered, insofar as possible, when making assessments of the potential adverse effects of thermal discharges on freshwater fish in natural situations (Brungs and Jones, 1977). It should be noted that the USEPA protocol does not address possible beneficial impacts of increased temperatures, which are especially pertinent to cooling lake situations, as demonstrated by increased growth through an extended growing season and early initiation of spawning by some species. Similarly, this protocol is universally applied to all types of water bodies without regard to the inherent differences between rivers and cooling lakes. Additionally, the protocol establishes no provisions for behaviorial or physiological adaptations or genetic variability. These protocol limitations, however, do not preclude their use, as they represent a consistent, methodical approach to the assessment of thermal impacts to fisheries. Temperature criteria used in this analysis were the Short-Term Maximum Temperature for adults ($STMT_{adult}$) and embryos ($STMT_{embryo}$), and the Maximum Weekly Average Temperature for growth ($MWAT_{growth}$) and spawning ($MWAT_{spawning}$).

Values for each evaluation criteria are summarized in Table 5-8 and are discussed for each RIS in Section 5.6. These criteria, based on the USEPA protocol, were derived by a comprehensive literature review for each RIS.

STMT (adult)

Survival of fish under natural conditions is dependent upon complex interaction of a variety of biotic and abiotic factors, including temperature. Fish are morphologically and physiologically adapted to survive rather wide fluctuations of seasonal and daily temperatures. However, artificially increased temperatures may influence fish survival.

Table 5-8. Maximum Weekly Average Temperatures (°C) for Growth and Spawning, and Short Term Maximum Temperatures (°C) for Adult and Embryo for Each Representative Important Species (RIS)

Species	MWAT (Growth)	MWAT (Spawning)	STMT (Adult)	STMT (Embryo)
Gizzard shad	32.0	21 -- April 27 -- May 29 -- June	35.5	29.0
Carp	35	21 -- April 24 -- May 26 -- June	39.0	26
Channel catfish	34	27 -- April, May 29 -- June	36.0	29
Bluegill	34.0	25 -- April, May 28 -- June 34 -- July, August	37.0	34.0
Largemouth bass	32.7	21 -- April-June	36.0	27.0
White crappie	30.3	19 -- April, May 23 -- June	31.0	23.0

Source: ESE, 1988.

Temperature responses governing survival of fish are divided into two areas: the "zone of tolerance," and the "resistance time." The zone of tolerance is the temperature range within which the fish can survive for an extended period of time. This zone is bounded by upper and lower incipient lethal temperatures which are dependent upon the recent thermal history of fish (i.e., the higher the acclimation temperature, the higher the upper incipient lethal temperature). The "incipient lethal temperature" is defined therefore as the highest (or lowest) temperature at which an animal can live for a given acclimation temperature.

At some point, however, an increase in acclimation temperature does not result in a corresponding increase in the incipient lethal temperature. This temperature is defined as the "ultimate incipient lethal temperature." More precisely, the ultimate incipient lethal temperature is the temperature above (or below) which an animal cannot survive indefinitely regardless of how high (or low) the acclimation temperature. At temperatures above the upper incipient lethal temperature, an organism can survive for a finite period of time, the resistance time. Resistance time gets shorter as exposure temperature becomes more extreme.

Lethal temperatures are typically related to the exposure time required to produce 50 percent mortality at a given acclimation temperature. In studies where tolerance limits are reported as the temperature at which 50 percent of the test animals die within 24 or 96 hours, the data are abbreviated as 24-hour TL_{50} and 96-hour TL_{50}, respectively.

Since 50 percent survival may not ensure population perpetuity, USEPA protocol stipulates subtraction of 2.0 C° from the 24-hour TL_{50} temperature, to produce 100 percent survival (Brungs and Jones, 1977). Laboratory studies have shown this to be an adequate safety factor. This upper temperature limit which permits 100 percent survival for 24 hours is defined by the USEPA as the Short-Term Maximum Temperature (STMT) for survival of juveniles and adults during the summer.

MWAT (Growth)

In nature, many factors interplay to either encourage or discourage growth. Water temperature is one of the most important factors which affects the growth of fish in that it affects metabolic activity, appetite, food conversion efficiency, susceptibility to disease or parasites, interspecific competition and other subtle ecological factors. For a given species, there is a range of temperature within which growth occurs; low or high temperature extremes may prohibit growth of fish.

USEPA protocol (Brungs and Jones, 1977) is designed to prevent inhibition of growth at high temperatures. While near-lethal temperatures are not suitable to support a growing fish population, optimum growth temperature likewise is not required throughout the summer. A realistic upper temperature limit that will allow adequate growth lies somewhere between the ultimate incipient lethal temperature and the optimum temperature for growth. Experimental studies indicate that this upper limit for growth is a temperature that is generally one-third of the range between the optimum temperature for growth and the ultimate incipient lethal temperature (Brungs and Jones, 1977). This is defined as the Maximum Weekly Average Temperature (MWAT) for Growth during the summer and can be determined from the following equation:

$$T_{MG} = T_G + \frac{T_L - T_G}{3}$$

where: T_{MG} = maximum weekly average temperature for growth,

T_G = optimum temperature for growth (other temperatures such as preferred temperature can be substituted if optimum data is unavailable), and

T_L = ultimate incipient lethal temperature (24-hour TL_{50}).

MWAT (spawning)

Maintenance of a fish population requires successful reproduction. In the spring, increasing temperatures stimulate reproductive behavior and the development of eggs and early life stages of warmwater fish. Although the rate of egg development and growth of early life stages generally increases with increasing temperatures, there is an upper limit above which detrimental effects will occur. For this reason, temperature criteria which have been developed by USEPA are designed to protect gamete formation, and spawning.

Criteria concerning the normal formation of gametes and onset of spawning is the Maximum Weekly Average Temperature for Spawning. This criterion is very conservatively defined as the optimal temperature for spawning (if known) or the middle of the range of temperatures at which spawning has been observed in nature. When the spawning period spans several months, the MWAT may be raised during the warmer months to the upper limit of observed spawning temperatures (Brungs and Jones, 1977).

STMT (embryo)

Another element critical to a population's reproductive potential is the survival of eggs and larvae and their successful recruitment into the population. Again, temperature maxima exist above which detrimental effects on eggs and larvae may occur.

The temperature criterion established by the USEPA protocol is the Short-Term Maximum Temperature for embryo survival ($STMT_{embryo}$). The accepted value of this criterion is the upper limit of the range of natural spawning temperatures. Temperatures at which spawning occurs in nature are considered acceptable for gonad development and production of viable eggs and sperm, while temperatures which exceed short-term limits for more than 1 day can reduce or prevent successful hatching of embryos.

5.5.2 Habitat Determination

The total amount and distribution of preferred habitat within each model cell was derived for each RIS species using existing habitat information as detailed by EIA (1980). In each case the amount of habitat in each cell is expressed as a percent of the total preferred habitat in the lake. Habitat preferences were defined for each species using habitat descriptions of Pflieger (1975) Scott and Crossman (1973), Smith (1979), Stuber et al. (1982a and 1982b), Williamson and Nelson (1982), Edwards and Twomey (1982), Edwards et al. (1982), and McMahon and Terrell (1982). However, the aquatic weed beds present during initial habitat analyses are no longer present in the lake. Percentages of preferred habitat for bluegill and largemouth bass were therefore revised to reflect this reduction in preferred habitat. The availability of spawning habitats was not detailed in the previous study for the 1955 pool elevation. For the purpose of this analysis therefore, the percent of littoral habitat (<5 feet) in each cell was derived and assumed to represent the available spawning habitat for all RIS species except channel catfish. Values for channel catfish spawning habitat (<10 feet) were derived using previous values (EIA, 1980).

5.5.3 Evaluation Methods and Conditions

Impact analysis was carried out by comparing the modeled distribution of various evaluation criteria temperatures (survival, growth, reproduction), based on unconstrained operation of one generating unit under 1955 meteorological conditions, with the distribution of preferred or spawning habitats. Thermal model outputs are presented in Section 4.0 and Appendix A, whereas specific temperatures and habitats of importance for each fish species are detailed in Section 5.6.

Distribution of habitats was derived first by graphical estimation of the area of each habitat type within each of the model lake segments for the 1955 worst case lake elevation. Habitats identified from the literature (Section 5.5.2) as preferred by a given species or used for spawning were then combined over the entire lake, and the percentage located in each lake segment determined. In this fashion, the percent of preferred or spawning habitat exceeding the species-specific criterion temperature was determined.

Discharge temperatures above the currently allowable limits would occur predominantly during the summer months (July-September) as discussed in Section 4.0. Accordingly, survival and growth of juvenile and adult fish were of most concern. Therefore, survival and growth criteria were evaluated for conditions occurring during the summer of 1955. Evaluation of 1955 conditions is presented not only because it appears to have been the warmest summer in 50 years, but also to be consistent with the 1980 study (EIA, 1980).

In natural systems, adult and juvenile mortality resulting from exposure to extremely warm temperatures is rare since fish can usually respond by avoiding such temperatures. Adverse thermal impacts may, therefore, be related to the amount of otherwise desirable (preferred) habitat that is avoided (and the associated amount of time during which such avoidance behavior is necessary based upon temperature regimes) for survival, growth or reproductive activity. For example, exclusion of fish from all available habitat by heating the entire water body above the ultimate incipient lethal temperature for even one day could theoretically end the fishery. Conversely, fish may indefinitely avoid a small thermal exclusion area with no noticeable effect on the population. Between these extremes, fish would be forced to occupy smaller areas of desirable habitat or move into less desirable alternative habitats. The influence of the exclusion area on fish survival is a function of the extent of the remaining preferred habitat, the amount and quality of available alternative habitat, and the amount of time the species is excluded from the habitat within the thermal exclusion zone.

Because detailed information is available on the distribution of various types of fish habitats in Clinton Lake (Section 5.5.2), the effect of thermal loading on each RIS species will be related to the amount of preferred habitat made unsuitable for growth or survival. It is assumed that the persistence of a relatively small exclusion zone for up to one week would result in no lasting effects on the survival of fish populations. Preferred habitats were defined, based on descriptions of typical habitat in pertinent scientific literature for each of the discussed fish species. The available preferred habitat is, therefore, represented by a conservative acreage value as other areas in the lake could be utilized on a short-term basis for survival and other life functions if required.

In this report, then, potential adverse impacts on survival were quantified in terms of the amount of preferred habitat in which 7-day average temperatures exceeded the STMT for Adult Survival.

The effect of elevated temperatures on fish growth also varies with the distribution of such temperatures relative to desirable habitats, and to temperature duration. Short-term elevations of temperatures above the MWAT for growth probably would have no detectable effect upon fish productivity. Furthermore, after a period of slow or no-growth, accelerated growth often occurs when more favorable conditions return. In this study it was assumed that adverse impacts on fish growth would not occur unless unfavorable temperatures occurred for 1 month.

Potential adverse impacts on growth were therefore quantified as the percent of preferred habitat in which the 30-day average temperature exceeded the MWAT for growth as per USEPA protocol (Brungs and Jones, 1977). However, the LARM output data were available for only 12 days in April and 29 days in October. Potential adverse impacts on growth during these months were therefore related to 12-day and 29-day averages, respectively.

Reproduction is more typically restricted to the spring. This is particularly true in cooling lakes where early initiation of spawning has been observed in several species (Larimore et al., 1979).

As with other evaluation criteria, potential impacts to spawning and embryo survival were related to the amount of spawning habitat within the thermal exclusion zone. Because the spawning season of most fish is relatively limited, potential adverse impact is quantified at the amount of spawning habitat expected to experience 7-day average temperatures greater than the MWAT for spawning.

Due to the relative lack of mobility of embryos and young larvae a more restrictive criterion is warranted to ensure embryo survival. Adverse impact to embryos is, therefore, evaluated in terms of spawning habitat with temperatures greater than the STMT for embryo survival on the warmest single day of each spawning month.

5.6 REPRESENTATIVE IMPORTANT SPECIES

5.6.1 Gizzard Shad

Life History

The gizzard shad (Dorosoma cepedianum) is an important and efficient herbivore, providing a link in the food web between plankton and predatory fish. The gizzard shad is important as a forage fish because of its direct use of plankton (as a food source), its abundance and high reproductive capacity, its general freedom from parasites, its rapid growth rate, and its utilization as food (especially while young)by important game fish (Miller, 1960).

The gizzard shad inhabits much of the eastern half of the United States and is most abundant in reservoirs and large streams and rivers where there is a low gradient (Trautman, 1957; Pflieger, 1975).

The species travels in large, constantly moving schools near the water surface. Food is filtered from the water and is generally composed of zooplankters during the first few weeks of life. When the fish attain a length of approximately 1 inch (2.5 cm) and more closely resemble an adult, they ingest more phytoplankton as well as zooplankton and occasionally small insect larvae (Miller, 1960; Pflieger, 1975).

The gizzard shad is a fast-growing fish, reaching its adult size of 9 to 14 inches (22.9 to 35.6 cm) in its third year (Pflieger, 1975). Growth is especially rapid during the first 5 to 6 weeks of life (Lagler and Applegate, 1943), and by the end of the first year the fish may reach a total length of about 4 to 5 inches in midwestern rivers and lakes (Miller, 1960; Pflieger, 1975). Sexual maturity is generally reached in the second or third year. Some individuals may live 10 years, although most live about 6 or 7 years (Jenkins, 1953; Pflieger, 1975). Seventy to 80 percent of the annual growth occurs during the summer months (Bodola, 1955). Shields (1973) reported that growth began at 15.5°C. The Commercial Fisheries Review (1961) notes that growth stopped in autumn when water temperatures dropped to 18.3°C.

The rapid growth of this species allows it to attain an adult size large enough to avoid excessive predation. This results in a large breeding stock and generally ample reproduction.

Observations of spawning gizzard shad have been reviewed by Miller (1960). He states that the majority of spawning within the temperate latitudes occurs during April, May and June when the water temperature is between 10°C and 21.1°C. Spawning occurs in the shallow water areas near the surface in slow moving water, and often in protected bays and inlets. The eggs and milt which are released by mixed schools of males and females sink to the bottom and adhere to the substrate (Miller, 1960; Pflieger, 1975). Spawning usually occurs when the water temperature is rising (Miller, 1960). Bodola (1955) found that hatching time ranged from 36 hours to 1 week depending on water temperature, whereas Pflieger (1975) noted that hatching occurred in about 4 days and the young begin to feed 5 days later.

Short-Term Maximum Temperature (STMT)--Juvenile and Adult Survival

The gizzard shad apparently is able to become acclimated to high water temperatures (Table 5-9). Strawn (1958, cited in Carlander, 1969) reported that gizzard shad can be acclimated to 35°C and withstand temperatures to 36.5°C. Clark (1969) reported upper lethal temperatures as high as 36°C. Hart (1952) reported an upper incipient lethal temperature 36.5° for Ohio gizzard shad, when acclimated to 35°C. Brungs and Jones (1977) estimated the upper and lower lethal temperatures for the gizzard shad to be 34.3°C and 10.8° respectively, when studies were conducted with an acclimation temperature 25°C. With an acclimation temperature of 30°C, the upper and lower lethal thresholds for gizzard shad rose to 35.9°C and 14.5°C. The lower thermal limit of gizzard shad has been reported to be 11°C and 20.0°C when acclimated at 25.0°C and 35.0°C, respectively (EPA, 1967).

Table 5-9. Gizzard Shad Spawning Times and Temperatures at Various Locations in the Midwestern United States

Date	Temperature (°C)	Location	Comment	Author
Mid-March to Late August		United States	Range	Miller (1960)
April-June	10.0-21.1		Most Spawning	
Early April-May		Missouri		Pflieger (1975)
Late April-Early May		Iowa		Harlan and Speaker (1956)
		Central Illinois River	Females running with milt	Forbes and Richardson (1920:47)
	19.4	Ohio		Langlois (1954)
Early May	15.6	Buckeye Lake, Ohio	Date when spawning usually begins	Warner (1941)
Early May-Late June	21.2	Iowa		Mayhew (1957)
Early June-Early July	>19.5	Lake Erie	Most spawning above this temperature	Bodola (1966)

Gammon (1971) during field studies on the Wabash River, determined the temperature preference of the gizzard shad was between 28.5°C and 31.0°C. More recently Yoder and Gammon (1976) reported a thermal preference of 29°C to 30.5°C on the Ohio River. Gizzard shad were collected by Jude <u>et al</u>. (1975) in Lake Michigan at water temperatures of 8 to 18°C with maximum catches at 10 to 12°C. Proffit and Benda (1971) collected gizzard shad at a water temperature of 37.5°C from a heated discharge in the White River, Indiana. After discarding field collection data from water strata with depleted oxygen levels, Dendy (1948) postulated that the distributional pattern of gizzard shad in Norris Lake, Tennessee, was based on thermal preference. With this method Dendy determined that the gizzard shad usually prefer temperatures between 22.5°C to 23.0°C.

It appears that the gizzard shad may be particularly vulnerable to cold shock. In winter, Agersborg (1930) observed that if shad moved from 28°C into waters of 24°C, they exhibited symptoms of imbalance. At 22°C they gulped air at the surface, and at 20°C they partially lost vision. Similarly, a decrease from 26°C to 20°C resulted in sudden death. Abrupt changes in temperature may cause mass deaths in this species (Miller, 1960).

Using data detailed in Brungs and Jones (1977), a STMT for survival of adults of 35.5°C was established. This value is 1°C lower than the highest recorded upper lethal temperature. However, because Proffit and Benda (1971) observed an upper avoidance temperature (a temperature obviously below the upper lethal temperature under field conditions) of 37.5°C on the White River, the value of 35.5°C (2°C less) was used as the STMT for adult survival.

Maximum Weekly Average Temperature (MWAT)--Growth

Growth of gizzard shad is limited principally to the summer months. Bodola (1955) indicates that 70 to 80 percent of annual growth occurs in the summer. Shields (1973) reported that growth begin at 15.5°C. Based upon this report, it is assumed that growth in the autumn ceases at this same temperature.

The MWAT for gizzard shad growth was calculated to be 32°C based upon an upper avoidance temperature of 37.5°C (used here in lieu of the ultimate incipient lethal temperature) and a preferred temperature of 29°C (Table 5-10).

Maximum Weekly Average Temperature (MWAT)--Spawning

The MWAT for gizzard shad spawning was established as 21°C for April, 27°C for May, and 29°C for June as this species is known to have a long spawning period. The April value was determined using the upper limit of the optimal spawning temperature (19 to 21°C) as delineated in USEPA protocol (Brungs and Jones, 1977) for spring spawning, whereas the June value was obtained by using the highest documented spawning temperature (29°C for summer spawning (Miller, 1960). The value for May (27°C) was selected as an intermediate value reflecting a continuing acclimation process throughout the spawning season.

Observations of spawning gizzard shad have been reviewed by Miller (1960). He states that the majority of spawning within the temperate latitudes occurs during April, May and June when the water temperature is between 10°C and 21.1°C. In Lake Erie, spawning has been reported from early June to early July at temperatures mostly above 19.4°C (Bodola, 1966), although spawning in Ohio has been reported in May (Bodola, 1966; Langlois, 1954). Mayhew (1957) reported spawning to occur at temperatures as high as 27.0°C whereas Miller (1960) reported spawning as high as 29°C.

STMT Embryo Survival

As indicated earlier in this section, gizzard shad typically spawn in May and June through the Midwest. Optimum spawning occurs from 19 to 21°C. The maximum recorded spawning temperature of 29°C (Table 5-14) has been selected as the STMT for embryo survival. Following spawning, Bodola (1955) found that hatching time ranged from 36 hours to 1 week depending on water temperature, whereas Pflieger (1975) noted that hatching occurred in 4 days and the young begin to feed 5 days later.

Table 5-10. Summary of Temperature (°C) Data for Gizzard Shad

Life Stage	Acclimation Temperature	Lower Incipient Lethal Limit	Lower Avoidance Temperature	Preferred Temperature	Upper Avoidance Temperature	Upper Incipient Lethal Limit	Spawning Range	Optimal Spawning Temperature	Reference
Adult	25	10.8	--	--	--	34.0, 34.5	--	--	Brungs & Jones, 1977
	30	14.5	--	--	--	36.0	--	--	Brungs & Jones, 1977
	35	20.0	--	--	--	36.5	--	--	Brungs & Jones, 1977
	*	--	23.5	22-29	30.0	--	--	--	Gammon, 1973
	*	--	--	--	--	--	16.7-26.7	19-21	Brungs & Jones, 1977
	*	--	--	--	--	--	24-25	--	Carlander, 1969
	*	--	--	--	--	--	27	--	Mayhew, 1957
	*	--	--	--	--	--	29	--	Miller, 1960
	*	--	--	--	37.5	--	--	--	Proffit & Benda, 1971
	*	--	20.5	--	--	--	--	--	Reutter & Herdendorf, 1974
	*	--	23.0	--	--	--	--	--	Dendy, 1948

$MWAT_{Growth}$ = 32; $MWAT_{Spawning}$ = 2 (April), 27 (May), and 29 (June); $STMT_{Adult}$ = 35.5; $STMT_{Embryo}$ = 29.

* Acclimation temperature unspecified.

Source: ESE, 1988.

Thermal Model Data Evaluation

As indicated previously, gizzard shad are rather tolerant of high temperatures. With an STMT for adult survival of 35.5°C no reductions in preferred habitat are expected during April, May, June or October under worst case modeled conditions (Figure 5-2). The percent of remaining habitat is reduced to 88.6 during the warmest 7-day period in July and August and increases to 99 percent in September (Table 5-11). This is similar to the results presented in the 1980 demonstration in which the percent of remaining habitat was 90 for July, 87 for August, and 100 for September (EIA, 1980). No evaluations of adult survival were made for April to June and October in the previous study.

No restrictions in preferred habitat for gizzard shad growth are anticipated during the months of April through June and October under the worst case operational conditions (Figure 5-2). However, reductions in available habitat are anticipated for July, August, and September: 81, 82 and 99 percent, respectively (Table 5-12). No comparisons with the previous thermal demonstration are possible, however, because a value for MWAT for growth was not determined.

Potential impacts to gizzard shad reproductive success under the worst case conditions were evaluated by examining reductions in preferred spawning and a habitat permitting embryo survival. The percent of preferred remaining habitat suitable for spawning was determined to be 76.4, 76.4, and 77.1 for the months of April, May, and June, respectively (Figure 5-3, Table 5-13). The consistency of these values was attributed to the increasing MWAT for spawning (21°C for April, 27°C for May, 29°C for June), as the season progressed. In contrast, the percent of remaining spawning habitat with temperatures less than the STMT for embryo survival exhibited a steadily declining trend from 93.8 in April to 89.4 in May and 70.6 in June (Table 5-14; Figure 5-3). In general the percent available habitat for embryo survival is larger than the percent of preferred remaining habitat with temperatures less than the MWAT for spawning. Thus ensures adequate survival of embryos in areas suitable for spawning. No spawning of gizzard

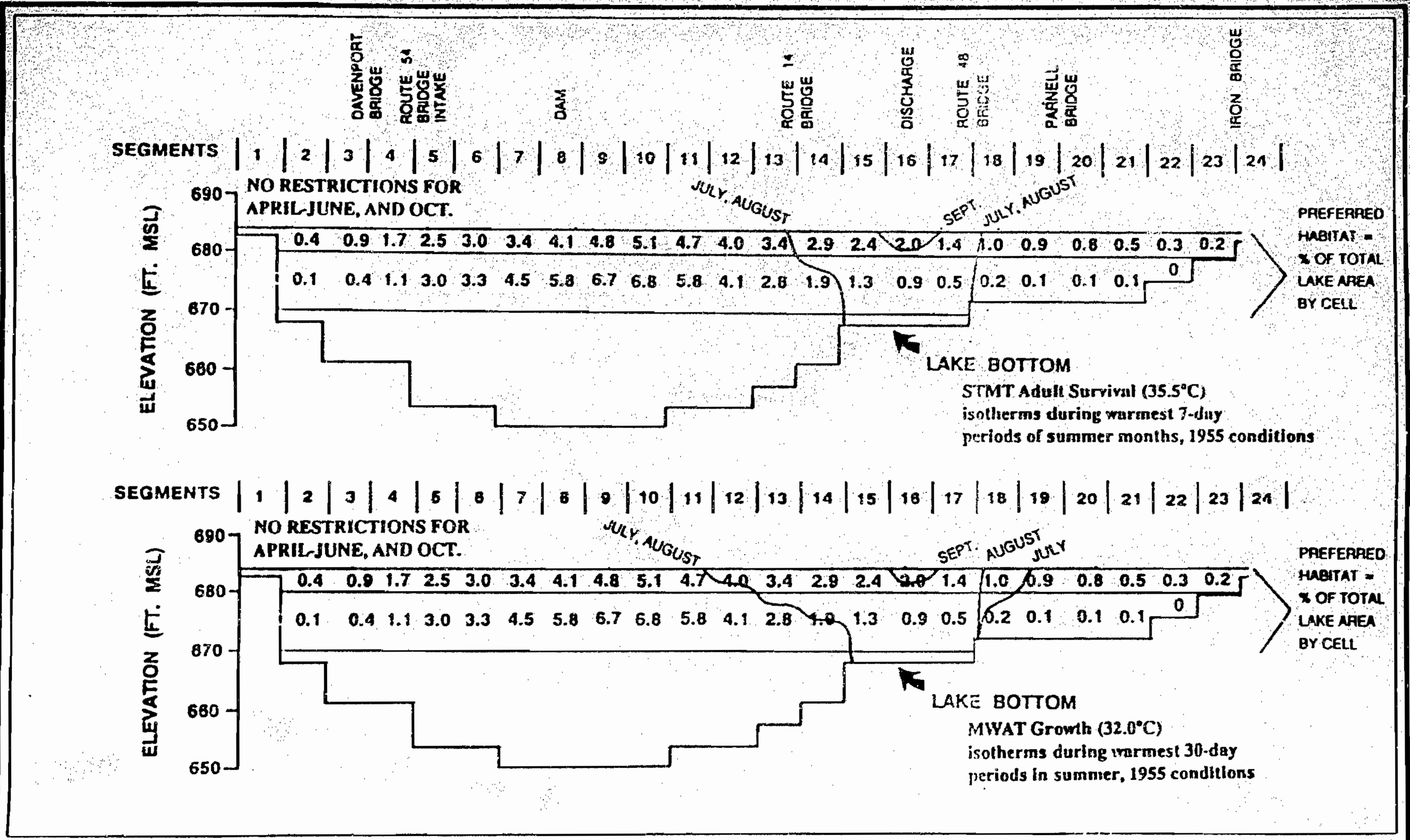

Figure 5-2
PERCENT PREFERRED HABITAT OF GIZZARD SHAD RELATIVE TO TEMPERATURES ASSURING SURVIVAL AND GROWTH DURING OPERATION OF ONE UNIT OF CLINTON POWER STATION UNDER 100% LOAD AND 1955 METEOROLOGICAL CONDITIONS

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Table 5-11. Estimated Percent of Available Habitat in Clinton Lake with Temperatures Less than the STMT for Adult Survival for Each RIS During the Warmest 7-Day Periods Under 100 Percent Plant Load and 1955 Meteorological Conditions

	Remaining Adult Survival Habitat (percent)						
Species	Apr	May	Jun	Jul	Aug	Sep	Oct
Gizzard shad	100	100	100	89	89	99	100
Carp	100	100	100	97	97	100	100
Channel catfish	100	100	100	75	75	100	100
Bluegill	100	100	100	96	96	100	100
Largemouth bass	100	100	100	96	96	100	100
White crappie	100	98	92	0.4	0.0	89	100

Source: ESE, 1988.

Table 5-12. Estimated Percent of Available Habitat in Clinton Lake with Temperatures Less than the MWAT for Growth for Each RIS During the Warmest 30-Day Periods Under 100 Percent Plant Load and 1955 Meteorological Conditions

Species	Remaining Growth Habitat (percent)						
	Apr*	May	Jun	Jul	Aug	Sep	Oct+
Gizzard shad	100	100	100	81	82	99	100
Carp	100	100	100	93	95	100	100
Channel catfish	100	100	100	75	77	100	100
Bluegill	100	100	100	96	96	100	100
Largemouth bass	100	100	100	89	96	99	100
White crappie	100	100	98	47	26	99	100

* 12-day average.
\+ 28-day average.

Source: ESE, 1988.

