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EFFECTS OF A HEATED DISCHARGE ON THE ECOLOGY OF THE MISSISSIPPI RIVER

316(a) Type I Demonstration on the
Monticello Nuclear Generating Plant,
Monticello, Minnesota

PREPARED FOR

NORTHERN STATES POWER COMPANY

PREPARED BY

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B. R. Oblad
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ECOLOGICAL SCIENCES DIVISION
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CLIENT NO. 6531

OCTOBER 1975

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CC 505

C-25-00-10-5-1922

October 28, 1975

Mr. Laurence Grotbeck
Northern States Power Company
414 Nicollet Mall
Minneapolis, Minnesota 55401

Dear Larry:

Enclosed are six (6) copies of the Monticello 316(a) Type I Demonstration and two copies of the Unpublished Data Sources. If you have any questions, please call.

Sincerely,

Brad Owen

Bradford B. Owen, Ph.D.
Project Manager

Enclosures

BBO/pcn

cc: P. V. Morgan
B. R. Johnson
B. C. Marcy
L. R. Love
D. S. Creyts
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10/1/91

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SUMMARY AND CONCLUSIONS

316(a) TYPE I DEMONSTRATION FOR THE MONTICELLO NUCLEAR GENERATING PLANT

SUMMARY AND CONCLUSIONS

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1. INTRODUCTION

The following summary and conclusions are based on the extensive physical, chemical and ecological studies conducted at the Monticello Site from 1968-1974. Rather than cite each study in the summary, pages of the main text of the 316(a) Type 1 demonstration are referenced, should more detailed information be desired.

EFFECTS OF A HEATED DISCHARGE ON THE ECOLOGY OF THE MISSISSIPPI RIVER

316(a) Type I Demonstration on the Monticello Nuclear Generating Plant, Monticello, Minnesota

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2. ENGINEERING AND HYDROLOGIC DATA

The Monticello Nuclear Generating Plant is a base load facility with a design generating capacity of 545 MWe. The cooling system of the Monticello Plant is constructed to operate in open cycle, helper cycle, partial recirculation and closed cycle modes. Normally, the open cycle mode is used during periods when the ambient river temperature is less than 68°F (20°C) and the helper cycle mode is used when temperatures exceed 68°F (20°C). The plant is operated at essentially full capacity at all times. Significant variability in heat rejection rates occur only during shut-down and start-up periods.

Thermal plume mapping surveys have been conducted 34 times during the 1971-1973 period. Of these, eight surveys have been selected to define variations in plume configuration under various seasonal, hydrologic and plant (cooling system) operating conditions. Compliance with applicable regulations was evaluated using the draft NPDES permit restrictions and Minnesota water quality standards.

River discharge and cooling system mode are the major factors influencing the spatial extent of the thermal plume generated by the Monticello Plant. Under extreme summer low flow conditions, non-compliance with the draft NPDES permit requirements and state water quality standards is indicated both with and without the use of cooling towers. With high flows, compliance with state water quality standards is achieved both with and without cooling towers. However, non-compliance with the draft NPDES permit is indicated. Under "normal" summer operations (near median river discharge and with cooling towers operated in the helper mode), compliance with these standards may be indicated. Occasional non-compliance with these standards is indicated for winter and seasonal transition periods. In some cases, non-compliance with the restrictions of the draft NPDES Permit is possible without violation of the state water quality standards.

Review of thermal survey results and historical discharge data indicated that during 70 percent of the period from June through September, the immediate discharge zone (the +90°F [+5°C] isotherm) extended over less than half of the river width and less than 700 feet below the plant outfall.

Water quality (other than temperature) in the Mississippi River is not appreciably affected by the operation of the Monticello Plant.

3. ECOLOGICAL DATA

3.1 PRIMARY PRODUCERS

Periphyton, phytoplankton and macrophyton are the three potential sources of primary production in the Mississippi River at the Monticello Site. Phytoplankton was not extensively investigated at the site but is assumed to have a minor role in river trophics as compared to periphyton.

Phytoplankton at the Monticello Site is dominated all year by diatoms (see p. 69), although green and blue-green algae become important in summer. Moyle (1940) indicated that blue-greens dominated some of the summer communities of the upper Mississippi River during his studies (see p. 70).

Periphyton was studied extensively at the Monticello Site. Studies were based on the algae that colonized artificial substrates. From 1968 through 1974, 134 taxa of algae were identified, the majority of which were diatoms.

Spring periphyton was dominated by diatoms, mainly *Gomphonema olivaceum*, *Diatoma vulgare*, *Synedra ulna* and *Navicula gracilis*. Peak production occurred in the summer when both diatoms and blue-greens were abundant. *Chroococcus minimus* was the major summer alga. Diatoms dominated in the fall when species of *Cocconeis* were very common.

Species composition of periphyton communities did not differ significantly between the intermediate discharge zone and the "ambient zone" (see p. 73). However, within the immediate discharge zone there was a shift in species dominance. *Stigeoclonium nanum*, *Characium pringsheimii* and *Achnanthes exigua* were more abundant in the immediate discharge than in other zones (see p. 73).

Species diversity was greatest in the immediate discharge in the spring (see p. 75) but no trends were discernible during other seasons. Similarly, chlorophyll *a* and total algae densities failed to show major differences among areas. The cumulative effects of the Monticello Plant discharges do not affect the overall balance of the periphyton communities of this region of the Mississippi River.

Few data exist on the macrophyton of the Mississippi River in the Monticello Plant area. Major taxa present include *Fontinalis antipyretica*, two *Potamogeton* species and *Cladophora glomerata*. These plants are assumed to play a minor role in river trophics as compared to periphyton.

3.2 ZOOPLANKTON

Zooplankton of the Monticello Site has not been investigated recently. Past studies show that few crustaceans inhabit the region. However, protozoans and rotifers may be common in the area (see p. 103). The trophic importance of zooplankton is considered to be limited in this portion of the Mississippi due to the small number of organisms that feed on zooplankton and due to the paucity of crustaceans in the zooplankton communities.

3.3 MACROINVERTEBRATES

Macroinvertebrate studies were initiated on a five-mile stretch of the Mississippi River in 1968 to gather baseline information before the construction of the Monticello Plant. Preoperational data include the results of investigations from the summer of 1968 to the end of 1970. Operational information has been collected since the plant start-up in 1971.

Two major types of habitat have been described from the survey area. In one habitat type, the backwater areas and protected shoreline areas where grasses and sedges grow, the water is usually less than two feet deep and the substrate is silt and mud. Current velocity in this habitat may fluctuate greatly throughout the year. Random qualitative collections were made along the shorelines and backwaters with invertebrate sweeping nets. In this habitat, the diverse fauna consisted of 11 orders, 32 families and 66 genera (see p. 164). Coleoptera, Ephemeroptera and Hemiptera were the dominant orders.

The main channel represents the other major type of habitat. Substrates are primarily gravel, rubble and boulders with some sand. Current velocity is substantial but fairly consistent. Qualitative analysis of four artificial substrate samplers placed in the central channel during 1968 produced representives of eight orders, 15 families, and 25 genera (see p. 167). Caddisflies and mayflies were the major components of the benthic fauna in the main channel, although five genera of stoneflies were also represented. Presence of these three orders is indicative of good water quality in this part of the Mississippi River.

In an extensive quantitative program from 1969 through 1972, concrete blocks (artificial substrates) were placed at two control stations above the intake and at six experimental stations below the proposed discharge (see p. 136). In operational years (1971 and 1972), 9 stations were in the outer discharge zones, although 3 of these were, at times, at ambient temperatures, and 4 stations wer in the intermediate discharge zone. None of the stations were in the immediate discharge zone.

Although major taxa composition remained the same (see pp. 169 to 175) in all stations, the percent contribution of dominant groups changed during operational years with a substantial percentage increase of caddisflies, particularly in 1972 (see p. 176).

A recolonization study in 1973 monitored one control station and one experimental station between July 1971 and July 1972 (see pp. 142-158). The experimental station was in the defined outer discharge zone, although over 50 percent of the time it fell within the +3°F (+2°C) isotherm (see p. 179). Caddisfly larvae reached higher population levels in the experimental station, while mayfly and dipteran numbers were reduced (see p. 181).

This increase of caddisflies was statistically significant in three of the eight sampling cycles (see p. 182). While increases and decreases in major taxa occurred in the thermal discharge zone, none of the major taxa were excluded. In 1972, maximum standing crop was reached one month earlier in the experimental station than in the control station, probably due to the constant elevated temperatures at the experimental station. Macroinvertebrate growth rates showed no significant differences between the heated water and control stations.

In a drift study, the experimental station was located in the intermediate discharge zone (see p. 140). Drift compositions at the experimental and control stations were not significantly different at the order level nor was the relative magnitude of the major taxa within each order significantly different. Elevated temperatures in the intermediate discharge zone (see p. 184) produced no measurable change in drift density as compared to the control station.

The adult light trap study provided a species list of the major taxa near the Monticello Site. There did not appear to be a significant change in the emergence periods of the major taxa, with the possible exception of *Macronemum zebratum*. *Macronemum zebratum* emerged two weeks earlier at the light trap near the thermal plume area than it did at the control light trap above the intake.

3.4 FISH

Various sampling gear and analytical methods were employed to examine the impact of the Monticello Plant on the balanced, indigenous fish populations of the Mississippi River. Sampling techniques included electrofishing, seining, trap nets, creel census and tagging (see pp. 189-192). Catch data were transformed to catch-per-unit-effort (catch per electrofishing-hour, catch per trap net set, catch per seine haul). Spawning sites and time of spawning were determined by examination of fish condition (state of maturity and condition factors).

Carp and shorthead redhorse were the most abundant species captured during pre-operational studies. Game fish were restricted to microhabitats within each sector, which limited their overall abundance (see p. 214).

After the plant went into operation, fish were found in the immediate discharge area regardless of whether or not the plant was generating. Rough fish species continued to dominate the catch in all areas (see p. 197), a reflection of the relative abundance seen during pre-operational studies. In 1973, rough fish were most abundant in the outer discharge area. The intermediate discharge area yielded greater catches than the immediate discharge area (see pp. 237, 255, 263). In 1974, rough fish were still least abundant in the immediate discharge area but were more abundant in the intermediate discharge area as compared to the outer discharge area, at least through June (see pp. 245, 259, 267). Game species were caught most frequently in the immediate discharge area in 1973; distribution was about even in the other areas (see pp. 239, 257, 265). In 1974, game fish were abundant in the intermediate discharge (see p. 261). In all cases, the catch of game fish was much lower than that of rough fish.

Seining studies were conducted both before and after plant operation. Stations in the adjacent water body segment and the intermediate discharge area were compared by rank correlation (see p. 203). The results indicated that species composition changes were minor. The immediate and outer discharge areas were not sampled in both years, therefore, no comparison could be made. Seining studies of young-of-the-year smallmouth bass and white sucker indicated that differences in abundance between the intermediate discharge area and ambient control stations were not statistically significant (see p. 204). It was speculated that there may have been some inhibitory action on spawning and/or egg incubation in the intermediate discharge area but that heat could not be singled out as the causative agent. Growth of young-of-the-year smallmouth bass and white suckers was significantly faster in the heated water (see pp. 204, 216).

Spawning studies were conducted for the dominant species in the area: shorthead redhorse, silver redhorse, white sucker and carp (see p. 204). Since the plant was down during most of the spawning periods of white sucker, shorthead redhorse and silver redhorse, anticipated impact must be inferred from the existing data. Carp preferred flooded areas off the main river, so the plant is not anticipated to have any impact on their spawning success. Spawning beds of other species were located in many areas around the plant site (see p. 271). Some of these beds are expected to be in the heated effluent. The impact is anticipated to be minimal because most spawning takes place in the spring and early summer when flows are high and heat should be rapidly dissipated. Also, most spawning areas likely to be in the heated effluent are in the intermediate discharge area, further reducing heat levels. Yellow perch and walleye overwintering in the discharge canal are expected to experience reduced spawning success (see p. 219).

A small sport fishery was found to exist in the immediate discharge area in the fall. High catches of smallmouth bass and walleye were noted (see p. 210). The occurrence of these fish in the fall is expected to establish a new fishery in the Monticello area for highly desired game species. A creel census of other areas near the plant indicated that a rather unsophisticated and under-utilized fishery existed.

Fish were attracted to the immediate discharge area during the winter months. The standing crop of fish in this area did not appear to be in excess of the carrying capacity as condition factors of these overwintering fish are comparable to published data for the species (see p. 340). Winter shutdowns are expected to result in fish kills due to cold shock. Winter cold shock mortality has not adversely affected fish populations in the river, based on catch-per-unit-effort data.

The major components of the balanced, indigenous population of fish inhabiting the area of the power plant have been minimally affected by plant operation. Rough fish dominated the catches of large species in operational years as in pre-operational years. Forage fish species composition was virtually unaffected. Fish frequenting the immediate discharge area included: smallmouth bass, black crappie, walleye, northern pike, carp, shorthead redhorse, silver redhorse and white sucker. Spawning of some species is expected to be inhibited by the heated discharge, but rapid dissipation of prohibitively high temperature water is expected to minimize impact. Fish kills are probable during the winter, however, the low standing crop in the immediate discharge area is expected to reduce impact. A potential sport fishery in the discharge canal is anticipated.

In summary, the balanced, indigenous population of fish at the Monticello Site is expected to be maintained with a minimum of impact.

4. CONCLUSIONS

Although there have been periods of non-compliance with thermal regulations (both state and NPDES permit), there is no indication of prior appreciable harm to the biota of the Mississippi River within the area of influence of the Monticello Nuclear Generating Plant.

- Water quality parameters measured (other than temperature) were not affected by the operation of the Monticello Plant.

- Primary producers displayed some shifts in periphyton species composition in the immediate discharge while maintaining a balanced community. Intermediate and outer discharge area periphyton communities were indistinguisable from those of the control area.

- Macroinvertebrates were dominated by caddisflies and the benthos standing crop maximum was one month earlier in the area immediately downstream from the discharge. Community stability was not measurably affected in discharge zones.

- Fish populations have not been noticeably altered in composition in the affected areas since the Monticello Plant started operation. Rough fish predominate but game fish are, at times, abundant in the immediate discharge. Minimal impact on spawning of local fishes is predicted.

The evidence presented in this demonstration indicates that the operation of the Monticello Nuclear Generating Plant has not produced appreciable harm and has not interfered with the maintenance of balanced indigenous populations at all trophic levels. Thus any effluent limitations would be "more stringent than necessary to assure the protection and propagation of a balanced indigenous population of shellfish, fish and wildlife" in the Mississippi River.

316(a) TYPE I DEMONSTRATION FOR THE MONTICELLO NUCLEAR GENERATING PLANT

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1. INTRODUCTION

This 316(a) type I demonstration is submitted in support of the continued operation of the present cooling facilities of the Monticello Nuclear Generating Plant. The Monticello Plant is owned and operated by Northern States Power Company (NSP) of Minneapolis, Minnesota and is located on the Mississippi River approximately three miles northwest of Monticello, Minnesota. From 1968 to the present there have been extensive biological, chemical and physical investigations of pre-operational and operational conditions of this plant. On the basis of these investigations this report is being submitted as evidence that the operation of the Monticello Plant has assured the "protection and propagation of a balanced, indigenous population of shellfish, fish and wildlife" within its area of influence on the Mississippi River.

Construction of the Monticello Plant was initiated in June 1967, and completed December 1970. Testing operations began January 1971 with commercial power generation commencing June 30, 1971. The Monticello plant is a boiling water reactor with a generating capacity of 545 MWe. Condenser cooling water is obtained from the Mississippi River. The cooling water system was designed to operate on any one or a combination of four modes, once-through, helper cycle (cooling towers operating with cooled water discharged to river), partial recycle (cooling towers operating with a fraction of water recirculated back to condenser) and closed cycle (cooling towers operating with all cooled water recycled to condenser). Water lost from the towers by evaporation or blowdown during closed cycle operation is replaced by makeup water from the river.

The biota of the Mississippi River near the Monticello site have been studied by various researchers since 1968. Dr. Alfred J. Hopwood, Dept. Biology, St. Cloud State College, St. Cloud, Minnesota directed studies involving fish, macroinvertebrates, and general water quality. Periphyton communities near the plant site were investigated initially by Dr. Alan J. Brook, Dept. Ecology and Behaviorial Biology, University of Minnesota and subsequently by Dr. Keith M. Knutson, Dept. Biology, St. Cloud State College.

These studies concentrated on the Mississippi from just upstream of the Monticello site to a bridge located in the town of Monticello, approximately four miles downstream. Data compiled from 1968 to 1971 represented baseline conditions; data of subsequent years showed the impact of the plant discharges on the river biota. The data generated from each year of study were presented in annual monitoring reports.

In each of the sections of the report, the following topics are addressed as appropriate to the section: compliance with water quality standards, both state and National Pollutant Discharge Elimination System (NPDES); and the maintenance of a balanced indigenous biota within the area of influence of the Monticello Plant.

2. ENGINEERING AND HYDROLOGIC DATA

2.1 INTRODUCTION

This section describes engineering characteristics of the cooling system of the Monticello Nuclear Generating Plant (Monticello Plant) and hydrologic characteristics of the thermal effluent and receiving stream. A description of the thermal plume and water quality of the Mississippi River in the vicinity of the Monticello Plant is provided to define the physical and chemical environment as influenced by plant operation.

2.2 PLANT OPERATING DATA

The Monticello Plant has a boiling water reactor. The net generating capacity of the plant is 545 MWe. Condenser cooling water (circulating water) is obtained from the Mississippi River. The circulating water system was designed to allow operation in any one or a combination of four modes: 1) once-through (water circulated to and from the Mississippi River), 2) helper cycle (cooling towers operating with cooled water discharged to the river), 3) partial recirculation (cooling towers operating, with a portion of the cooled water recirculated back to the intake) and 4) closed cycle (cooling towers operating with all cooled water recirculated back to the intake). The main components of the Monticello circulating water system are shown in Figure 2.2.1.

Two circulating water pumps, located in the intake structure, produce a flow of 280,000 gpm [624 cfs (cubic feet per second)] during combined (2-pump) operation and 174,000 gpm (388 cfs) during individual (1-pump) operation. The two circulating water pumps deliver water through twin 90-inch-diameter lines to the low pressure shell of the condenser. A cross connection at the pump permits single pump operation if necessary. The circulating water is discharged through both shells of the twin-shell, single-pass, dual-pressure condenser with divided water boxes. The design heat removal rate of the condenser is 3.76×10^9 Btu/hr at maximum load and with turbine valves wide open. At this load and with 60°F (15.6°C) circulating water, the two circulating water pumps operating at their combined rated capacity of 280,000 gpm (624 cfs) can maintain a back-pressure of 1.25 inches mercury absolute in the low pressure condenser and 1.71 inches mercury absolute in the high pressure condenser.