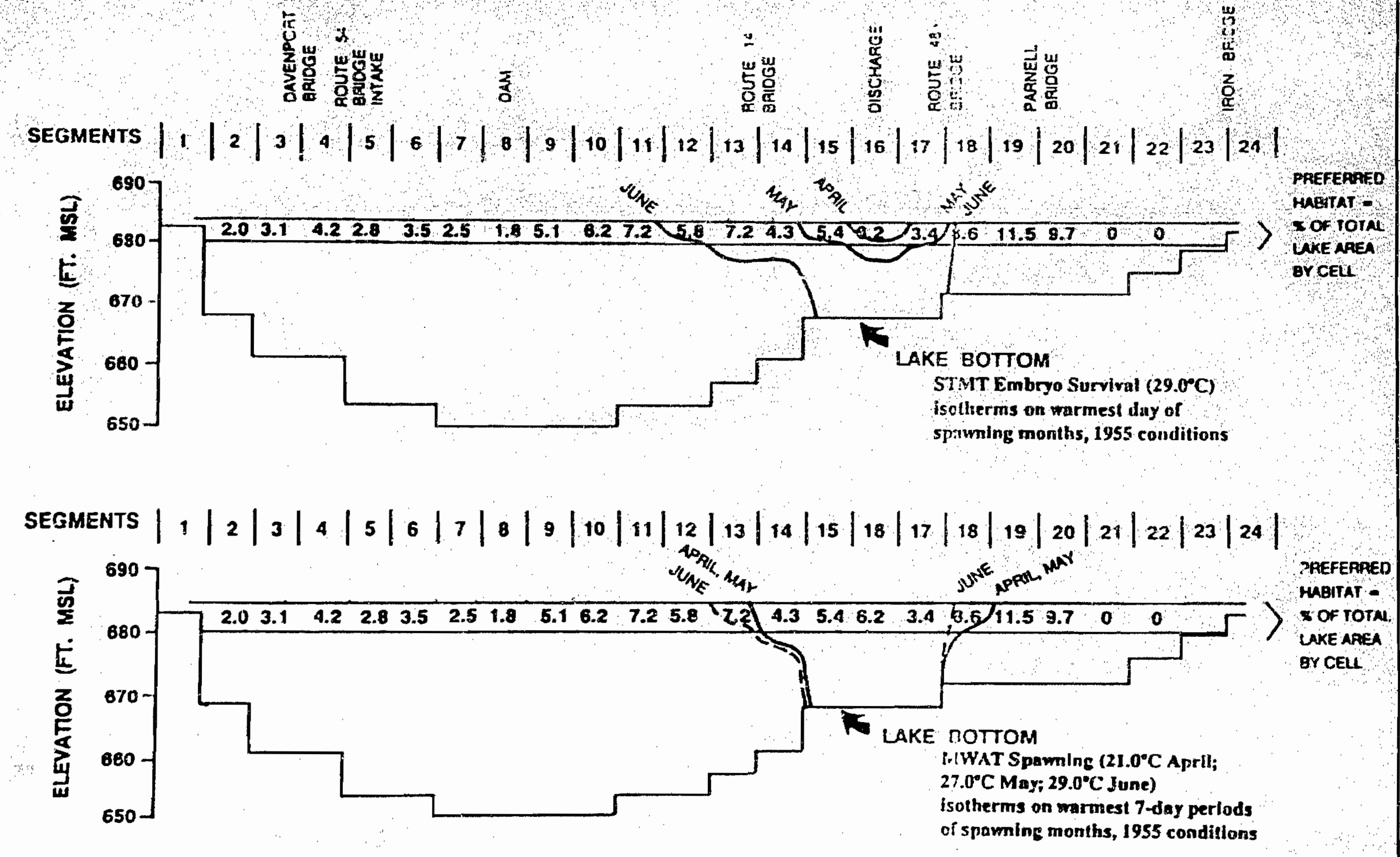

Figure 5-3

PERCENT SPAWNING HABITAT OF GIZZARD SHAD RELATIVE TO TEMPERATURES ASSURING REPRODUCTION DURING OPERATION OF ONE UNIT OF THE CLINTON POWER STATION UNDER 1955 FLOW AND METEOROLOGICAL CONDITIONS

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Table 5-13. Estimated Percent of Available Spawning Habitat in Clinton Lake with Temperatures Less than the MWAT for Spawning Each RIS During the Warmest 7-Day Periods Under 100 Percent Plant Load and 1955 Meteorological Conditions

Species	Remaining Spawning Habitat (percent)				
	April	May	June	July	August
Gizzard shad	97	38	31	0.0	--
Carp	79	44	20	0.0	0.0
Channel catfish	97	38	31	0.0	--*
Bluegill	94	65	59	62	62
Largemouth bass	76	0.0	0.0	--	--
White crappie	40	0.0	0.0	--	--

* Indicates a typical non-spawning month for this RIS species.

Source: ESE, 1988.

Table 5-14. Estimated Percent of Available Spawning Habitat in Clinton Lake with Temperatures Less than the STMT for Embryo Survival for Each RIS During the Warmest 1-Day Periods Under 100 Percent Plant Load and 1955 Meteorological Conditions

	Remaining Spawning Habitat (percent)				
Species	April	May	June	July	August
Gizzard shad	94	89	71	--	--
Carp	85	73	4	0.0	0.0
Channel catfish	97	78	32	0.0	--*
Bluegill	69+	100	97	24	32
Largemouth bass	90	81	36	--	--
White crappie	57	22	0.0	--	--

* Indicates a typical non-spawning month for this RIS species.
\+ Unavailable habitat (31 percent) due to temperatures below spawning range.

Source: ESE, 1988.

shad is expected to occur in July or August even under ambient conditions as historically young-of-the-year gizzard shad have reached 30 to 50 mm in length by August (Illinois Power, 1987).

Clinton Lake Fisheries Data

Data collected throughout the 1978 through 1987 monitoring period revealed that gizzard shad are abundant throughout the lake (Table 5-15). Collections through 1986 (baseline conditions) indicate that gizzard shad were most abundant at the sampling stations in the eastern portion of the lake. This portion of the lake includes the area of the plant discharge into the lake (Station 2). Collections made during the summer of 1987 during operation testing when temperatures were sporadically above ambient indicate that gizzard shad capture rates were higher at all sampling stations throughout the lake. Capture rates at Station 2, the most thermally influenced area, also increased dramatically indicating that operational testing, which increased temperatures approximately 4°C above ambient (to about 30°C) in July, had no observable detrimental effect on the gizzard shad population.

Summary

Gizzard shad are an important and abundant forage species in Clinton Lake. Minimal impacts are predicted for adult and larval survival, growth, and reproduction under worst case conditions as large percentages of acceptable habitats are available.

The modeled temperature data represents extreme worst case conditions. Under these conditions it is apparent that the gizzard shad population will be only slightly impacted in terms of habitat lost due to unsuitably high temperatures. Data collected in 1987 have documented an increase in gizzard shad populations under operational testing conditions. This combined with the predictive temperature assessment suggests that under normal plant operating conditions this species will thrive in Clinton Lake and that even under extreme thermal conditions most of the preferred habitat within the lake will provide acceptable water temperatures.

Table 5-15. Summary of Electrofishing Catch Per Effort (1 Hour) for Gizzard Shad Collected During the Summer Season, Clinton Lake, 1978-1987

Study Year	Lake Sampling Stations					
	4.5	4	8	13	2	16
1978	150	143	161	--	164	179
1979	218	201	192	--	293	228
1980	331	266	169	--	354	341
1981	231	544	219	650	343	259
1982	881	377	563	334	681	484
1983	607	201	206	175	517	486
1984	568	463	265	527	1,589	1,305
1985	859	706	162	608	1637	1,892
1986	612	313	309	415	410	978
1978-86 (average)	495	357	250	452	665	684
1987	938	1,017	1,033	1,174	1,286	3,060

Source: Illinois Power, 1978-1988.

5.6.2 Common Carp

Life History

The common carp is one of the largest and most widely distributed cyprinid fishes in the world. It is tolerant of organic and silt pollution which partially accounts for its rapid spread in the United States following its introduction into North America in 1877. Today, only Alaska and Hawaii are reported being without known populations of this fish (Lee et al., 1980).

Although its flesh is eaten, the carp is often considered to be a "rough" species. Carp become so abundant in suitable habitats that their feeding behavior often cause habitat deterioration by increasing turbidity and destroying aquatic vegetation (Pflieger, 1975). More total pounds of carp are taken commercially in the Missouri and Mississippi Rivers than any other species (Pflieger, 1975).

Carp are not schooling fish but frequently occur in loose aggregations (Pflieger, 1975). The species feed mostly on bottom organisms such as chironomids and other aquatic insects, zooplankton, phytoplankton, and plant materials. Feeding occurs most actively in the late evening and early morning. They are most abundant in lakes, reservoirs and in low gradient, warmwater streams containing abundant organic material. The species may weigh up to 60 pounds (27.2 kg) and have a life span of 12 years. They attain a length of approximately 6.5 inches (16.5 cm) after the first year. Individuals mature sexually at ages 2 to 4 with the males maturing earlier (Carlander, 1969; Pflieger, 1975; Trautman, 1957).

A great deal is known about the reproductive habits and requirements of the carp because they spawn nearshore. In the spring or early summer carp gather in large numbers, usually near submerged weeds or roots. The species spawns from April to June in Illinois (Richardson, 1913), mid-May to Mid-August in Wisconsin (Black, 1948), and late March to late June in Missouri (Pflieger, 1975) with some spawning occurring until early autumn. Fogle (1961) has stated that carp in South Dakota spawn twice a year.

Short Term Maximum Temperature (STMT)--Juvenile and Adult Survival

Adult and juvenile carp are tolerant of a wide range of temperatures. Specimens of this fish, acclimated between 25 and 27°C and heated at a rate of 3C° per hour, had a lethal threshold of 40 to 41°C (Horoszewicz, 1973, cited in Brungs and Jones, 1977) (Table 5-16). Brungs and Jones (1977) reported that carp, when acclimated to 26°C had a 24-hour TL_{50} at 36°C. None of these specimens survived temperatures over 36.9°C. Brungs and Jones (1977) also reported that the upper lethal temperature ranged from 31 to 34°C for carp acclimated to 20°C. Brown (1974) reported an upper incipient lethal limit for carp at 36°C when acclimated at 26°C. Gammon (1973) observed the upper avoidance temperature of 34.5°C on the Wabash River, whereas Proffit and Benda (1971) captured carp at temperatures up to 36.1°C on the White River in Indiana.

Preferred temperatures of carp also vary with acclimation temperature. For example, individuals acclimated at 10 and 15°C preferred temperatures of 17°C (Brungs and Jones, 1977; Pitt _et al_. 1956), individuals acclimated at 25°C preferred 27°C (Pitt _et al_, 1956) and individuals acclimated at 35°C preferred temperatures of 31 and 32°C (Pitt _et al_, 1956; Brown, 1974).

The STMT for adult and juvenile carp survival was defined as 39°C based on the highest reported upper incipient lethal limit (41°C) as reported by Brungs and Jones (1977). This value (41°C) is higher than most reported lethal limits (e.g., 36°C, Brown, 1974). However, because acclimation temperatures in Clinton Lake are expected to be greater than those used in the reported studies (26°C), the higher value is considered more appropriate for the Clinton Lake thermal regimes.

Table 5-16. Summary of Temperature (°C) Data for Common Carp

Life Stage	Acclimation Temperature	Lower Incipient Lethal Limit	Lower Avoidance Temperature	Preferred Temperature	Upper Avoidance Temperature	Upper Incipient Lethal Limit	Spawning Range	Optimal Spawning Temperature	Reference
Juvenile/ Adult	10	--	--	17.0	--	--	--	--	Brungs & Jones, 1977
	15	--	--	17.0	--	--	--	--	Pitt, et al, 1956
	20	--	--	25.0	--	--	--	--	Pitt, et al, 1956
	20	--	--	--	--	31-34	--	--	Brungs & Jones, 1977
	25	--	--	27.0	--	--	--	--	Pitt, et al, 1956
	26	--	--	--	--	36	--	--	Brown, 1974
	26	--	--	--	--	41	--	--	Brungs & Jones, 1977
	30	--	--	31.0	--	--	--	--	Pitt, et al, 1956
	35	--	--	32.0	--	--	--	--	Brown, 1974
	35	--	--	31.0	--	--	--	--	Pitt, et al, 1956
	*	--	27	--	34.5	--	--	--	Gammon, 1973
	*	--	--	28.2-31.9	--	--	--	--	Neill, 1971
	*	--	--	--	--	--	14.0-26.0	19.0-23.0	Swee & McCrimmon, 1966
	*	--	--	--	--	--	<33 (hatch)	21	Brungs & Jones, 1977
	*	--	--	--	--	--	14.5-25.0	--	Brown, 1974
Larvac	25	--	--	16.0-30.0+	--	--	--	--	Brown, 1974

$MWAT_{Growth}$ = 35; $MWAT_{Spawning}$ = 21 (April), 24 (May), 26 (June); $STMT_{Adult}$ = 39; $STMT_{Embryo}$ = 26.

* Acclimation temperature unspecified.
\+ Range for larval development.

Source: ESE, 1988.

MWAT--Growth

The MWAT for growth of carp was calculated to be 35°C. This value was calculated based on an upper lethal limit of 41°C and a preferred temperature of 32°C (Table 5-16). The preferred temperature was substituted for the optimum temperature for growth as this temperature was not available in the reviewed literature.

MWAT--Spawning

Three values for the MWAT for spawning were determined based on the extended spawning season of carp: 21°C for April, 25°C for May, and 25°C for June. The value for April (21°C) was derived by using the optimal spawning temperature. The MWAT for June was determined by using the upper limit of the observed spawning range (26°C) as reported by Brungs and Jones (1977) whereas the value for May (24°C) was derived as a mathematical intermediate value reflecting increased temperature tolerance with the progression of the spawning season.

Carp spawning has been observed to occur between 14 and 26°C with an optimum range of 19 to 24°C (Swee and McCrimmon, 1966). However, the maximum temperature for incubation during thermal shock was determined to be as high as 33°C (Brungs and Jones, 1977). A temperature range for larval development from 16 to 30°C was reported by Tatarko (1965, cited in Brown 1974) for larvae acclimated to 25°C.

STMT Embryo Survival

STMT for carp embryo survival was established as 26°C. As discussed previously, this value corresponds to the upper limit of the natural spawning range (Swee and McCrimmon, 1966) (Table 5-16). While Brungs and Jones (1977) reported an STMT for embryo survival as 33°C, this value was based on thermal shock studies involving 10-minute exposures rather than the 24-hour exposures as defined for this demonstration.

Thermal Model Data Evaluation

No restrictions on either survival or growth were evident during the months of April through June, September and October (i.e., 100 percent remaining habitat) (Figure 5-4; Tables 5-11 and 5-12). Minor restrictions in preferred habitat suitable for adult survival were evident in July and August (97.4 percent remaining habitat) (Table 5-11). Similarly, high percentages of remaining habitat adequate for growth were demonstrated for July and August (93.1 and 95.0 percent, respectively). These values are consistently higher than preferred habitat percentages derived during the previous demonstration. The percent of habitat adequate for carp survival in the previous study were 70, 63 and 97 percent for the months of July, August and September, respectively (EIA, 1980). Available habitat reported in this study was higher due to a 4°C higher STMT for adult survival (39°C) than the STMT temperature previously used. Similarly, higher percentages of preferred habitat adequate for growth were available than in the previous study: July at 72 percent; August at 60 percent; September at 90 percent (EIA, 1980). Again, these differences are the result of a higher MWAT for growth value: 35°C as compared to 32°C used in the previous study.

Spawning of carp during the warmest 7-day periods of each month was limited to 78.6, 44.0 and 20.4 percent of the available spawning habitat during April, May and June in Clinton Lake under the modeled worst case operational conditions (Figure 5-5; Table 5-13). In contrast, the percent of remaining habitat allowing embryo survival during the warmest 1-day period of each month was 85.0, 72.8 and 3.7 percent for April, May and June (Table 5-14). No habitats were suitable for either spawning or embryo survival in July or August under the modeled conditions. However, carp typically complete most of their spawning prior to July.

Clinton Lake Fisheries Data

Common carp have been routinely collected in Clinton Lake during the environmental monitoring studies conducted on the lake. In general, carp capture rates have decreased in recent study years compared to the years immediately after impoundment (Table 5-17). The collected data indicate that

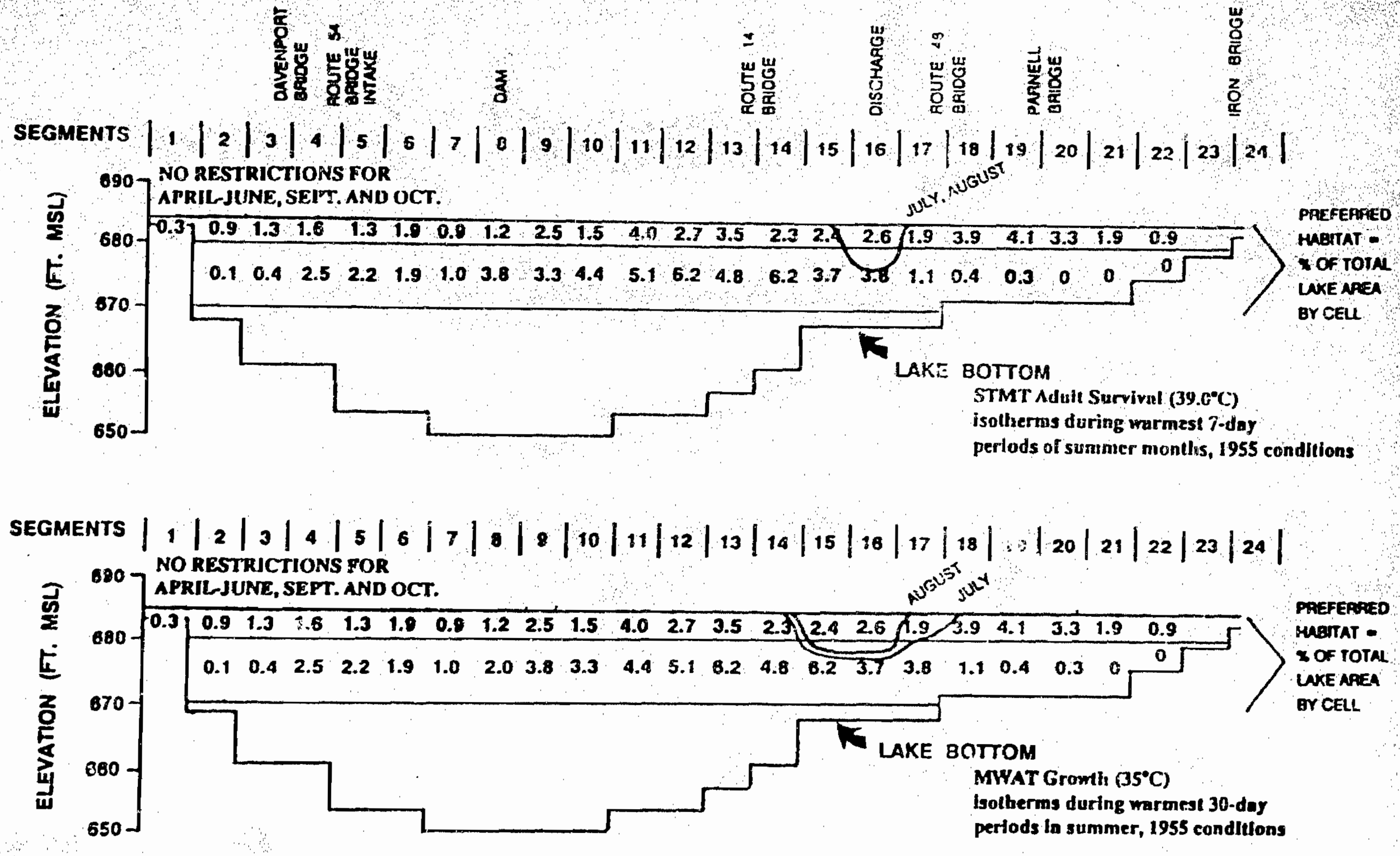

Figure 5-4
PERCENT PREFERRED HABITAT OF CARP RELATIVE TO TEMPERATURES ASSURING SURVIVAL AND GROWTH DURING OPERATION OF ONE UNIT OF CLINTON POWER STATION UNDER 100% LOAD AND 1955 METEOROLOGICAL CONDITIONS

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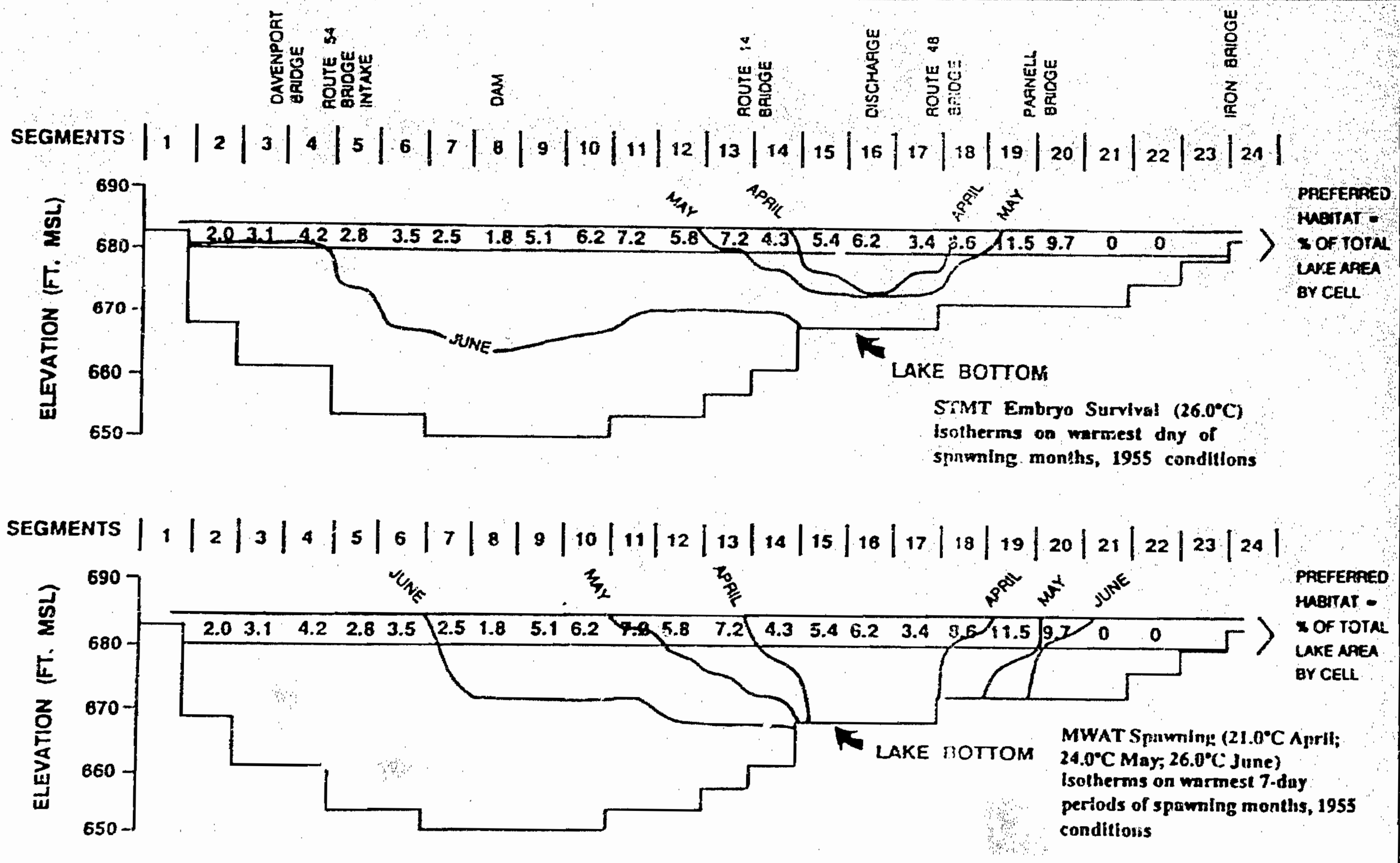

Figure 5-5

PERCENT SPAWNING HABITAT OF CARP RELATIVE TO TEMPERATURES ASSURING REPRODUCTION DURING OPERATION OF ONE UNIT OF THE CLINTON POWER STATION UNDER 1955 FLOW AND METEOROLOGICAL CONDITIONS

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carp have been common throughout the lake. Collections in 1987 were typically below the baseline average at all sampling locations and suggest a continuing decline in abundance of this species throughout the lake. Relative capture rates among sampling stations in 1987, however, were similar to those from 1978 through 1986 (i.e., high catch rates at Station 4.5 and moderate catch rates at other stations) indicating that the elevated summer (1987) temperatures associated with operational testing did not influence the distribution of carp in the lake.

Summary

Carp are common throughout Clinton Lake and are "creeled" by some anglers. The extreme worst case temperatures modeled for this study indicate only minor restrictions to carp survival and growth. Throughout the modeled time period temperatures within the acceptable range to assure carp survival and growth prevail throughout Clinton Lake with the exception of small areas near the discharge canal outfall in July and August.

Reproduction (i.e., spawning and embryo survival) under the modeled conditions is limited to April, May and June. Much of the preferred spawning habitat for carp is within acceptable temperature ranges throughout April and May whereas in June most of the appropriate habitat is too warm for successful reproduction. Temperature conditions in July and August are too warm and preclude successful spawning during these months; at Clinton Lake, however, carp spawning principally occurs prior to July.

The cumulative modeled data reveal that based upon published temperature data carp survival and growth will be little affected under worst case conditions. Successful reproduction, however, will principally be limited to April and May as water temperatures are too high after May to enable significant reproduction. Since carp typically spawn in May and early June in Illinois, it is apparent that successful reproduction will occur but perhaps at a somewhat lower level or earlier in the season than "typical" temperature years.

Table 5-17. Summary of Electrofishing Catch Per Effort (1 Hour) for Carp Collected During the Summer Season, Clinton Lake, 1978-1987

Study	Lake Sampling Stations					
Year	4.5	4	8	13	2	16
1978	159	37	18	--	43	106
1979	98	176	74	--	69	82
1980	101	102	113	--	180	98
1981	64	66	160	102	73	73
1982	34	46	116	79	58	122
1983	54	51	127	69	39	117
1984	53	33	38	25	68	27
1985	53	25	38	25	33	27
1986	42	7	31	24	14	54
1978-86 (average)	73	60	79	54	64	78
1987	50	28	28	17	21	31

Source: Illinois Power, 1978-1988.

5.6.3 Channel Catfish

Life History

The channel catfish is an abundant fish that is important both as a sport fish and a commercial fish throughout its range. This fish provides sport fishing in rivers and lakes and is especially important in larger prairie streams where other sport fish are not abundant. The channel catfish is an important segment of the commercial fisherman's catch in the larger rivers and is propagated in ponds to sell for stocking and food (Pflieger, 1975; Trautman, 1957). Channel catfish inhabit lakes and moderate to large low gradient rivers. They usually occur in clean, deeper water with sand, gravel or rubble bottoms rather than the shallower, more turbid, vegetated areas frequented by bullheads. During the day, they are most often found in deeper holes under rock outcroppings or submerged logs. Channel catfish are capable of tolerating low dissolved oxygen concentrations, down to about 1 ppm.

Channel catfish feed on or near the bottom upon a wide variety of organisms: including fish, aquatic insects, crayfish, mollusks, other invertebrates and plant material. Catfish less than 4 inches (10.2 cm) in length feed almost exclusively on aquatic insects whereas adults eat larger items of a wide variety (Pflieger, 1975). Bailey and Harrison (1948) stated that during the warmer months the channel catfish feeds actively during both day and night, while Pflieger (1975) indicated that they feed at night and remain inactive during the day. Stevens and Tiemeier (1969) reported that the channel catfish are most active at dawn and dusk.

Stauffer et al. (1976) found that channel catfish living at ambient temperatures had eaten significantly more organisms and had a higher diversity index value of food items than channel catfish from the area of a heated discharge. Neely and Pearson (1977) found differences in the diet of individuals from ambient and discharge habitats during the summer months when the catfish in the discharge area ate more fish and less aquatic vegetation than those catfish in ambient areas. The results of these studies may be a reflection of food availability.

Spawning occurs in late May through July at water temperatures between 21 and 29°C (70 to 85°F) (Brungs and Jones, 1977). Eggs are laid in secluded, semi-dark nests built by the male in holes, beneath undercut banks, in log jams or under rocks, in water up to 10 feet deep. Males protect the nest after eggs are laid. Hatching occurs within 5 to 10 days at 24 to 28°C and the newly hatched fish remain on the bottom for 2 to 5 days before swimming to the surface to feed.

STMT Adult and Juvenile Survival

Channel catfish appear to be thermally resistant. Cherry et al. (1975), reported that channel catfish had a preferred temperature of 30.5°C when acclimated at 30°C (Table 5-18). Similarly, Cheetham et al. (1976) also reported a preferred temperature of 30.5°C and a critical temperature maximum of 40.5°C when acclimated to 32°C.

In a study on the upper avoidance temperatures of the channel catfish Cherry et al. (1975) found that upper avoidance temperatures ranged from 25 to 35°C and lower avoidance temperatures varied from 4 to 23°C at acclimation temperatures of 6 to 30°C (Table 5-18).

For this demonstration the STMT for adult and juvenile survival was determined to be 36°C based on a reported upper incipient lethal limit of 38.0°C (Brungs and Jones 1977) when acclimated to 34°C. When acclimated to 32°C, Cheetham et al., (1976) reported a critical temperature maximum (CTM) of 40.5°C and a preferred temperature of 30.5°C. However, the CTM is not equivalent to the upper incipient lethal limit and therefore was not used for this analysis.

MWAT Growth

Data compiled by Brown (1974) indicate that growth for channel catfish is optimal between 28 and 32°C and is suboptimal below 23.9°C. In contrast, Shrable et al. (1969) and Chen (1976) suggested that growth was optimal between 26° and 29°C and ceased below 18°C (Starostka and Nelson, 1974). The MWAT for growth was calculated to be 34°C based on an upper incipient lethal

Table 5-18. Summary of Temperature (°C) Data for Channel Catfish

Life Stage	Acclimation Temperature	Lower Incipient Lethal Limit	Lower Avoidance Temperature	Preferred Temperature	Upper Avoidance Temperature	Upper Incipient Lethal Limit	Spawning Range	Optimal Spawning Temperature	Reference
Juvenile/Adult	6	--	4	18.9	25	--	--	--	Cherry *et al.*, 1975
	9	--	7	20.4	26	--	--	--	Cherry *et al.*, 1975
	12	--	--	17.0	--	33.5	--	--	Cheetham *et al.*, 1976
	12	--	13	19.9	29	--	--	--	Cherry *et al.*, 1975
	15	--	14	21.7	30	--	--	--	Cherry *et al.*, 1975
	15	--	--	--	--	30.0	--	--	Brungs & Jones, 1977
	16	--	--	21.0	--	35.0*	--	--	Cheetham *et al.*, 1976
	18	--	16	22.9	30	--	--	--	Cherry *et al.*, 1975
	20	3	--	--	--	32.0	--	--	Brungs & Jones, 1977
	20	--	--	22.0	--	36.0*	--	--	Cheetham *et al.*, 1976
	21	--	19	26.1	32	--	--	--	Cherry *et al.*, 1975
	24	--	--	24.8	--	38.0*	--	--	Cheetham *et al.*, 1976
	25	--	23	29.4	33	35.5	--	--	Cherry *et al.*, 1975
	25	--	--	--	--	33.5	--	--	Carlander, 1969
	25	--	--	30.0-32.0	--	35.0	--	--	Brown, 1974
	26	--	--	--	--	37.0	--	--	Brungs & Jones, 1977
	27	--	23	29.5	34	--	--	--	Cherry *et al.*, 1975
	28	--	--	27.0	--	39.0*	--	--	Cheetham *et al.*, 1976
	30	--	23	30.5	35	--	--	--	Cherry *et al.*, 1975
	30	--	--	--	--	37.0	--	--	Brungs & Jones, 1977
	32	--	--	30.5	--	40.5*	--	--	Cheetham *et al.*, 1976
	34	--	--	--	--	38.0	--	--	Brungs & Jones, 1977
	+	--	--	--	--	--	--	27	Brungs & Jones, 1977
	+	--	--	--	--	--	15.5-29.5	27	Brown, 1942; Clemens & Sneed, 1957
Larvae	+	--	--	--	--	35.0-38.0	--	--	Moss & Scott, 1961; Allen & Strawn, 1968
	29	--	--	29.0-30.0	--	31.0	--	--	Brungs & Jones, 1977

$MWAT_{Growth}$ = 34.0; $MWAT_{Spawning}$ = 27 (April and May), 29 (June and July); $STMT_{Adult}$ = 36; $STMT_{Embryo}$ = 29.