Additional water is taken from the service pump bay (located in the intake structure) by the station cooling, screen wash, make-up, residual heat removal and fire protection pumps. The plant cooling system (for miscellaneous bearing, heat exchangers, etc.) is supplied by three 6,000 gpm (13 cfs) pumps. Under normal conditions, one pump is operated during the winter and two are operated during the summer. Under extreme circumstances, all three plant cooling pumps can be operated. This cooling water is combined with the plant circulating water following its use in the plant.

The screen wash system is supplied by one 1,500 gpm (3 cfs) pump. This system has a cross-over capability with the fire protection system. Normally screen wash water is discharged directly to the river downstream from the intake.

Make-up water is supplied by two 14,000 gpm (31 cfs) pumps only during closed cycle operation. These pumps replace water lost to the circulating water system by cooling tower evaporation, drift, and blowdown.

The fire protection system includes one 50 gpm (0.1 cfs) pump to keep the system pressurized and two 1,500 gpm (3 cfs) supply pumps plus the crossover with the screen wash system.

Two 50 gpm (0.1 cfs) well pumps supply the plant potable water system, seal injection system and demineralizer make-up system. Normally, only one pump is run intermittently to meet supply requirements.

A 36-inch deicing line runs from the condenser discharge line to the intake structure. When water temperatures approach freezing, the warm condenser effluent can be delivered to the intake structure to keep the area ice-free. Steam can also be delivered to the intake structure for this purpose.

During open cycle operation, cooling water is circulated from the river intake structure through the condenser to the discharge structure. Here, the water enters a 1,000-foot-long canal (Section 2.5) and returns to the river about 1,500 feet downstream from the intake.

For the three remaining modes of operation, the Monticello Plant is equipped with two induced-draft cooling towers which are designed to remove heat rejected to the circulating water system over the range of expected operating loads. The system provides sufficient operational flexibility to return either all, part, or none of the cooled water to the circulating water pump intake (representing closed cycle, partial recycle and helper or open cycle, respectively). Conversely, none, part, or all of the cooled water may be returned directly to the river via the discharge canal.

Each cooling tower is a nine cell, induced draft, cross flow redwood tower with one 26-foot-diameter fan per cell. The fans are driven by 200-hp, 1800-rpm motors. Control equipment for the fans is located in a small fan control house adjacent to each tower.

Circulating water from the main condensers, mixed with plant heat exchanger service water flows through parallel chambers at the discharge structure. Here, during cooling tower use, the flow is diverted by two parallel (145,000 gpm [323 cfs]) cooling tower pumps. Cooled water to be recycled flows by gravity from each tower basin through 84-inch-diameter steel pipes with motor operated control gates. The lines converge into a single 108-inch-diameter pipe which conveys water to the intake structure, where the flow diverges to parallel circulating water pump basins.

Blowdown from the tower basins flows through overflow weirs to inlets for conveyance to the discharge canal. The weirs permit control of the rate of overflow. Discharge at the canal is through the cooling tower discharge structure which is designed to prevent erosion of the canal banks. Provision is also made for draining the tower basins through these discharge lines by manual operation of a tower gate.

Cooling tower characteristics are as follows:

COOLING TOWER CHARACTERISTICS

Number of towers	2
Type	Crossflow
Cells per tower	9
Tower size, LxWxH overall	270 ft x 59 ft x 61 ft
Height, curb to stack/stack	47 ft/14 ft
Static pumping head above curb	42.7 ft
Materials, framework and fill	Heart redwood
Rated Performance	
Water flow, total for two towers	290,000 gpm (646 cfs)
Water temperature, entering/leaving	116.9°F/90°F (44°C/32.2°C)
Heat transfer	3,900 x 10^6 Btu/hr
Wet bulb temperature	73°F (22.8°C)
Fans	
Number per cell	1
Number of blades/diameter	6/26 ft
Fan speed/TIP speed	146 rpm/11,900 rpm
Capacity per fan	1,266,000 SCFM
Fan bhp	149 bhp
Motor hp/speed	200 hp/1,800 rpm
Fan blade material	Aluminum, sovapon-coated

During closed cycle operation with full cooling tower capacity, the circulting water flow is isolated from the river by closing the control gates at the inlet and discharge structures. During such operations the control gates in the recirculation lines in the cooling tower basins are open. Operation in the closed cycle and partial recycle modes is intended for periods of low river flow when plant appropriation of water is limited by the terms of the Minnesota Department of Natural Resources (MDNR) permit. This permit dictates that when river flow at the plant is less than 860 cfs but greater than 240 cfs, the maximum allowable appropriation from the river shall not exceed 75 percent of the river flow at the intake. During river flow above 860 cfs the plant may withdraw no more than 645 cfs.

The reciruculation gates may be partially opened to allow variable recirculation. Therefore, with the cooling towers operating, the operating mode may vary from helper cycle to full closed cycle, depending upon the amount of flow being recirculated to the intake. For example, when the river flow at the intake is very near but less than 860 cfs, the amount of flow recirculated is minimal since nearly all of the 645 cfs (the plant's average water requirement) is available from the river. As the allowable appropriation decreases, the amount of flow recirculated must increase. Therefore, at extremely low river flows the operating mode approaches a fully closed cycle operation.

The recirculating water system is operated on helper cycle by closing the recirculation gates and returning water from the cooling tower basins directly to the river via the basin overflow weirs and the cooling tower discharge structure.

Open cycle operation (cooling towers not in service) is used during all cold weather months except as required to comply with the MDNR permit relative to maximum water appropriation. When appropriation must be restricted, the plant will recycle some water which, in turn, will require cooling tower operation. To date, minimum river flow has been 970 cfs. Therefore, the 75 percent restriction imposed by the MDNR permit has not yet governed plant operation.

Helper cycle operation is used during the warm months of the year, consistent with NSP agreement with Minnesota Pollution Control Agency (MPCA) of May 8, 1972. According to this agreement, cooling towers will be operated in the helper cycle mode whenever river temperatures consistently exceed 68°F (20°C). This period is generally from Memorial Day through Labor Day. The average number of days with river temperatures exceeding 68°F (20°C) during 1970-1972 summer periods was as follows:

Month	Number of Days 68°F Exceeded
April	0.0
May	14.2
June	25.9
July	29.5
August	27.4
September	7.0
October	0.0

Since the Monticello Plant is a base-load facility, it is operated at design load (545 MWe) when it is in operation. Hence, only this load status is relevant to this description of plant operation.

Circulating water characteristics are outlined as follows for the once-through cooling mode:

Load	545 MWe	
Condenser Cooling Water Flow Rate[1]	174,000 gpm 280,000 gpm	(1 pump) (2 pumps)
Condenser ΔT	44.2°F (24.6°C) 27.1°F (15.1°C)	(1 pump) (2 pumps)

[1]Circulating water flow does not vary as a function of plant load.

Time-temperature profiles for open cycle and helper cycle modes of operation (the only two major modes utilized at the Monticello Plant) are shown in Figure 2.2-2. Average and maximum conditions are considered. These plots consider the sequence of temperature states experienced from ambient intake to discharge to the river. Data presented by WAPORA (1975) indicate that about 20 minutes after discharge is required to reach +5°F (2.8°C) and more than 200 minutes is required to reach ambient temperatures.

Typical rates of heat rejection to the receiving stream for the Monticello Plant are listed in Table 2.2-1. The values are representative of the indicated operation modes and assume maximum capacity (559 MWe) unless stated otherwise. Heat rejection rates for non-open cycle modes were estimated assuming summer river temperatures of 80°F (26.7°C) and summer wet bulb temperature of 73°F (22.8°C). During the winter these cooling system modes are not used.

Heat rejection rate as a function of plant load is shown in Table 2.2-2 and in Figures 2.2-3 and 2.2-4. Significant temporal variation in heat rejection rates by the Monticello Plant occurs only during plant shutdown and subsequent start-up periods. Estimates of the resultant temporal variation in temperature are shown in Figures 2.2-5 and 2.2-6. These estimates were made using a condenser ΔT of 27.1°F (15.1°C) for two-pump (normal) operation and 44.2°F (24.6°C) for single-pump operation. The following shutdown and start-up schedule was assumed for typical (non-emergency) cases:

Shutdown

- 60% capacity reached in 0.5 hour
- zero load reached in 3.0 hour
- additional 0.5 hour to get off-line

Start-up

- 3 hours to reach 60% capacity
- 1 additional hour to reach 100% of design capacity

Shutdowns at the Monticello Plant during the 1971 to 1975 period are as follows:

+ 7- 5-71	4- 8-72	* 11- 6-73
+ 7-14-71	4-21-72	*+11-14-73
8- 7-71	+ 5-12-72	* 2-16-74
8- 9-71	5-23-72	*+ 3-15-74
8-20-71	+ 6- 2-72	+ 5-21-74
8-22-71	7- 1-72	+ 6- 6-74
8-26-71	7-10-72	6-10-74
9- 5-71	7-21-72	6-11-74
9- 9-71	+ 9-23-72	6-14-74
9-25-71	*+12-15-72	6-19-74
9-28-71	* 12-27-72	+ 7- 3-74
* 11-12-71	*+ 3- 3-73	7- 8-74
* 2- 6-72	+ 5-25-73	7-15-74
* 2-11-72	5-26-73	+ 8-30-74
* 2-26-72	6-16-73	*+11- 8-74

* 3- 3-72	+7-31-73	* 11-15-74
* 3-18-73	+9-28-73	*+ 1- 9-75
* 3-24-72		

*Denotes shutdown during "cold shock" susceptibility period- November to April.

+Denotes scheduled shutdown.

Consumptive use projections are shown in Table 2.2-3.

2.3 HYDROLOGIC INFORMATION

From 1926 through 1970, NSP recorded Mississippi River flows at St. Cloud, Minnesota, about 25 miles upstream from the Monticello Plant. The frequency of low flow events at St. Cloud is indicated in Figure 2.3-1. Low flow frequency information for the 12 months of the year and four seasons is presented in Appendix A. These data indicate that low flow events are most likely to occur during the late summer (August and September) and during the winter (December through February). The magnitude of low flows estimates for St. Cloud is indicated below:

Duration of Low Flow (Days)	Return Period (Years) 5	10	40	100
7	810 cfs	620 cfs	410 cfs	320 cfs
14	870 cfs	660 cfs	430 cfs	330 cfs
30	940 cfs	710 cfs	460 cfs	360 cfs
60	1050 cfs	800 cfs	530 cfs	420 cfs
90	1150 cfs	890 cfs	600 cfs	470 cfs

The record daily minimum flow at St. Cloud is 200 cfs (observed on July 31, 1934).

The closest gaging station downstream from the Monticello Plant is operated by the U.S. Geological Survey (USGS) and is located at Anoka, Minnesota, about 20 miles downstream from Monticello. The frequency of low flow events at Anoka is shown in Figure 2.3-2. Monthly and seasonal low flow summaries are presented in Appendix B. These data indicate a seasonal discharge cycle similar to that at St. Cloud. However, due to drainage from tributary basins between Monticello and Anoka, discharge is significantly greater at Anoka and low flows are less severe (Table 2.3-1). The magnitude of low flow estimates at Anoka is listed below:

Duration of Low Flow (Days)	Return Period (Years) 5	10	40	100
7	1360 cfs	1080 cfs	730 cfs	570 cfs
14	1430 cfs	1120 cfs	750 cfs	600 cfs
30	1500 cfs	1170 cfs	780 cfs	630 cfs
60	1620 cfs	1260 cfs	840 cfs	680 cfs
90	1740 cfs	1360 cfs	910 cfs	730 cfs

A broader perspective of the flow regime near the Monticello Plant is provided by the flow duration curves for St. Cloud and Anoka (Figures 2.3-3 and 2.3-4). A median daily flow of about 3,300 cfs at St. Cloud (1926-1970) and 4,900 cfs at Anoka (1931-1973) is indicated. Additional flow duration data are provided in Appendix C (St. Cloud) and Appendix D (Anoka) and are summarized in Table 2.3-1.

Data on the thermal stratification characteristics of the Mississippi River at the Monticello Plant are presented in Section 2.6 (Thermal Plume Characteristics) for ambient and plume (downstream) areas.

During 1971 through 1973, thermal data were collected during 34 surveys of the river reach from above the plant to about 3.8 miles below the plant. Data from these surveys indicate a relatively homothermal pattern upstream from the plant discharge in the vicinity of the plant intake. This ambient homogeneous pattern results from the relatively shallow (<10 feet) depth of the river in the reach just upstream from the plant. Because of the shallowness of the river, water quality stratification of the river in this area is not expected. Thermal stratification induced by the Monticello thermal effluent is discussed in Section 2.6.

Ambient water temperatures at the Monticello Plant site have been measured using the Palmer continuous-recording temperature system. Summarizations of temperature data collected at temperature Stations 1 and 2 (comparable to Stations 1 and 2 in Figure 3.1-1, which are located upstream from the Monticello Plant) during the 1969 to 1975 period are presented in Appendix E. These data show near-freezing water temperatures through late March (when the river is iced over) and maximum water temperatures in excess of 80°F (26°C) during July and August. Summer maxima vary from year to year and are apparently inversely related to river flow (WAPORA 1975). One-day and 7-day average temperature occurences at the Monticello Plant intake during 1970-197[illegible] and at the Whitney Plant intake (about 25 miles upstream from Monticello) during 1965-1969 are shown in Figures 2.3-5 and 2.3-6, and 2.3-7 and 2.3-8, respectively.

Ambient temperatures at the Monticello Plant can be expected to occasionally exceed the upper limits indicated in the state water quality standards (Appendix G). For example, maximum daily temperatures observed at St. Cloud from 1962 through 1967 are as follows:

Month	Maximum Observed Daily Temperature	Water Quality Standard for Month
January	33°F (0.6°C)	40°F (4.4°C)
February	33°F (0.6°C)	40°F (4.4°C)
March	36°F (2.2°C)	48°F (8.9°C)
April	58°F (14.5°C)	60°F (15.6°C)
May	72°F (22.2°C)	72°F (22.2°C)
June	80°F (26.7°C)	78°F (25.6°C)
July	85°F (29.5°C)	83°F (28.3°C)
August	82°F (27.8°C)	83°F (28.3°C)
September	74°F (23.4°C)	78°F (25.6°C)
October	64°F (17.8°C)	68°F (20.0°C
November	49°F (9.5°C)	50°F (10.0°C)
December	42°F (5.6°C)	40°F (4.4°C)

Data presented in Figures 2.3-6 and 2.3-8 further illustrate this potential for ambient temperatures to exceed the water quality standards.

2.4 METEOROLOGICAL DATA

Monthly averages of dry bulb temperature, wet bulb temperature, solar radiation and cloud cover are presented below. These data are for Minneapolis - St. Paul, about 35 miles southeast of the Monticello Plant. Air temperature information representative of the plant area (WAPORA 1975) is summarized in Table 2.4-1. Wind roses are shown in Figure 2.4-1. Average annual potential evapotranspiration at the site is about 24 inches (Figure 2.4-2). About 80 percent of this occurs in the May through October period (USACE 1970).

	Dry Bulb (°F)	Wet Bulb (°F)	Dew Point (°F)	Solar Radiation (Langleys)	Cloud Cover[1]
January	12.9	11.8	5.7	168.0	6.5
February	17.9	16.4	9.9	260.0	6.2
March	29.3	26.6	20.3	368.0	6.7
April	45.4	39.5	31.9	426.0	6.5
May	58.0	50.3	43.1	496.0	6.4
June	67.8	60.0	54.7	535.0	6.0
July	72.9	64.9	60.4	557.0	4.9
August	71.0	63.6	59.3	486.0	5.1
September	60.7	54.6	49.8	366.0	5.1
October	50.8	45.3	39.3	237.0	5.4
November	32.9	30.2	25.1	146.0	6.9
December	19.2	17.9	12.6	124.0	6.9

[1] Clear sky = 0, half-clear = 5, complete cover = 10.

2.5 OUTFALL CONFIGURATION AND OPERATION

The following describes the outfall (a single discharge canal) of the Monticello Plant. Other operational characteristics are presented in Section 2.2 (Plant Operating Data).

(1) Length of discharge canal = 1000 ft

(2) Width of discharge canal = 90 ft (at plant end)
100 ft (at river confluence)
= 62 ft (bottom)

(3) Depth of discharge canal = 6 ft (mean)

(4) Angle of discharge = 22° (with respect to river flow direction)

(5) Velocity of discharge = 1.3 fps (at plant discharge to canal)
= 0.5 fps (estimated at discharge to river)

Beyond the point of discharge to the river, velocities are those of the river, which vary widely with river discharge rate.

2.6 THERMAL PLUME CHARACTERISTICS

The configuration of the thermal plume of the Monticello Plant was mapped on 34 occasions during 1972-1973. These thermal surveys encompass a variety of ambient temperatures, cooling water and river flow rates, and cooling tower operation modes (Table 2.6-1). Data collected on the following dates will be discussed in detail to provide a representative description of the thermal plume:

Plume Survey Dates

8/13/71	5/23/72
8/19/71	8/30/72
9/20/71	9/7/72
2/23/72	7/30/73

Data from the August 13, 1971 and August 19, 1971 surveys are used to describe a late summer case under low flow conditions (about 1,100 cfs), with and without cooling tower operation, respectively. The August 30, 1972 and September 7, 1972 surveys describe the late summer period under relatively high flow conditions (greater than 11,000 cfs) with and without cooling tower operation, respectively. A typical summer condition is depicted by the July 30, 1973 data; river flow was close to the median low flow and cooling towers were in use during this survey. The February 23, 1972 data show a typical winter plume configuration. Spring and fall transitional periods are described using May 23, 1972 and September 20, 1971 data. Plume survey data for these dates are illustrated in Appendix F.

For these survey dates, the following descriptive characteristics will be used to present and to interpret the results of the thermal surveys:

(1) the extent of the +3°F (2°C) isotherm; intermediate discharge zone

(2) the extent of the +9°F (5°C) isotherm; immediate discharge zone

(3) compliance with applicable water quality standards.

For item (3), thermal guidelines indicated in the draft NPDES Permit for the Monticello Plant were used. The draft Monticello Plant NPDES Permit lists the following restrictions on the thermal discharge:

(i) The discharge shall not raise the temperature of the receiving water at the edge of the mixing zone specified below either by more than 2.8°C (5°F) above the natural based on the monthly average of the maximum daily temperatures or above the following weekly average temperatures* whichever is less:

January	4.4°C (40°F)	July	28.3°C (83°F)
February	4.4°C (40°F)	August	28.3°C (83°F)
March	8.9°C (48°F)	September	25.6°C (78°F)
April	15.6°C (60°F)	October	20.0°C (68°F)
May	22.2°C (72°F)	November	10.0°C (50°F)
June	25.6°C (78°F)	December	4.4°C (40°F)

*Where the background weekly average temperature of natural origin is normally higher than that specified for a particular month, the natural weekly average temperature may be used as the limiting value which shall not be exceeded at the edge of the mixing zone.

(ii) The mixing zone for the thermal effluents shall not extend more than 305 meters (1,000 feet) beyond the point of discharge. The total mixing zone at any transect of the receiving water shall contain no more than twenty-five (25) percent of the cross sectional area and/or volume of flow of the river and shall not extend over more than fifty (50) percent of the width.

Two interpretations of these thermal discharge restrictions were used for this demonstration to judge compliance using the thermal plume survey data. In the first interpretation (referred to as Interpretation 1), the mean of the daily maximum ambient temperatures for the calendar month during which the survey was made was computed. A ΔT of +5°F was then added to this monthly mean and this sum was used as the maximum allowable temperature at the edge of the defined mixing zone. In the second interpretation (referred to as Interpretation 2), the maximum allowable temperature rise above the ambient at the edge of the mixing zone would be 5°F. If the average ΔT at the edge of the mixing zone was less than or equal to 5°F (over a month), then compliance is indicated for that month. For an individual day, one could judge compliance by comparing the size of the +5°F isotherm with the defined mixing zone and infer that, if similar conditions persisted throughout the month, then compliance (or non-compliance) would be indicated.

<u>Summer Plume Configuration-Low Flow Case</u>

August 13, 1971 plume survey data (Figures F-1 and F-2 in Appendix F) are used here to represent the typical late summer, low flow case. Average river and plant operation conditions for the survey are as follows:

River-Plant Conditions: August 13, 1971

Ambient temperature	= 74.4°F (23.6°C)
Condenser ΔT^1	= 28.8°F (16.0°C)
Plant ΔT^1	= 11.2°F (6.2°C)
Plant Load	= 510.0 MWe
Plant Discharge Flow	= 509.8 cfs
River Discharge	= 1140 cfs

[1] ΔT computed with respect to upstream ambient temperature.

Both cooling towers were in operation during this survey.

The data presented in Figure F-1 indicate that the +3°F (+2°C) or 77.4°F (25.2°C) isotherm extends to the vicinity of the State Highway 25 Bridge (Monticello Bridge) located about 3.8 miles below the plant discharge. At the surface, this isotherm extends approximately halfway across the river for two-thirds of this reach. The +9°F (+5°C) or 83.4°F (28.6°C) isotherm was very small during the August 13, 1971 survey. The surface isotherm extended only about 100 feet below the discharge.

Rapid vertical mixing was evident during the August 13, 1971 plume survey. At the discharge to the river, a surface to bottom difference of 10°F (5.5°C) was observed. Isotherm lines were nearly vertical at a distance of about 500 feet below the outfall (Figure F-2). The +3°F (+2°C) isotherm reached the bottom of the river approximately 200 feet below the discharge canal. The +9°F (+5°C) isotherm did not reach the river bottom.

The average maximum ambient temperature for August 1971 was 71.6°F (22.0°C) (Table E-1 in Appendix E). During the August 13, 1971 survey, the 76.6°F (71.6 + 5°F) isotherm extended to the vicinity of the Monticello Bridge. This indicates non-compliance with the draft NPDES Permit guidelines according to Interpretation 1 described above. Patches of water with temperatures greater than 5°F (2.8°C) above ambient (or 79.3°F [26.3°C]) were observed more than 1,500 feet below the discharge (Figure F-1). This indicates non-compliance with the draft NPDES Permit according to Interpretation 2.

However, Minnesota water quality criteria (Appendix G) indicate a maximum allowable (weekly average) temperature of 83°F (28.4°C) for the month of August. This is approximately equivalent to the +9°F level discussed above. The small size of the 83°F (28.4°C) isotherm (Figure F-1) indicates compliance with the state water quality standards during this survey.

The August 19, 1971 plume survey data (Figures F-3 and F-4) represent a case similar to that of August 13, 1971, with the exception that cooling towers were not in use. Average river and plant operation conditions were as follows:

River-Plant Condition: August 19, 1971

Ambient temperature	= 77.9°F (25.5°C)
Condenser ΔT[1]	= 26.8°F (14.9°C)
Plant ΔT[1]	= 24.9°F (13.9°C)
Plant Load	= 508.2 MWe
Plant Discharge Flow	= 585.0 cfs
River Discharge	= 1142 cfs

[1] ΔT computed with respect to upstream ambient temperature.

The thermal plume was substantially larger during the August 19 survey than was observed on August 13, 1971, due to the use of a once-through cooling mode. The +3°F (+2°C) or 80.9°F (27.2°C) isotherm extended well beyond the Monticello Bridge (Figure F-3); temperatures at the bridge (over 3 miles below the outfall) ranged from 85° to 87°F (29.5° to 30.5°C). The +3°F (+2°C) isotherm extended (at the surface) half the width of the river from a point about 500 feet below the outfall to a point about 2 miles below the discharge. Beyond that point, it extended about 20 percent of the width of the stream to a point over 3 miles below the discharge.

As was observed during the August 13 survey, rapid vertical mixing was evidenced on August 19, 1971. Significant vertical stratification was not observed beyond a point about 500 feet below the outfall (Figure F-4).

The 83°F (28.4°C) isotherm (the state water quality standard for temperature for August) extends over more than 50 percent of the river width from about 1400 feet below the outfall to beyond the Monticello Bridge. Below a point about 2 miles below the discharge this temperature was exceeded over the entire river cross section (Figure F-4). Using the indicated mixing zone guidelines, these results indicate non-compliance with the state water quality standards and draft NPDES Permit guidelines during this survey period.

<u>Summer Plume Configuration-High Flow Case</u>

The August 30, 1972 and September 7, 1972 plume survey results (Figures F-5 through F-8) are presented here as examples of late summer conditions with high river flows. River and plant operation conditions on these survey dates were as follows:

River-Plant Conditions

	August 30, 1972	September 7, 1972
Ambient temperature	71.3°F (21.9°C)	64.7°F (18.2°C)
Condenser ΔT^1	27.6°F (15.3°C)	29.4°F (16.4°C)
Plant ΔT^1	15.2°F (8.5°C)	29.4°F (16.4°C)
Plant Load	566.8 MWe	566.8 MWe
Plant Discharge Flow	633 cfs	596 cfs
River Discharge	14,796 cfs	10,750 cfs

[1]ΔT computed with respect to upstream ambient temperature.

Both cooling towers were in operation during the August 30 survey and both were out during the September 7 survey.

During the August 30, 1972 survey, the +3°F (+2°C) or 74.3°F (23.5°C) isotherm enclosed a very narrow (<50 ft wide) band along the south shore (plant shore) of the Mississippi River. Isolated patches of water above this temperature were noted as far as one mile below the outfall (Figure F-5). The +9°F (+5°C) or 80.3°F (26.9°C) isotherm did not extend downstream from the discharge canal (Figure F-5 and F-6).

During the September 7, 1972 survey, the +3°F (+2°C) or 67.7°F (19.9°C) isotherm extended (at the surface) over 20 to 50 percent of the river width to beyond the Monticello Bridge (Figure F-7). The +9°F (+5°C) or 73.7°F (23.2°C) isotherm enclosed a narrow (<100 ft) band of water extending about 2000 feet below the discharge.

Under these conditions of high river discharge, horizontal mixing, and to a lesser degree, vertical mixing are diminished. The plume was vertically stratified along the plant shore to a point beyond 500 feet below the discharge (Figure F-8).

During August and September 1972, the monthly average maximum temperatures were 69.5°F and 62.6°F, respectively (Table E-1). Ambient water temperatures during the August 30 and September 7 surveys were slightly above these monthly means. During the August 30 survey, the 74.5°F (69.5 + 5°F) isotherm extended in a narrow band along the plant shore for about 3,200 feet. The 5°F above ambient or 76.3°F isotherm extended to a point about 400 feet below the outfall. These results indicate non-compliance with the NPDES Permit according to Interpretation 1 and compliance according to Interpretation 2 during the August 30 survey. During the September 7 survey, the 67.2°F (62.2°F + 5°F) isotherm was comparable to the +3°F (+2°C) (above ambient) isotherm just discussed. The +5°F above ambient or 69.6°F isotherm extended to the vicinity of the MOnticello Bridge. This indicates non-compliance according to both interpretations of the draft permit restrictions.

However, during the August 30 survey, the 83°F (28.4°C) (the water quality standard for August) isotherm did not extend beyond the end of the discharge canal (Figure F-5). During the September 7 survey, the 78°F (25.6°C) (the water quality standard for September) isotherm extended approximately 200 feet below the outfall (Figure F-7). The small size of the zones enclosed by these isotherms indicates compliance with state water quality standards during both of these thermal plume surveys. Under these high flow conditions compliance with these standards (Appendix G) is indicated both with and without the use of cooling towers.

Summer Plume Configuration-Typical Case

Data collected during the July 30, 1973 thermal plume survey are presented here as representing a typical summer condition. Of the surveys conducted (Table 2.6-1), the river discharge on this date (2411 cfs) was closest to (while remaining below) the summer median river discharge (Appendix C). Cooling towers were in use during this survey. This is the normal conditional mode during the summer. Average river and plant operation conditions during the survey are as follows:

River-Plant Conditions: July 30, 1973

Ambient Temperature	= 69.5°F (20.9°C)
Condenser ΔT^1	= 29.8°F (16.6°C)
Plant ΔT^1	= 12.6°F (7.0°C)
Plant Load	= 544.1 MWe
Plant Discharge Flow	= 577.7 cfs
River Discharge	= 2411 cfs

[1] ΔT computed with respect to upstream ambient temperature.

During the July 30, 1973 survey, the +3°F (+2°C) or 72.5°F (22.5°C) isotherm extended (at the surface) over about 50 percent of the width from a point about 1000 feet below the outfall to the vicinity of the Monticello Bridge (Figure F-9). The +9°F (+5°C) or 78.5°F (25.9°C) isotherm extended about 500 feet below the discharge and perhaps 100 feet from the plant shore (Figure F-9).

Vertical mixing of the plume was fairly rapid in the vicinity of the outfall. Horizontal mixing was more limited. At distances of less than 200 feet below the outfall and more than 900 feet below the outfall, isotherm lines were essentially vertical, indicating the absence of vertical stratification (Figure F-10). The river was vertically stratified for a brief period about 500 feet below the discharge. The +3°F (72.5°F) isotherm reached the river bottom immediately below the plant outfall but was not observed beyond 500 feet below the outfall. The maximum temperatures observed at the river bottom were about 82°F (27.8°C) observed below the outfall for a distance of about 200 feet.

For July 1973, the monthly average of maximum daily temperatures above the Monticello Plant was 77.4°F (25.2°C) (Table E-2). The 82.4°F (77.4°F + 5°F) (28.0°C) isotherm extended approximately 250 feet downstream from the discharge and at most 100 feet from the plant shore. The +5°F above ambient or 74.5°F (23.6°F) isotherm extended beyond 1,000 feet below the discharge. These results indicate compliance with water quality standards and Interpretation 1 of the draft NPDES Permit restrictions and non-compliance according to Interpretation 2.

Winter Plume Configuration

Data from the February 23, 1973 plume survey are presented here to represent the winter plume configuration (Figures F-11 and F-12). Average river and plant operation conditions were as follows:

River-Plant Conditions: February 23, 1972

Ambient Temperature	= 32.7°F (0.4°C)
Condenser ΔT[1]	= 30.1°F (16.7°C)
Plant ΔT[1]	= 29.8°F (16.6°C)
Plant Load	= 560.8 MWe
Plant Discharge Flow	= 640.0 cfs
River Discharge	= 3840 cfs

[1]ΔT computed with respect to upstream ambient temperature.

The open cycle cooling mode is used during the winter. A plume survey was also conducted on February 22, 1972 under essentially the same river and plant load conditions but with a cooling water flow of 320 cfs. No appreciable differences were noted in the downstream plumes measured on these two dates. About half of the river surface was ice-covered during these surveys.

The +3°F (+2°C) or 35.7°F (2.1°C) isotherm observed during the February 23 survey enclosed about 25 percent of the river cross section to the vicinity of the Monticello Bridge. Vertical mixing was completed within 500 feet of the discharge (Figure F-12). The +9°F (+5°C) or 41.7°F (5.4°C) isotherm enclosed a narrow band (25 to 100 feet) along the south (plant) shore for a distance of about 2 miles below the plant outfall. Maximum river bottom temperatures of about 44° to 46°F (6.7° to 7.8°C) were observed below the discharge for about 3,200 feet downstream.

The average monthly maximum ambient temperature for February 1972 was 34.3°F (1.3°C) (Table E-1). During the February 23, 1972 thermal plume survey, the 39.3°F (34.3°F + 5°F) (4.1°C) isotherm extended to the vicinity of the Monticello Bridge over 3 miles below the point of discharge. The +5°F (+2.8°C) isotherm also extended to the vicinity of the MOnticello Bridge. This indicates non-compliance with the standards defined in the draft NPDES Permit according to both Interpretations 1 and 2.

Spring Plume Configuration

The Monticello thermal plume configuration during the spring high flow period was characterized using May 23, 1972 survey data. This date is probably a poor representation of typical spring conditions but it is the earliest ice-free survey conducted. Average river and plant operation conditions during this survey were as follows:

Plant-River Conditions:	May 23, 1972
Ambient Temperature	= 70.4°F (21.4°C)
Condenser ΔT^1	= 13.6°F (7.6°C)
Plant ΔT^1	= 13.1°F (7.3°C)
Plant Load	= 570.0 MWe
Plant Discharge Flow	= ---
River Discharge	= 13,750 cfs

[1] ΔT computed with respect to upstream ambient temperature.

The +3°F (+2°C) or 73.4°F (23.0°C) isotherm enclosed about 40 percent of the river cross-section near the outfall. This rapidly diminished to between 10 and 25 percent and extended to a point about 2.5 miles below the discharge (Figures F-13 and F-14). The +9°F (+5°C) or 79.4°C (26.4°C) isotherm dissipated within 200 feet below the discharge. Vertical mixing of the thermal effluent was essentially completed within 200 feet below the discharge (Figure F-14). Maximum observed river bottom temperatures between 75° and 81°F (23.9° and 27.2°C) were observed up to about 200 feet below the outfall.

The mean maximum ambient temperature for May 1972 was 60.3°F (15.7°C) (Table E-1). However, the upstream ambient temperature during the survey was 70.4°F (21.4°C). The monthly average maximum temperature level is not a reasonable base to assess compliance with the standards; discharge at the ambient temperature (70.4°F) (21.4°C) would produce an apparent violation of the draft NPDES Permit thermal guidelines. Thus the temperature level of 72°F (22.2°C) (the alternate temperature indicated in the draft permit) was used as the base temperature for this evaluation. During the May 23, 1972 survey, the 72°F (22.2°C) isotherm extended about to the vicinity of the Monticello Bridge. This indicates non-compliance with the standards.

Autumn Plume Configuration

The autumn transition period is represented here by the results of the September 20, 1971 survey. Average river and plant conditions during this survey were as follows:

River-Plant Conditions: September 20, 1971

Ambient Temperature	= 61.0°F (16.1°C)
Condenser ΔT^1	= 23.1°F (12.9°C)
Plant ΔT^1	= 13.2°F (7.4°C)
Plant Load	= 508.6 MWe
Plant Discharge Flow	= 633.0 cfs
River Discharge	= 1215 cfs

[1]ΔT computed with respect to upstream ambient temperature.

Cooling towers were operated in a partial helper cycle mode during this survey.

The +3°F (+2°C) or 64°F (17.8°C) isotherm (at the surface) varied with the meanders of the river channel and covered from 50 to 100 percent of the width of the river. With the exception of this meandering, little change in the plume was noted between a point about 1,000 feet below the outfall and the Monticello Bridge (Figure F-15).

The +9°F (+5°C) or 70°F (21.1°C) surface isotherm formed a tongue extending into the river about 300 feet and downstream about 700 feet from the outfall. Vertical mixing was not completed until about 1,500 feet below the discharge. Maximum observed river bottom temperatures of 71°F (21.7°C) occurred only at Transect 3 (500 feet below the outfall). Bottom temperatures of 65°F (18.4°C) extended to the Monticello Bridge (Figure F-16).

The mean maximum ambient water temperature for September 1971 was 63.7°F (17.6°C) (Table E-1). During the September 20, 1971 survey, the 68.7°F (63.7°F + 5°C) (20.4°C) isotherm extended about 750 feet below the outfall and extended over less than 25 percent of the river cross-section. Compliance with the draft permit standards is indicated using Interpretation 1. The +5°F (2.8°C) above ambient or 66°F (18.9°C) isotherm extended to the vicinity of the Monticello Bridge indicating non-compliance with the permit restrictions using Interpretation 2.

Immediate and Intermediate Discharge Areas

The preceding sections have presented thermal plume configurations measured under varying river flow and plant operation conditions. These configurations are representative of conditions observed throughout the four seasons. To provide additional insight, estimates of the spatial extent of the plume 70 percent of the time during the months June through September were made. These are gross approximations made to provide a definition of immediate and intermediate discharge areas. Information from the following plume surveys was used to characterize these "70 percent" cases:

Month	Survey Date	River Discharge (cfs)	River Discharge (cfs) Exceeded 70% of Time
June	6/22/71	4,224	3,900
July	7/30/73	2,410	2,500
August	8/2/71	2,048	1,900
September	9/20/71	1,215	2,200

The discharges "exceeded 70 percent of time" were estimated from data presented in Appendix C. As indicated by the preceding description of plume configuration, the areal extent of the plume is to a large degree inversely related to flow. Thus, the extent of the thermal plume under these "70 percent discharge" conditions represents an upper limit on plume size for that time of year (and cooling system mode); 70 percent of the time the plume is expected to be smaller than that characterizing the "70 percent discharge" case. Table 2.6-2 summarizes the estimated maximum plume extension 70 percent of the time for the months considered. These estimates assume cooling tower operation for June, July and August.

NSP is currently conducting a study to develop a more analytical method for predicting the mixing and spreading characteristics of the Monticello Plant thermal discharge. This study should provide a more definitive definition of the immediate and intermediate discharge zones under various conditions of river flow, temperature, and plant operation mode.

2.7 CHEMICAL AND WATER QUALITY DATA

Water quality data accumulated for the Mississippi River at the Monticello Plant site are summarized in Table 2.7-1. The variability of each parameter is shown for the preoperational period before 1971 and the operational period since 1971. In general, the average value of the parameters for the operational years 1972 and 1973 fell within the range of averages for the other years. Variation in river discharge from year to year is probably the major factor contributing to the observed differences.

Table 2.7-2 shows dissolved oxygen measurements for the four years of monitoring at three stations on the Mississippi River, one located above the plant and two below. These data clearly show that the dissolved oxygen values of the operational period are very similar in range and absolute value to the data from these stations in the preoperational years. The data also indicate that there was no significant difference in dissolved oxygen between the upstream and downstream samples.

These data support the contention that the effect of pumping water through a power plant's cooling system has no significant effect on the water quality of the river other than the change in temperature due to added heat.