* CTM (Critical Temperature Maximum).
\+ Acclimation temperature unspecified.

Source: ESE, 1988.

limit of 38°C and a preferred temperature of 32°C as reported by Brown (1974).

MWAT Spawning

Spawning of channel catfish has been observed from March through July (Stevens, 1959; Cross, 1951; both cited in Carlander, 1969). The channel catfish spawns in the Midwest between the last week of May through the third week of July (Brader and Rosen, 1966; Pflieger, 1975). Spawning temperatures have been reported to be from 15.5 to 29.5°C (Brown, 1942; Clemens and Sneed, 1957), with an optimal spawning temperature of 27°C (Brungs and Jones, 1977; Brown, 1942; and Clemens and Sneed, 1957).

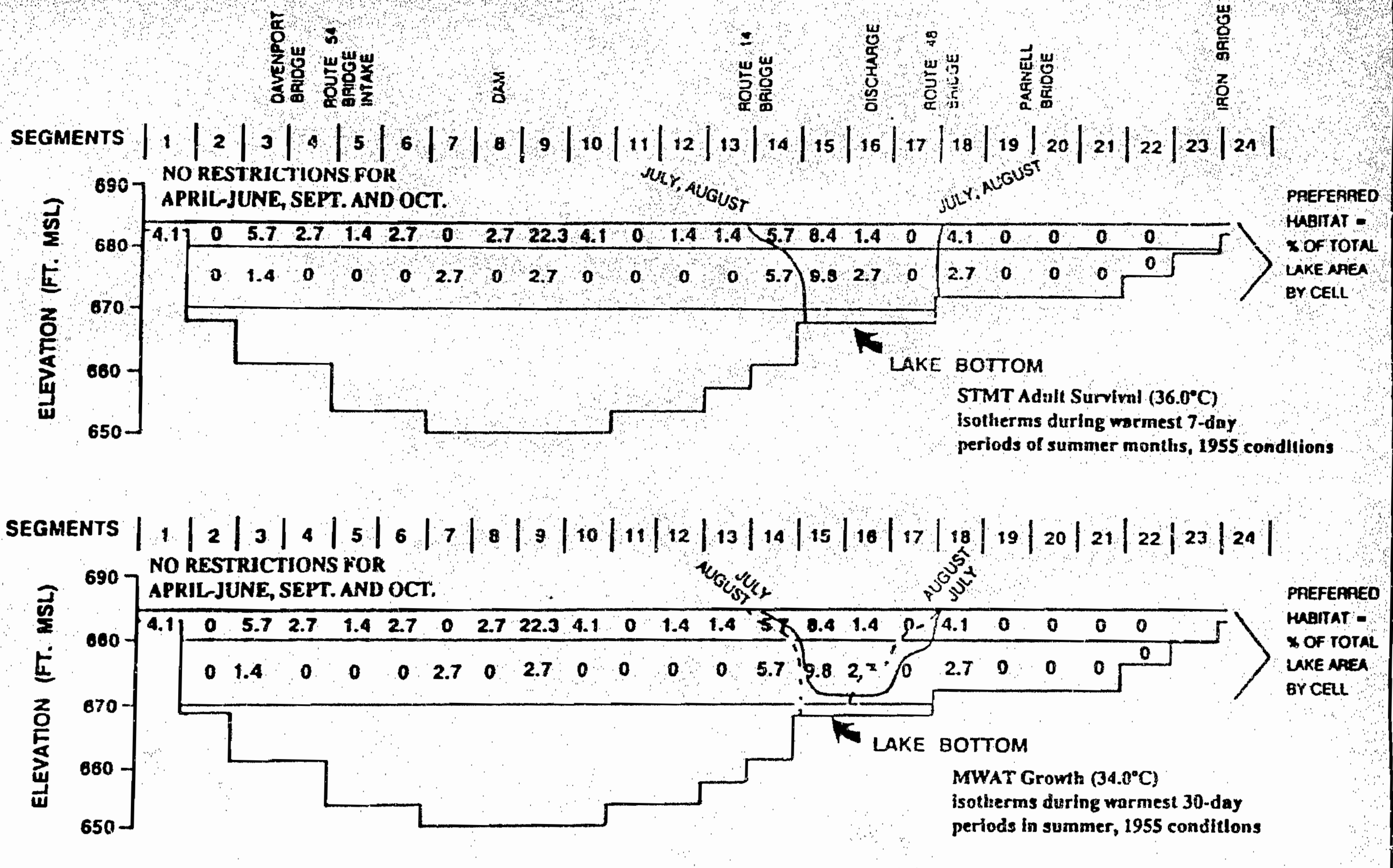
Two values for the MWAT for spawning were determined for channel catfish: 27°C for April and May, and 29°C for June and July (Table 5-18). The latter value was determined using the maximum spawning temperature whereas the former value was determined using the optimal spawning temperature.

STMT Embryo Survival

As discussed previously for channel catfish, the observed range of spawning temperatures is from 15.5 to 29.5°C (Brown, 1942; Clemens and Sneed, 1957). The value of 29°C was used as the STMT for embryo survival as suggested by Brungs and Jones (1977). This value represents the upper end of the observed range of spawning temperatures.

Thermal Model Data Evaluation

Channel catfish demonstrated good survival and continued growth throughout much of Clinton Lake under 1955 operational modeled conditions. During the warmest 7-day periods of each month channel catfish survival and growth was unrestricted during April to June, September and October (Figure 5-6). In July and August, however, channel catfish survival was limited to 74.9 percent of the available habitat (Table 5-11). This compared well with the results of the previous study in which 82, 74 and 99 percent of the available habitat had temperatures low enough to ensure survival in July, August and September, respectively. In contrast, the percent of remaining



STMT Adult Survival (36.0°C)
isotherms during warmest 7-day
periods of summer months, 1955 conditions

MWAT Growth (34.0°C)
isotherms during warmest 30-day
periods in summer, 1955 conditions

Figure 5-6
PERCENT PREFERRED HABITAT OF CHANNEL CATFISH RELATIVE TO TEMPERATURES ASSURING SURVIVAL AND GROWTH DURING OPERATION OF ONE UNIT OF CLINTON POWER STATION UNDER

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habitat adequate for growth in July, August and September were 74.9, 76.8 and 100 percent, respectively (Table 5-12 and Figure 5-6). These values are higher than those reported during these months in the previous study: July at 62 percent; August at 56 percent; September at 81 percent. Higher percentages in this demonstration were attributable to an MWAT for growth that was 2°C higher than that used in the previous study.

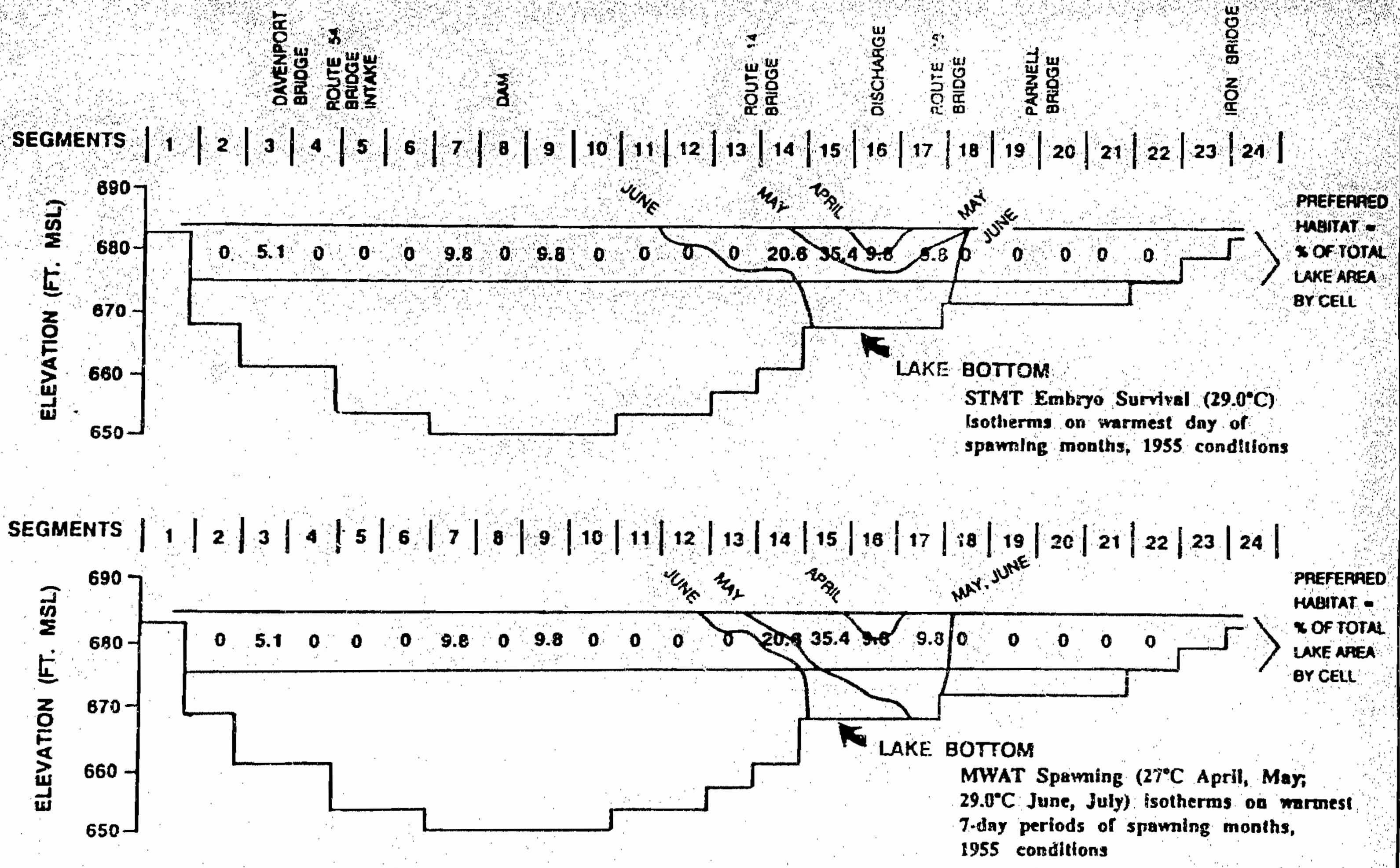
Available preferred spawning habitat for channel catfish declined from 96.7 percent in April, to 38 percent in May, to 31 percent in June and to 0 percent in July (Figure 5-7; Table 5-13). These values were obtained using MWAT for spawning values of 27°C for April and May, and 29°C for June and July. The percent of spawning habitat with temperatures ensuring embryo survival exhibited a similarly declining trend. A total of 96.7 percent of the remaining habitat was available in April as compared to 78.1 percent in May, 31.7 percent in June, and 0 percent in July (Table 5-14). Because these percentages are either equal to or greater than the MWAT for spawning percentages, embryo survival will be ensured in areas where spawning occurs under modeled conditions.

Clinton Lake Fisheries Data

Channel catfish capture rates via electrofishing have historically been low throughout the Clinton Lake environmental monitoring program (Table 5-18). This species, however, is abundant throughout the lake with the low electrofishing capture rates being an artifact of this technique's inability to readily collect channel catfish. Comparison of preoperational and operational testing (1987) study year data indicate no apparent difference in the abundance of channel catfish in the lake either spatially or temporally.

Summary

Channel catfish are an important sport and commercial fish species throughout its range. In Clinton Lake, this species is abundant and commonly taken by anglers. Channel catfish survival and growth is predicted to be good even under the modeled worst case conditions. Survival and growth occur unrestricted throughout the reservoir in all modeled months except July and



STMT Embryo Survival (29.0°C) isotherms on warmest day of spawning months, 1955 conditions

MWAT Spawning (27°C April, May; 29.0°C June, July) isotherms on warmest 7-day periods of spawning months, 1955 conditions

Figure 5-7

PERCENT SPAWNING HABITAT OF CHANNEL CATFISH RELATIVE TO TEMPERATURES ASSURING REPRODUCTION DURING OPERATION OF ONE UNIT OF THE CLINTON POWER STATION UNDER 1955 FLOW AND METEOROLOGICAL CONDITIONS

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Table 5-19. Summary of Electrofishing Catch Per Effort (1 Hour) for Channel Catfish Collected During the Summer Season, Clinton Lake, 1978-1987

Study Year	Lake Sampling Stations					
	4.5	4	8	13	2	16
1978	0	1	0	--	0	1
1979	0	2	0	--	3	1
1980	1	0	2	--	0	0
1981	0	1	0	0	0	1
1982	1	3	0	0	0	1
1983	2	3	0	0	1	1
1984	0	1	1	0	2	2
1985	1	0	0	0	4	3
1986	4	1	1	1	0	3
1978-86 (average)	1	1	0.5	0.2	1	1
1987	2	0	1	0	1	5

Source: Illinois Power, 1978-1988.

August. During these two months, approximately 25 percent of the preferred habitat in the lake is too warm to support channel catfish survival and/or growth. This area of exclusion (from which catfish will move out of and into more suitable temperature areas) is in close proximity to the discharge canal outfall with the remaining 75 percent of the preferred habitat in the lake maintaining sufficiently low temperatures, in July and August, to easily sustain channel catfish survival and growth.

Channel catfish reproductive success will apparently be impacted under the modeled worst case conditions. Available preferred spawning habitat will be plentiful only in April under the modeled conditions. In May and June approximately 30 percent of the preferred spawning habitat will be cool enough to assure spawning and larval survival whereas in July the entire lake will be too warm to assure successful reproduction. Based upon this scenario it is evident that reproduction of channel catfish as a population will be suboptimal under the modeled conditions as the typical spawning period for this species is late May through July. Due to the warmer acclimation temperatures associated with Clinton Lake it is likely that reproduction will occur earlier than 'normal' in the reservoir. Additionally, some reproduction can occur during 'normal' spawning times in May and June as some of the lake will remain at adequate temperatures for reproduction.

Under worst case conditions it is apparent that adult channel catfish survival and growth will not be adversely affected whereas reproduction will likely be below that associated with typical temperature regimes.

5.6.4 Bluegill

Life History

The bluegill is one of the most popular and common sunfishes in North America. This panfish provides fishing opportunities in many natural lakes and is almost universally stocked in man-made ponds and lakes as forage for largemouth bass and for sport fishing.

The original distribution of this popular panfish is difficult to determine because of its widespread introduction into fishing ponds. In the United States, bluegill is found principally east of the Rocky Mountains and are abundant in the Mississippi River drainage. Bluegill have been introduced into other areas, such as California, where it is now quite common.

Bluegill inhabit a wide range of warmwater habitats, but are most frequent in shallow, weedy areas of ponds, lakes and slow-moving rivers. It is most abundant in warm, clear, non-flowing waters containing scattered beds of aquatic vegetation. The bluegill is not tolerant of high turbidity and siltation (Trautman, 1957; Pflieger, 1975).

The feeding habits of the bluegill are well known. Aquatic insects, primarily chironomids, and aquatic plants make up much of the diet of adult bluegill. This diet is supplemented by other aquatic and terrestrial invertebrates, small fish, and during the spawning season, fish eggs. Young bluegill feed on zooplankton, gradually changing to larger food as they grow (Morgan, 1951; Pflieger, 1975). Whitaker and Schlueter (1973) found that the bluegill of the White River, Indiana, feed mostly on chironomids and Trichoptera larvae both within and outside of the thermal plume of a heated discharge. These authors also noted that the large bluegill fed heavily on small forage fish. Hathaway (1927) found the amount of food consumed by the bluegill doubled when the water temperature increased from 10°C to 20°C.

The spawning habits of bluegill have been discussed by Breder (1936). The male builds a shallow depression in a firm substrate of gravel, sand or mud at a water depth of approximately 2.5 feet (0.8 m). The time of year at which bluegill spawn varies throughout their range. Evermann and Clark (1920) cited June as being the peak spawning month for the bluegill in Indiana. Pflieger (1975) indicated that while the spawning peak is in June, spawning occurs from late May through August in Missouri. The optimum spawning temperature was listed as 25°C (Brungs and Jones, 1977). After spawning, the nest is protected by the male until the eggs hatch and the larvae have left the nest. Hatching generally occurs from 2 to 3 days after fertilization at temperatures of 22.2 to 22.8°C (Morgan, 1951). The spawning times of bluegill in the midwestern United States are summarized in Table 5-20.

STMT Adult Survival

Bluegill can apparently become acclimated to and is tolerant of high water temperatures. Cairns (1956) found that when acclimated at 30°C the upper lethal temperature was 33.8 to 35.5°C or even 37°C for adult bluegill. Hickman and Dewey (1973) found the ultimate incipient upper lethal temperature for adult bluegill is 35.5°C when acclimated at 21.5°C (Table 5-21).

Holland et al. (1974) and Cherry et al. (1977) both reported upper incipient lethal limits between 37 and 39°C when acclimated to 25 and 36°C temperatures. Utilizing the USEPA protocol and this published data, the STMT for adult survival (37°C) was established based on the high values reported by these workers.

MWAT Growth

The reported preferred temperature of bluegill ranges from 18.9 to 32°C depending on acclimation temperature. Cherry, et al. (1975) conducted numerous studies to determine avoidance temperatures and preferred temperatures. When acclimated at 30°C, the preferred temperature was 32°C while the upper avoidance temperature was 35°C (Table 5-21).

Growth of bluegill is expected to occur from spring to fall with the best growth occurring when water temperatures are between 15.6 and 27°C. (Rounsefell and Everhart, 1953). No growth is expected to occur below 10°C or above 30°C (Anderson, 1959; Emig, 1966). The MWAT for growth was determined to be 34°C using the upper incipient lethal limit of 39°C and the preferred temperature (in lieu of the optimum growth temperature) of 32°C (Cherry et al, 1975).

Table 5-20. Bluegill Spawning Times in the Midwestern United States

Date	Location	Reference
Late May-August	Wisconsin	Snow *et al.*, 1970
May	Illinois	Richardson, 1913
May-August	Ohio	Morgan, 1951
June	Indiana	Evermann and Clark, 1920
Late May-August	Missouri	Pflieger, 1975

Source: ESE, 1988.

Table 5-21. Summary of Temperature (°C) Data for Bluegill

Life Stage	Acclimation Temperature	Lower Incipient Lethal Limit	Lower Avoidance Temperature	Preferred Temperature	Upper Avoidance Temperature	Upper Incipient Lethal Limit	Spawning Range	Optimal Spawning Temperature	Reference
Adult	6.0	--	4	18.9	25.0	--	--	--	Cherry et al., 1975
	9.0	--	7	20.4	26.0	--	--	--	Cherry et al., 1975
	12.0	--	13	19.9	29.0	--	--	--	Cherry et al., 1975
	15.0	--	14	21.7	30.0	--	--	--	Cherry et al., 1975
	15.0	3	--	--	--	31.0	--	--	Brungs & Jones, 1977
	18.0	--	16	22.9	30.0	--	--	--	Cherry et al., 1975
	20.0	5	--	--	--	32.0	--	--	Brungs & Jones, 1977
	21.5	--	23	--	--	35.5	--	--	Hickman & Dewey, 1973
	24.0	--	--	29.4	33.0	--	--	--	Cherry et al., 1975
	25.0	7	--	--	--	33.0	--	--	Brungs & Jones, 1977
	25.0	--	--	--	--	37.0-39.0	--	--	Holland et al., 1974
	27.0	--	23.0	29.4	34.0	--	--	--	Cherry et al., 1975
	30.0	11	26.0	32.0	35.0	--	--	--	Cherry et al., 1975
	30.0	--	--	--	--	37.0	--	--	Cairns, 1956
	30.0	11	--	--	--	36.0	--	--	Hart, 1952
	36.0	--	--	--	--	37.0-39.0	--	--	Cherry, et al 1977
	*	--	--	--	--	--	19-32	25	Brungs & Jones, 1977
	*	--	--	--	--	--	22-34	--	Banner & Van Arman, 1973
	*	--	--	27.2-32.6	--	--	--	--	Neill, 1971
	*	--	--	27.4	--	--	--	--	Reutter & Herdendorf, 1974
	*	--	--	30.5	--	--	--	--	Reynolds et al., 1976

$MWAT_{Growth} = 34$; $MWAT_{Spawning} = 25$ (April and May), 28 (June), 34 (July and August); $STMT_{Adult} = 37$; $STMT_{Embryo} = 34$.

* Acclimation temperature unspecified.

Source: ESE, 1988.

MWAT Spawning

Everman and Clark (1920) indicated that June was the optimal spawning time of bluegill in Indiana, whereas May was reported to be the primary spawning period of bluegill in Illinois (Richardson, 1913). Pflieger (1975) indicated that spawning in Missouri occurs from late May to August.

Yolk sac larvae remain near the nest until the yolk sac is absorbed, then form schools in open water (Warner, 1969), where they feed on zooplankton. The schools return to shallower water when they reach 25 mm (1 inch) in size, and feed increasingly on insects as available, especially midge larvae (Keast, 1965; Seaburg and Moyle, 1964; and Applegate et al., 1967).

Bluegill are tolerant of, and even prefer, higher temperatures than most fish (Table 5-21). Bluegill are known to repeatedly spawn within a temperature range of 19 to 32°C (Brungs and Jones, 1977), with an optimal spawning temperature of 25°C. In contrast, Banner and Van Armann (1973) indicated that spawning occurred within a range of 22 to 34°C. Because of the extended spawning period for bluegill, three MWAT values for spawning were derived: 25°C for April and May, 28°C for June, and 34°C for July and August. The value for April to May represents the optimal spawning temperature whereas the value for July and August represents the maximum of the reported spawning range. The value for June (28°C) reflects an intermediate spawning temperature. This temperature represents a value less than the mathematical mean between May and July. Use of the mathematical mean, 29.5°C, results in greater habitat availability in July than in June. This result appears unrealistic; consequently, a more conservative intermediate temperature, 28°C, was selected to represent the incrementally greater habitat exclusion as water temperatures increase throughout the spawning period.

STMT Embryo Survival

The STMT for embryo survival was determined as per USEPA protocol to be 34°C, corresponding to the maximum reported spawning temperature (Banner and Van Arman, 1975). As discussed previously, bluegill spawn repeatedly from April to August. Spawning occurs within a range of temperatures from 22 to 34°C, with a optimum of 25°C (Table 5-21).

Thermal Model Data Evaluation

Bluegill is perhaps the most thermally tolerant of the RIS species selected for this evaluation. Only minor reductions in habitat suitable for adult survival and growth were demonstrated (Figure 5-8). No reductions in preferred habitat for survival or growth were evident in April through June, and September and October. In addition a total of 95.7 percent (i.e., only 4 percent not suitable due to temperature) of bluegill habitat was suitable for survival and growth in July and August (Tables 5-11 and 5-12). These results compared well with those reported in the previous study where at least 90 percent of its habitat remained in all evaluation months under 1955 worst case conditions.

High percentages of preferred habitat for bluegill spawning and embryo survival also remain in Clinton Lake throughout the spawning period. The percent of remaining spawning habitat with 7-day average temperatures lower than the MWAT for spawning were 93.8 in April, 64.9 in May, 59.1 in June, and 62.0 in July and August (Figure 5-9; Table 5-13). A slight increase in the percent of available habitat in July and August was the artifact of increasing the MWAT value from 28°C in June to 34°C in July and August. Bluegill also exhibited high availability of habitats adequate for embryo survival. No habitat restrictions were evident in May (i.e., 100 percent availability), while 96.9 percent remained in June, 24.5 percent in July, and 31.6 percent in August (Table 5-14). No reductions in habitat for embryo survival were evident in April that resulted from thermal additions. The low STMT value (68.8 percent), however, was the result of temperatures below the observed spawning range. Thus, the percent of available habitat demonstrates the early initiation of the spawning season resulting from the addition of thermal inputs. It is apparent that without thermal inputs temperatures throughout the lake would be below the observed spawning temperature range thus precluding spawning during April.

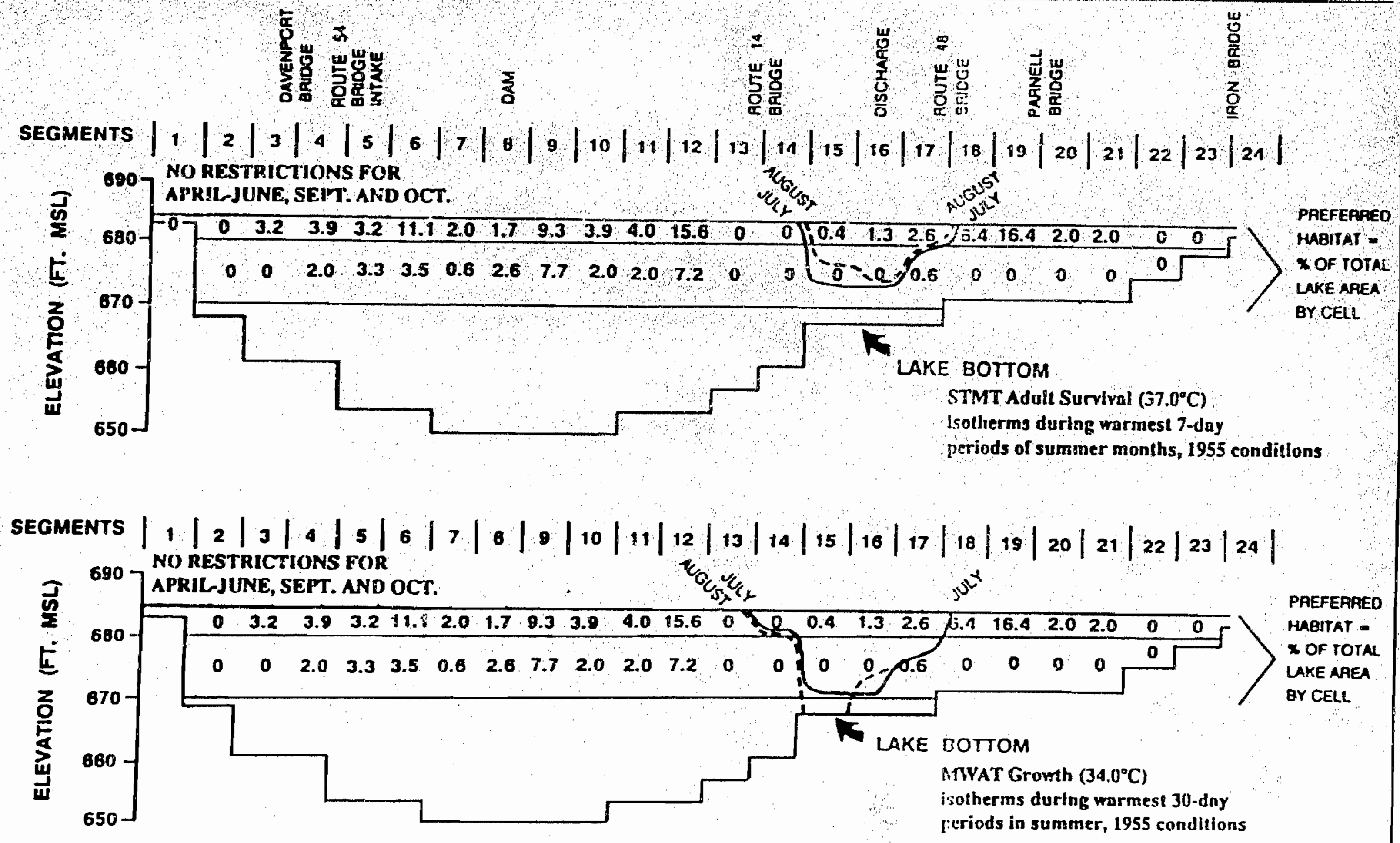

Figure 5-8
PERCENT PREFERRED HABITAT OF BLUEGILL RELATIVE TO TEMPERATURES ASSURING SURVIVAL AND GROWTH DURING

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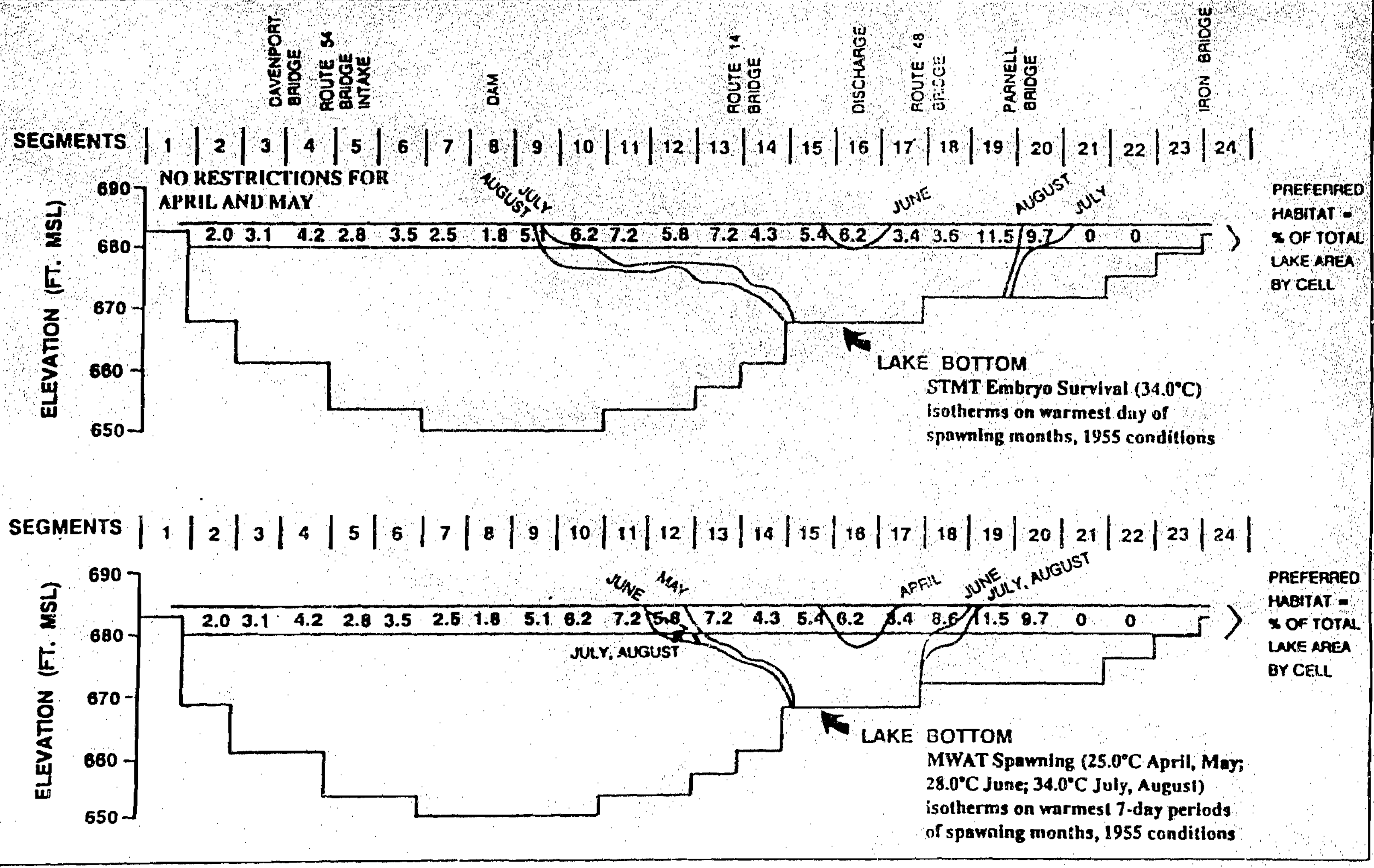

Figure 5-9
PERCENT SPAWNING HABITAT OF BLUEGILL RELATIVE TO TEMPERATURES ASSURING REPRODUCTION DURING OPERATION OF ONE UNIT OF THE CLINTON POWER STATION UNDER 1955 FLOW

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Clinton Lake Fisheries Data

Data collected during the 1978-1987 monitoring period have documented the abundance of bluegill throughout the lake. In general, prior to operational testing in 1987, capture rates at Station 2 (discharge canal area) were the lowest (42 per hour) whereas the highest capture rates occurred at mid-lake Station 8 (76 per hour). During the summer of 1987, capture rates were highest at Stations 2 and 4.5. This increase in capture rates at Station 2 indicates the increased temperatures associated with operational testing (Delta T 4°C) did not adversely affect the abundance of bluegill at Station 2 as capture rates increased by over 70 percent from the preoperational average (Table 5-22).