In order to ensure adequate heat transfer efficiency on the condenser tubes, the cooling system is chlorinated. The following outlines the chlorination procedure and other related factors:

(1) Chlorine is injected automatically every six hours (4 times per day) for one-half hour except during shutdowns or outages.

(2) Chlorine demand of intake water is determined about every three months; an injection level resulting in a free available of 0.5 mg/l is estimated.

(3) The discharge canal is sampled weekly for free available chlorine.

(4) Chlorine is measured weekly at the discharge of circulating water pumps to ensure a concentration of 0.5 to 0.6 mg/l at this point.

A study of the chlorination program at the Monticello Plant has been initiated.

2. References

Marks, L. S. 1951. Standard Handbook for Mechanical Engineers. McGraw Hill, New York.

USACE. 1970. Upper Mississippi River Comprehensive Basin Study. Vol. III. St. Louis.

WAPORA. 1975. Monticello Nuclear Generating Plant. 316(a) Demonstration.

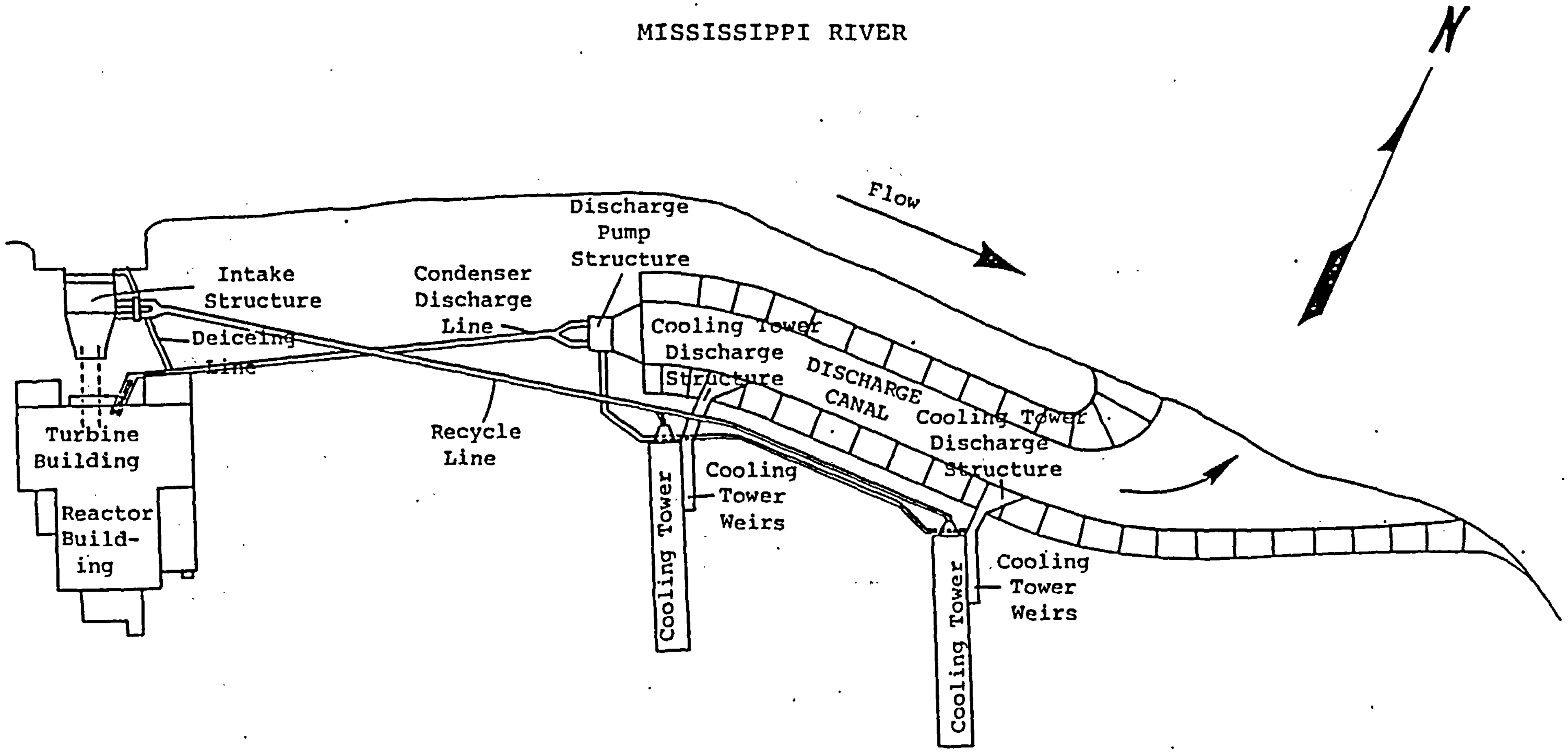
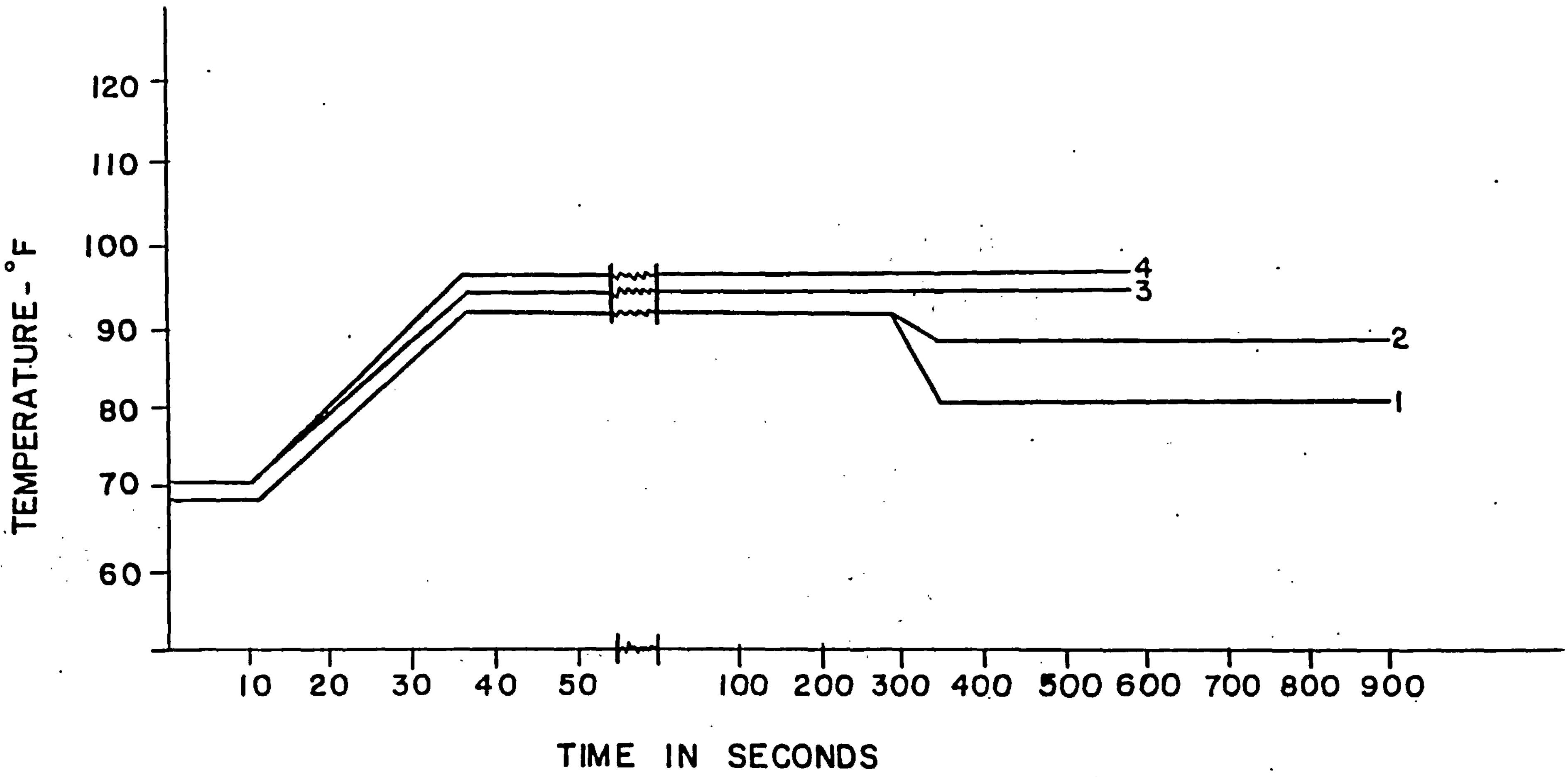


FIGURE 2.2-1

PLOT PLAN OF MONTICELLO NUCLEAR GENERATING PLANT
CIRCULATING WATER SYSTEM

FIGURE 2.2-2

Time vs. Temperature Plot for Monticello Nuclear Generating Plant



LEGEND:

1	JULY 5, 1972	WORST 'AVERAGE' CONDITION	}	HELPER CYCLE
2	JULY 5, 1972	WORST 'MAXIMUM' CONDITION		
3	JUNE 22, 1972	WORST 'AVERAGE' CONDITION	}	OPEN CYCLE
4	JUNE 22, 1972	WORST 'MAXIMUM' CONDITION		

FIGURE 2.2-3

Monticello Nuclear Generating Plant
Heat Rejection to River vs. Load Helper Mode (typical values) Summer-(2 pump operation)

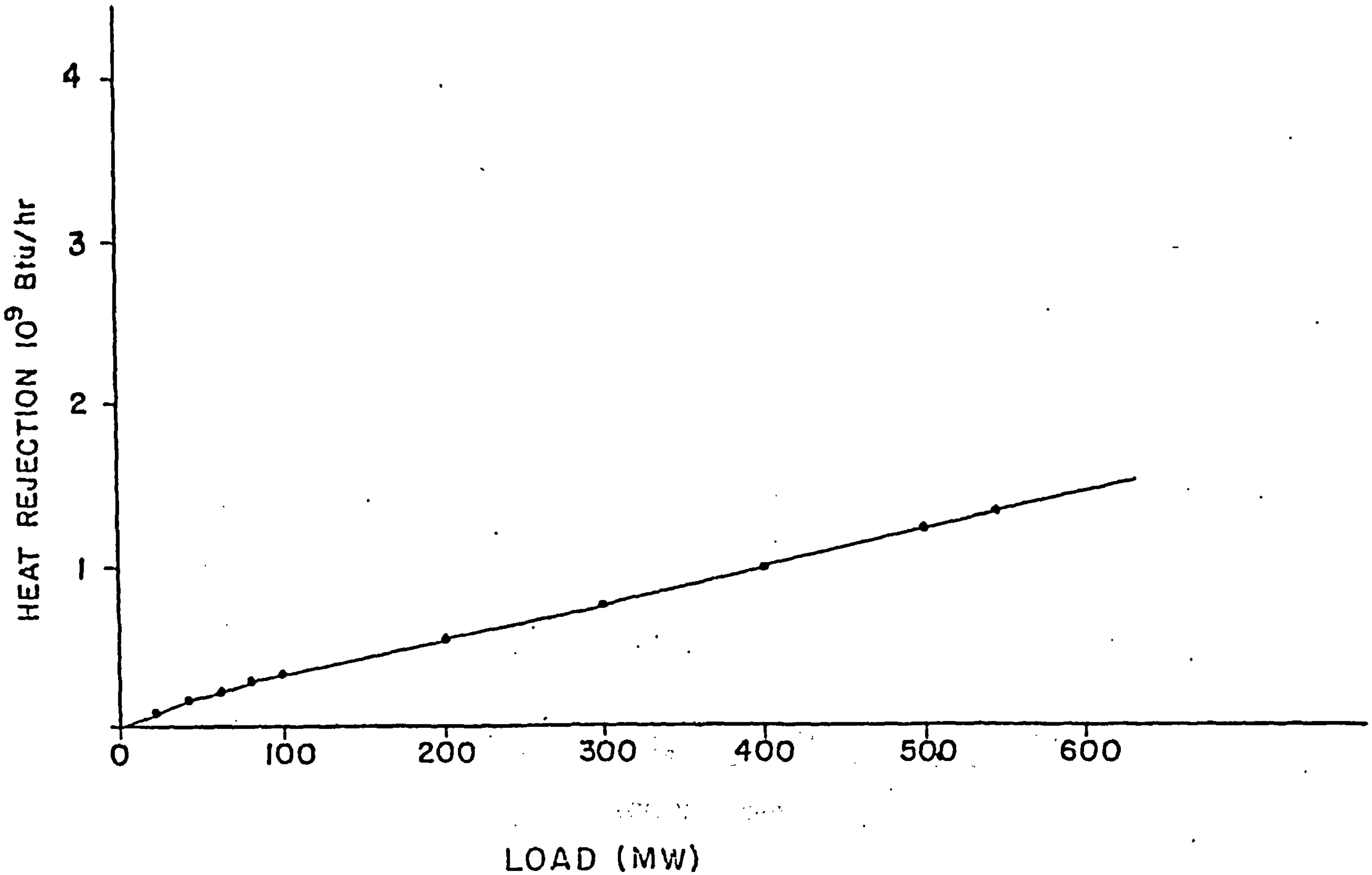


FIGURE 2.2-4

Monticello Nuclear Generating Plant
Heat Rejection to River vs. Load Open Cycle (typical values) Summer

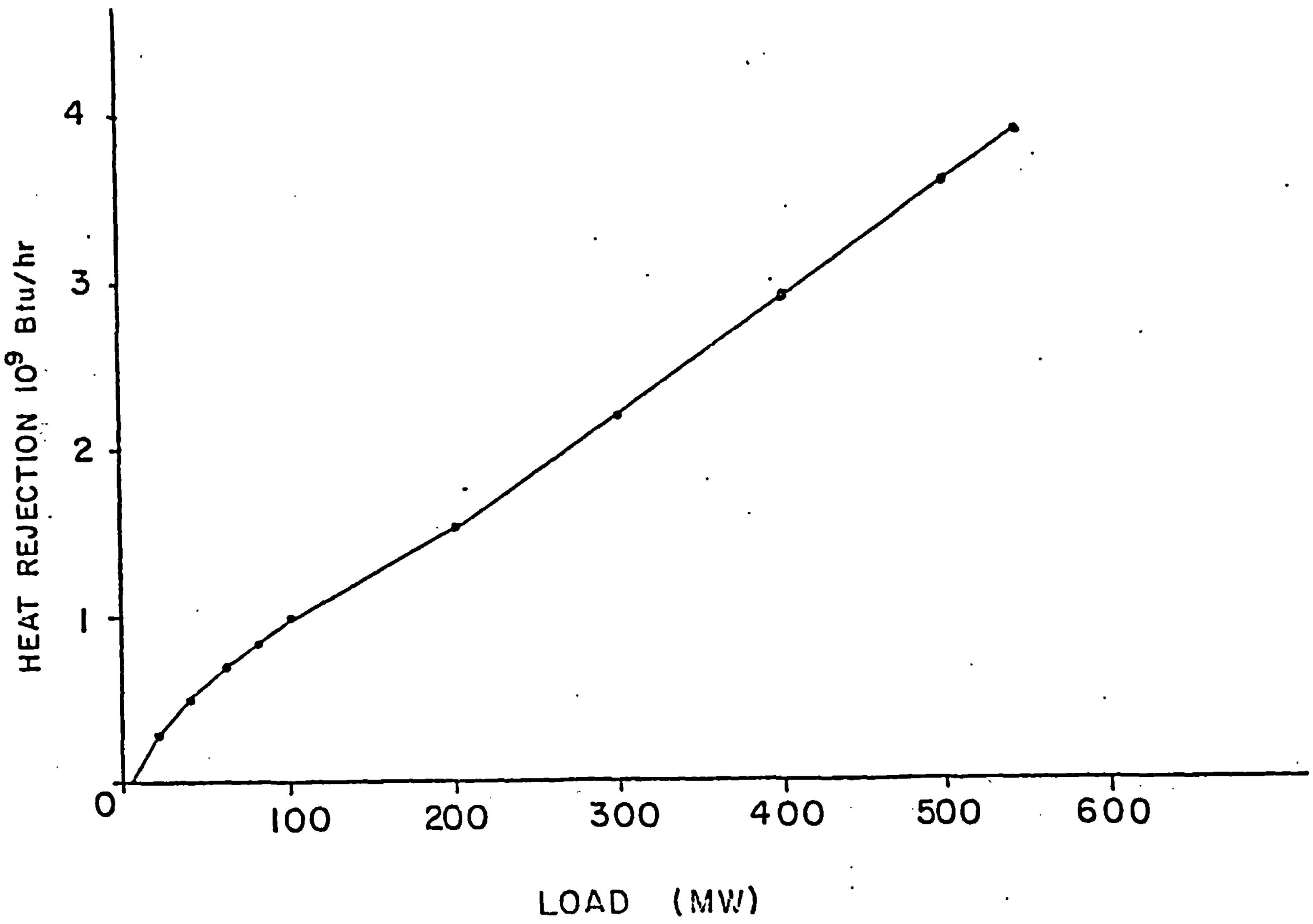


FIGURE 2.2-5

Condenser ΔT vs. Time Relation for Typical Plant Shut-Down Sequence

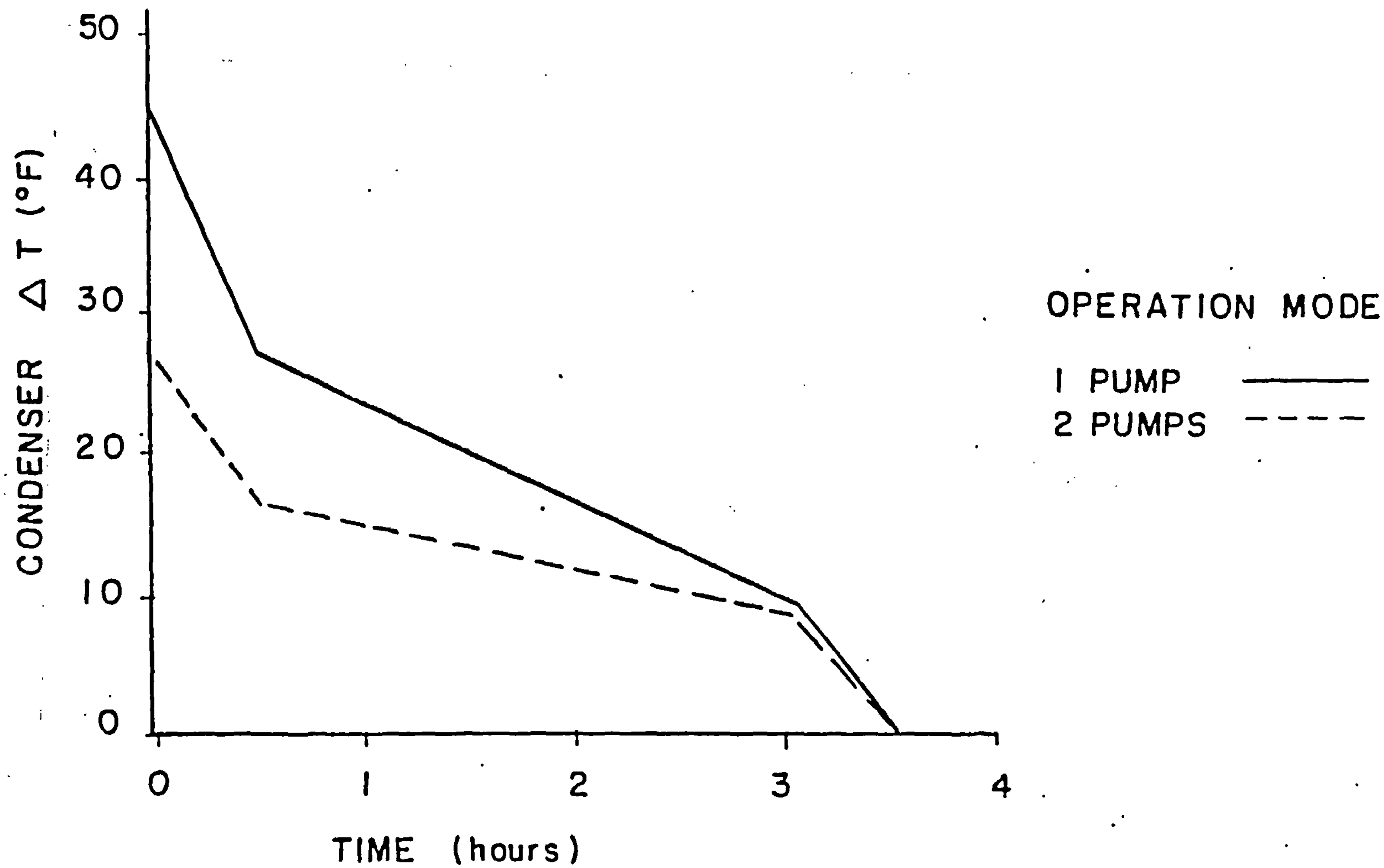


FIGURE 2.2-6

Condenser ΔT vs. Time Relation for Typical Plant Start Up Sequence

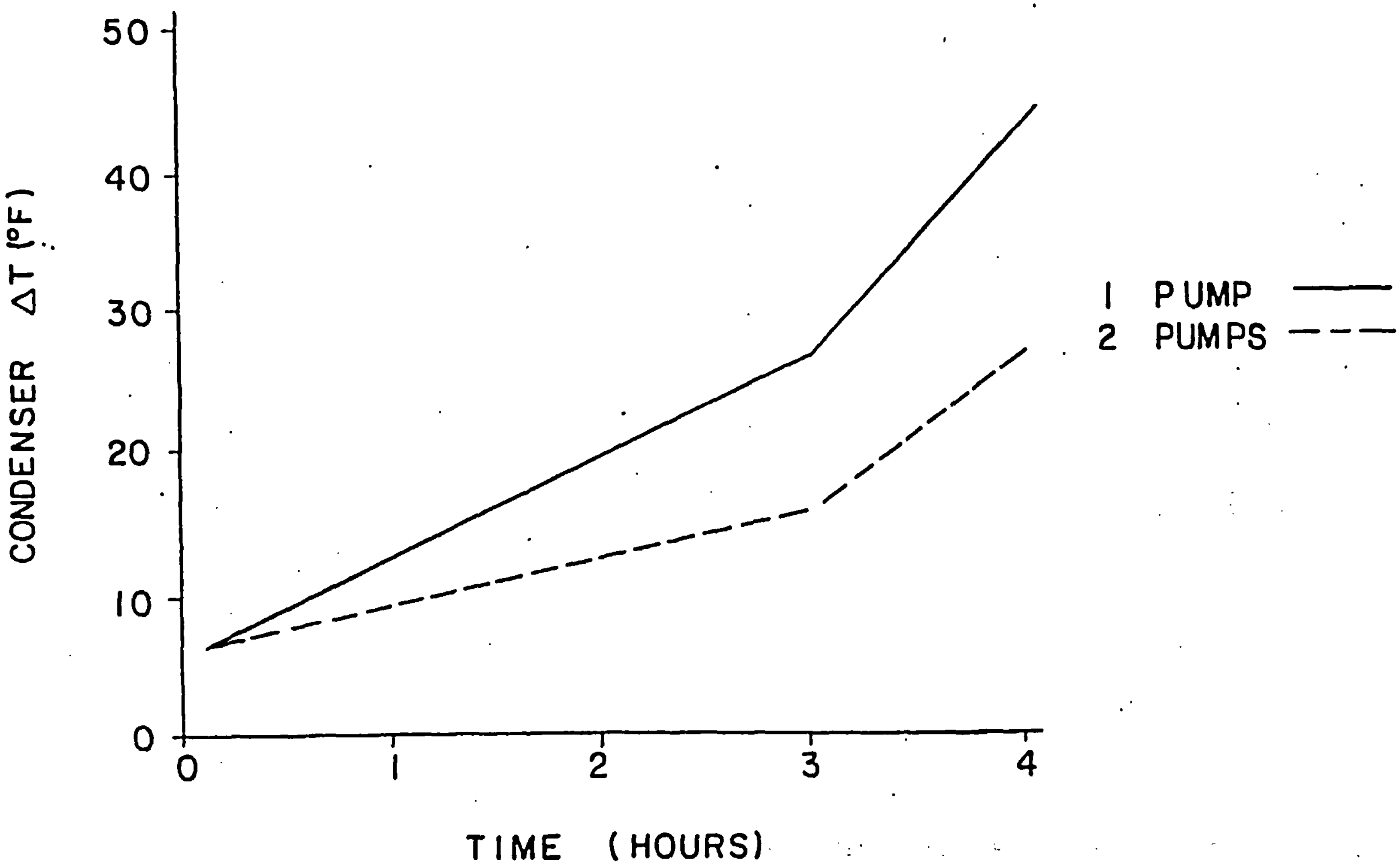
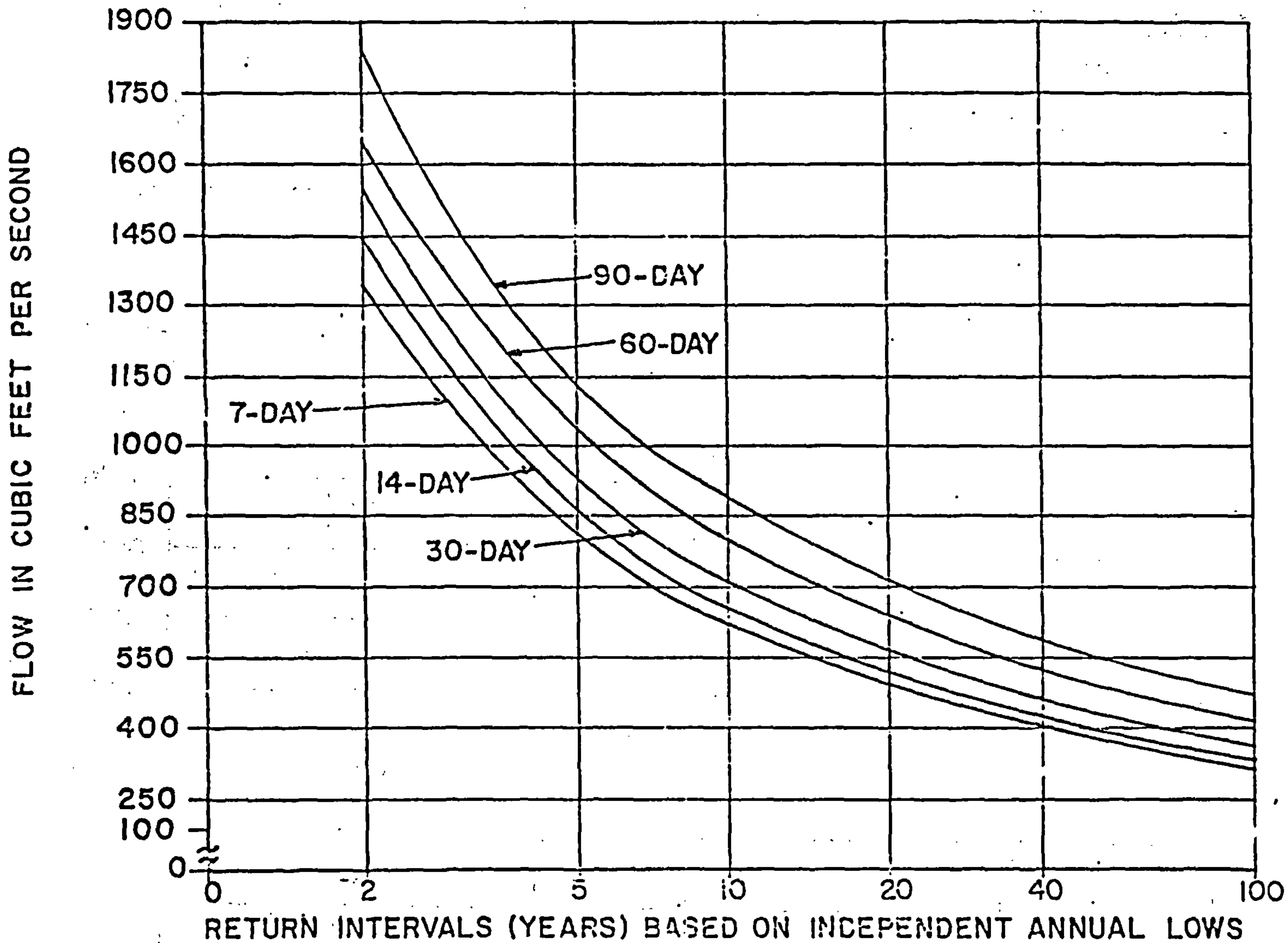
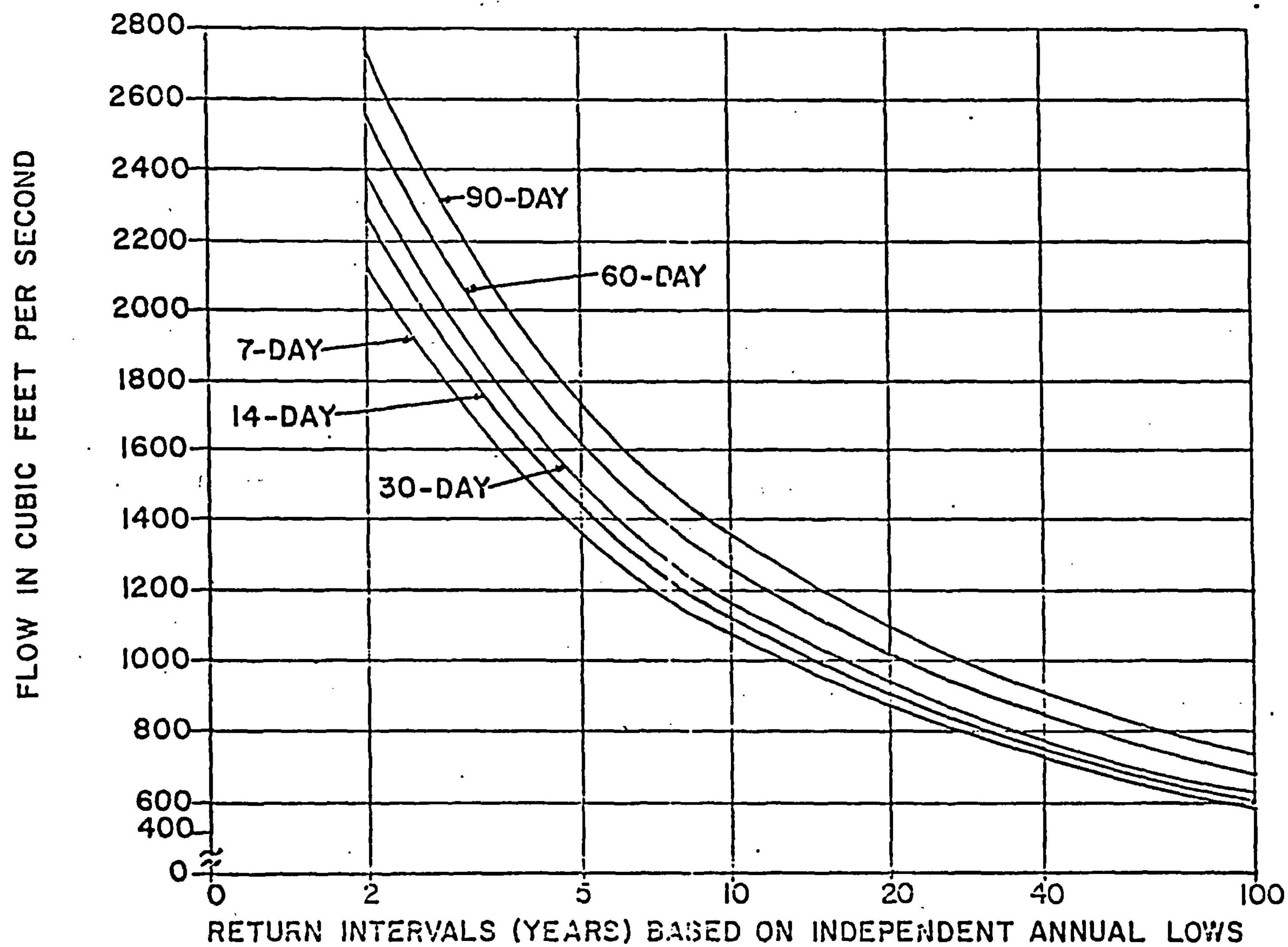


FIGURE 2.3-1



CONSECUTIVE DAY AVERAGE-LOW FLOW FREQUENCIES
MISSISSIPPI RIVER NEAR ST. CLOUD, MINNESOTA (1926-1970)

FIGURE 2.3-2



CONSECUTIVE DAY AVERAGE-LOW FLOW FREQUENCIES
MISSISSIPPI RIVER NEAR ANOKA, MINNESOTA (1931-1973)

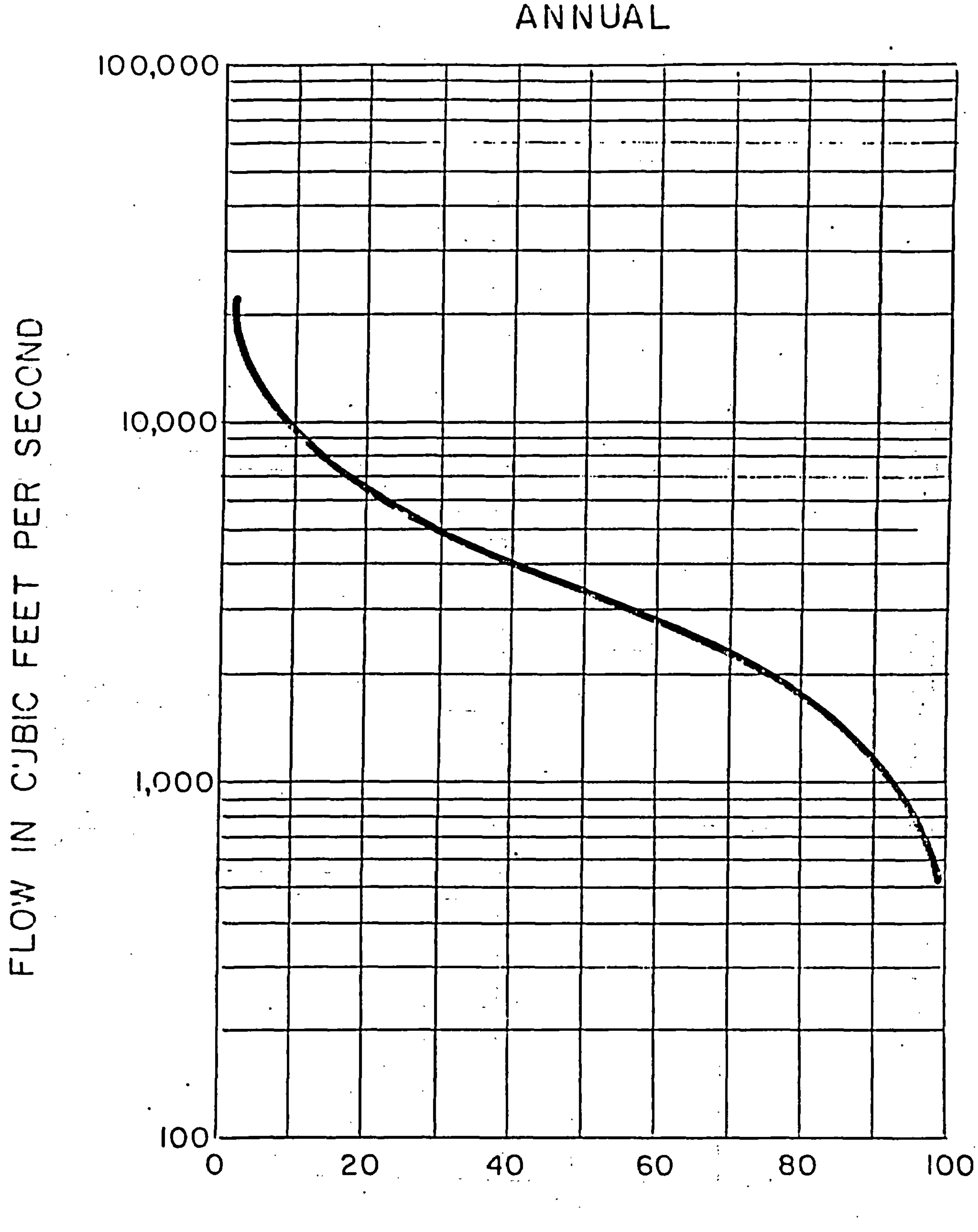


FIGURE 2.3-3

Annual Flow Duration Curve for Mississippi River at St. Cloud, Minnesota. 1926-1970.