Summary

Bluegill is an important and abundant sport fish species throughout its range. Based upon published literature data bluegill appear to be the most thermally tolerant of the RIS selected for evaluation.

No reduction in available habitat for survival and growth associated with high water temperatures were evident in April, May, June, September or October under the modeled conditions. Only minor reductions of preferred habitat (4.3 percent of the preferred lake habitat) exceeded survival and growth criteria temperatures in July and August. Similarly, high percentages of preferred habitat remain within acceptable temperature ranges, for spawning and embryo survival, throughout the April through August spawning period.

Bluegill populations in Clinton Lake will successfully tolerate the modeled worst case operational thermal conditions in terms of adult survival and growth. Reproduction should be good as high percentages of preferred spawning habitat will remain within acceptable temperature limits throughout the entire spawning period. The minor habitat restrictions associated with warm water temperatures indicate that reproductive success will be less than that associated with more "typical" temperature regimes but will be adequate

Table 5-22. Summary of Electrofishing Catch Per Effort (1 Hour) for Bluegill Collected During the Summer Season, Clinton Lake, 1978-1987

Study Year	Lake Sampling Stations					
	4.5	4	8	13	2	16
1978	19	10	29	--	49	23
1979	45	55	63	--	57	80
1980	46	51	94	--	85	104
1981	35	19	90	64	22	26
1982	19	31	126	45	29	41
1983	42	60	71	38	28	64
1984	67	83	93	51	34	16
1985	90	74	72	56	55	53
1986	108	102	42	55	20	108
1978-86 (average)	52	54	76	52	42	57
1987	85	61	54	49	72	65

Source: Illinois Power, 1978-1988.

for good recruitment into the population as only 5 percent of the preferred habitat will be restricted in June in terms of embryo survival.

5.6.5 Largemouth Bass

Life History

Largemouth bass are typically found in ponds, shallow lakes, shallow bays of large lakes and backwaters of large, slow flowing rivers. They are also common in reservoirs of all sizes, which are frequently stocked. This species is rarely found in water deeper than 20 feet (6 meters). Normal habitat is soft-bottomed areas with tree stumps and/or emergent or submergent vegetation. These fish avoid dissolved oxygen concentrations of 1.5 ppm or lower.

Adult largemouth bass typically feed on fish, crayfish and insects. In midwestern reservoirs, gizzard shad are the main forage species along with minnows and other forage species.

Spawning generally occurs from late April through June (Eddy and Underhill, 1974), although largemouth bass spawned approximately 2 weeks earlier in the heated arm of a cooling lake than in the unheated area (Larimore et al., 1979). Nesting habitat varies, but is usually a shallow (less than 5 feet), soft-bottomed area in aquatic vegetation (Balon, 1975). Males initiate nest building when water temperatures reach 15.6°C making the largemouth one of the earliest nesting sunfishes. Optimum spawning temperature is 21°C (Brungs and Jones, 1977). Males guard and fan the demersal, adhesive eggs, apparently to keep them oxygenated (Dudley and Sipper, 1975). Eggs hatch in about 5 days. Embryos will develop over the range from 13 to 26°C with an optimum at 20°C (Brungs and Jones, 1977).

STMT Adult Survival

The STMT of adult survival was calculated to be 36°C, 2°C below the ultimate upper incipient lethal temperature reported by Cincotta et al. (1982). Largemouth bass are more tolerant of high temperatures than many fish species (Table 5-23). Upper incipient lethal limits of largemouth bass

Table 5-23. Summary of Temperature (°C) Data for Largemouth Bass

Life Stage	Acclimation Temperature	Lower Incipient Lethal Limit	Lower Avoidance Temperature	Preferred Temperature	Upper Avoidance Temperature	Upper Incipient Lethal Limit	Spawning Range	Optimal Spawning Temperature	Reference
Adult	15	10*	--	--	--	30*	--	--	EIA, 1980
	20	15*, 5.5+	--	--	--	30*, 32.5+	--	--	EIA, 1980
	22	--	--	30.0	--	--	--	--	Reynolds & Casterlin, 1978
	25	15*	--	--	--	35*, 34.5+	--	--	EIA, 1980
	30	15*, 11.8+	--	--	--	35*, 36.4+	--	--	EIA, 1980
	35	20*	--	--	--	35*	--	--	EIA, 1980
	**	--	--	27.0-30.0	30	--	--	--	Clugston, 1973
	**	--	25.5	27.0	29	--	--	--	Contant, 1975
	**	--	--	--	--	38.0	15.6-21.1	--	Cincotta *et al.*, 1982
	**	--	--	30.2	--	--	--	--	Reynolds *et al.*, 1975
	**	--	--	26.6-27.7	--	--	--	--	Dendy, 1948
	**	--	--	27.0	--	--	16.0-27.0	21.0	Brungs & Jones, 1977
Larvae	**	--	--	--	--	32.1+	--	--	McCormick & Wegner, 1981
Eggs	**	--	--	--	--	29.1+	--	--	McCormick & Wegner, 1981

$MWAT_{Growth}$ = 32.7; $MWAT_{Spawning}$ = 21 (April-June); $STMT_{Adult}$ = 36; $STMT_{Embryo}$ = 27.

* 100 percent survival for 48 hours.
\+ 24-hour LT_{50}.
** Acclimation temperature unspecified.

Source: ESE, 1988.

were determined to be 30°C, 32.5 (24 hour TL_{50}) 35, 36.4 (24 hour TL_{50}), and 35°C at acclimation temperatures of 15, 20, 25, 30 and 35°C (EIA, 1980). A significantly high value of 38°C was reported by Cincotta et al. (1982).

MWAT Growth

The MWAT for growth was calculated to be 32.7°C based on an ultimate incipient lethal limit value of 38°C and a preferred temperature of 30°C (also upper range for optimal growth). Optimal growth temperatures of largemouth bass range from 24 to 30°C (Mohler, 1966; Coutant, 1975; Brungs and Jones, 1977; Carlander, 1977) while little growth occurs below 15°C (Mohler, 1966) or above 36°C (Carlander, 1977).

Growth of largemouth bass is quite variable and may depend on local environmental conditions including temperature, turbidity, dissolved oxygen, and population levels. For example, in Lake Shelbyville individuals attained a length of 153 mm the first year and lengths of 244, 306, 330 and 361 mm in succeeding years. In contrast, growth of largemouth bass in Lake Sangchris, a cooling reservoir, was 121 mm the first year and 274, 358, 411 and 444 in succeeding years (Larimore et al., 1979) primarily due to the extended growing season produced by the higher water temperatures. Particularly rapid growth of largemouth bass has been documented at Baldwin cooling pond (Smithson et al., 1986). Mean total length of young of the year individuals was 232 mm by December while Age-1 individuals had a mean total length of 355 mm.

MWAT Spawning

An MWAT for spawning was selected at 21°C as this value represents the optimal spawning temperature and the maximum spawning temperature as reported by Cincotta et al. (1982). Spawning of largemouth bass typically occurs from April to June. Optimal spawning habitat consists of shallow areas with substrates of gravel, sand or vegetation. Cincotta et al. (1982) reported a range of spawning temperatures of 15.6 to 21.1°C whereas Brungs and Jones (1977) reported a range of 16 to 27°C. Optimal spawning temperature is considered to be 21°C (Brungs and Jones, 1977).

STMT Embryo Survival

Brungs and Jones (1977) reported the STMT (Keast and Webb, 1966) for embryo survival to be 27°C. This value is also used here as it represents the upper limit of the reported spawning temperature range.

After spawning, newly hatched young remain in the nest until the yolk is absorbed, then rise from the bottom, form schools and begin to feed. Growth is rapid and varies with temperature between 20°C (Brungs and Jones, 1977) and 35.5°C. Diet changes occur with increased fish size from zooplankton to aquatic insects; subsequently, predation upon small fish, frogs and crayfish begins during the first year of life.

Thermal Model Data Evaluation

Largemouth bass exhibited excellent survival and growth throughout the modeled evaluation period. The percentage of preferred habitats within the acceptable STMT for adult survival (36°C) were 100 percent from April through June, September, and October (Figure 5-10; Table 5-11). Preferred habitats were slightly restricted (e.g., 4.5 percent) in July and August. These results were slightly higher than percentages predicted in the previous study (July at 92 percent, August at 85 percent, and September at 99 percent). This was primarily attributable to the higher STMT for adult survival used in this evaluation (36°C). A similarly high degree of habitats were available for adequate growth. One hundred percent of the available habitats had temperatures adequate for growth from April through June, and September. Growth was slightly restricted in other months with percentages of remaining preferred habitats at 89.4 percent in July, 95.5 percent in August, and 99.5 percent in September (Table 5-12; Figure 5-10). This compared well with the results of the previous study in which 92 percent were available in July, 86 percent in August, and 99 percent in September. Again, values reported in this evaluation demonstrate similar impacts to those reported in the previous demonstration.

Largemouth bass spawning may be restricted to the month of April or earlier under operational worst case conditions. A total of 76.4 percent of the

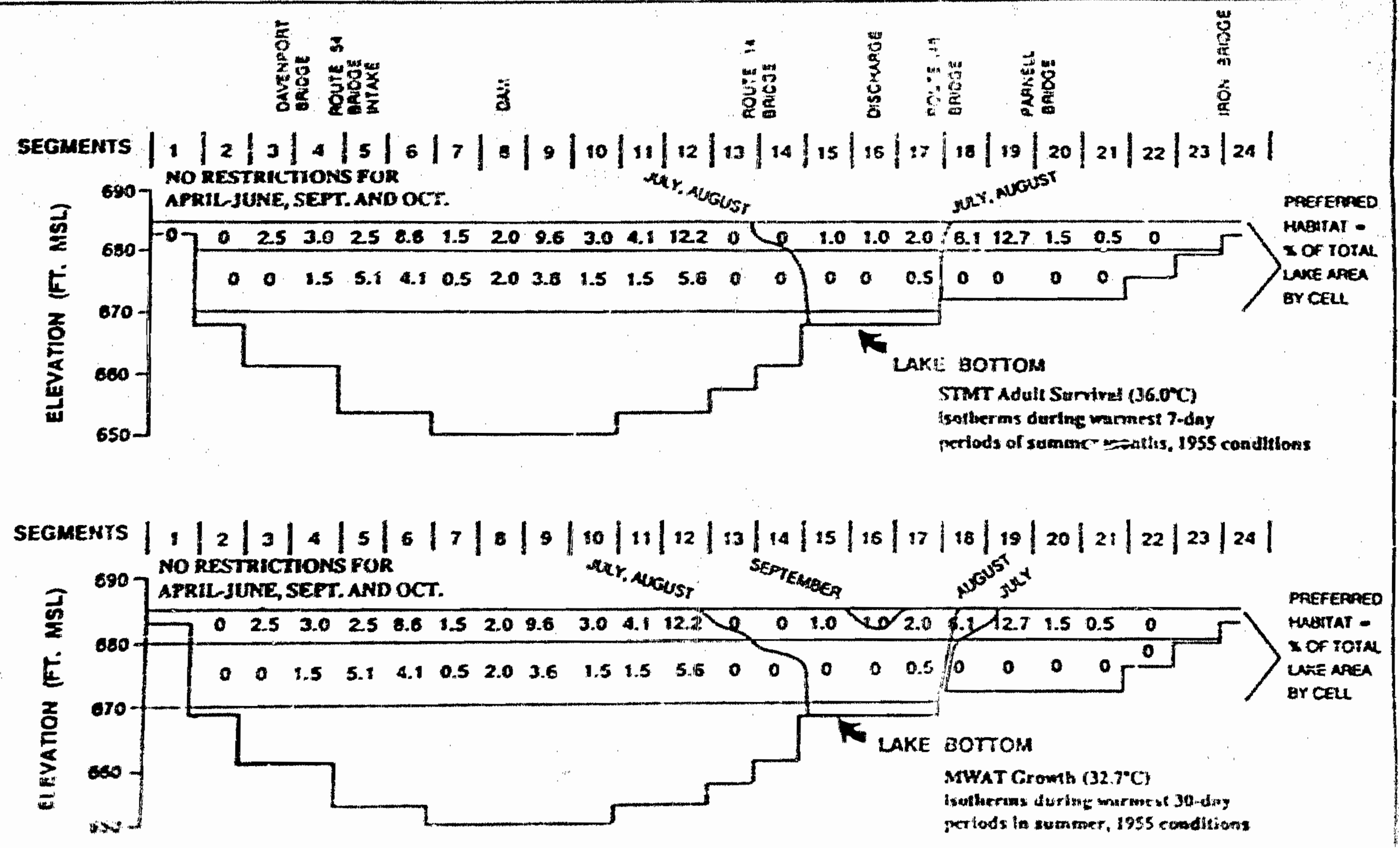

Figure 5-10
PERCENT PREFERRED HABITAT OF LARGEMOUTH BASS RELATIVE TO TEMPERATURES ASSURING SURVIVAL AND GROWTH DURING OPERATION OF ONE UNIT OF CLINTON POWER STATION UNDER 100% LOAD AND 1955 METEOROLOGICAL CONDITIONS

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preferred spawning habitat was available in April as compared to 0 percent in May and June (Figure 5-11; Table 5-13). However, even under ambient modeled conditions spawning of largemouth bass is prevented from occurring due to elevated temperatures in preferred spawning habitats (Figure 5-12). Embryo survival was adequate. Approximately 90.4 percent of the preferred spawning habitats were available for embryo survival in April, 80.7 percent in May, and 36.3 percent in June (Table 5-14). Thus, the suitability of habitats for a considerable period following the spawning period (April) ensures the survival of embryos and their potential recruitment into the population.

Clinton Lake Fisheries Data

Largemouth bass capture rates were especially high in 1978 and have subsequently stabilized at a lower rate in recent years (Table 5-24). The collected data indicate that during the summer capture rates were generally similar spatially among sampling stations from 1978-1986. During the summer of 1987, largemouth bass capture rates at most sampling locations were similar or slightly higher than the preoperational average. At sampling Station 2, however, the largemouth bass capture rate increased by over 50 percent from preoperational levels documenting that the increased water temperatures did not negatively impact largemouth bass distribution in the reservoir. This increase in capture rates may, however, be associated with water flow from the discharge canal into this area of the lake.

Summary

Largemouth bass is one of the most highly sought after fish species by anglers. This species is common in Clinton Lake and sustains a viable sport fishery. Based upon the modeled temperature data it is evident that the largemouth bass populations will exhibit good survival and growth throughout the lake under the worst case operational conditions. No thermal restrictions to survival or growth will be associated with the modeled temperatures in April, May, June, September or October. In the warmest months (July and August) only 5 percent of the lake will be thermally restrictive in terms of adult survival whereas adult growth will be restricted in 10 percent of the lake in July, 5 percent in August, and less than 1 percent in September.

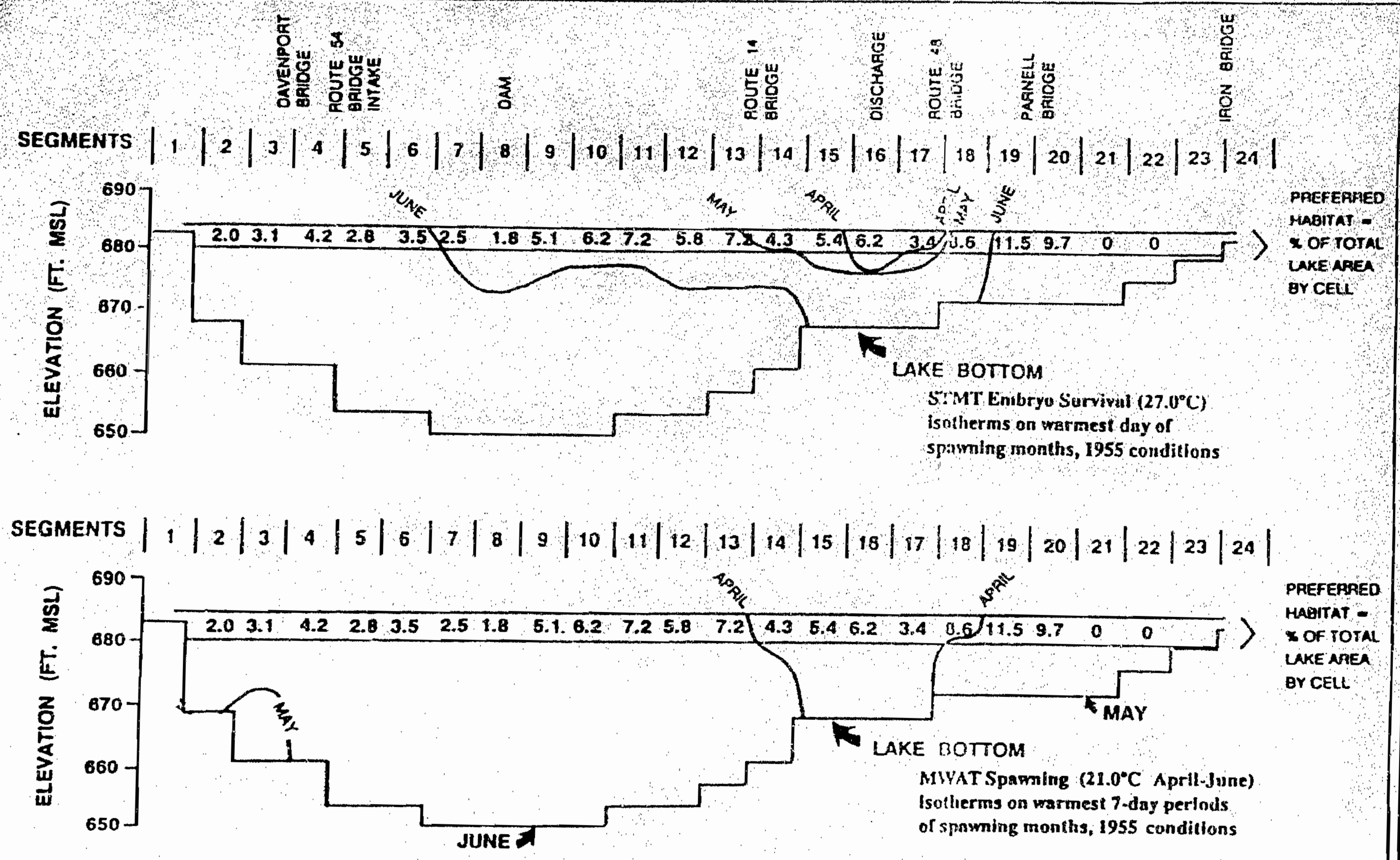

Figure 5-11

PERCENT SPAWNING HABITAT OF LARGEMOUTH BASS RELATIVE TO TEMPERATURES ASSURING REPRODUCTION DURING OPERATION OF ONE UNIT OF THE CLINTON POWER STATION UNDER 1955 FLOW AND METEOROLOGICAL CONDITIONS

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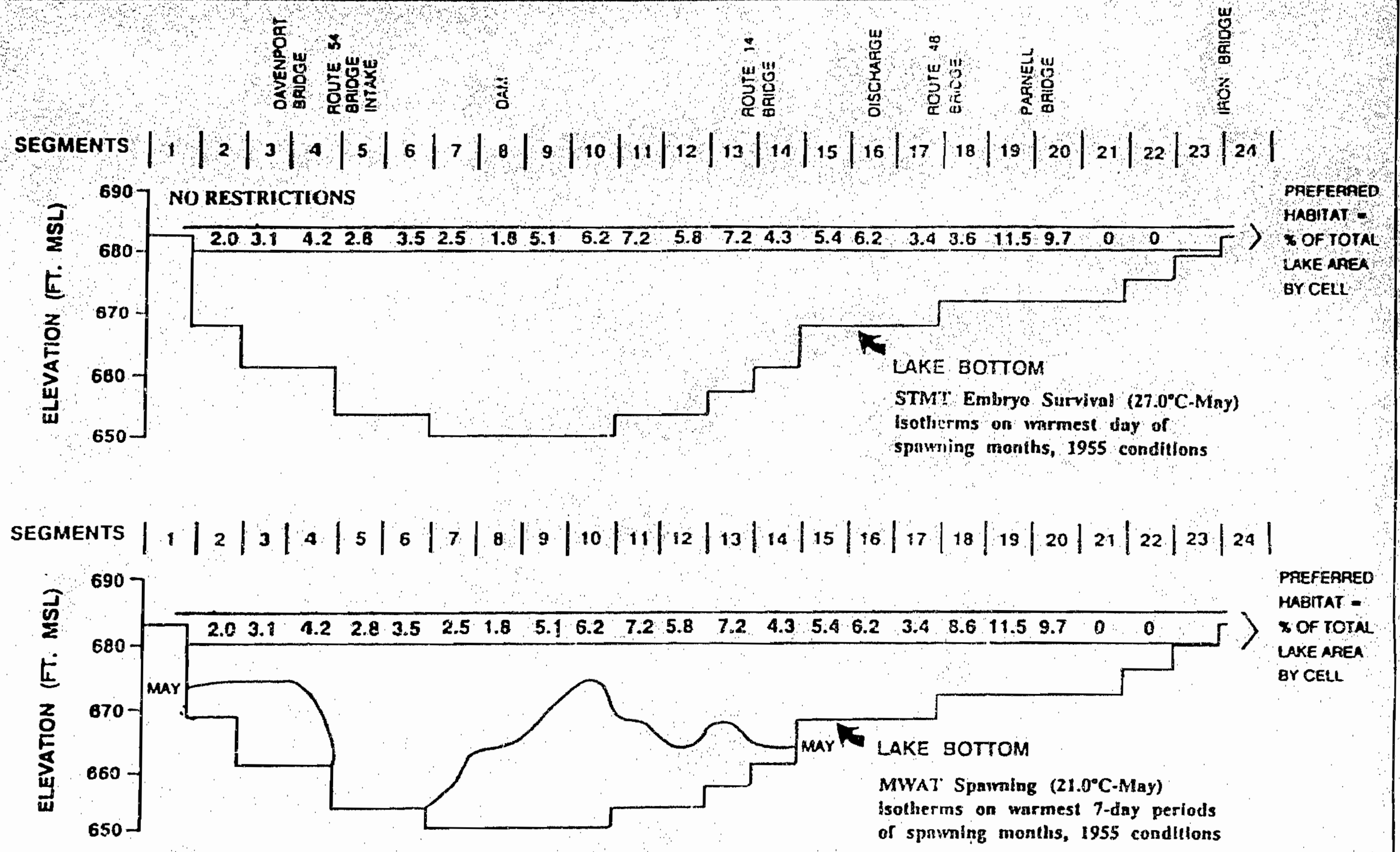

STMT Embryo Survival (27.0°C-May) isotherms on warmest day of spawning months, 1955 conditions

MWAT Spawning (21.0°C-May) isotherms on warmest 7-day periods of spawning months, 1955 conditions

Figure 5-12
PERCENT SPAWNING HABITAT OF LARGEMOUTH BASS RELATIVE TO TEMPERATURES ASSURING REPRODUCTION UNDER AMBIENT 1955 FLOW AND METEOROLOGICAL CONDITIONS DURING THE MONTH OF MAY

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Table 5-24. Summary of Electrofishing Catch Per Effort (1 Hour) for Largemouth Bass Collected During the Summer Season, Clinton Lake, 1978-1987

Study Year	Lake Sampling Stations					
	4.5	4	8	13	2	16
1978	135	87	225	--	110	121
1979	58	41	41	--	69	71
1980	33	29	30	--	29	35
1981	46	29	34	34	23	30
1982	24	31	41	30	42	25
1983	14	45	25	20	33	20
1984	37	30	44	24	23	16
1985	18	27	37	22	10	13
1986	44	53	46	61	33	28
1978-86 (average)	45	41	58	32	41	40
1987	45	56	55	51	63	31

Source: Illinois Power, 1978-1988.

Although adult survival and growth will be affected very little during the modeled temperature year, reproductive success (i.e., spawning and embryo survival) may be influenced more distinctly. This is apparently due to temperature limitations causing 76.4 percent of the preferred spawning habitat to be within acceptable temperature ranges in April and 0 percent in May and June. Higher percentages of available habitat, however, are available for embryo survival during these months. It is anticipated that some largemouth bass spawning will occur in April rather than the more typical May spawning of this species. Early spawning due to the presence of thermally enriched water is common in cooling lakes; consequently, the potential for lost spawning time in June is likely to be irrelevant. It is evident, however, that reproduction will be below optimal under these worst case conditions.

5.6.6 White Crappie

Life History

White crappie are found in a variety of warm water, relatively still habitats including ponds, lakes, slow-moving rivers and deep pools, in streams, oxbows, and backwater habitats. They form loose aggregations, generally occurring in sheltered coves of lakes with cover such as vegetation or standing timber during the day, and in more open water at depths up to 15 feet or more at night.

Food of white crappie varies with season, location and age. Young crappie feed on predominately microcrustaceans while adults typically feed on fish (e.g., gizzard shad) and aquatic insects (Pflieger, 1975).

Crappie spawning occurs earlier than in many other centrarchids (April through June) at temperatures of 10.5 to 27°C (Morgan, 1954). Ill-defined nests are made on a variety of substrates, including gravel, sand, plant roots or algal growth. (Breder, 1936; Balon, 1975; Morgan, 1954). Generally, shallow (<4 feet) protected areas with vegetation or brush are chosen, although nests have been noted as deep as 20 feet. Eggs hatch in 1 to 5 days at temperatures of 14 to 24°C (Brungs and Jones, 1974) with the fry dispersing several days after hatching.

STMT Adult Survival

The STMT for adult survival was calculated to be 31°C based on the upper incipient lethal limit reported by Brungs and Jones (1977). While crappie are the most intolerant of high temperatures of any of the RIS (Table 5-25). Brungs and Jones (1977) reported an upper incipient lethal limit of 33°C with an acclimation temperature of 29°C. Temperatures preferred by white crappie were 8, 10, 26 and 29°C when acclimated at 3, 9, 24 and 27°C, respectively.

MWAT Growth

An MWAT for growth was calculated to be 30.3°C using a preferred temperature of 29°C and an upper incipient lethal limit of 33°C. The range of temperatures necessary for growth of white crappie is from 17 to 30°C (Edwards et al., 1982). Preferred temperatures range from 8 to 29°C depending on acclimation temperature (Brungs and Jones, 1977). Gammon (1973) observed a temperature preference of 26 to 27°C near a thermal effluent on the Wabash River.