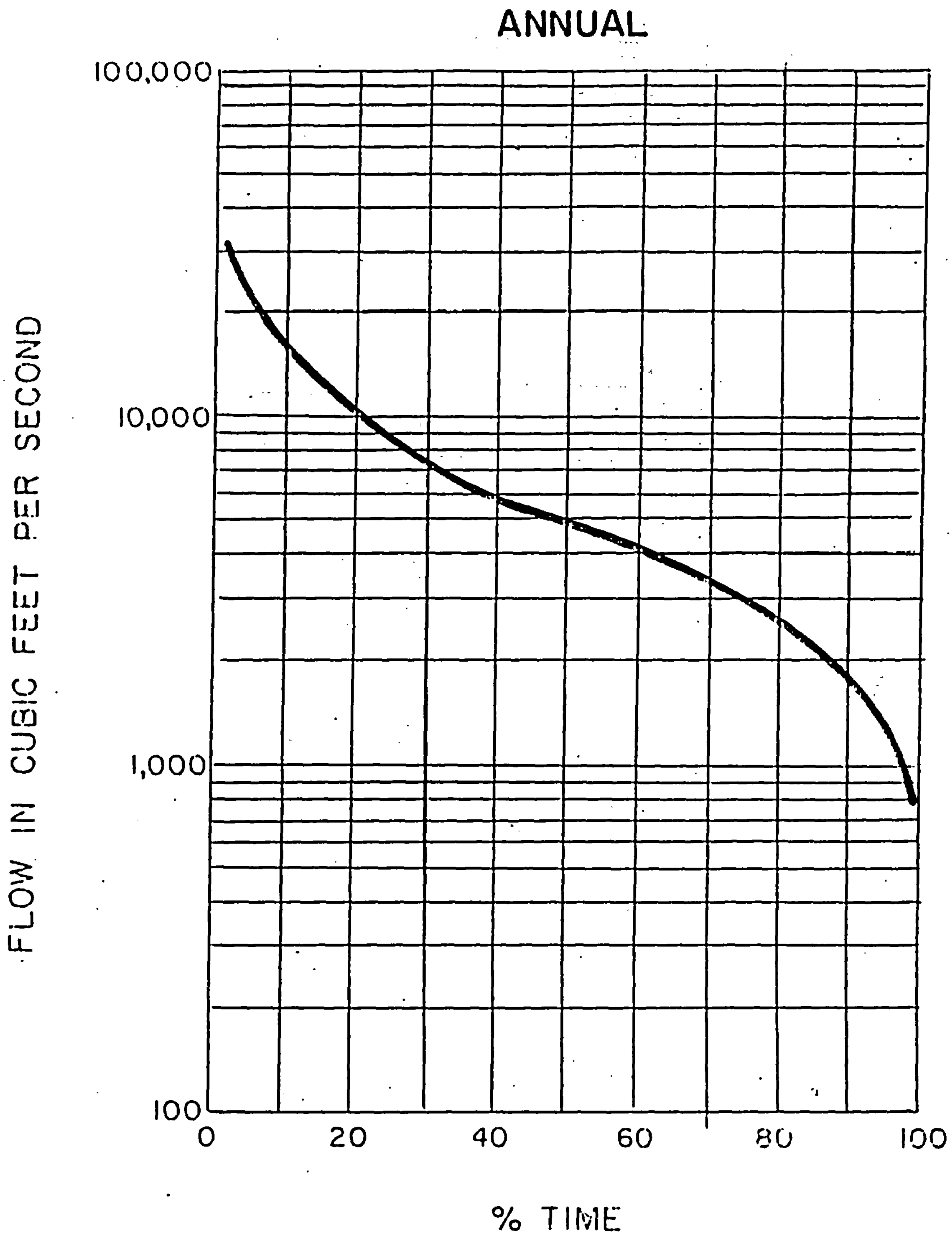


FIGURE 2.3-4

Annual Flow Duration Curve for Mississippi River at Anoka, Minnesota. 1931-1973.

FIG. 2.3-5

MISSISSIPPI RIVER AT MONTICELLO (1970-1972)

DAILY AVERAGE TEMPERATURE OCCURRENCES

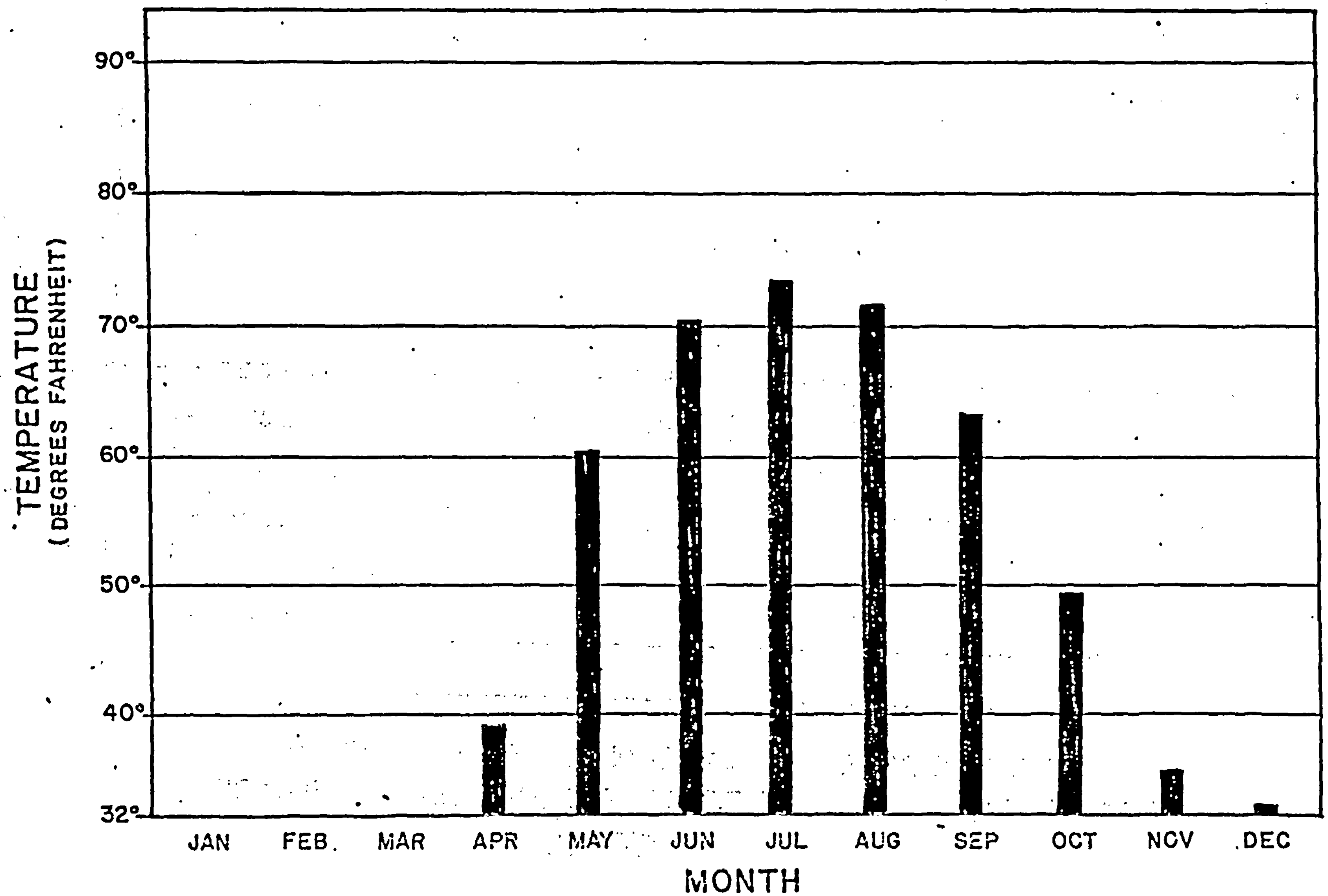


FIG. 2.3-6
MISSISSIPPI RIVER AT MONTICELLO (1970-1972)
7-DAY AVERAGE TEMPERATURE OCCURRENCES

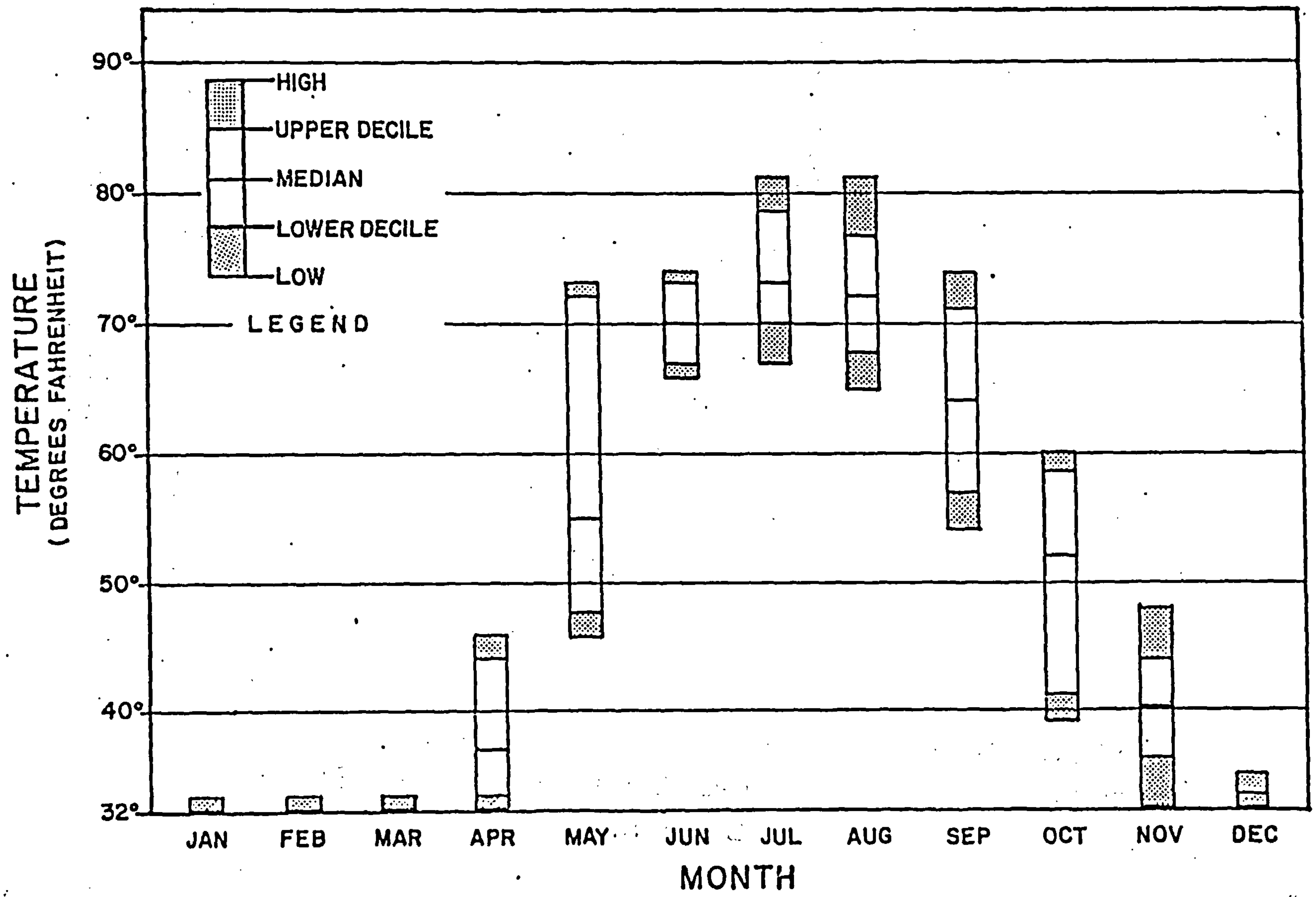


FIG. 2.3-7

MISSISSIPPI RIVER AT WHITNEY (1965-1969)

DAILY AVERAGE TEMPERATURE OCCURRENCES

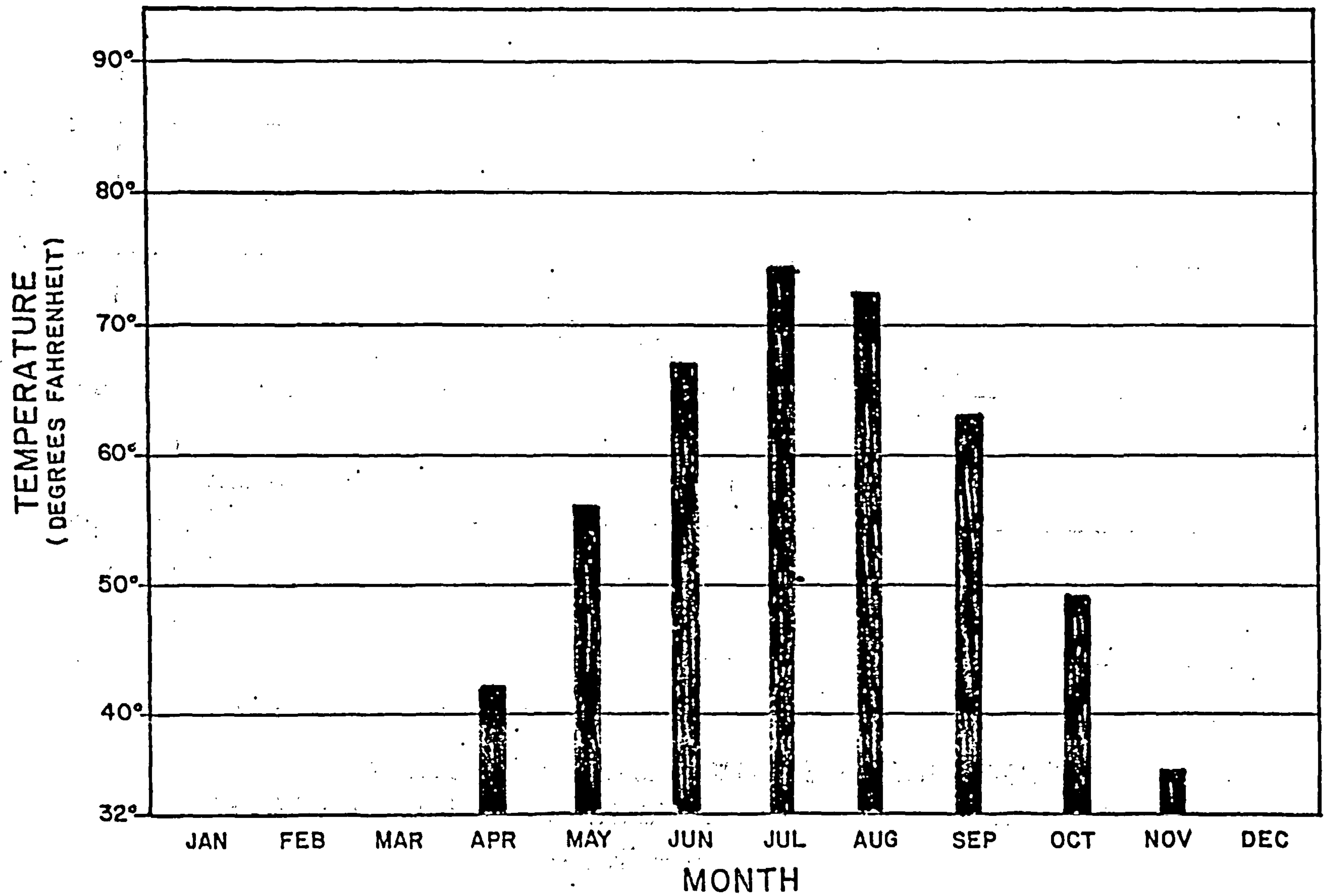


FIG. 2.3-8

MISSISSIPPI RIVER AT WHITNEY (1965-1969)

7-DAY AVERAGE TEMPERATURE OCCURRENCES

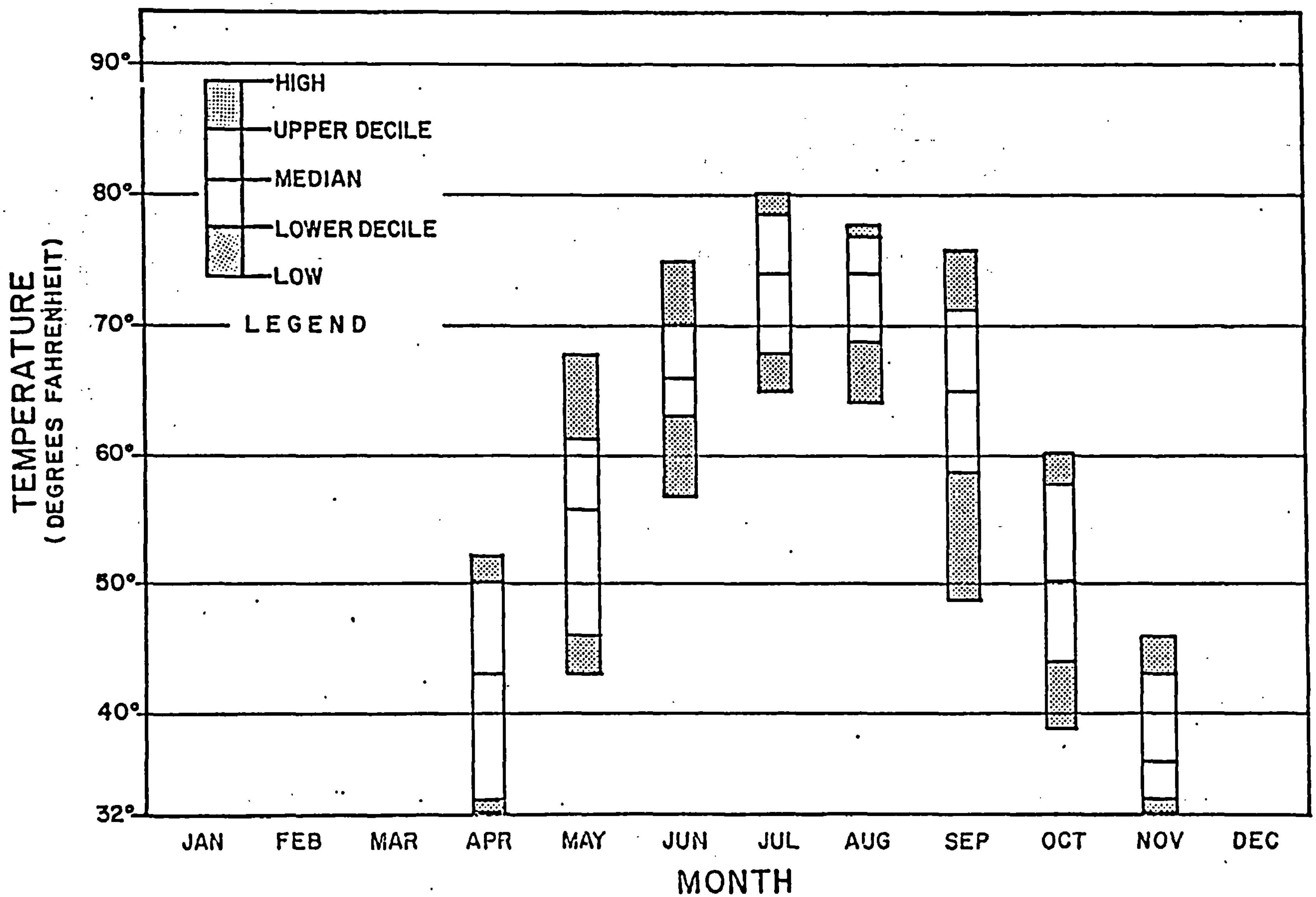


FIGURE 2.4-1

Annual Wind Roses at Monticello, Minnesota

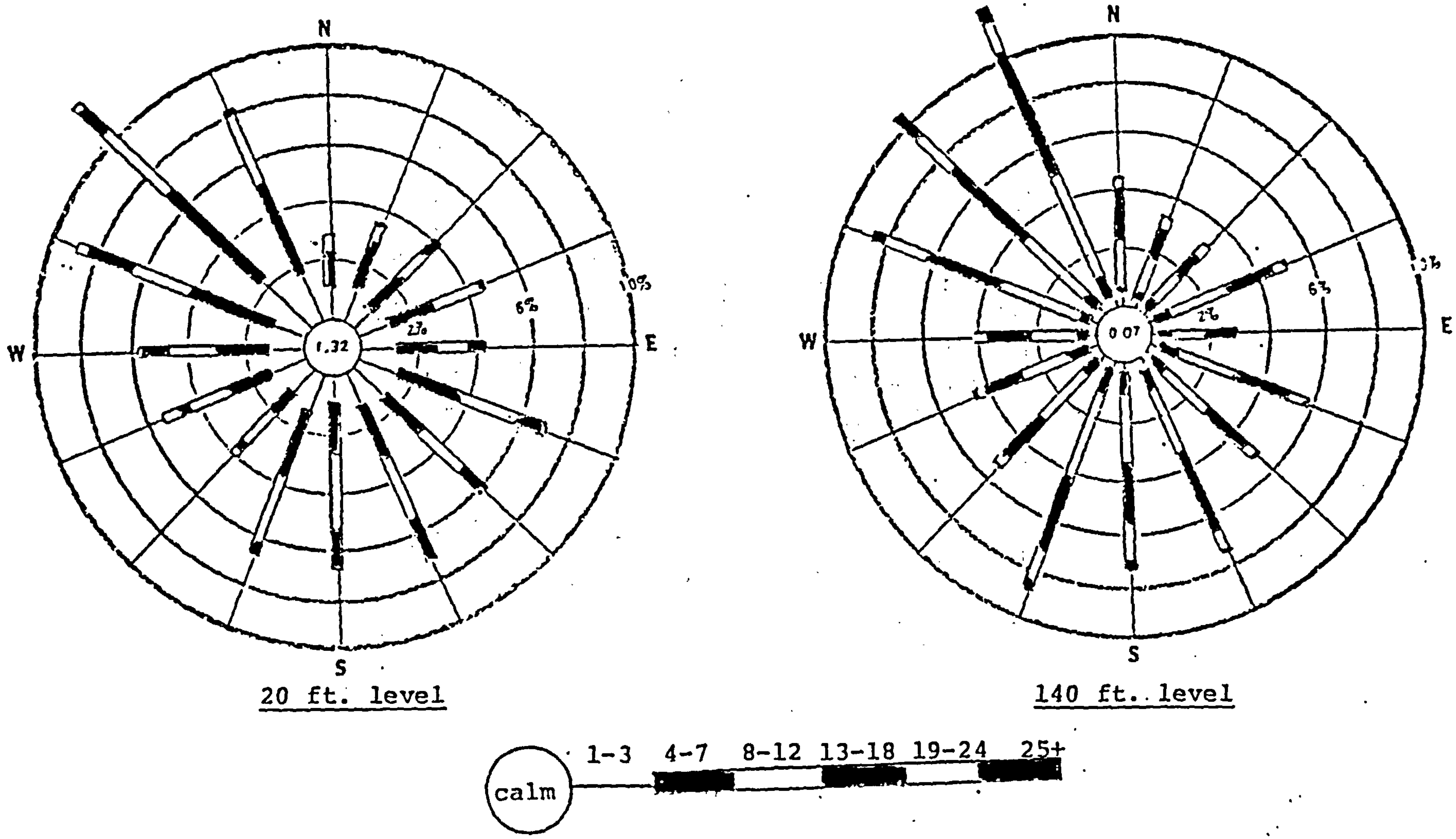


FIGURE 2.4-2

Average Annual Evapotranspiration Isotherms

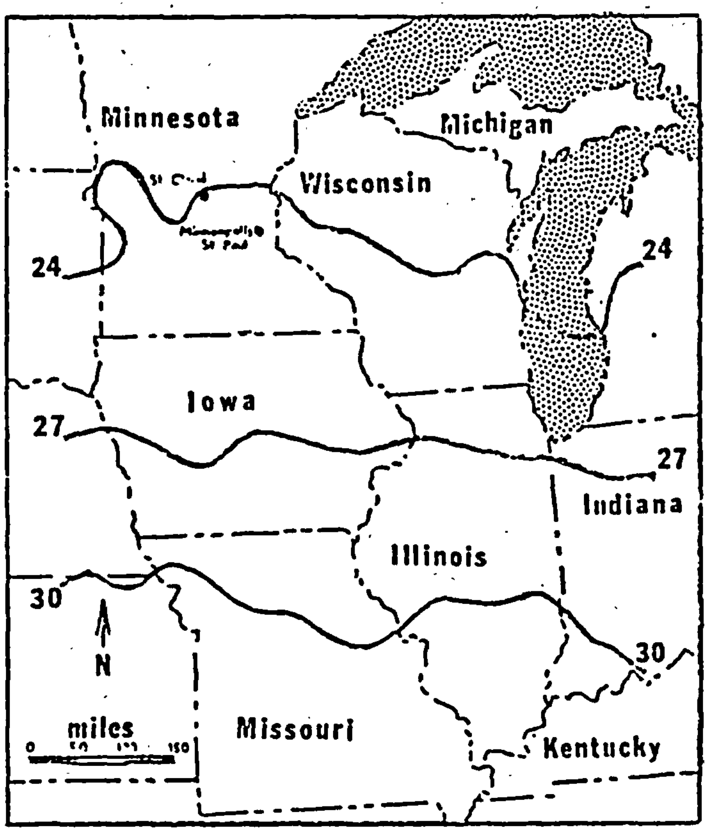


TABLE 2.2-1

TYPICAL HEAT REJECTION RATES FOR SUMMER AND WINTER USING ALTERNATIVE COOLING SYSTEM OPERATION MODES

Cooling System Mode	Heat Rejection Rate (10^9 Btu/hr) Winter	Summer
Open Cycle		
559 MWe	4.0	4.0
545 MWe	3.9	3.9
Helper Cycle		
545 MWe	N/A[1]	1.3
Partial Recirculation	N/A	0.8
Closed Cycle	N/A	0.06

[1]Not applicable. These cooling modes not employed during the winter.

TABLE 2.2-2

HEAT REJECTION SUMMARY[1]

Net Station Output (MW)	Net Station Heat Rate (MBTU/KWH)	Total Heat Rejection Rate (MBTU/KWH)	Total Heat Rejection (MBTU/HR)	Heat Rejection to River (MBTU/HR)[2] Open Cycle	Helper Cycle
20	17,900	14,487	290	267	92
40	16,300	12,887	515	476	163
60	15,500	12,087	725	669	230
80	14,400	10,987	879	811	278
100	14,000	10,587	1,059	977	335
200	11,800	8,387	1,677	1,548	531
300	11,300	7,887	2,366	2,184	749
400	11,250	7,837	3,135	2,893	992
500	11,200	7,787	3,894	3,593	1,232
545	11,170	7,757	4,228	3,902	1,338

[1] Based on long range forecasts of generator and boiler characteristics.

[2] At full load, for typical case assumed, for open cycle operation, 90% of total heat rejection is to river; for helper cycle, 32% of total heat rejection is to river.

TABLE 2.2-3

CONSUMPTIVE WATER USE SUMMARY FOR MONTICELLO NUCLEAR GENERATING PLANT[1]

Mode of Loss	Fresh Water Consumption gpm	cfs
Average Plant Loss Rate:		
1 circulating pump operating	1,105	2.5
2 circulating pumps operating	1,743	3.9
Average Monthly Loss Rate:	1,743	3.9
Average Annual Loss Rate:	1,743	3.9
Evaporation and Drift from Cooling Towers Only:		
Open Cycle	0	0.0
Helper	5,655	12.6
Partial Recirculation (75%)	6,050	13.5
Closed:		
Typical	8,079	18.0
Maximum	8,348	18.6
River Evaporation Increase Due to Plant Heat Rejection[2]		
Open Cycle	3,329	7.4
Helper	1,196	2.7
Partial Recirculation	687	1.5
Closed (Typical)	52	0.1

---

[1]General assumptions and comments:

a. Flows are based on contract data, except maximum which is based on Marks (1951); 1% of cooling tower flow as evaporation loss per 10°F of cooling range. Reduction of 0.002 x flow for drift loss is from contract data.

b. Withdrawal flows determined from pump contract data. Consumption and evaporation (plant only) = 0.006 x withdrawal.

c. Monthly breakdown is difficult to estimate due to variation of river temperatures and meteorological conditions which affect plant operation and cooling tower performance.

[2]Estimated assuming loss rate of 0.43 pounds per 1000 Btu rejected.

TABLE 2.3-1

ESTIMATES OF MEDIAN LOW FLOW AT ST. CLOUD AND ANOKA, MINNESOTA [From 1926-1970 (St. Cloud) and 1931-1970 (Anoka) flow duration data presented in Appendices C and D]

Month	Median Flow (cfs) St. Cloud	Median Flow (cfs) Anoka
January	2,360	3,600
February	2,150	3,400
March	2,710	4,400
April	7,400	13,700
May	7,600	11,600
June	5,700	8,400
July	3,600	5,700
August	2,900	4,250
September	3,000	4,300
October	3,200	4,400
November	3,000	4,400
December	2,570	3,700

TABLE 2.4-1

AIR TEMPERATURES FOR MONTICELLO PLANT AREA (°F)[1]

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Maximum	21	24	38	55	68	77	83	80	72	59	40	26
Minimum	3	6	20	35	46	56	61	59	50	39	24	10
Mean	12	15	29	45	57	66	72	70	61	49	32	18
Extreme Max	59	61	82	91	105	103	107	104	105	90	75	63
Extreme Min	-38	-34	-30	4	20	33	42	38	22	8	-18	-29

[1]From WAPORA 1975; data are computed from 54 years of data at St. Cloud and Minneapolis-St. Paul.

TABLE 2.6-1

RIVER AND PLANT OPERATING CHARACTERISTICS DURING THERMAL PLUME SURVEYS, MONTICELLO NUCLEAR GENERATING PLANT

Survey Date	Average Intake Temp, °F	Average Canal Discharge T, °F	Average Plant Load, MW	Discharge Flow, cfs	River Flow, cfs	Cooling Tower Operation During Survey
6/22/71	76.2	90.4	560	555	4,224	Both in service, four fans off
7/1/71	73.3	87.9	567	565	6,234	Not in service
7/6/71	76.8	99.3	552	561	4,533	Both in service, all fans off
8/2/71	67.1	80.5	519	529	2,048	Both in service
8/3/71	68.2	92.1	521	606	2,048	Not in service
8/13/71[1]	74.3	85.6	510	510	1,140	Both in service, one fan off
8/19/71[1]	77.9	102.8	508	585	1,142	Not in service
9/2/71	74.1	85.8	480	636	1,536	Both in service
9/20/71[1]	60.8	74.2	509	633	1,215	Partial helper cycle
11/9/71	35.2	61.5	524	208	18,656	Partial recirculation
2/22/72	32.3	82.4	557	320	3,840	Not in service
2/23/72[1]	33.2	62.5	561	640	3,840	Not in service
3/1/72	32.3	60.3	530	624	3,840	Not in service
4/4/72	33.0	77.3	580	323	910[2]	Not in service

TABLE 2.6-1 (Continued)

Survey Date	Average Intake Temp, °F	Average Canal Discharge T, °F	Average Plant Load, MW	Discharge Flow, cfs	River Flow, cfs	Cooling Tower Operation During Survey
5/23/72[1]	70.4	83.5	570	---	910[2]	Not in service
6/22/72	68.5	99.2	569	624	5,550	Not in service
7/5/72	70.2	90.6	566	624	3,755	One tower in service
8/3/72	----	80.1	456	---	18,901	Both in service
8/14/72	----	86.6	563	654	16,960	Both in service
8/18/72	----	88.8	563	624	14,450	Both in service
8/23/72	----	82.4	565	635	14,200	Both in service
8/30/72[1]	----	86.5	567	630	14,976	Both in service
9/7/72[1]	----	94.1	567	596	10,750	Not in service
9/15/72	----	94.2	567	581	6,656	Not in service
6/19/73	----	73.6	---	---	1,790	Shutdown
6/27/73	----	92.6	572	24	2,410	One bank not in service
7/2/73	----	85.8	544	376	1,790	Both in service
7/5/73	----	86.3	543	---	2,277	Both in service

TABLE 2.6-1 (Continued)

Survey Date	Average Intake Temp, °F	Average Canal Discharge T, °F	Average Plant Load, MW	Discharge Flow, cfs	River Flow, cfs	Cooling Tower Operation During Survey
7/12/73	----	89.6	538	581	2,155	Both in service
7/16/73	----	84.6	545	577	1,920	Both in service
7/19/73	----	86.8	498	552	2,219	Both in service
7/25/73	----	89.0	542	580	1,792	Both in service
7/30/73[1]	----	82.1	544	578	2,410	Both in service
8/13/73	----	86.7	546	590	5,376	Partial service

[1] These surveys described in detail in section 2.6.

[2] Flow not available; only water elevation.

TABLE 2.6-2

ESTIMATED EXTENT OF THERMAL PLUME REPRESENTING THE MAXIMUM SIZE 70 PERCENT OF THE TIME FOR THE SUMMER MONTHS

Month	+9°F Isotherm[1]		+3°F Isotherm[2]	
	Downstream Extent (ft)	Maximum Width[3] (ft)	Downstream Extent (ft)	Maximum Width[3] (ft)
June	300	100	~18,500[4]	350
July	500	50	~18,500[4]	350
August	650	150	~18,500[4]	350
September	700	250	~18,500[4]	700[5]

[1] Represents immediate discharge area.

[2] Represents intermediate discharge area.

[3] Surface isotherm.

[4] Estimated distance to Monticello Bridge (State Highway 25 Bridge).

[5] Entire width in some areas (average about 75% coverage).

TABLE 2.7-1

SUMMARY OF WATER QUALITY DATA COLLECTED IN THE MISSISSIPPI RIVER NEAR THE MONTICELLO NUCLEAR GENERATING PLANT, 1969-1973[1]

Analysis in mg/l	1969			1970			1971		
	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
Solids									
Total	138	257	196	171	241	203	172	250	202
Dissolved	122	214	185	151	235	190	166	230	192
Suspended	0.4	72	11	1	36	13	3	20	10
Hardness (as $CaCO_3$)									
Total	88	180	150	112	176	156	100	170	141
Calcium	64	118	99	84	116	105	70	116	99
Magnesium	24	67	51	28	65	51	30	8	42
Alkalinity (as $CaCO_3$)									
Total	86	172	143	108	170	154	90	168	133
Phenolphthalein	0	12	3	0	8	1	0	0	0
Gases									
Ammonia, Nitrogen, N	-	-	-	0	0.12	0.05	0.00	0.22	0.15
Anions									
Chloride, Cl	-	-	-	0.4	1.6	0.9	0.70	9.40	3.64
Nitrate Nitrogen, N	-	-	-	0.0	0.22	0.12	0.250	0.370	0.286
Sulfate, SO_4	-	-	-	5.7	10.0	7.5	7.50	10.75	9.10
Total Soluble Phosphorus, P	-	-	-	0.01	0.057	0.035	0.026	0.053	0.043
Silica, SiO_2	1	10.3	5.7	1.7	10.5	6.9	6.8	11.2	9.5

TABLE 2.7-1 (Continued)

Analysis in mg/l	1969			1970			1971		
	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
Cations									
Sodium, Na	3.1	5.9	4.8	3.4	6.9	5.3	3.1	6.5	4.1
Total Iron, Fe	0	0.67	0.27	0	0.9	0.36	0.11	0.50	0.24
Miscellaneous									
Color, APHA units	25	80	45	5	90	35	25	90	66
Turbidity, JTU	1	8	3	1.3	17.	3.9	3.1	13.0	6.7
Ryzner Index at 77°F	6.7	8.3	7.3	6.7	7.9	7.3	7.4	8.3	7.7
Conductivity, µmhos	185	334	291	213	337	303	200	333	279
pH	7.6	8.5	8.1	7.5	8.5	8.0	7.4	7.9	7.7

1. Yearly averages of all samples analyzed

TABLE 2.7-1 (Continued)

Analysis in mg/l	1972 Minimum	1972 Maximum	1972 Average	1973 Minimum	1973 Maximum	1973 Average
Solids						
Total	169	288	207	136	219	182
Dissolved	145	276	188	121	217	169
Suspended	3	60	19	0	22	9
Hardness (as $CaCO_3$)						
Total	108	180	148	110	180	143
Calcium	80	122	101	76	120	99
Magnesium	28	64	48	30	60	45
Alkalinity (as $CaCO_3$)						
Total	105	170	139.0	105	181	140
Phenolphthalein	2	6	0	0	4	0.5
Gases						
Ammonia Nitrogen, N	0	.28	.06	0.00	0.51	0.04
Anions						
Chloride, Cl	.23	7.12	2.06	0.24	1.80	0.37
Nitrate Nitrogen, N	.05	.37	.237	0.00	1.15	0.29
Sulfate, SO_4	5.4	30	13.47	5.30	14.00	8.90
Total Soluble Phosphorus, P	.014	.069	.045	0.000	0.063	0.030
Silica, SiO_2	5.0	13.6	10.2	2.3	13.6	8.7
Cations						
Sodium, Na	1.5	6.2	4.0	3.1	6.4	4.8
Total Iron, Fe	0.04	2.0	0.77	0.18	0.62	0.33

TABLE 2.7-1 (Continued)

Analysis in mg/l	1972 Minimum	1972 Maximum	1972 Average	1973 Minimum	1973 Maximum	1973 Average
Miscellaneous						
Color, APHA Units	30	90	58.3	15	100	53
Turbidity	2.0	20.0	7.3	1.7	15.0	5.1
Ryznar Index at 77°F	6.87	8.04	7.40	6.74	7.94	7.25
Conductivity, µmhos	204	364	287	222	350	286
pH	7.5	8.4	8.0	7.7	8.6	8.1
Biochemical Oxygen Demand, BOD	.9	2.8	1.68	0.70	4.70	1.64
Temperature, °C	.1	36.4	15.1	0.2	27.2	13.2
Dissolved Oxygen	5.2	13.4	9.4	8.3	13.0	10.7

TABLE 2.7-2

MONTHLY AND ANNUAL AVERAGE VALUES FOR DISSOLVED OXYGEN (mg/l) IN MISSISSIPPI RIVER WATER TAKEN FROM ONE STATION ABOVE (1) AND TWO BELOW (2 AND 3) THE NSP MONTICELLO GENERATING PLANT DURING THE YEARS 1968 THROUGH 1972

Years	1968			1969			1970			1971			1972		
Stations	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
January	-	-	-	10.5	11.0	11.0	10.7	10.9	11.4	10.5	9.8	9.6	11.0	10.4	10.6
February	-	-	-	10.5	10.25	10.5	11.4	11.2	11.8	8.8	9.3	9.5	9.8	9.9	-
March	-	-	-	12.0	12.0	12.0	11.9	11.7	13.3	9.1	8.8	9.5	9.5	9.8	10.5
April	-	-	-	11.0	11.0	10.5	12.5	13.5	13.0	11.9	11.6	9.8	10.2	10.0	10.5
May	-	-	-	9.0	9.3	9.0	10.1	9.9	9.8	10.5	10.5	10.0	8.0	7.0	7.6
June	7.5	7.75	-	9.0	8.5	9.0	7.6	7.5	7.8	8.0	7.6	7.7	8.9	8.6	8.7
July	7.3	7.3	7.3	8.4	8.4	8.5	9.0	11.7	9.7	7.7	7.6	7.6	9.3	7.9	9.1
August	8.3	8.5	8.5	9.0	9.0	9.1	8.0	9.6	8.8	7.1	8.7	8.0	7.7	7.4	7.2
September	8.8	-	9.0	8.5	8.3	8.3	8.6	8.7	9.7	10.3	7.6	7.7	8.3	7.8	8.0
October	10.0	-	9.5	12.5	13.3	12.5	9.4	9.0	9.0	11.1	11.0	10.2	9.1	10.1	10.4
November	12.8	-	12.5	14.5	14.0	13.0	12.4	11.9	12.0	10.6	11.0	11.3	13.6	10.4	12.9
December	12.5	-	14.0	15.5	14.0	15.0	12.1	11.5	11.7	12.7	12.6	12.6	14.1	10.1	12.7
Annual Average AVE.	9.6	7.9	10.1	10.9	10.8	10.7	10.3	10.6	10.7	9.9	9.7	9.4	10.0	9.1	9.8

3 ECOLOGICAL DATA

In this section, ecological data pertinent to the Monticello Site are presented. For certain biota, especially phytoplankton and zooplankton, data from the site are essentially lacking and literature of local ecological significance is discussed.