MWAT Spawning

A value of 23°C was used as MWAT for spawning to coincide with a similar STMT value. White crappie typically spawn in ill-defined nests from April through June when temperatures are between 10.5 and 27°C. (Morgan, 1954). In contrast, Brungs and Jones (1977) reported that spawning occurred from March to July between 14 and 23°C with optimum temperatures of 16 to 20°C. Two MWAT for spawning values were derived based on white crappie's prolonged spawning season: 19°C for April and May (representing the optimum spawning period and temperature), and 23°C for June. While the extraordinarily high value reported by Morgan (27°C) would allow for the assignment of an MWAT value of 27°C, this does not correspond to Siefert's (1968) results that showed embryo survival decreasing above 23°C.

Table 5-25. Summary of Temperature (°C) Data for White Crappie

Life Stage	Acclimation Temperature	Lower Incipient Lethal Limit	Lower Avoidance Temperature	Preferred Temperature	Upper Avoidance Temperature	Upper Incipient Lethal Limit	Spawning Range	Optimal Spawning Temperature	Reference
Juvenile/ Adult	3	--	--	8	--	--	--	--	Brungs & Jones, 1977
	5	--	--	10	--	--	--	--	Brungs & Jones, 1977
	24	--	--	26	--	--	--	--	Brungs & Jones, 1977
	27	--	--	28, 29	--	--	--	--	Brungs & Jones, 1977
	29	--	--	--	--	33	--	--	Brungs & Jones, 1977
	*	--	--	--	--	--	14-23	16-20	Brungs & Jones, 1977
	*	--	22	26-27	27	--	--	--	Gammon, 1973
Larvae	*	--	14.4	18.9-19.4	22.8	--	--	--	Siefert, 1968

$MWAT_{Growth}$ = 30.3; $MWAT_{Spawning}$ = 19 (April and May), 23 (June); $STMT_{Adult}$ = 31; $STMT_{Embryo}$ = 23.

* Acclimation temperature unspecified.

Source: ESE, 1988.

STMT Embryo Survival

The STMT for embryo survival was determined to be 23°C in order to ensure maximum survival as determined by Siefert (1968). As discussed previously, spawning may occur within a temperature range of 10.5 to 27°C. Siefert (1968) indicated, however, that successful incubation and embryo survival was highest between 18.9 and 19.4°C, and decreased below 14.4°C and above 23°C.

Thermal Model Data Evaluation

Survival and growth of white crappie was ensured in more than 90 percent of its available habitat during the months of April, May, June and October (Figure 5-13). During July only 0.4 percent of the original habitat was available for survival which then decreased to 0 percent in August (Table 5-11). Thus, under modeled worst case operational conditions white crappie would be eliminated from Clinton Lake. Indeed, even under ambient conditions, STMT for survival was exceeded throughout the lake thus eliminating it from Clinton Lake (EIA, 1980). Although survival is unlikely under the modeled operational conditions, 47.0 and 25.7 percent of the habitats in July and August would allow adequate growth under the 30-day average temperature conditions (Table 5-12).

If survival were low, white crappie may be reintroduced into Clinton Lake by utilizing Illinois Power's rearing pond network. Currently there are three functional rearing ponds (two others scheduled to be constructed) that may be used to produce white crappie for reintroduction into the lake. These ponds are constructed in such a way that allow their complete draining directly into Clinton Lake, thus minimizing fish mortality relating to drawdown and transportation to release areas. White crappie is the only RIS species that may potentially be eliminated from the lake under 1955 conditions. Because of its vulnerability and its sport fishing value, under worst case conditions production in rearing ponds may be dedicated to white crappie in order to accelerate recovery of the population.

White crappie spawning is limited to the month of April (40.4 percent available habitat) (Table 5-13). Again, no spawning habitat is available

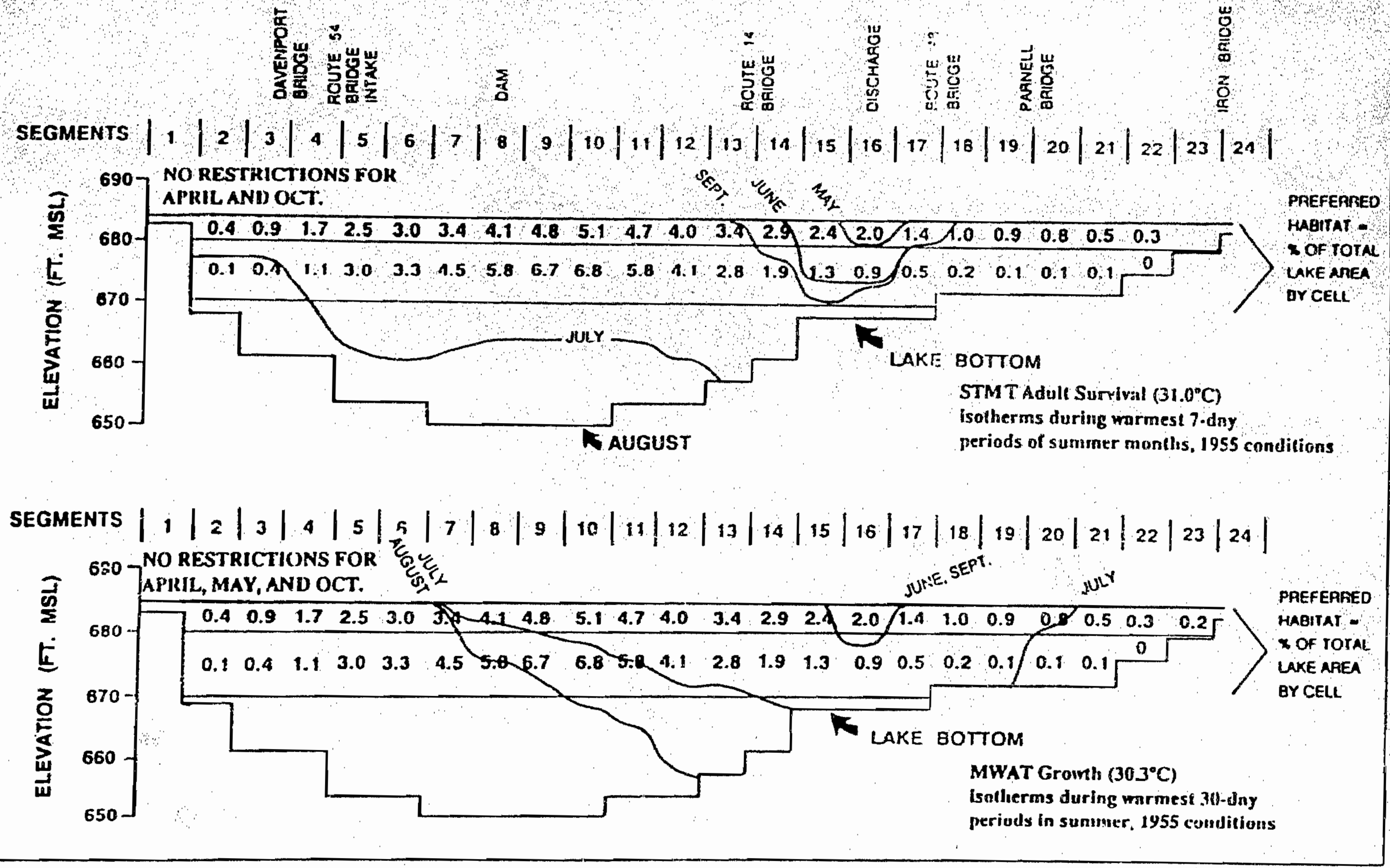

Figure 5-13
PERCENT PREFERRED HABITAT OF WHITE CRAPPIE RELATIVE TO TEMPERATURES ASSURING SURVIVAL AND GROWTH DURING OPERATION OF ONE UNIT OF CLINTON POWER STATION UNDER 100% LOAD AND 1955 METEOROLOGICAL CONDITIONS

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during the months of May and June under either operational or ambient conditions (Figures 5-14 and 5-15). Embryo survival is restricted to 57 percent of the preferred habitat in April and 21.9 percent of the habitat in May (Table 5-14). Again, the percentages of available habitat for embryo survival are greater than percentages of successful spawning habitat, increasing the likelihood of embryo survival and ultimate recruitment into the population.

Clinton Lake Fisheries Data

Summertime white crappie capture rates throughout the 1978-1987 monitoring period have documented low abundance of this species at Stations 8 and 13 with moderate to high capture rates at the remaining sampling stations (Table 5-26). Collections made in the summer of 1987 during preoperational testing revealed higher capture rates at all sampling stations compared to the preoperational average. This increase was particularly apparent at Stations 4.5, 4, 2 and 16. The overall increase in white crappie catch rates was evidently associated with increased populations throughout the lake. The increase in catch rates at Station 2 which documented summer temperatures of almost 30°C is important and suggests that no adverse association with the thermal effluent occurred in 1987. This is particularly important because the STMT for adult survival is 31°C and temperatures approaching 30.0°C apparently did not influence the distribution of white crappie in the lake..

Summary

White crappie is an important and abundant sport fish species. Angling is particularly popular for this species in the spring of the year. White crappie may be the most thermally sensitive of the RIS selected for evaluation.

Based upon the model operational temperatures, it is evident that under the worst case conditions utilized in this evaluation, white crappie may be eliminated from Clinton Lake due to lake-wide temperatures exceeding the STMT for survival in July and August. It is also apparent, under ambient model

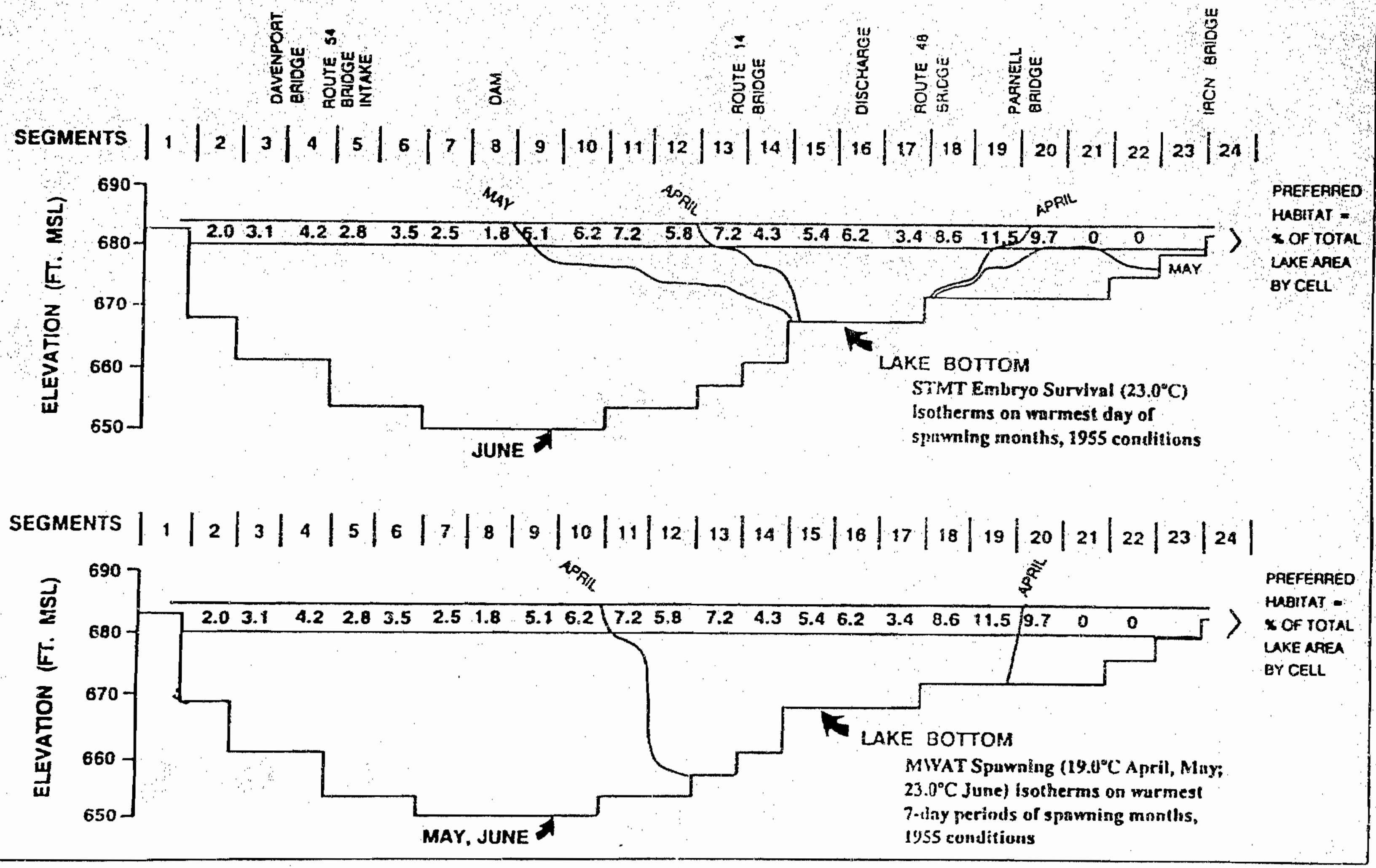

Figure 5-14

PERCENT SPAWNING HABITAT OF WHITE CRAPPIE RELATIVE TO TEMPERATURES ASSURING REPRODUCTION DURING OPERATION OF ONE UNIT OF THE CLINTON POWER STATION UNDER 1955 FLOW AND METEOROLOGICAL CONDITIONS

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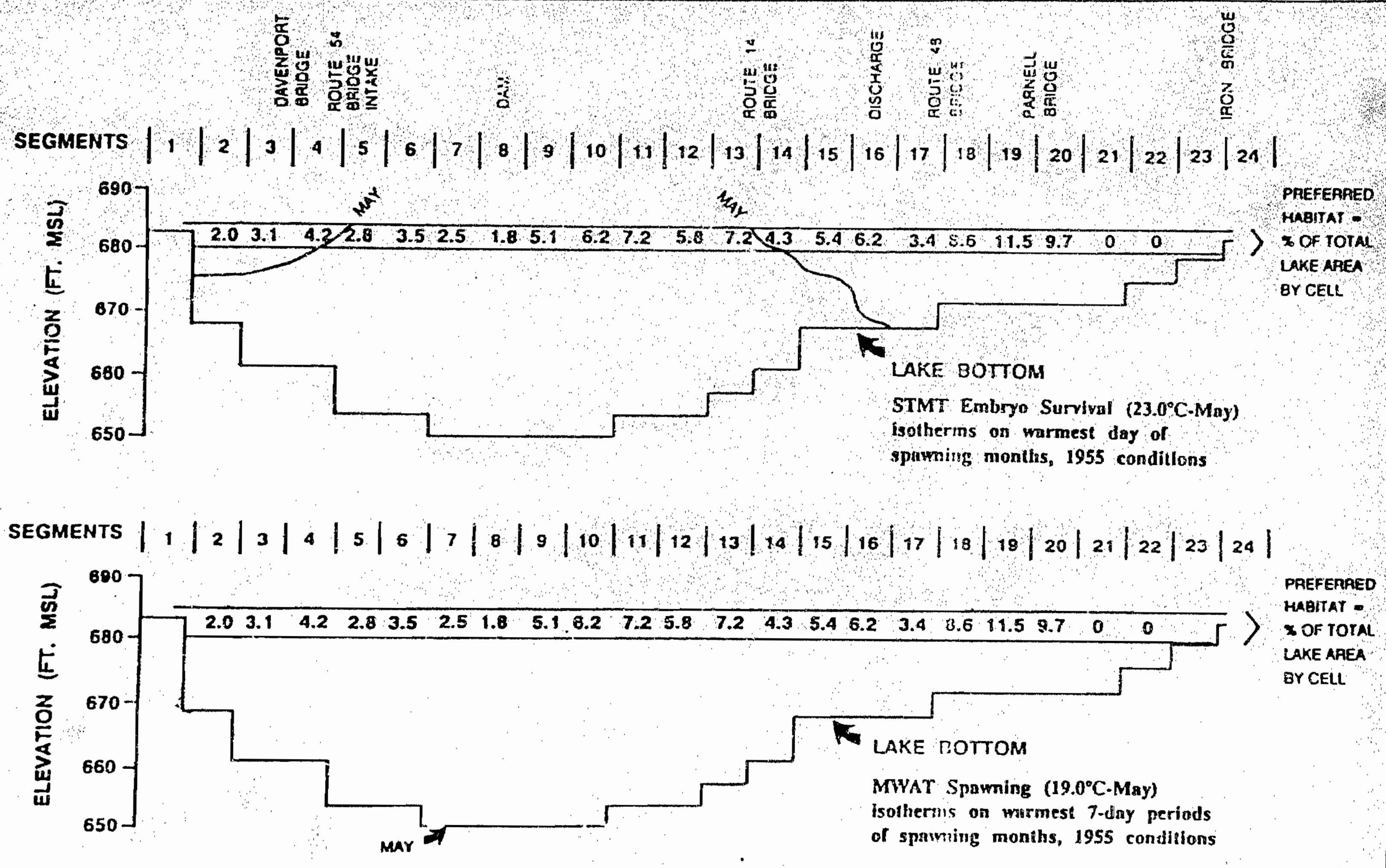

STMT Embryo Survival (23.0°C-May) isotherms on warmest day of spawning months, 1955 conditions

MWAT Spawning (19.0°C-May) isotherms on warmest 7-day periods of spawning months, 1955 conditions

Figure 5-15
PERCENT SPAWNING HABITAT OF WHITE CRAPPIE RELATIVE TO TEMPERATURES ASSURING REPRODUCTION UNDER AMBIENT 1955 FLOW AND METEOROLOGICAL CONDITIONS DURING THE MONTH OF MAY

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Table 5-26. Summary of Electrofishing Catch Per Effort (1 Hour) for White Crappie Collected During the Summer Season, Clinton Lake, 1978-1987

Study Year	Lake Sampling Stations					
	4.5	4	8	13	2	16
1978	1	1	0	--	0	0
1979	19	2	0	--	7	2
1980	36	22	3	--	3	6
1981	7	53	0	0	1	5
1982	44	34	9	0	33	72
1983	50	56	0	4	27	45
1984	95	27	2	2	85	18
1985	66	35	3	6	36	26
1986	121	79	5	13	48	55
1978-86 (average)	49	34	2	4	27	25
1987	95	113	2	14	75	120

Source: Illinois Power, 1978-1988.

conditions that elimination of white crappie would occur since the STMT for survival was exceed throughout the lake in August.

The modeled temperatures also indicate that springtime reproduction will be limited to April (a typical spawning month for this species along with May) where 40 percent of the preferred spawning habitat will remain sufficiently cool for successful reproduction (i.e., spawning and embryo survival) to occur.

In a worst case year, as modeled for this evaluation, white crappie spawning success will be limited in the spring and overall species survival unlikely during July and August. This situation would, however, also occur under ambient modeled conditions. To compensate for the loss of this species, Illinois Power would use its rearing ponds to restock white crappie, or other species should this worst case scenario occur.

5.7 COLD SHOCK

Although not addressed in the thermal model or in the species-specific evaluation the potential for cold shock occurs at all power plant sites. During normal plant operation in the winter, a large mass of heated water will be present in Clinton Lake. In the event of an interruption of the thermall discharge, the lake will begin to cool. Based upon the 1980 Thermal Demonstration, the cooling rate will vary between -0.07°C per hour and -0.008°C per hour. Although little species-specific cold shock data is available it has been determined that bluegill, a species apparently sensitive to cold shock, can survive a cooling rate of -0.11°C per hour (EIA, 1980) indicating that bluegill should not be influenced by cold shock at Clinton Lake.

The low potential for adverse impacts to Clinton Lake fish populations from cold shock is further emphasized by an interruption of the thermal discharge in the winter of 1988. During this outage, discharge temperatures dropped quickly and no fish mortality within the lake was documented.

6.0 COMPARISON TO PREVIOUS THERMAL DEMONSTRATION

The evaluation methods utilized in this evaluation were similar to those used in the 1980 evaluation. Thermal data for the model and the criteria temperatures, however, were updated for this study. Differences in the net results between the two studies are associated with the updated temperature data.

Evaluation criteria and the calculation of these criteria were the same in the two evaluations. Recent literature, however, has added to the published thermal data base for the RIS selected for evaluation. In general, this recent data enabled small increases in adult survival and growth temperatures over those established in 1980. Increases to bluegill spawning temperatures and decreases to white crappie spawning and embryo survival temperatures were also made in an effort to more accurately reflect these important temperatures (Table 6-1).

Comparison of available preferred habitat for adult survival and growth between the two study years are presented in Tables 6-2 and 6-3, respectively. Comparisons for spawning and embryo survival can not be made as their criteria were not thoroughly evaluated under 1955 modeled conditions in the 1980 study.

The adult survival data under the modeled worst case operational (1955) conditions indicate little substantive change in available preferred habitat for survival between the two studies. In general, no real net change was established for gizzard shad. Small increases (1988 versus 1980 study) in available preferred habitat were documented for bluegill and largemouth bass, whereas small decreases were established for channel catfish and white crappie. Large increases in available preferred habitat, however, were documented for common carp (Table 6-2).

Table 6-1. Comparison of Evaluation Criteria Temperatures Used During the 1980 and Current Thermal Demonstrations for Clinton Lake

Species	Evaluation Criteria	Temperatures (°C)		
		EIA, 1980*	Current Study	Net Difference
Gizzard shad	STMT Adult Survival	35	35.5	+0.5
	MWAT Growth	--	32.0	NA
	MWAT Spawning	20-29	21-29	0
	STMT Embryo Survival	29	29.0	0
Common carp	STMT Adult Survival	34	39	+5.0
	MWAT Growth	32	35	+3.0
	MWAT Spawning	21-26	21-26	0
	STMT Embryo Survival	26	26	0
Channel catfish	STMT Adult Survival	35.8	36	+0.2
	MWAT Growth	32	34	+20
	MWAT Spawning	27-29	27-29	0
	STMT Embryo Survival	29	29	0
Bluegill	STMT Adult Survival	35.5	37	+1.5
	MWAT Growth	33.0	34	+1.0
	MWAT Spawning	25-32	25-34	0 to +2.0
	STMT Embryo Survival	34	34	0
Largemouth bass	STMT Adult Survival	34.4	36	+1.6
	MWAT Growth	32.7	32.7	0
	MWAT Spawning	21	21	0
	STMT Embryo Survival	27	27	0
White crappie	STMT Adult Survival	31	31	0
	MWAT Growth	28	30.3	+2.3
	MWAT Spawning	19-27	19-23	0 to -4.0
	STMT Embryo Survival	27	23	0 to -4.0

* Basis for previously approved thermal limits.

Source: ESE, 1988.

Table 6-2. Comparison of Estimated Percent of Preferred Available Habitat in Clinton Lake with Temperatures Less than the STMT for Adult Survival for Each RIS During the Warmest 7-Day Periods Under Modeled 100 Percent Load and 1955 Meteorological Conditions

Species	Available Preferred Habitat (Percent) for Survival						
	April	May	June	July	August	September	October
Gizzard shad							
1988*	100	100	100	89	89	99	100
1980**	--	--	--	90	87	100	--
Difference	NA	NA	NA	-1	+2	-1	NA
Common carp							
1988	100	100	100	97	97	100	100
1980	--	--	--	70	73	97	--
Difference	NA	NA	NA	+27	+24	+3	--
Channel catfish							
1988	100	100	100	75	75	100	100
1980	--	--	--	82	74	99	--
Difference	NA	NA	NA	-7	+1	+1	--
Bluegill							
1988	100	100	100	96	96	100	100
1980	--	--	--	96	92	99	--
Difference	NA	NA	NA	0	+4	+1	NA
Largemouth bass							
1988	100	100	100	96	96	100	100
1980	--	--	--	92	85	99	--
Difference	NA	NA	NA	+4	+11	+1	NA
White crappie							
1988	100	98	92	0.4	0	89	100
1980	--	--	--	0	0	94	--
Difference	NA	NA	NA	+0.4	0	-5	NA

* Current Study.
** EIA, 1980 (basis for previously approved thermal limits.

Source: ESE, 1988.

Table 6-3. Comparison of Estimated Percent of Preferred Available Habitat in Clinton Lake with Temperatures Less than the MWAT for Growth for Each RIS During the Warmest 30-Day Periods Under Modeled 100 Percent Load and 1955 Meteorological Conditions

	Available Preferred Habitat (Percent) for Survival						
Species	April	May	June	July	August	September	October
Gizzard shad							
1988*	100	100	100	81	82	99	100
1980**	--	--	--	--	--	--	--
Difference	NA	NA	NA	NA	NA	NA	NA
Common carp							
1988	100	100	100	93	95	100	100
1980	--	--	--	72	60	90	--
Difference	NA	NA	NA	+21	+35	+10	NA
Channel catfish							
1988	100	100	100	75	77	100	100
1980	--	--	--	62	56	81	--
Difference	NA	NA	NA	+13	+21	+19	--
Bluegill							
1988	100	100	100	96	96	100	100
1980	--	--	--	96	93	97	--
Difference	NA	NA	NA	0	+3	+3	NA
Largemouth bass							
1988	100	100	100	89	96	99	100
1980	--	--	--	92	86	99	--
Difference	NA	NA	NA	-3	+10	0	NA
White crappie							
1988	100	100	98	47	26	99	100
1980	--	--	--	0	0	6	--
Difference	NA	NA	NA	+47	+26	+96	--

* Current Study.

** EIA, 1980 (basis for previously approved thermal limits).

Source: ESE, 1988.

Adult growth data for the RIS under the modeled conditions generally documented increased preferred habitat availability for most species during the current study compared to 1980 (Table 6-3).

The significance of the differences between the two studies is important in relation to the modeled temperatures. The modeled temperatures in the current study, utilizing the updated operational data, were higher than those used in the 1980 evaluation. Since available preferred habitat for survival remained relatively constant or increased considerably as in the case of common carp, and the habitat preferred for growth increased substantially for the RIS, it is evident that the increase in modeled worst case operational temperatures throughout Clinton Lake will not adversely affect the RIS species any more than was determined in the 1980 study.

7.0 SUMMARY AND CONCLUSIONS

Potential impacts to the Clinton Lake fishery resulting from Clinton Power Station thermal effluents under the worst case meteorological conditions and the unconstrained operation were examined. Temperatures predicted by the LARM were used to quantify areas of potential impact based on the USEPA protocol.

Six Representative Important Species (RIS) were selected for the analysis that represented the various reproductive and feeding guilds of the Clinton Lake fishery. These were gizzard shad, common carp, channel catfish, bluegill, largemouth bass, and white crappie. Potential impacts, of the worst case modeled conditions, to each of the RIS species were evaluated with respect to adult survival and growth, spawning, and embryo survival.

7.1 ADULT SURVIVAL

Adult survival of each of the RIS was evaluated using the STMT for adult survival. Specific results of these analyses includes the following:

- Survival of common carp, bluegill, and largemouth bass is ensured within >95 percent of their preferred habitats in July and August and 100 percent of their preferred habitats during other months;
- Channel catfish and gizzard shad exhibited moderate reductions in preferred habitat (75 and 89 percent availability respectively) during July and August; and
- White crappie is completely eliminated from Clinton Lake during July and August, necessitating restocking. Minor habitat reductions are evident in May, June, and September.

7.2 ADULT GROWTH

Potential impacts on growth of each RIS species were evaluated using the MWAT for growth. Potential impacts include the following:

- Growth of all RIS is virtually unaffected (i.e., no reductions) during the months of April to June, September, and October;

(>90 percent) but decreased steadily throughout the normal spawning period;

- Carp habitat availability was high in April (85 percent) but decreased to zero percent in July and August; and
- Survival of white crappie embryo was most restrictive of any RIS with only 57 percent habitat availability in April and 0 percent in June.

7.5 COMPARISON WITH PREVIOUS THERMAL EVALUATIONS

Evaluation methods in the current study and the 1980 study were similar. Minor changes were made in modeled temperatures and some criteria temperatures were based on more recent data to assess the worst case thermal conditions and impacts. Differences between the studies indicate negligible differences in preferred available habitat for adult survival and increases in available habitat for growth in the current study compared to 1980. This is significant in that modeled temperatures were higher in this study than in 1980 indicating that even though worst case temperatures may be higher than estimated in 1980, the impacts to the fishery will be similar to those previously determined.

7.6 GENERAL COMMENTS

The biological evaluation of the predicted worst case thermal discharges was undertaken using USEPA protocol as described in Brungs and Jones (1977). In addition to representing worst case thermal conditions, by utilizing unconstrained (i.e., 100 percent load) operating conditions in conjunction with worst case meteorological conditions (1955), this evaluation also includes 1955 water levels which will be approximately 5 feet below normal reservoir pool. This condition reduces the volume and area of the lake thereby reducing the amount of preferred (and available) habitat of RIS and other fish species available for this evaluation.

This biological evaluation, therefore, represents a conservative utilization of USEPA protocol. Similarly, the well documented beneficial impacts of increased temperatures within cooling lakes as demonstrated by increased growth through an extended growing season and early initiation of spawning by some species has not been emphasized in this evaluation.

The evaluated conditions using the most up-to-date data available has indicated little difference to RIS from that previously predicted in 1980, even though modeled lake water temperatures were higher in this evaluation. Some habitat restrictions associated with low water level and warm temperatures will be encountered by RIS under the modeled conditions. These restrictions, however, will not significantly impact any of the RIS evaluated except white crappie. This species would be severely impacted even without plant operation under 1955 conditions. Should white crappie be severely impacted by worst case conditions, Illinois Power Company has fish rearing ponds which could be utilized to restock this species.

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APPENDIX A

Temperature Summaries

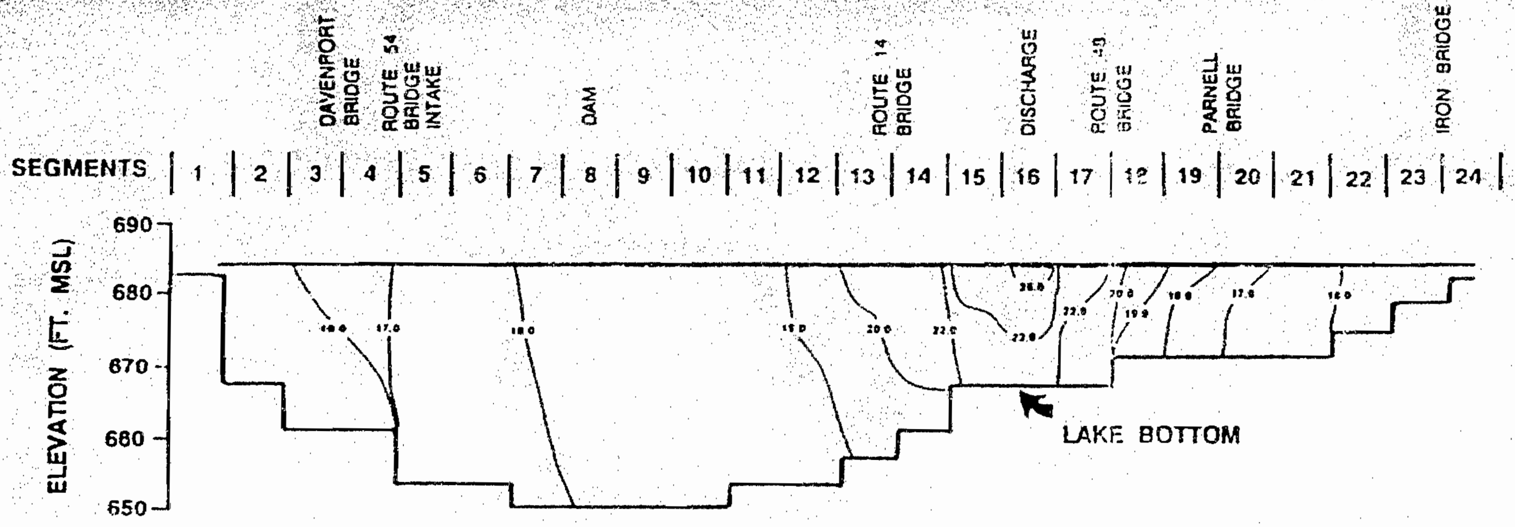

Figure A-13
HIGHEST 29-DAY AVERAGE WATER TEMPERATURE IN CLINTON LAKE FOR OCTOBER 1955 UNDER ONE UNIT OPERATION AT 100% LOAD

ENVIRONMENTAL SCIENCE
AND ENGINEERING, INC.

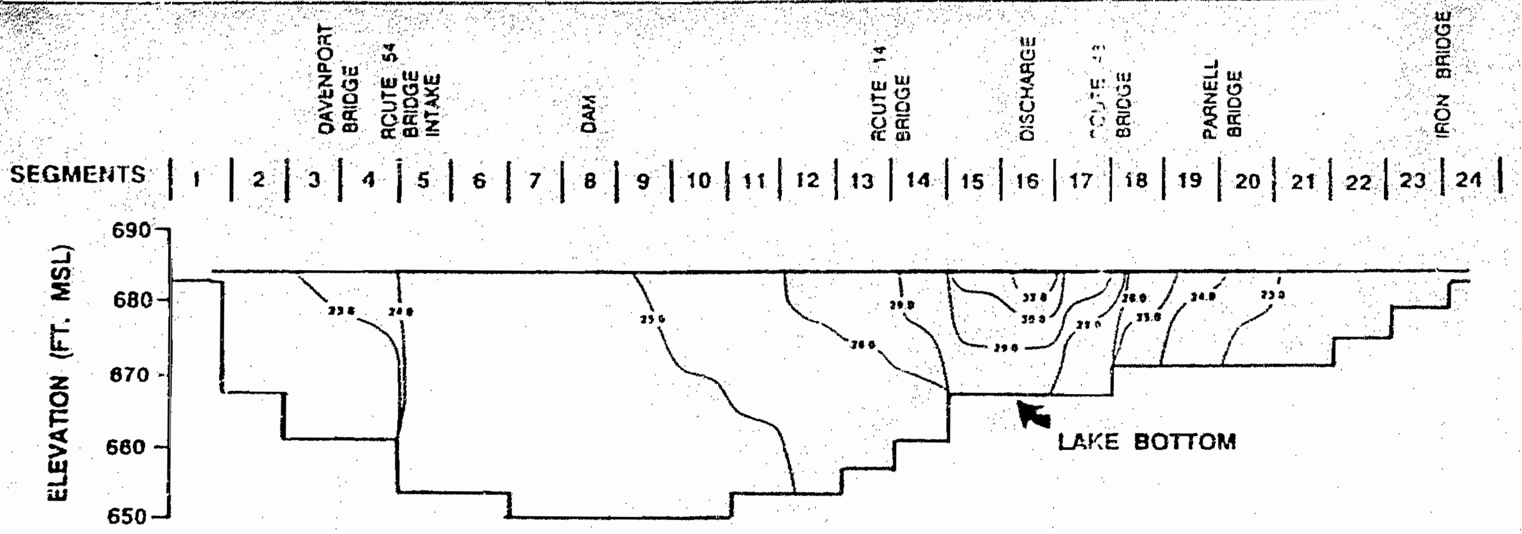

Figure A-12
HIGHEST 30-DAY AVERAGE WATER TEMPERATURE IN CLINTON LAKE FOR SEPTEMBER 1955 UNDER ONE UNIT OPERATION AT 100% LOAD

ENVIRONMENTAL SCIENCE
AND ENGINEERING, INC.

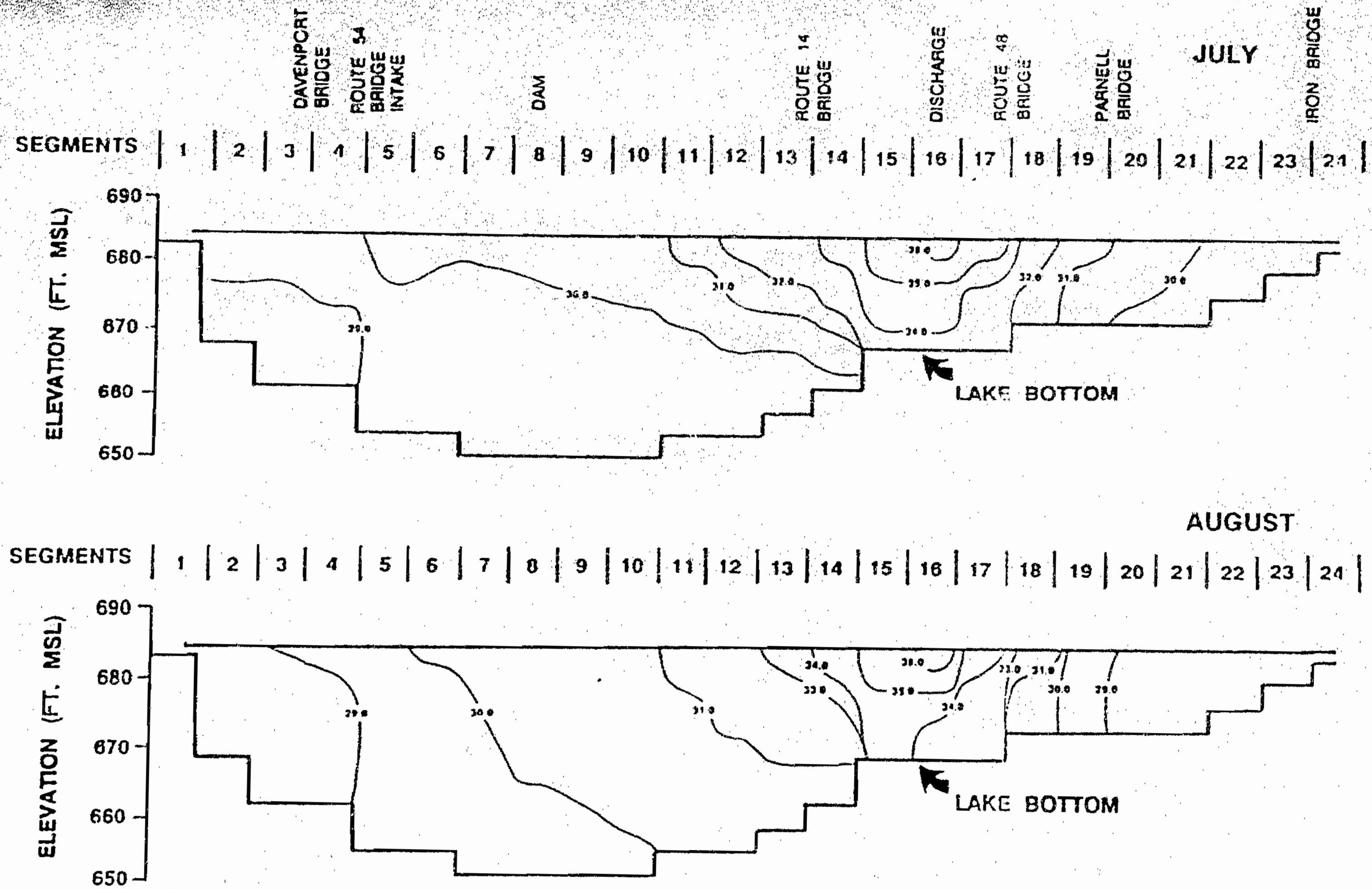

Figure A-11

HIGHEST 30-DAY AVERAGE WATER TEMPERATURE IN CLINTON LAKE FOR JULY-AUGUST 1955 UNDER ONE UNIT OPERATION AT 100% LOAD

ENVIRONMENTAL SCIENCE
AND ENGINEERING, INC.

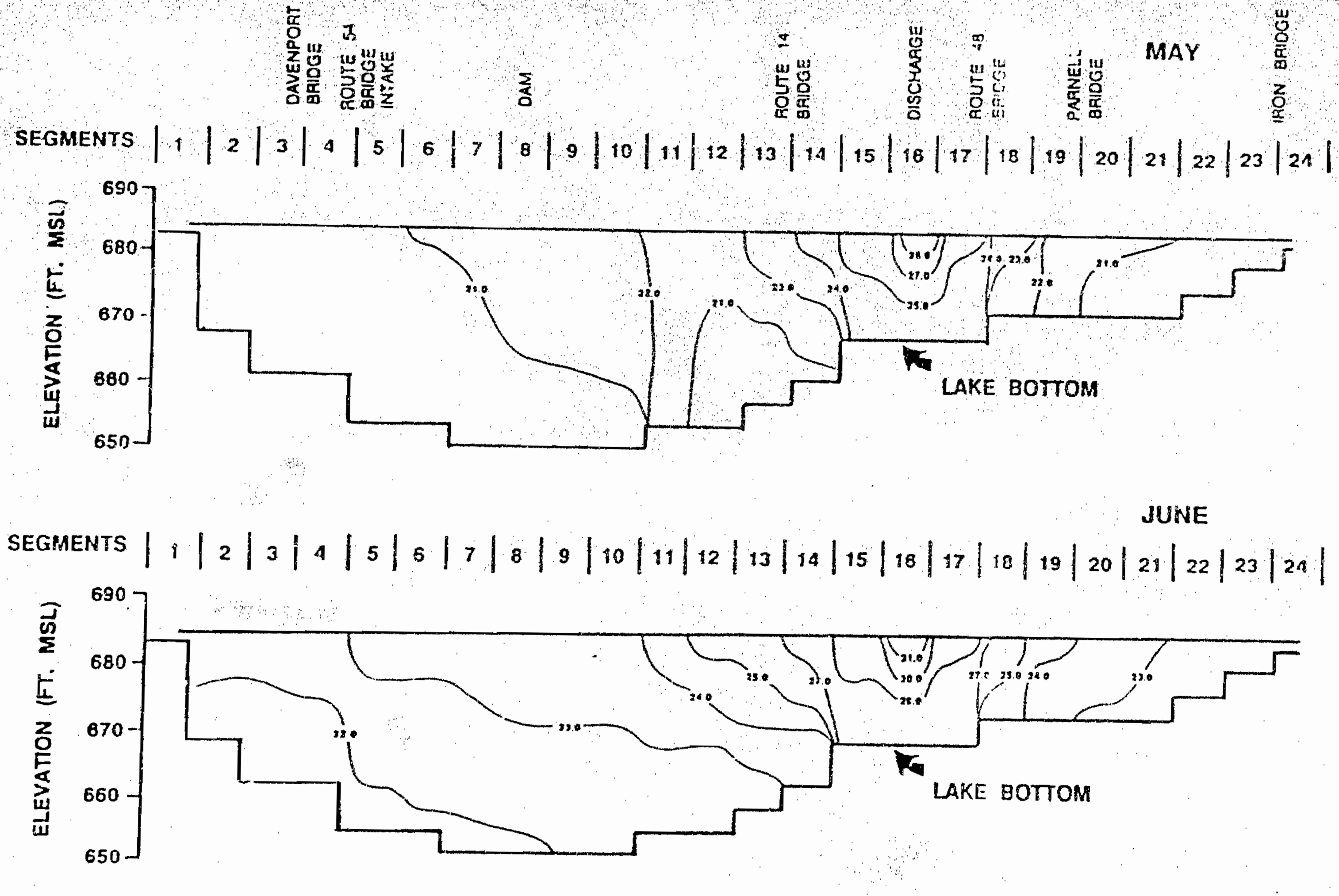

Figure A-10
HIGHEST 30-DAY AVERAGE WATER TEMPERATURE IN CLINTON LAKE FOR MAY-JUNE 1955 UNDER ONE UNIT OPERATION AT 100% LOAD

ENVIRONMENTAL SCIENCE
AND ENGINEERING, INC.

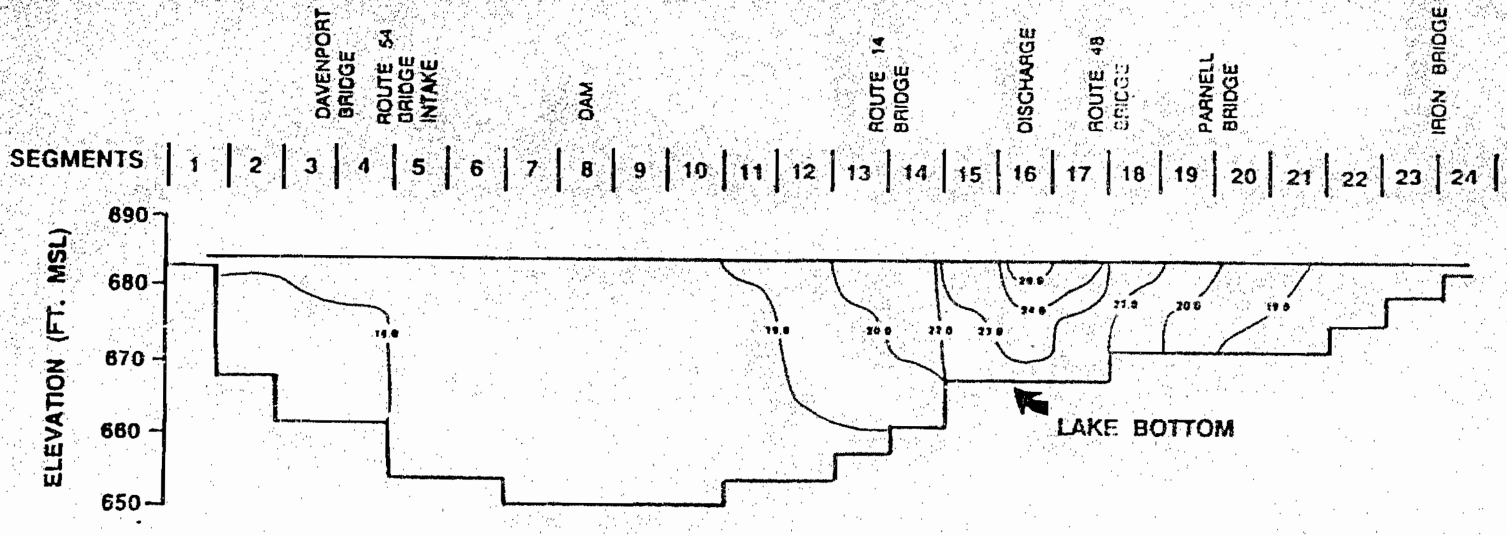

Figure A-9
HIGHEST 12-DAY AVERAGE WATER TEMPERATURE IN CLINTON LAKE FOR APRIL 1955 UNDER ONE UNIT OPERATION AT 100% LOAD

ENVIRONMENTAL SCIENCE AND ENGINEERING, INC.

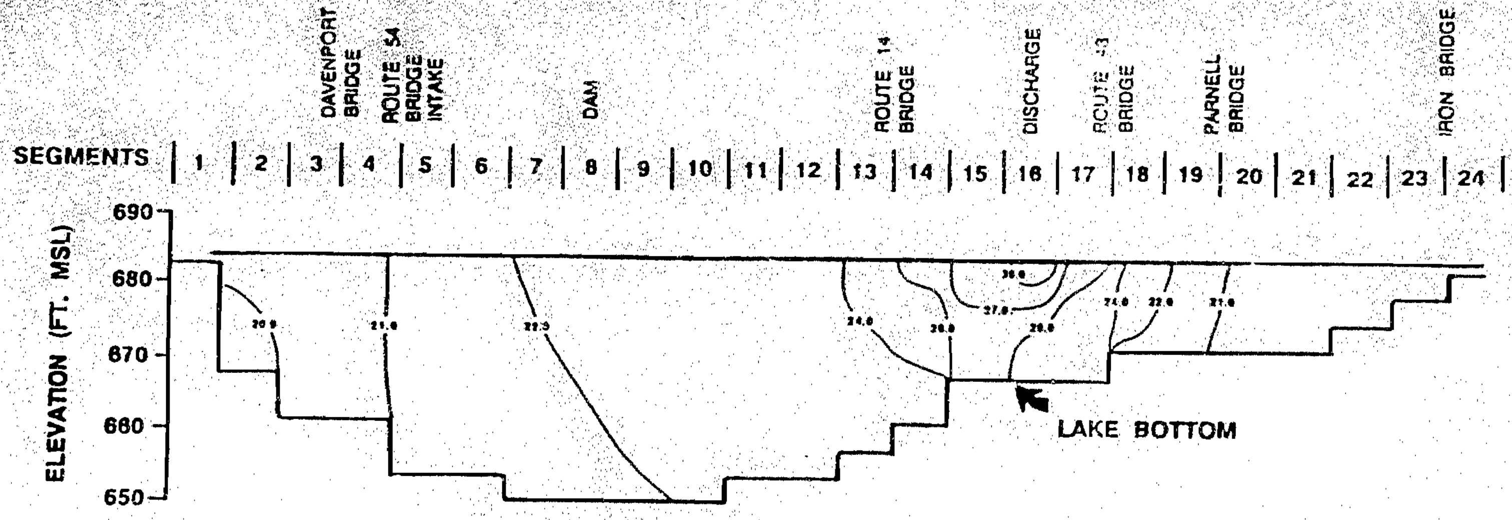

Figure A-8

HIGHEST 7-DAY AVERAGE WATER TEMPERATURE IN CLINTON LAKE FOR OCTOBER 1955 UNDER ONE UNIT OPERATION AT 100% LOAD

ENVIRONMENTAL SCIENCE
AND ENGINEERING, INC.

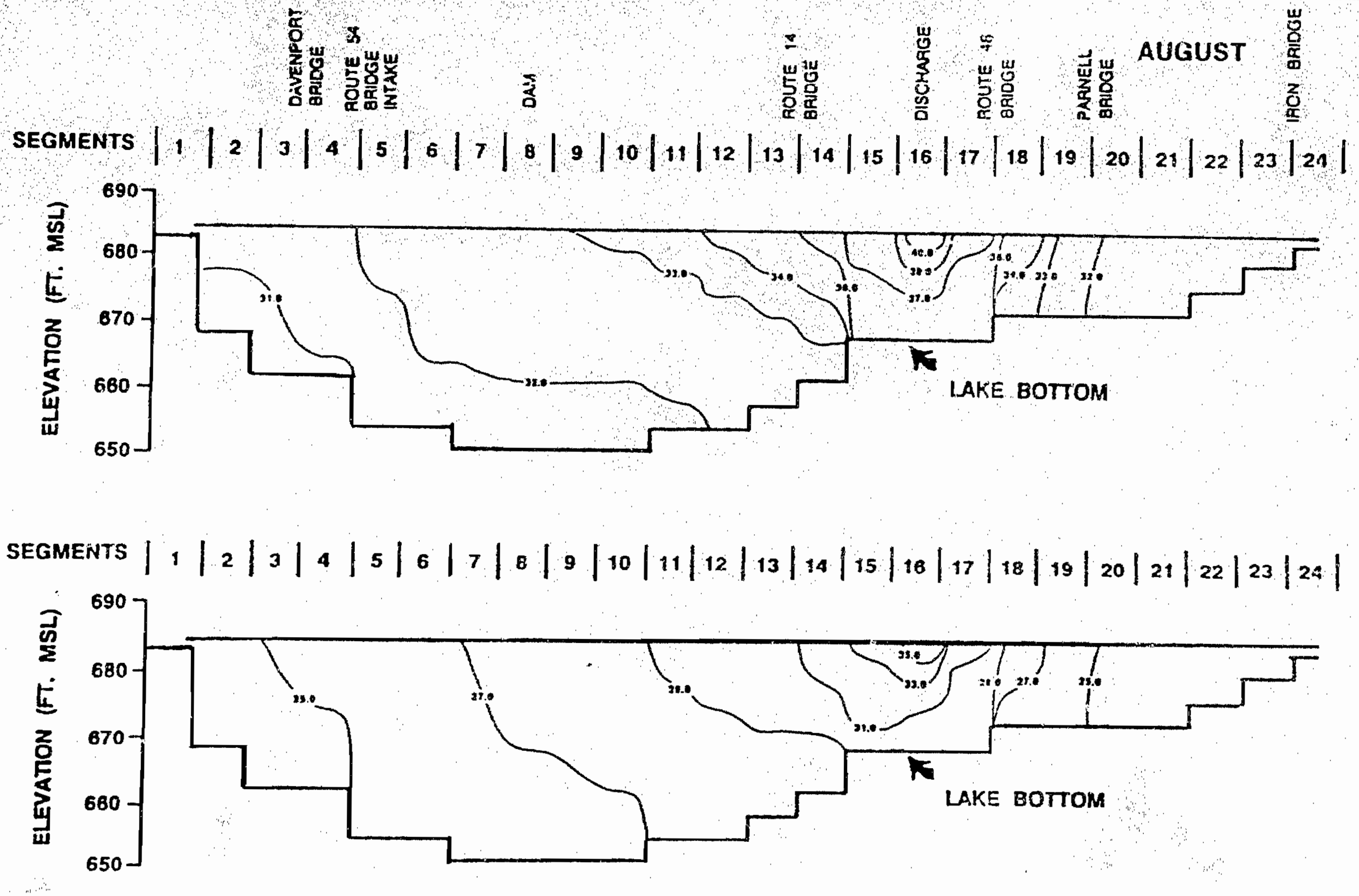

Figure A-7

HIGHEST 7-DAY AVERAGE WATER TEMPERATURE IN CLINTON LAKE FOR AUGUST-SEPTEMBER 1955 UNDER ONE UNIT OPERATION AT 100% LOAD

ENVIRONMENTAL SCIENCE
AND ENGINEERING, INC.

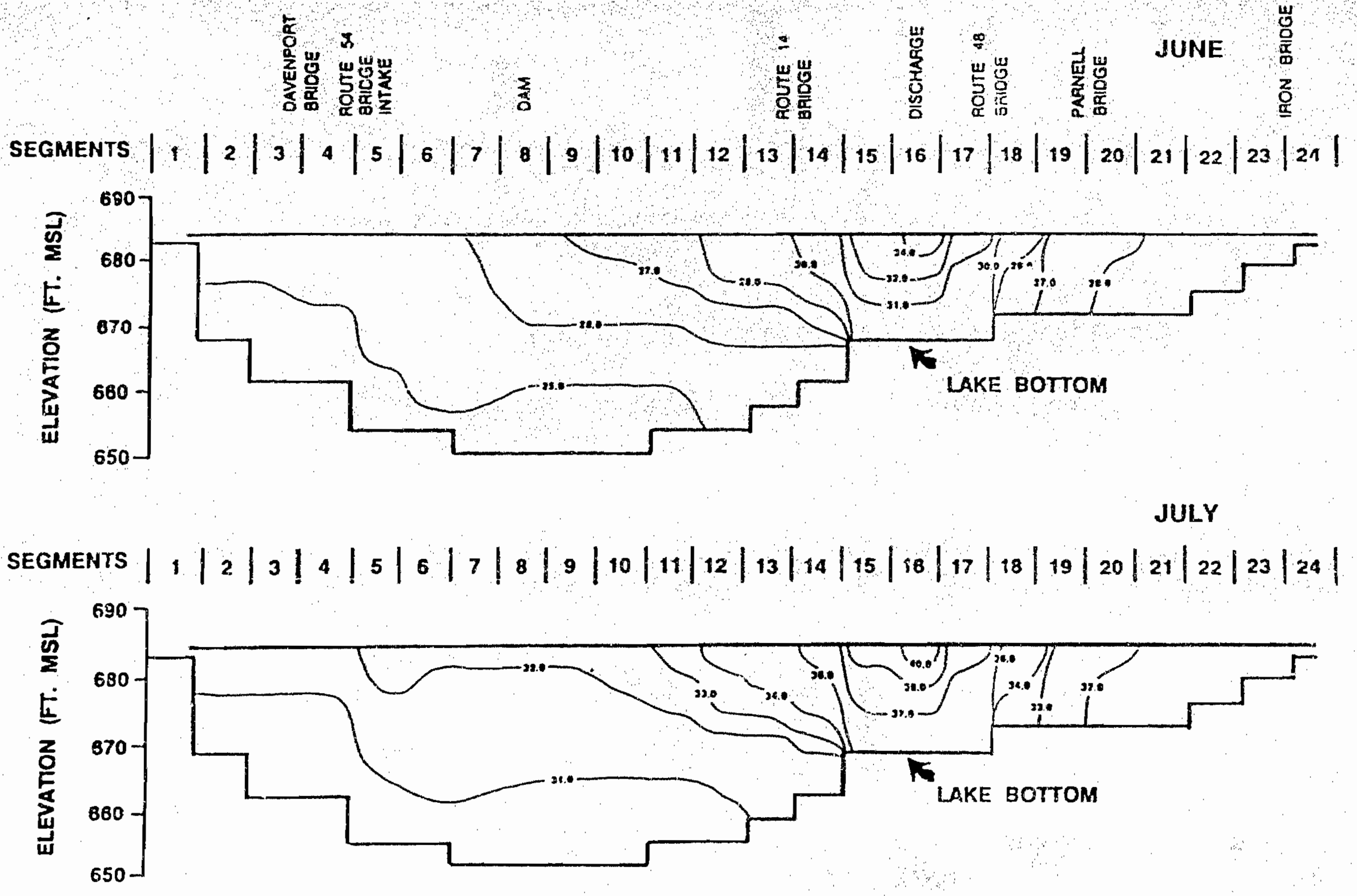

Figure A-6
HIGHEST 7-DAY AVERAGE WATER TEMPERATURE IN CLINTON LAKE FOR JUNE-JULY 1955 UNDER ONE UNIT OPERATION AT 100% LOAD

ENVIRONMENTAL SCIENCE
AND ENGINEERING, INC.

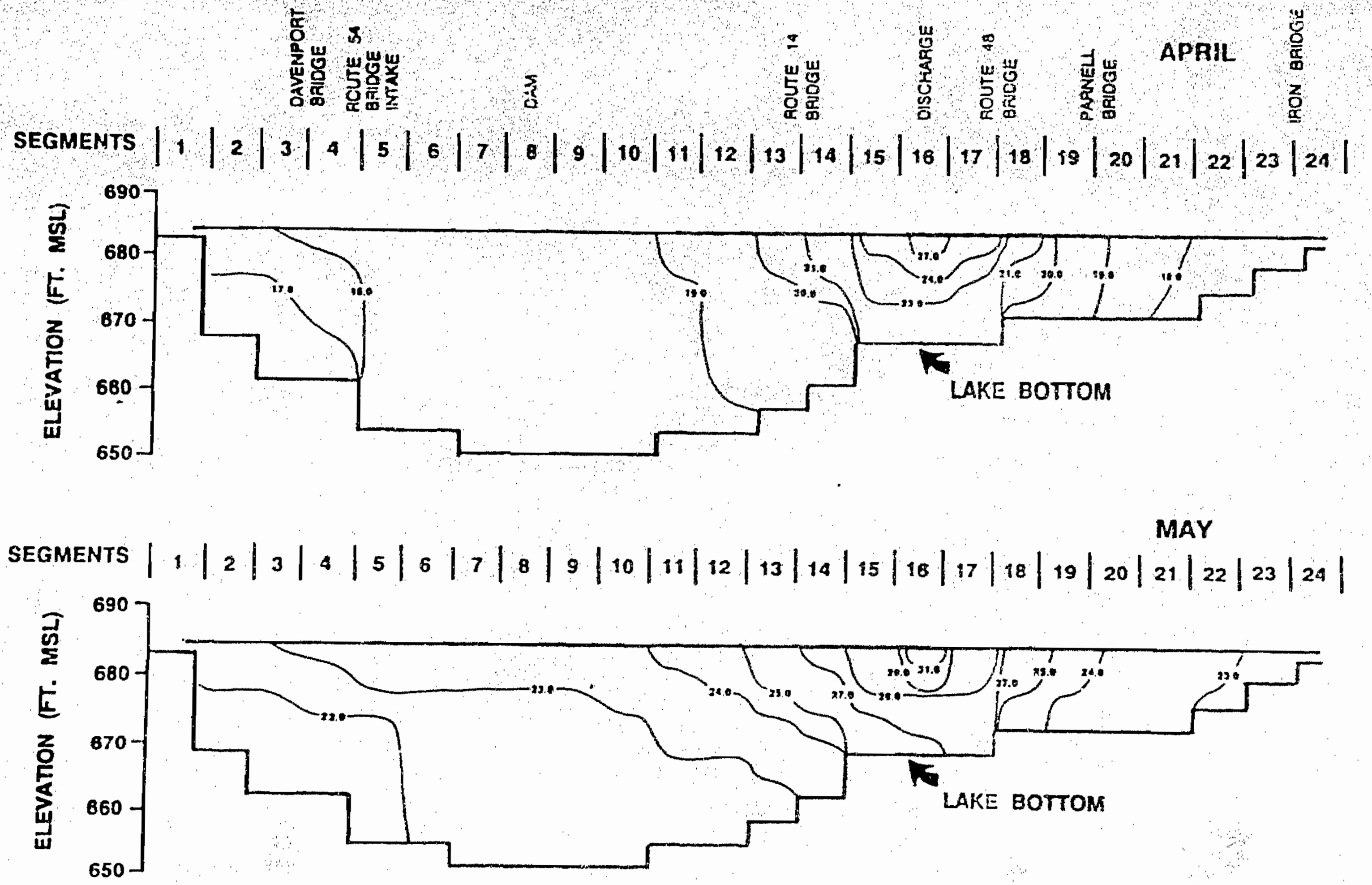

Figure A-5

HIGHEST 7-DAY AVERAGE WATER TEMPERATURE IN CLINTON LAKE FOR APRIL-MAY 1955 UNDER ONE UNIT OPERATION AT 100% LOAD

ENVIRONMENTAL SCIENCE
AND ENGINEERING, INC.

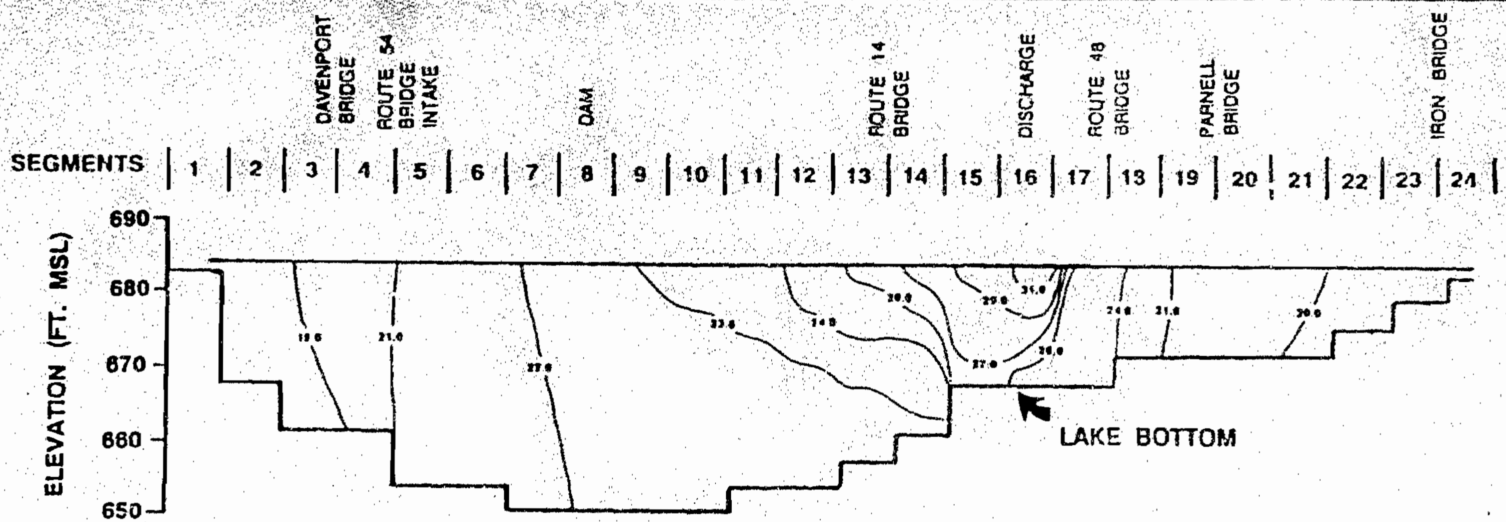

Figure A-4

HIGHEST 1-DAY AVERAGE WATER TEMPERATURE IN CLINTON LAKE FOR OCTOBER 1955 UNDER ONE UNIT OPERATION AT 100% LOAD

ENVIRONMENTAL SCIENCE
AND ENGINEERING, INC.

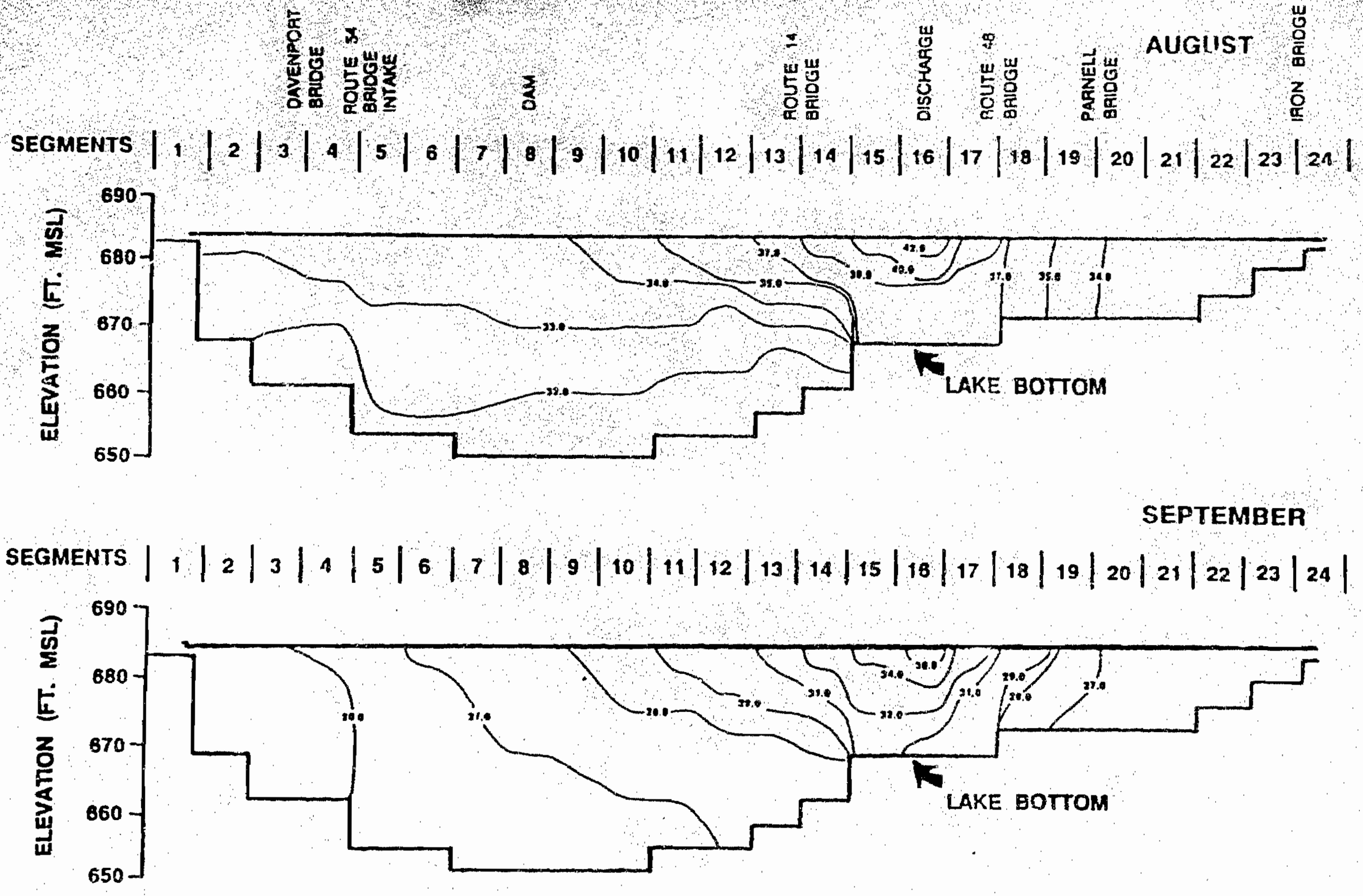

Figure A-3
HIGHEST 1-DAY AVERAGE WATER TEMPERATURE IN CLINTON LAKE
FOR AUGUST-SEPTEMBER 1955 UNDER ONE UNIT OPERATION AT 100% LOAD

ENVIRONMENTAL SCIENCE
AND ENGINEERING, INC.

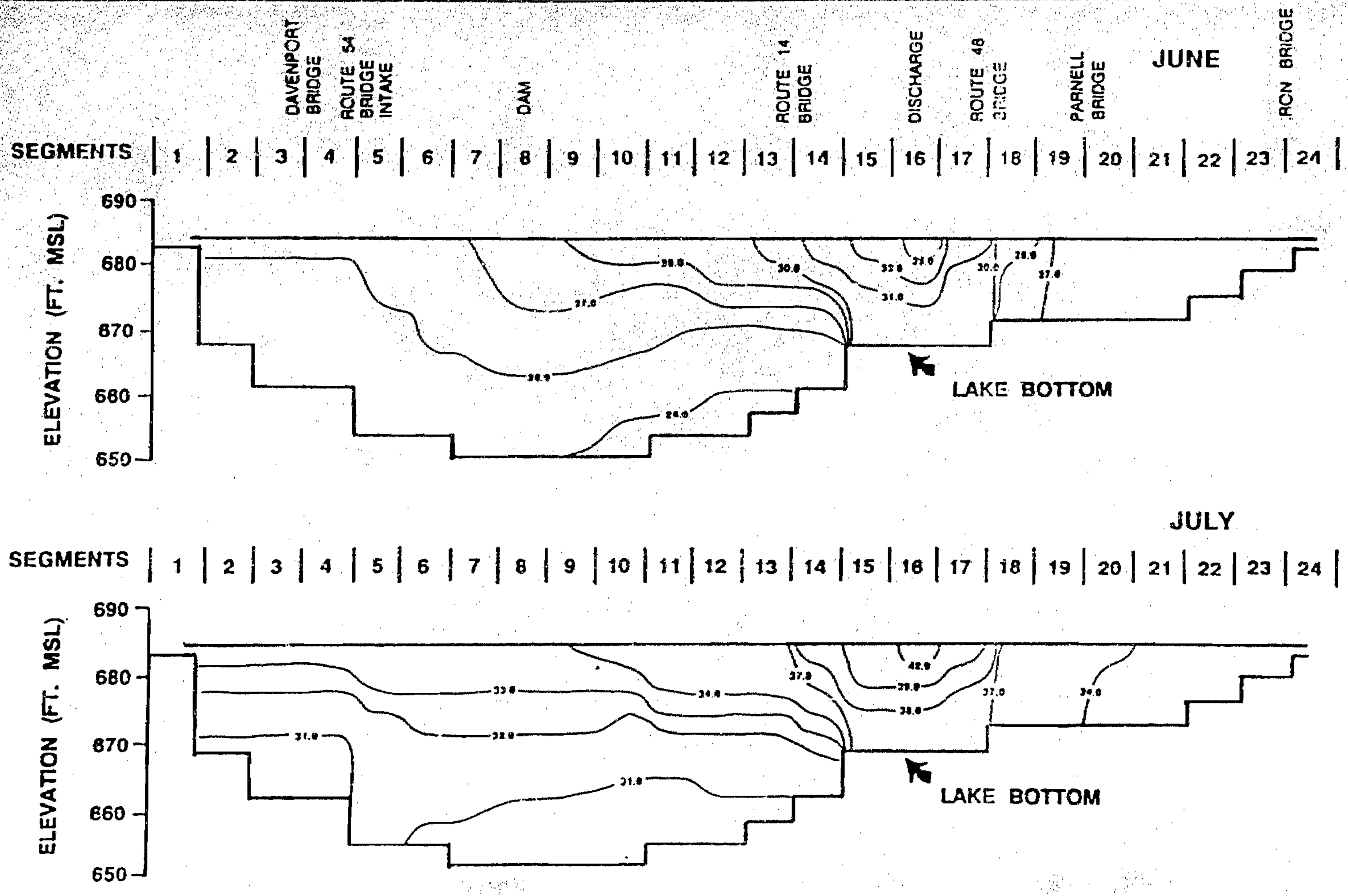

Figure A-2

HIGHEST 1-DAY AVERAGE WATER TEMPERATURE IN CLINTON LAKE FOR JUNE-JULY 1955 UNDER ONE UNIT OPERATION AT 100% LOAD

ENVIRONMENTAL SCIENCE
AND ENGINEERING, INC.

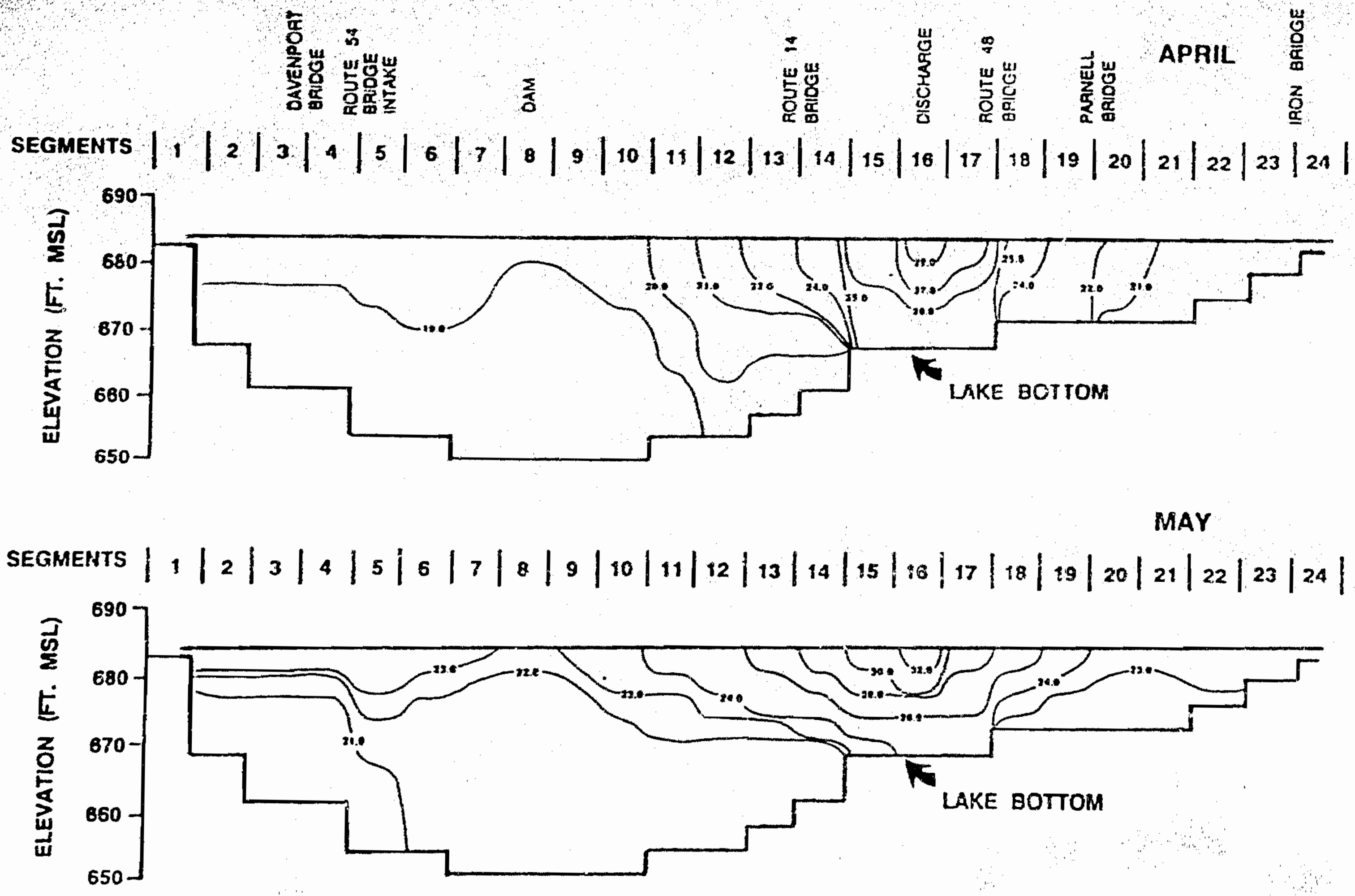

Figure A-1

HIGHEST 1-DAY AVERAGE WATER TEMPERATURE IN CLINTON LAKE FOR APRIL-MAY 1955 UNDER ONE UNIT OPERATION AT 100% LOAD

ENVIRONMENTAL SCIENCE AND ENGINEERING, INC.

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C-EC88-51/IPCB.1
03/30/89

ILLINOIS POLLUTION CONTROL BOARD
PCB NO. 88-97

PREPARED TESTIMONY OF
RICHARD E. HALL

My name is Richard E. Hall, and I live at 11255 Graben Drive, St. Ann, Missouri. Presently I am employed as Department Manager, Environmental Assessment and Toxicology Department of Environmental Science and Engineering, Inc. (ESE), 11665 Lilburn Park Road, St. Louis, Missouri. My area of technical specialization is aquatic biology. My academic training consists of a Bachelor of Science degree in environmental biology from Eastern Illinois University, Charleston, Illinois in 1975 and a Master of Science degree in zoology from Eastern Illinois University, Charleston, Illinois in 1977. I am a Certified Fisheries Scientist by the American Fisheries Society.

I have managed numerous projects dealing with aquatic ecology, primarily for the electric utility industry, and have participated in projects on the Missouri, Ohio, Illinois, Mississippi, Wabash, and Kaskaskia Rivers as well as a variety of cooling reservoirs including Duck Creek Reservoir, Gibbons Creek Reservoir, Newton Lake, Lake Baldwin, Lake Sangchris, Powerton Lake, Braidwood Cooling Pond, and Clinton Lake. I was appointed Environmental Assessment and Toxicology Department Manager for the Midwest Regional Office of ESE in 1986. My experience includes 316(a) studies at 22 midwestern power stations and 316(b) studies at nine stations. I am presently serving as Project Manager for the 1986/1988 Ohio River Ecological Research Programs. These research programs are sponsored by a consortium of midwestern utilities, including American Electric Power Service Corporation, TVA, and others. I recently served as Project Manager for a 316(b) study at the Thomas Hill Power Station (Missouri) on behalf of Associated Electric Cooperative, Inc. as well as Project Manager for a multidisciplinary thermal impact study at Gibbons Creek Station in Texas for the Texas Municipal Power Agency. Additionally, I managed a multi-year fisheries monitoring and impingement study at the Dresden Nuclear Station for Commonwealth Edison

Company as well as an oil spill study at Newton Lake for Central Illinois Public Service Company. At Central Illinois Light Company's Duck Creek Station, I managed a biological and thermal investigation to assess the fishery resources and to model existing and future thermal impacts.

Dr. John Edinger already has described the Clinton Lake hydrothermal model development and lake temperature structure. The scope of the study presented in Exhibit E included first an assessment of fisheries impacts under LARM 3 conditions and second a qualitative comparison of this impact to that expected under the presently permitted discharge temperature of 108.3°F. This impact assessment is detailed in Section 5 of Exhibit E. I had the lead technical responsibility for the preparation of that section and will briefly summarize its contents.

Exhibit E presents the detailed assessment of potential impacts on the Clinton Lake fishery modeled under LARM 3 conditions. This analysis is supplemental to that of the LARM 1,assessment previously submitted to the Illinois Pollution Control Board (PCB 81-82), and is intended to address the potential effects of discharge temperatures exceeding those currently permitted. Currently permitted discharge temperatures could be exceeded by one unit operation only during the summer months of July through September. The original assessment was restricted to this time period, but the current assessment reviewed the biologically important period of April through October.

The analysis focused on six species of fish: bluegill, largemouth bass, white crappie, gizzard shad, carp, and channel catfish. These representative, important species (RIS) were selected due to their abundance in Clinton Lake, their use as important species in the 1980 Thermal Demonstration and their importance in the reservoir either as a sport species or forage species. These species cumulatively can be considered representative of the range of potential reaction to the thermal loading of Clinton Lake and are important to the maintenance of a balanced fish community. Two species (black crappie and black bullhead) used in the 1980 demonstration were not evaluated in this demonstration. These species were not considered important representatives of the Clinton Lake fish community. In addition, their temperature tolerances are similar to other RIS selected for evaluation in this demonstration.

Potential adverse effects on survival, growth, and reproduction were evaluated to the extent possible for each species of fish. Impacts on survival and growth were examined using modeled LARM 3 conditions. LARM 3 conditions include 100 percent load, 1955 meteorological conditions, and a low reservoir level of 685.5 ft. msl. The original modeling (LARM 1) used 1955 as representing severe conditions for air temperatures and low lake level. Potential impacts on reproduction, including spawning and survival of embryos, were assessed for operational and ambient 1955 conditions because even the naturally occurring conditions in 1955, with no heat input from the station, would influence reproduction, growth and survival for each species.

The general procedure for evaluation of impact on survival, growth and reproduction of each species was as follows:

- Critical temperatures for survival, growth and reproduction were developed when possible from existing scientific literature, following U.S. Environmental Protection Agency protocol.
- The species-specific critical temperatures were applied to the predicted lake temperature results to define the boundary between acceptable water areas and those with excessively warm temperatures, during the warmest periods of each month.
- Preferred (that is, most typical) living and spawning habitats were defined for each species from existing scientific literature.
- Using information generated from Illinois Power Company's ongoing monitoring program, the distribution of these habitats within the Lake was determined.
- The distribution of acceptable temperature was compared to the distribution of preferred habitats, resulting in an estimate of the percentage of preferred habitat that would be thermally acceptable for each species in each month.
- The impacts, in terms of thermal exclusion areas under LARM 3 conditions were compared to the LARM 1 conditions detailed in the 1980 environmental assessment.

Evaluation methods in the LARM 3 study and the LARM 1 study were similar. Temperatures were updated to reflect more recent data on the temperature tolerances of fishes and were utilized to assess the predicted thermal conditions and impacts.

GLVHT Model Simulation

Since the completion of the biological evaluation presented in Exhibit E, Dr. Edinger has used the GLVHT model to predict lake temperatures under the 1 in 30 year conditions. Since the proposed temperature limits are based upon the 1 in 30 year lake temperatures, a new biological assessment was made using these predicted temperatures. The remainder of my testimony serves to update Exhibit E with the biological assessment for the 1 in 30 year lake temperatures. The GLVHT model temperatures were evaluated using the same criteria as detailed in Exhibit E. The results of the 1 in 30 year assessment were compared to the LARM 1 results which were the basis for the board's existing thermal limitation. The comparisons are shown in Tables 1 through 4, and illustrate the incremental biological impact associated with the proposed temperature limits.

Specific results of the impact assessment under GLVHT simulations for the 1 in 30 year lake temperatures are as follows:

ADULT SURVIVAL (Table 1)

- Impacts on survival habitat are minimal and similar to LARM 1 for bluegill, gizzard shad, largemouth bass, and less for carp.
- Survival habitat was not available for white crappie in either study or under ambient conditions in LARM 1.
- The amount of habitat for survival of channel catfish was reduced from 82 percent to 67 percent.

ADULT GROWTH (Table 2)

- Impacts on habitat for growth are minimal and similar to LARM 1 for gizzard shad, bluegill, largemouth bass and less for carp and channel catfish.
- Habitat for growth for white crappie was not available in July and August under LARM 1 and minimally available under GLVHT 1 in 30.

Habitat availability in September however was greater under the GLVHT study.

SPAWNING (Table 3)

Habitat availability for spawning was not evaluated during the LARM 1 study. Under 1 in 30 year GLVHT modeled conditions:

- Spawning of gizzard shad is restricted to April and May;
- Spawning of common carp is restricted to April;
- Spawning of channel catfish is limited to April and May, with habitat restrictions;
- Bluegill spawning is not available in May and June and restricted in July and August;
- Largemouth bass spawning is restricted to April; and
- White crappie spawning is not available under the modeled conditions.

EMBRYO SURVIVAL (Table 4)

In general, embryo survival restrictions are less severe than the spawning restrictions for each species and month. Consequently when successful spawning occurs available embryo survival habitat exceeds available spawning habitat for the GLVHT modeled conditions.

GENERAL COMMENTS

The biological evaluation, both in Exhibit E and as supplemented by this testimony, used the USEPA protocol as described in Brungs and Jones (1977). The evaluation included abnormally warm thermal conditions described in the modeling study and the lake at approximately 5 feet below normal pool. This water level condition reduces the volume and area of the lake thereby reducing the amount of preferred (and available) habitat of RIS and other fish species available for this evaluation.

This biological evaluation, therefore, represents a conservative utilization of USEPA protocol. Similarly, the well documented beneficial impacts of increased temperatures within cooling lakes, as demonstrated by increased growth through an extended growing season and early initiation of spawning by some species, was not considered in this evaluation. Further limitations of the protocol are discussed in subsequent testimonies.

The evaluated conditions using the most up-to-date data available has indicated little difference to RIS from that previously predicted in 1980, even though modeled lake water temperatures were higher in this evaluation. Some habitat restrictions associated with low water level and warm temperatures will be encountered by RIS under various modeled conditions. These restrictions, however, will not significantly impact any of the RIS evaluated except white crappie. This species would be severely impacted even without plant operation under ambient 1955 conditions as well as under modeled conditions.

The Clinton Lake aquatic community is monitored by Illinois Power Company's ongoing monitoring program as previously described. Additionally, a fisheries management program is being conducted jointly by Illinois Power Company and the Illinois Department of Conservation to enhance the sport fishery in the lake.

Based on all these considerations, we concluded that under the modeled conditions, operation of one Clinton Power Station generating unit will not adversely affect maintenance of a balanced and diverse fishery in Clinton Lake. Further studies, such as, Illinois Power Company's continuing Environmental Monitoring Program will provide valuable data in assessing any influence Clinton Station operations may have on the fishery of Clinton Lake.

Table 1. Comparison of Estimated Percent of Preferred Available Habitat in Clinton Lake with Temperatures Less than the STMT for Adult Survival for Each RIS During the Warmest 7-Day Periods Under Modeled Conditions

Species	Available Preferred Habitat (Percent) for Survival						
	April	May	June	July	August	September	October
Gizzard shad							
GLVHT (1 in 30)*	100	100	94.1	86.7	86.7	97.1	100
LARM 1 (1955)+	--	--	--	90	87	100	--
Difference	NA	NA	NA	-3.3	-0.3	-2.9	NA
Common carp							
GLVHT (1 in 30)	100	100	100	95.5	95.5	100	100
LARM 1 (1955)	--	--	--	70	73	97	--
Difference	NA	NA	NA	+25.5	+22.5	+3.0	NA
Channel catfish							
GLVHT (1 in 30)	100	100	95.9	69.1	69.1	95.9	100
LARM 1 (1955)	--	--	--	82	74	99	--
Difference	NA	NA	NA	-12.9	-4.9	-3.1	NA
Bluegill							
GLVHT (1 in 30)	100	100	98.7	98.3	98.3	98.7	100
LARM 1 (1955)	--	--	--	96	92	99	--
Difference	NA	NA	NA	+2.3	+6.3	-0.3	NA
Largemouth bass							
GLVHT (1 in 30)	100	100	99	95.5	95.5	99	100
LARM 1 (1955)	--	--	--	92	85	99	--
Difference	NA	NA	NA	+3.5	+10.5	0	NA
White crappie							
GLVHT (1 in 3	100	87.6	25.5	0	0	46.9	98.0
LARM 1 (1955)	--	--	--	0	0	94	--
Difference	NA	NA	NA	0	0	-47.1	NA

* One in 30 year conditions for each month.

\+ EIA, 1980 (basis for previously approved thermal limits).

Source: Hunter/ESE, 1989.

Table 2. Comparison of Estimated Percent of Preferred Available Habitat in Clinton Lake with Temperatures Less than the MWAT for Growth for Each RIS During the Warmest 30-Day Periods Under Modeled Conditions

	Available Preferred Habitat (Percent) for Growth						
Species	April	May	June	July	August	September	October
Gizzard shad							
GLVHT (1 in 30)*	100	98	92.0	69.3	69.3	97.1	100
LARM 1 (1955)+	--	--	--	--	--	--	--
Difference	NA	NA	NA	NA	NA	NA	NA
Common carp							
GLVHT (1 in 30)	100	100	97.4	87.5	87.5	100	100
LARM 1 (1955)	--	--	--	72	60	90	--
Difference	NA	NA	NA	+15.5	+27.5	+10.0	NA
Channel catfish							
GLVHT (1 in 30)	100	100	97.2	66.3	66.3	98.6	100
LARM 1 (1955)	--	--	--	62	56	81	--
Difference	NA	NA	NA	+4.3	+10.3	+17.6	NA
Bluegill							
GLVHT (1 in 30)	100	100	98.7	95.1	95.1	98.7	100
LARM 1 (1955)	--	--	--	96	93	97	--
Difference	NA	NA	NA	-0.9	+2.1	+1.7	NA
Largemouth bass							
GLVHT (1 in 30)	100	100	98	95.5	95.5	99	100
LARM 1 (1955)	--	--	--	92	86	99	--
Difference	NA	NA	NA	+3.5	+9.5	0	NA
White crappie							
GLVHT (1 in 30)	100	97.5	80.5	4.6	4.6	81.7	100
LARM 1 (1955)	--	--	--	0	0	6	--
Difference	NA	NA	NA	+4.6	+4.6	+75.7	NA

* One in 30 year conditions for each month.
+ EIA, 1980 (basis for previously approved thermal limits).

Source: Hunter/ESE, 1989.

Table 3. Comparison of Estimated Percent of Preferred Available Habitat in Clinton Lake with Temperatures Less than the MWAT for Spawning for Each RIS During the Warmest 7-Day Periods Under Modeled Conditions

	Available Preferred Habitat (Percent) for Spawning				
Species	April	May	June	July	August
Gizzard shad					
GLVHT (1 in 30)*	30.7	5.1	0	--	--
LARM 1 (1955)	--	--	--	--	--
Difference	NA	NA	NA	NA	NA
Common carp					
GLVHT (1 in 30)	30.7	0	0	--	--
LARM 1 (1955)	--	--	--	--	--
Difference	NA	NA	NA	NA	NA
Channel catfish					
GLVHT (1 in 30)	90.2	5.1	0	0	--
LARM 1 (1955)	--	--	--	--	--
Difference	NA	NA	NA	NA	NA
Bluegill					
GLVHT (1 in 30)	93.8	0	0	37.9	37.9
LARM 1 (1955)	--	--	--	--	--
Difference	NA	NA	NA	NA	NA
Largemouth bass					
GLVHT (1 in 30)	30.7	0	0	--	--
LARM 1 (1955)	--	--	--	--	--
Difference	NA	NA	NA	NA	NA
White crappie					
GLVHT (1 in 30)	0	0	0	--	--
LARM 1 (1955)	--	--	--	--	--
Difference	NA	NA	NA	NA	NA

* One in 30 year conditions for each month.

Source: Hunter/ESE, 1989.

Table 4. Comparison of Estimated Percent of Preferred Available Habitat in Clinton Lake with Temperatures Less Than the STMT for Embryo Survival for Each RIS During the Warmest Single Day Under Modeled Conditions

Species	Available Preferred Habitat (Percent) for Survival				
	April	May	June	July	August
Gizzard shad					
GLVHT (1 in 30)*	93.8	24.5	0	--	--
LARM 1 (1955)	--	--	--	--	--
Difference	NA	NA	NA	NA	NA
Common carp					
GLVHT (1 in 30)	85.0	0	0	0	0
LARM 1 (1955)	--	--	--	--	--
Difference	NA	NA	NA	NA	NA
Channel catfish					
GLVHT (1 in 30)	90.2	24.4	0	0	--
LARM 1 (1955)	--	--	--	--	--
Difference	NA	NA	NA	NA	NA
Bluegill					
GLVHT (1 in 30)	100	93.8	73.5	30.7	30.7
LARM 1 (1955)	--	--	--	--	--
Difference	NA	NA	NA	NA	NA
Largemouth bass					
GLVHT (1 in 30)	88.4	0	0	--	--
LARM 1 (1955)	--	--	--	--	--
Difference	NA	NA	NA	NA	NA
White crappie					
GLVHT (1 in 30)	37.9	0	0	--	--
LARM 1 (1955)	--	--	--	--	--
Difference	NA	NA	NA	NA	NA

* One in 30 year conditions for each month.

Source: Hunter/ESE, 1989.

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Revision: 1
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Project No. 8888-08
Non-Safety Related

Illinois Power Company

Supplemental Passive Cooling of Circulating Water
At Clinton Power Station - Unit 1

Prepared By: / T. G. Zaki Date: 10-22-91
H. J. Nielsen/T. G. Zaki

Reviewed By: Date: 10/22/91
S. C. Mehta

Approved By: Date: 10/22/91
R. J. Peterson

TABLE OF CONTENTS

1.0 INTRODUCTION

Sargent & Lundy (S&L) has prepared this report at the request of Illinois Power Company (IPC) to investigate the possibility of using passive cooling techniques in order to limit the circulating water discharge temperature to Clinton cooling lake to 99°F (daily average temperature). In the course of the investigation, S&L performed the following tasks:

1. Evaluate the drop in circulating water temperature due to natural cooling at the surface of the discharge flume and at drop structures.

2. Propose different techniques for cooling the circulating water in the discharge flume by passive means in order to limit the discharge to Clinton cooling lake to 99°F for summer conditions.

3. Provide a technical and economic evaluation of the passive techniques considered, and recommend as to whether any of these techniques are feasible.

This report briefly presents the results of Task 1. In regard to Tasks 2 and 3, different passive cooling methods are presented subsequently, each method is evaluated technically and economically, and a conclusion is drawn regarding its feasibility.

2.0 HISTORICAL REVIEW

Since 1972, a number of studies have been performed using the S&L computer program LAKET in order to evaluate the performance of Clinton cooling lake under different operating conditions. References 1, 2, 3 and 4 are examples of these studies.

Also, a number of studies were performed by S&L to evaluate the performance of "non-passive" supplemental cooling systems that could be used to limit the discharge to the cooling lake to a specific predetermined temperature.

Reference 5 considers the possibility of using mechanical draft cooling towers, natural draft cooling towers or spray modules to limit the discharge flume temperature to a range of 90°F to 95°F.

In reference 6, the feasibility of using a cooling scheme where cooled water from Clinton lake is used to dilute the water discharged from the spray canal, thereby maintaining a 96°F discharge temperature to the lake, is investigated. This study concluded that no scheme using dilution is economically justified when compared to a scheme using only spray modules. Spray module performance is evaluated in reference 7, while in reference 8 an economic comparison is made between cooling towers and spray modules.

Spray module performance is further evaluated in reference 9. In reference 10, the previous study of spray modules versus cooling towers is updated, and two additional schemes, gravity flow cooling towers and spray cooling with dilution, are investigated.

3.0 OPERATING CONDITIONS AND DISCHARGE TEMPERATURE LIMITS

Based on references 11 and 12, the surface area of the discharge flume is approximately 2.868×10^6 ft^2, the average cross sectional area is 2067 ft^2. The typical temperature rise across the condenser is 23°F, the circulating water flow, with three circulating pumps, is 610,000 gpm, and the service water flow is 39,000 gpm. This amounts to a total plant heat rejection of about 1.793×10^{11} Btu/day.

The meteorological conditions used throughout this report are based on reference 13. The 1% dry bulb ambient temperature is 95°F, with a daily range of 21°F, the 1% wet bulb temperature is 79°F, and the corresponding average wind speed is approximately 7 mph (5.8 mph at 2-ft. level). The short-wave solar radiation, for clear sky conditions, is 2,550 Btu/ft^2/day. A net short-wave solar radiation of 2,008 Btu/ft^2/day is considered, assuming a cloud cover of 50% and water reflectance of 6%.

Based on reference 14, and on the above meteorological conditions, the equilibrium temperature, T_E, of a water body at Clinton site is estimated at 86.8°F. This is the "natural" surface temperature of both the discharge flume and the cooling lake.

Reference 14 is also used to calculate the coefficient of heat transfer at the discharge flume surface. Based on the above weather and operating conditions, this is estimated at 303.7 Btu/ft^2/°F/day. The heat flux at the discharge flume surface is dependent upon the heat transfer coefficient at that surface, the surface area and the difference between the surface temperature and the equilibrium temperature of the circulating water in the discharge flume. Based on these values, the heat loss over the entire surface of the discharge flume is estimated at 2.003×10^{10} Btu/day.

This gives rise to about 2.57°F drop in the temperature of the circulating water due to natural cooling at the surface of the discharge flume.

The contribution of the drop structures to the cooling of circulating water is also estimated. The heat loss due to evaporative cooling is dependent upon the wind speed, the projected area of the water spray created by the drop structure, and the difference between the enthalpy of saturated air at the water surface temperature and that of saturated air evaluated at the ambient wet bulb temperature. Based on these values, the heat loss due to the natural water spray at the drop structures is estimated at 4.73×10^{8} Btu/day, giving rise to a drop in the temperature of circulating water of only 0.06°F.

The present plant operating permit thermal limitations are that the daily average temperature at the second drop structure shall not exceed 99°F for more than 44 days of the rolling 12 month period and that the daily average temperature shall never exceed 108.3°F. For the purpose of providing a reference against which the cooling effectiveness of passive cooling devices may be evaluated, the target heat loss of the device is the amount required to cool circulating water from a condenser discharge temperature of 109.8°F to 99°F. This is about 8.419×10^{10} Btu/day.

4.0 PASSIVE COOLING TECHNIQUES

The goal of these techniques is to enhance the heat flow from the circulating water in the discharge flume to the surrounding media by passive means. In general, cooling takes place by convection, radiation and by evaporation at the water surface. Heat also flows by conduction through the canal walls to the ground. The latter mechanism is generally considered to result in negligible effects. Accordingly, the present study focuses on enhancing the heat loss through the surface of the circulating water at the discharge flume. For this purpose, the following techniques are considered:

1. Shading the flume surface from solar radiation
2. Spray devices driven by fluid velocity
3. Fins (dry, wetted and rotating)
4. Natural draft gravity-flow cooling towers

All the above are passive techniques that enhance heat loss at the water surface. The mechanisms upon which these techniques depend are explained in the following section:

4.1 SHADING THE FLUME SURFACE FROM SOLAR RADIATION

The surface of the flume can be totally or partially shaded from short-wave solar radiation by canopy structures or by planting trees on the south bank of the canal. Regardless of the method used, shading the flume surface from the sunlight reduces the short-wave radiation absorbed by the water, and accordingly reduces the equilibrium temperature, T_E, of the circulating water in the flume. However, the equilibrium temperature of the lake water surface, and accordingly, the temperature of the water at the condenser inlet and the discharge to the flume, is unchanged. The heat transfer at the flume water surface is dependent upon both the heat transfer coefficient at that surface and the difference between the water surface temperature, T_S, and equilibrium temperature, T_E. The effect of shading the flume surface on increasing the driving temperature difference is greater than its effect on decreasing the heat transfer coefficient. Therefore, shading the flume surface gives rise to a higher heat flow rate at the water surface and accordingly lower temperature of the water discharged to the lake. Based on a 100% shading, it is found that the heat transfer coefficient is decreased by about 23 Btu/ft^2/°F/day (and therefore results in less cooling), while the driving temperature difference is increased by about 12.8°F which enhances cooling. This provides an additional natural cooling at the flume surface of about 8.73 x 10^9 Btu/day, giving rise to a drop of about 1.12°F in the temperature of the circulating water in the discharge flume.

4.2 SPRAY DEVICES DRIVEN BY FLUID VELOCITY

Evaporative cooling can be enhanced by producing a water spray at the flume surface. Unlike a mechanical spray module, a "passive" spray device uses the kinetic energy of the flowing water to produce a water spray. An example of such a device is a two-dimensional nozzle-like curved duct, which is mounted close to the water surface. Flowing through this device, the water top layer changes its flow direction and gains head at the expense of its own kinetic energy. This provides a "natural" water spray that enhances evaporative cooling. Heat loss due to this mechanism is dependent upon the wind speed, the projected area of the water spray, and the difference between the enthalpy of saturated air at the water surface temperature and that of saturated air evaluated at the ambient wet-bulb temperature. These devices can be located in the void areas between the drop structures.

The spray projected area in this case is estimated at 850 ft^2 and the corresponding additional cooling is estimated at 2.043×10^9 Btu/ft^2/day. This gives rise to a drop in the circulating water temperature of about 0.26°F. This technique, however, is not technically proven, and there is no field or experimental data to support the above estimated values.

4.3 FINS (DRY, WETTED AND ROTATING)

Fins can be used to enhance cooling by increasing the surface area through which heat is lost to the ambient. In the case of using dry fins, convective heat transfer is the only mechanism that can be enhanced. In order to limit the discharge to the cooling lake to 99°F for summer conditions, a drop of about 10.8°F in the temperature of the circulating water in the discharge flume is required. This requires the removal of about 8.419×10^{10} Btu/day. Based on a fin efficiency of 60%, the total fin area required to allow for such heat flow is estimated at 5.777×10^7 ft^2. This is equivalent to about 288,000 fins, where the size of one fin is 10 ft. x 10 ft. However, the surface area of the flume allows for only half this number of fins, due to air circulation considerations, which limits the cooling capacity of this scheme to 50% of the target heat loss.

Cooling can be further enhanced by using wetted fins. These are aluminum fins whose surface is coated with a water absorbing material that acts like a wick and keeps the fin surface wet. This mechanism allows for an increase of about 40% in the driving temperature difference, thus decreasing the required fin area estimated above by 30%.

Also, rotating fins can be used to promote heat transfer from the cool fin surface to the hot water surface by direct contact. These are spherical or cylindrical bodies that can be made of less expensive materials than those used in solid fins, and their surface is coated with water absorbing material. These fins are allowed to rotate about their own axis while floating on the water surface, and they depend upon the surface friction with flowing water, or upon surface mounted pedals to provide the rotation. As they rotate, their upper surface loses heat to the ambient, while the lower surface gains heat from the water. This technique is expected to perform slightly better than wetted fins of the same surface area.

4.4 NATURAL DRAFT GRAVITY-FLOW COOLING TOWERS

Using cooling towers to extract heat from circulating water in power plants is a well proven technique. A natural draft cooling tower is a passive cooling device when it depends on gravity rather than pumps in producing the flow of circulating water through the fill. The 44 ft. drop provided by the two drop structures can be used for that purpose. The possibility of using natural draft cooling towers at Clinton power station was considered in a study prepared by S&L in 1974 (Reference 5).

5.0 TECHNICAL AND ECONOMIC EVALUATION

The performance of the proposed passive cooling devices is evaluated against the target heat loss, which is the amount required to cool circulating water from a condenser discharge temperature of 109.8°F to 99°F. This is about 8.419×10^{10} Btu/day.

The limiting case of the first scheme is when the surface of circulating water in the discharge flume is totally shaded from the short-wave solar radiation. This provides an additional cooling of 1.12°F of the circulating water in the discharge flume, which is about 10.4% of the target heat loss. The cost of this scheme depends upon the method used to shade the flume. However, no further consideration is given to this scheme since it fails to meet the target cooling loss.

The second scheme, using spray devices, depends upon the water velocity since it provides the spray head. The water velocity along the flume is very low, 0.7 ft/sec, except at the drop structures. Accordingly, any practical use of such a device is limited to that area of the water flow, which provides a very limited projected area of the water spray. As estimated in the previous section, the maximum additional cooling capacity of this scheme is equivalent to a temperature drop of 0.26°F of the circulating water, which is about 2.4% of the required capacity. Also, the above estimated capacity needs to be compared with field or experimental data before any serious consideration of using such a device. Based on the above, the possibility of using that scheme at the Clinton station is not considered.

The estimated performance of fins (third scheme) indicates they are capable of providing only half the cooling capacity required to bring the water temperature down to 99°F. This requires the usage of about 144,000 fins of solid heat conducting material, where the size of each fin is 10 ft. x 10 ft. Without recoursing to a detailed cost estimate, the quantity of material required for this scheme indicates that the order of magnitude cost is prohibitively high as compared with other schemes, such as cooling towers. The rotating fin scheme has more potential since these can be made of less expensive material. However, the quantity of material required for this scheme is still high. Moreover, this scheme is not technically proven, and no field or experimental data is readily available to support its estimated performance.

The Clinton site is potentially suitable for the natural draft gravity-flow cooling tower scheme since a 44 ft. drop can be provided by the two drop structures. This scheme is capable of meeting 100% of target heat loss. However, based on the study prepared by S&L in 1974 (Reference 5), the cost of a natural draft cooling tower is about 70% higher than that of a mechanical draft cooling tower. According to that study, the cost of the natural draft cooling tower scheme amounted to $24,750,000 in 1974. Based on an average escalation rate of 4.5%, the cost of the present scheme is estimated at $52,300,000. Also, the location and constructability of a mechanical draft gravity-flow cooling tower at Clinton station considered in Reference 10 could be applied for the natural draft cooling tower scheme.

6.0 SUMMARY AND CONCLUSIONS:

The amount of additional cooling that can be obtained from the passive cooling techniques considered in this study and their approximate cost are summarized below:

Technique	Cooling Capacity °F	Percentage of Target Loss %	Approximate Cost $
Natural cooling * at flume surface	2.57	23.8	-
Natural cooling * at drop structure	0.06	0.6	-
100% shading at flume surface	1.12	10.4	Considerably lower than a cooling tower
Natural spray devices	0.26	2.4	Considerably lower than a cooling tower
Fins (dry, wetted, rotating)	5.40	50.0	Order of 10^7
Gravity-flow natural draft cooling towers	10.80	100.0	52,300,000

* Already in use at Clinton Station

The techniques that are based on shielding from sunlight, spraying of water and using fins have been used to assist in cooling residential and industrial structures. They perform acceptably in certain applications, however, in the case of the nuclear power generating plant the quantity of heat rejected is enormously greater and is beyond the capability of these techniques. The only technique which would perform adequately is to use a cooling tower. A natural draft cooling tower qualifies for the term "Passive Cooling Device" when the flow of circulating water through the fill is produced gravitationally rather than by pumps. The Clinton site is potentially suitable for this technique since the discharge flume consists of two drop structures in which the circulating water falls 44 ft. Since the height of the fill in towers of recent design is only 25 ft., the tower can be fed by gravity if it is located somewhere between the first drop structure and the lake.

7.0 REFERENCES:

1. S&L Calc, MAD #72-72 Rev. 0

2. S&L Calc, MAD #72-148 Rev. 0

3. S&L Calc, MAD #73-166 Rev. 0, 73-202 Rev. 0, 73-237 Rev. 0

4. S&L Calc, MAD #75-70 Rev. 0

5. S&L Calc, MAD #73-124 Rev. 0, 73-138 Rev. 0, 73-244 Rev. 0, 73-334 Rev. 0, 74-79 Rev. 0

6. S&L Calc, MAD #75-196 Rev. 0

7. S&L Calc, MAD #75-237 Rev. 0

8. S&L Calc, MAD #75-216 Rev. 0

9. S&L Calc, MAD #77-270 Rev. 2

10. S&L Calc, MAD #76-379 Rev. 2, 76-410 Rev. 2, 77-65 Rev. 2

11. Updated Safety Analysis Report, Clinton Power Station, Rev. 1.

12. S&L Drawings #S04-1117 Rev. E, S04-1118 Rev. E, S04-1119 Rev. E, S04-1120 Rev. D, S04-1121 Rev. D, S20-1115 Rev. F, S20-1116 Rev. D, S20-1119 Rev. B, S20-1120 Rev. A.

13 Handbook of Fundamentals, ASHRAE 1989.

14. An Analytical and Experimental Study of Transient Cooling Pond Behavior, Department of Civil Engineering, Massachusetts Institute of Technology, Report #161, 1973.

15. S&L Calc, ATD #91-0130, Rev. 1

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Decatur, Illinois
September 29, 1992

Mr. T. L. Davis A-17

Clinton Power Station

Electric Production Costs Associated with Constraining the Station to Not Exceed Current Discharge Flume Thermal Limit [1]

In response to your September 23 request, Planning Activities has estimated the cost in the summer of 1993 to the Illinois Power - Soyland Power (IPSP) Pool of potential deratings of the Clinton Power Plant as identified in your request [2]. The cost impact is based upon incremental production costs with Clinton derated compared to Clinton operating at full power. Incremental production costs include the additional fuel, variable operation and maintenance and interchange purchase costs incurred by the IPSP Pool. The analysis reflects forecasted 1993 system conditions adjusted to reflect weather conditions during a summer experienced once every 10 years.

Given the conditions set forth above, the IPSP Pool production costs would be expected to increase by $365,000 (1993$) if Clinton were derated.

Please contact me at extension 6463 if you have any questions concerning this analysis.

EF Stoneburg
Edward F. Stoneburg
Supervisor - Electric Planning
Planning Activities

EFS/dmr

---

[1] Daily average flume discharge temperatures are not to exceed 108.3 °F on any day and not to exceed 99 °F more than 44 days during a moving 365-day period.

[2] Linear power level reductions from zero percent on June 15 to 12 percent on June 30, from 12 percent on August 12 to zero percent on September 1, and a two-day power level reduction of 10 percent in early August. Reduced power levels were determined based upon 100 percent power, 100 percent circulating water flow, the lake starting at normal pool, and a meteorological summer like that experienced every one year in 10.

10

BEFORE THE ILLINOIS POLLUTION CONTROL BOARD

In the matter of:	)	
	)	
Petition of Illinois Power Company (Clinton Power Station), for Hearing Pursuant to 35 Ill. Adm. Code § 302.211(j) to Determine Specific Thermal Standards	)))))	PCB No. 92-_______ (§ 302.211(j) Hearing)

AFFIDAVIT OF THOMAS L. DAVIS

I, Thomas L. Davis, on oath do depose and state:

1. I am an Environmental Technical Specialist in the Water Pollution Control Section of the Environmental Affairs Department of Illinois Power Company ("Illinois Power"). I am a registered professional engineer in Illinois and Pennsylvania.

2. As part of my responsibilities, I was involved in preparing Illinois Power's Petition for Hearing to Determine Specific Thermal Standards Pursuant to 35 Ill. Adm. Code § 302.211(j), and certain of the Figures, Tables and Exhibits attached thereto or submitted therewith. Specifically, I was involved in coordinating the information which is presented in paragraphs 12-18, 20, 23.c, 52-55, and 60-63. I also was responsible for providing Figures 3-5, Table 3, and Exhibit 1. Additionally, Exhibit 2, the Environmental Monitoring Program Water Quality Report, was prepared by certain individuals at Illinois Power (including myself) for submission to the Illinois Environmental Protection Agency ("IEPA") to satisfy certain regulatory requirements. This report also is being submitted as an exhibit in the present proceeding because of the relevance of the information presented therein.

3. To the best of my knowledge, the information presented or depicted in the above-referenced paragraphs, Figures, Table and Exhibit is true and correct. Certain of this information was provided to me from individuals employed by Illinois Power who have personal knowledge of

the truth and correctness of the information so provided. In addition, I myself have personal knowledge of the truth and correctness of certain of this information. Finally, as noted above, Exhibit 2 was prepared for submission to the IEPA in satisfaction of certain regulatory requirements; and, to the best of my knowledge, the information presented or depicted therein is true and correct.

FURTHER AFFIANT SAYETH NOT.

Thomas L. Davis

Thomas L. Davis

Subscribed and sworn to before me
this 30 day of September 1992.

Notary Public

My Commission Expires: 8/4/93

"OFFICIAL SEAL"
William H. Witts
Notary Public, State of Illinois
My Commission Expires 8/4/93

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To Eric Lohrenz	From Tom Davis
Co.	Co.
Dept. Schiff Hardin & Waite	Phone # 217-424-7322
Fax # 312-258-5600	Fax # 217-362-7649

11

BEFORE THE ILLINOIS POLLUTION CONTROL BOARD

In the matter of:	)	
	)	
Petition of Illinois Power Company (Clinton Power Station), for Hearing Pursuant to 35 Ill. Adm. Code § 302.211(j) to Determine Specific Thermal Standards	)	PCB No. 92-_______
	)	(§ 302.211(j) Hearing)

AFFIDAVIT OF JOHN E. EDINGER

I, John E. Edinger, on oath do depose and state:

1. I am President and Principal Scientist at J.E. Edinger Associates, Inc., 37 West Avenue, Wayne, Pennsylvania ("Edinger Associates").

2. I received a Bachelors of Civil Engineering from Union College in 1960 and a PhD in Water Resources and Physical Oceanography from The Johns Hopkins University in 1965. My area of expertise is environmental hydrology with particular emphasis on waterbody dynamics and hydrothermal analysis. I started the consulting firm of Edinger Associates in 1974.

3. For the present proceeding, Illinois Power retained Edinger Associates to perform a hydrothermal modeling verification for Clinton Lake, using lake temperature data and Station operating data for the years 1989-1991, and also to determine the adequacy of the presently applicable temperature limits for the reccirculated condenser cooling water discharge to Clinton Lake from the Clinton Power Station. Edinger Associates has prepared a report addressing both of those two points, which report is being submitted as Exhibit 4 to Illinois Power's Petition to Determine Specific Thermal Standards Pursuant to 35 Ill. Adm. Code § 302.211(j) ("Petition"). The Edinger Associates report also is referenced at various places in the Petition.

4. To the best of my knowledge, the information presented or depicted in Exhibit 4, the Edinger Associates report, is true and correct. Certain of this information was provided to

Edinger Associates from individuals employed by Illinois Power who have personal knowledge of the truth and correctness of the information so provided. In addition, I myself have, or my associate Edward Buchak has, personal knowledge of the truth and correctness of certain of this information.

FURTHER AFFIANT SAYETH NOT.

John E. Edinger

Subscribed and sworn to before me
this 29th day of September 1992.

Kathryn Jo Wilson
Notary Public

My Commission Expires: Dec. 18, 1993

OFFICIAL SEAL
KATHRYN JO WILSON
NOTARY PUBLIC STATE OF ILLINOIS
MY COMMISSION EXP DEC. 18,1993

12

BEFORE THE ILLINOIS POLLUTION CONTROL BOARD

In the matter of:	)	
	)	
Petition of Illinois Power Company	)	
(Clinton Power Station), for	)	PCB No. 92-_______
Hearing Pursuant to 35 Ill. Adm.	)	
Code § 302.211(j) to Determine	)	(§ 302.211(j) Hearing)
Specific Thermal Standards	)	

AFFIDAVIT OF GARY D. MATTHEWS

I, Gary D. Matthews, on oath do depose and state:

1. I am the Supervisor - Reliability Engineering for Illinois Power Company ("Illinois Power") at the Clinton Power Station ("Station").

2. As part of my responsibilities, I was involved in preparing Illinois Power's Petition for Hearing to Determine Specific Thermal Standards Pursuant to 35 Ill. Adm. Code § 302.211(j) (the "Petition"), and certain of the Figures, Tables and Exhibits attached thereto or submitted therewith. Specifically, I was involved in coordinating the information which is presented in paragraphs 1-11, 81, 83 and 84. I also was responsible for providing Figures 1 and 2, Tables 1 and 2, and Exhibit 8. Additionally, I provided the Station operating data referenced in paragraph 21 of the Petition to J.E. Edinger Associates, Inc. ("Edinger"), for use in preparing Exhibit 4.

3. To the best of my knowledge, the information presented or depicted in the above-referenced paragraphs, Figures, Tables and Exhibit, as well as the Station operating data provided by me to Edinger, is true and correct. Certain of this information was provided to me from individuals employed by Illinois Power who have personal knowledge of the truth and correctness

of the information so provided. In addition, I myself have personal knowledge of the truth and correctness of certain of this information.

FURTHER AFFIANT SAYETH NOT.

Gary D. Matthews

Subscribed and sworn to before me
this 30th day of September, 1992.

Linda S French
Notary Public

OFFICIAL SEAL
LINDA S. FRENCH
NOTARY PUBLIC, STATE OF ILLINOIS
MY COMMISSION EXPIRES 9-1-96

My Commission Expires: 9-1-96

13

BEFORE THE ILLINOIS POLLUTION CONTROL BOARD

In the matter of:)
)
Petition of Illinois Power Company)
(Clinton Power Station), for) PCB No. 92-142
Hearing Pursuant to 35 Ill. Adm.)
Code § 302.211(j) to Determine) (§ 302.211(j) Hearing)
Specific Thermal Standards)

AFFIDAVIT OF JAMES A. SMITHSON

I, James A. Smithson, on oath do depose and state:

1. I am the Director - Outreach and Assessment, in the Environmental Affairs Department of Illinois Power Company ("Illinois Power").

2. As part of my responsibilities as Director - Outreach and Assessment, I was involved in preparing Illinois Power's Petition for Hearing to Determine Specific Thermal Standards Pursuant to 35 Ill. Adm. Code § 302.211(j) ("Petition"), and certain of the Figures, Tables and Exhibits attached thereto or submitted therewith. Specifically, I was involved in coordinating the information which is presented in paragraphs 24-51, and 65-80 of the Petition. I also was responsible for providing Figures 6-15, and Exhibit 5. Additionally, Exhibit 3, the Environmental Monitoring Program Biological Report, was prepared at my direction by certain individuals at Illinois Power for submission to the Illinois Environmental Protection Agency ("IEPA") to satisfy certain regulatory requirements. This report also is being submitted as an exhibit in the present proceeding because of the relevance of the information presented therein. Finally, Illinois Power employees working under my supervision provided J.E. Edinger Associates, Inc. ("Edinger") with the lake temperature data referenced in paragraphs 20 and 22 of the Petition, which data was used by Edinger in preparing Exhibit 4.

3. To the best of my knowledge, the information presented or depicted in the above-referenced paragraphs, Figures, and Exhibit, as well as the lake temperature information provided

to Edinger, is true and correct. Certain of this information was provided to me from individuals employed by Illinois Power who have personal knowledge of the truth and correctness of the information so provided, and I myself have personal knowledge of the truth and correctness of certain of this information. In addition, as noted above, Exhibit 3 was prepared for submission to the IEPA in satisfaction of certain regulatory requirements; and, to the best of my knowledge, the information presented or depicted therein is true and correct.

4. Two exhibits, Exhibits 6 and 7, were prepared at Illinois Power's request by Environmental Science and Engineering, Inc., for use in proceeding PCB 88-97. Although these documents were not prepared by Illinois Power, I was involved in their preparation (as were other Illinois Power employees) and, to the best of my knowledge, I believe the information presented therein to be true and correct.

FURTHER AFFIANT SAYETH NOT.

James A. Smithson

Subscribed and sworn to before me
this 7 day of October, 1992

William H Witts
Notary Public

My Commission Expires: 8/4/93

"OFFICIAL SEAL"
William H. Witts
Notary Public, State of Illinois
My Commission Expires 8/4/93

14

BEFORE THE ILLINOIS POLLUTION CONTROL BOARD

In the matter of: Petition of Illinois Power Company (Clinton Power Station), for Hearing Pursuant to 35 Ill. Adm. Code § 302.211(j) to Determine Specific Thermal Standards	PCB No. 92-______ (§ 302.211(j) Hearing)

AFFIDAVIT OF EDWARD F. STONEBURG

I, Edward F. Stoneburg, on oath do depose and state:

1. I am the Supervisor - Electric Planning for Illinois Power Company ("Illinois Power"). As part of my responsibilities, I was involved in preparing the analysis submitted as Exhibit 9 to Illinois Power's Petition for Hearing to Determine Specific Thermal Standards Pursuant to 35 Ill. Adm. Code § 302.211(j) (the "Petition"). Exhibit 9 is discussed beginning at paragraph 85 of the Petition.

2. The information presented in Exhibit 9 is true and correct to the best of my knowledge. I obtained certain of this information from individuals employed by Illinois Power who have personal knowledge of the truth and correctness of the information so obtained. In addition, I myself have personal knowledge of the truth and correctness of certain of this information.

FURTHER AFFIANT SAYETH NOT.

Edward F. Stoneburg

Edward F. Stoneburg

Subscribed and sworn to before me
this 30 day of September, 1992.

Darlena D. Wallace
Notary Public

My Commission Expires: 9-25-94

"OFFICIAL SEAL"
Darlena D Wallace
Notary Public, State of Illinois
My Commission Expires 9-26-94