In order to best provide a demonstration of "absence of prior appreciable harm", ecological data are presented according to the Minnesota Guide for 316(a) species information (MPCA 1975, p. 7-8) and community studies (MPCA 1975, p. 29-32). Trophic levels other than fish are stressed as communities.

In the following presentation, operational biotic data are frequently organized into the following categories: (1) immediate discharge area - the immediate area in rivers that is within the 9°F (5°C) isotherm 70 percent or more of the time, (2) intermediate discharge area - the portion of the river water-body segment beyond the immediate discharge area and within the 3°F (2°C) isotherm 70 percent or more of the time, (3) outer discharge area - the portion of a river water-body segment beyond the intermediate discharge area (MPCA 1975, p. 56-57). Other terminology used is defined in the appropriate sections.

Biotic data are provided from collections of varying time intervals. However, in most cases data were available on monthly or other intervals that were in excess of that requested by the MPCA.

Thus, data are not presented by the seasonal conditions: "Summer maximal temperature, fall transitional regime, winter minimal temperature and spring transitional regime" (MPCA 1975, p. 8) but are presented by collection date to provide more complete understanding of seasonal biotic phenomena.

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3.1 PRIMARY PRODUCERS

3.1.1 INTRODUCTION

Periphyton and phytoplankton are usually the principal primary producers in flowing waterways. They convert inorganic nutrients into organic materials by utilizing light energy through the process of photosynthesis. In calm and deep waters, phytoplankton is the major primary producer, whereas in shallow lakes, ponds and rivers, periphyton is the main primary producer. In some shallow bodies of water, aquatic vascular plants may also be important primary producers.

There are three sources of primary production in the Mississippi River: macrophytes, phytoplankton, and periphyton. According to Moyle's (1940) studies, macrophytes are important in the upper Mississippi River system. However, in the stretch of the river studied near the Monticello Site, macrophytes were essentially lacking. Although phytoplankton may be important in some large rivers, the studies conducted at the Monticello Site from 1968 to 1973 indicate that there is little or no true plankton in the river. This is probably due to high current velocity which carries phytoplankton downstream at a fast rate. Many investigators have reported that river plankton represents the displaced organisms from backwaters and scoured organisms from the river bed (periphyton). Periphyton is likely the major source of primary production at the Monticello Site (Colingsworth 1969, p. 1).

3.1.2 PHYTOPLANKTON

Phytoplankton, the plant component of the plankton community, is an assemblage of algae that in rivers largely has its origins in backwaters and from the periphyton community. At any point of collection, phytoplankton represents the cumulation of upstream inputs from various sources. The density of algae in phytoplankton samples is largely a function of the amount of dilution and scouring resulting from changes in flow. Thus, the ephemeral nature of phytoplankton of rivers often makes the study of this community inconclusive with regards to the evaluation of the ecological status at the sampling points.

The early studies conducted by Wiebe (1928) and Reinhard (1931) on the upper Mississippi River describe a phytoplankton community dominated by diatoms, the most abundant of which were *Cyclotella meneghiniana*, *Melosira granulata*, *Asterionella formosa*, *Fragilaria capucina*, *Diatoma vulgare*, *Synedra ulna*, and *Stephanodiscus* spp. Reinhard's (1931) studies indicate that there was a vernal pulse in late May. Diatoms comprised the major portion of the summer flora as reported by both investigators. Although a number of green and blue-green algae were observed, none were extremely abundant. The common species of green algae, in order of their importance, were *Scenedesmus quadricauda*, *Actinastrum hantzschii*, *Pediastrum duplex*, and certain desmids. The blue-green algae which occurred frequently were species of *Anabaena*, *Aphanizomenon*, *Merismopedia*, *Coelosphaerium* and *Microcystis*.

Moyle (1940, p. 28-29) described three types of plankton communities in the summer flora of the upper Mississippi River system. In two types of plankton communities, the community structure was dominated by blue-green algae. The most abundant blue-green genera were Anabaena, Coelosphaerium, Microcystis, Aphanocapsa and Aphanizomenon. The common green algae were Pediastrum, Closterium and Scenedesmus. Diatoms were relatively less important, being represented by the genera Navicula, Stephanodiscus, Fragilaria and Melosira. The third type of community was characterized by a diatom group; the most common genera encountered were Navicula and Surirella. The important green algae were the same as reported for the other two types of plankton communities.

Mischuk (undated) investigated the primary producers of the upper Mississippi River near the Monticello Site and noted that the phytoplankton community was dominated by diatoms throughout the year. Diatoms accounted for 67.3 percent of the total phytoplankton. Chlorophyta comprised 29.9 percent of the total phytoplankton and was second in importance. The summer flora was still a diatom-dominated community but green algae assumed considerable importance and accounted for 35.9 percent of the total plankton. Blue-green algae were moderately represented in the summer plankton flora.

3.1.3 PERIPHYTON

Periphyton may be defined as the community of attached plants, excluding macrophytes, that develop on underwater substrates. Periphyton of the Mississippi River near the Monticello Site has been studied from 1968 to the present. Studies were based on algae that had colonized artificial substrates.

Thirteen sampling stations were established along a four-mile section of the river near the Monticello Site (Figure 3.1-1). The samples were collected with a modified diatometer, using glass microscope slides as substrate. The slides were submersed at each sampling station for colonization by the river algae for one month intervals in winter and two week intervals in summer. The floating samplers maintained slides at a fixed depth of six to nine inches.

At the end of each exposure interval, the slides were removed and the samples were analyzed by four different mentods: (1) species enumeration, (2) pigment analysis, (3) dry weight biomass determination and (4) photography of the slides. Samples were prepared for microscopic examination by staining the algae on the glass slides with Lugol's solution for 15 seconds, then rinsing and mounting the sample with Turtox CMC-10 under a coverglass. All algal species in 30 random microscope fields were identified and counted. The results were reported as cells/cm^2. Nomarski interference and phase contrast microscopes were used for enumeration and species identification. Pigment analyses followed the methods of Lorenzen 1967 (cited in Knutson 1971).

In 1971, Station 3A was introduced to collect samples from the discharge canal. In 1973, sampling was reduced to statistically paired stations (Figure 3.1-2). The statistically paired stations were 2 and 11, 7 and 3, and 9 and 6. Stations 3, 6 and 11 were located near the west bank, and were affected by the thermal effluent. They will be considered to be usually within the intermediate discharge zone [ΔT more than 3°F (2°C)]. Discharge canal Station 3A will be considered to be within the immediate discharge zone [ΔT more than 9°F (5°C)]. Stations 7 and 9 will be considered outer discharge zone stations. Station 2 was above the discharge and is the control station, although, because of the similarity in temperature, Knutson (1974, 1975) considered stations 2, 7 and 9 to be statistically comparable and called them "ambient water" stations.

A total of 134 algal taxa were collected from the periphyton of the Mississippi River near the Monticello Site from 1968 through 1974. The majority of these were diatoms. A composite species list is presented in Table 3.1-1.

Tables 3.1-2 through 3.1-6 show the total periphyton cell densities from 1969 through 1974. Counts were variable from year to year and among seasons of the year, but there was a general trend of large populations from June to mid-September. Periphyton species composition was similar in pre-operational and operational years. In winter, production was low, primarily due to low temperature and ice cover. The community structure was dominated by diatoms, the most abundant of which was *Gomphonema olivaceum*. There was an early maximum in spring with diatoms still the predominant group. The most common diatom species were Gomphonema olivaceum, Diatoma vulgare, Synedra ulna, and Navicula gracilis. Peak production occurred during the summer. The summer flora was dominated by blue-greens and diatoms. The most common summer species were small coccoid algae of the genus Chroococcus. Chroococcus minimus was very abundant in the summer of 1973, and was responsible for the high 1973 densities as compared to the summer periphyton densities of the previous years (Tables 3.1-7 to 3.1-12). Diatoms were the dominant organisms in the fall during the study years, with Cocconeis placentula and Cocconeis pediculus the most common species.

There was no noticeable difference in species composition among the intermediate discharge zone (Stations 3, 6, 11), the outer discharge zone (Stations 7, 9) and the control (Station 2) during 1972 and 1973 (Tables 3.1-11 and 3.1-12). The most abundant species in all three zones were Cocconeis placentula and Chroococcus minimus, followed by Gomphonema parvulum, Cocconeis pediculus, Diatoma vulgare and Gomphonema olivaceum.

Decreased algal densities and a shift in species dominance were usually found at Station 3A in 1971-1974, as compared to intermediate, outer and control zones. Temperatures at Station 3A averaged 14-20°F (7.8-11.1°C) above ambient. The discharge periphyton community was usually dominated by Chroococcus minimus, Stigeoclonium nanum, and Characium pringsheimii. Achnanthes *exigua* was also common in the discharge. This eurythermal diatom is found in thermal springs and has optimum growth above 86°F (30.0°C) (Knutson 1974, p. C-417).

Chlorophyll *a* concentrations were generally highest in late summer and fall during 1969, 1970, 1971 and 1974. Peak chlorophyll *a* values occurred in July 1972 and April 1973. A second pulse in chlorophyll *a* failed to occur in the summer of 1973 concurrent with high densities of *Chroococcus minimus*, probably due to the extremely small size of this species. No chlorophyll *a* could be extracted from samples exposed for 30 days beneath the ice during study years prior to 1973. Samples from Station 6 averaged 1.43 $\mu g/cm^2$ during January through March 1973 and the bridge station yielded an average of 1.95 $\mu g/cm^2$ chlorophyll *a*. These increases in midwinter chlorophyll *a* values were likely due to the heated discharge flow and lack of ice cover (Knutson 1974, p. C-407).

Chlorophyll *a* standing crops were lower in heated areas of the river and in the discharge canal in 1971 than in the "ambient" stations (control and outer discharge areas) for 60 percent of the collection dates, and higher for 15 percent of the collection dates (Knutson 1972, p. 10). F-tests and T-tests indicated that in 1972 there were no significant differences between any of the discharge zones and the "ambient" zone (Knutson 1973, p. C-431). T-tests indicated that no significant differences in chlorophyll *a* occurred between the control and the outer or intermediate zones in 1973 (Knutson 1974, p. C-406). However, the immediate discharge zone averaged lower standing crops than other zones. In 1974, the intermediate zone stations averaged 18 percent lower chlorophyll a standing crops than the "ambient" stations (control and outer discharge areas). The immediate discharge station averaged lower chlorophyll a and had displaced peaks in production. The generally reduced pigment standing crops of Station 3A were not usually seen 550 feet downstream at Station 3, indicating that discharge effects are very limited in area.

Shannon diversity indices were computed for periphyton communities of 1972 and 1974 (Table 3.1-13 and 3.1-14). There were low numbers of species on many dates although low diversities were not necessarily the result of low numbers of species. Diversity was generally greatest at all stations in fall and spring and lowest in mid-summer. The only discernible trend among the stations was that in 1973 Station 3A (immediate discharge zone) had the greatest number of species as well as highest diversity in the spring, although in other seasons no marked differences were obvious in either 1972 or 1973.

The periphyton communities of the control, outer and intermediate discharge stations did not show significant differences in biomass (chlorophyll a), numbers, or species composition. Three species (Achnanthes exigua, Characium pringshemii and Stigeoclonium nanum) were, at times, abundant in the immediate discharge (Station 3A) but not at the cooler water stations. The immediate discharge station generally supported lower chlorophyll a standing crops.

However, even at Station 3A the periphyton communities can be considered balanced and useful to the trophic webs of the river. Thus the cumulative effects of the Monticello Plant discharges do not affect the balance of the periphyton communities.

3.1.4 MACROPHYTON

Aquatic vascular plants and other macroscopic plants are seldom the major source of primary production in flowing waters. However, they are often found in shallow or slow-moving areas unless substrates are unsuitable. The majority of aquatic vascular plants are higher plants which respond to seasonal changes much the same as terrestrial plants. Consequently, they usually grow best in warm seasons and die as fall and winter approach. Thus the ecological significance of these plants as primary producers is seasonally limited. In the non-growing seasons, these plants contribute to the detritus of a river as they decompose. Even while growing, aquatic vascular plants are seldom consumed by aquatic fauna. However, they may play an important role in stabilizing substrates and in providing habitat for algae and invertebrates. Vascular plants also provide cover for fish. In some rivers, vascular plants may contribute significantly to the dissolved oxygen concentration.

There have been no recent detailed studies of aquatic vascular plants of the upper Mississippi River. Moyle (1940) surveyed the upper Mississippi River and reported 81 species, of which 15 species of emergent or submerged vascular plants were common. *Vallisneria americana*, *Potamogeton americanus*, and *Potamogeton pectinatus* were the most common submerged species.

Studies conducted at the Monticello Site in 1968, 1969 and 1970 indicate that macrophytes are essentially lacking in the stretch of the river being studied. The high current velocity results in shifting sand and gravel which are unsuitable substrates for colonization by vascular plants. Three species of aquatic plants were reported at the study area: water moss, *Fontinalis antipyretica*, was quite common in the river while *Potomogeton americanus* and *Potamogeton pectinatus* were restricted to pools. Hopwood (1975, p. 1) has stressed that much of the previously unidentified green masses seen in the Monticello area of the Mississippi River is probably *Cladophora glomerata*, a green alga, which is an important primary producer.

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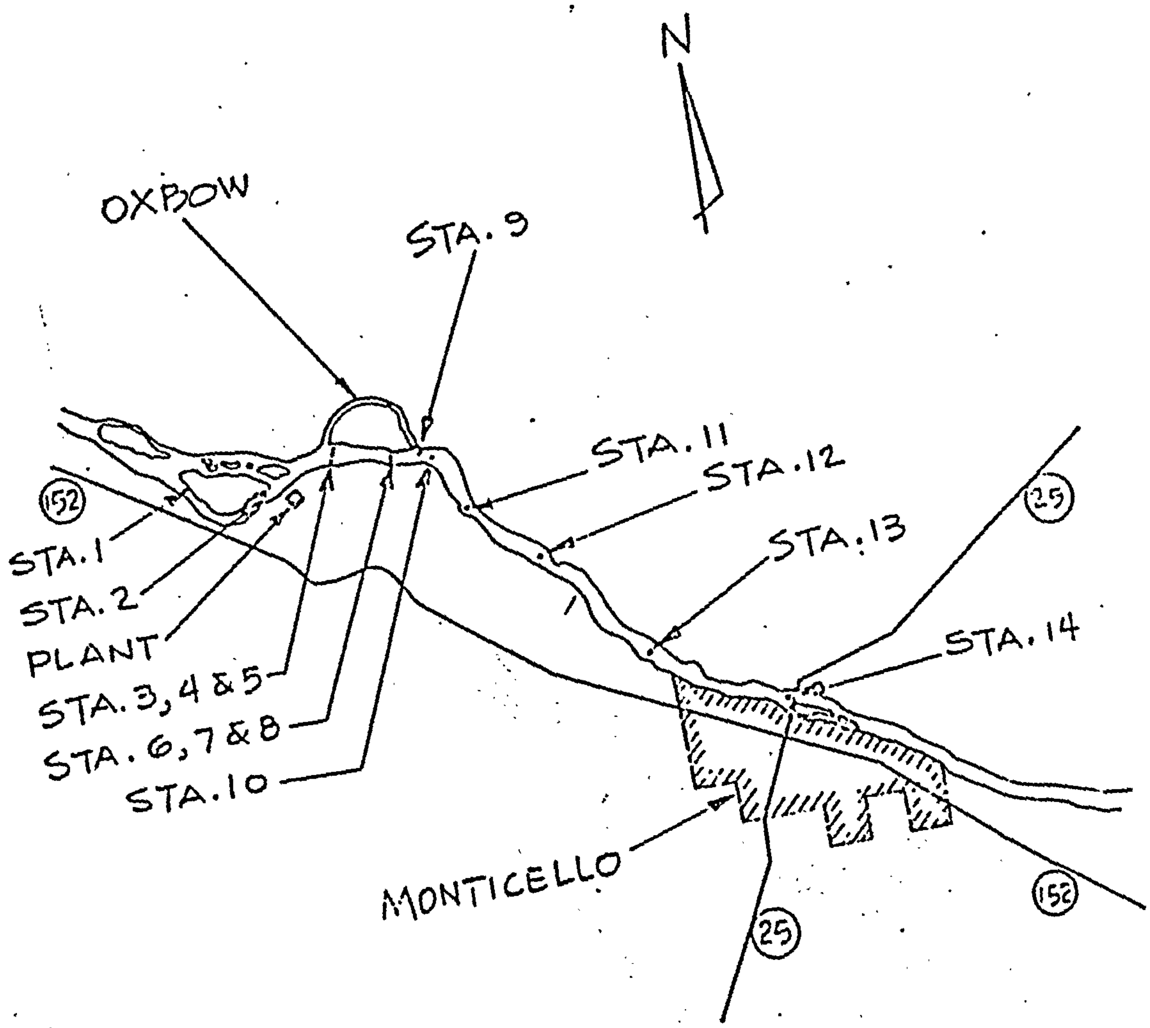

FIGURE 3.1-1

Mississippi River Periphyton Stations, 1968-1972

(From Colingsworth 1969)

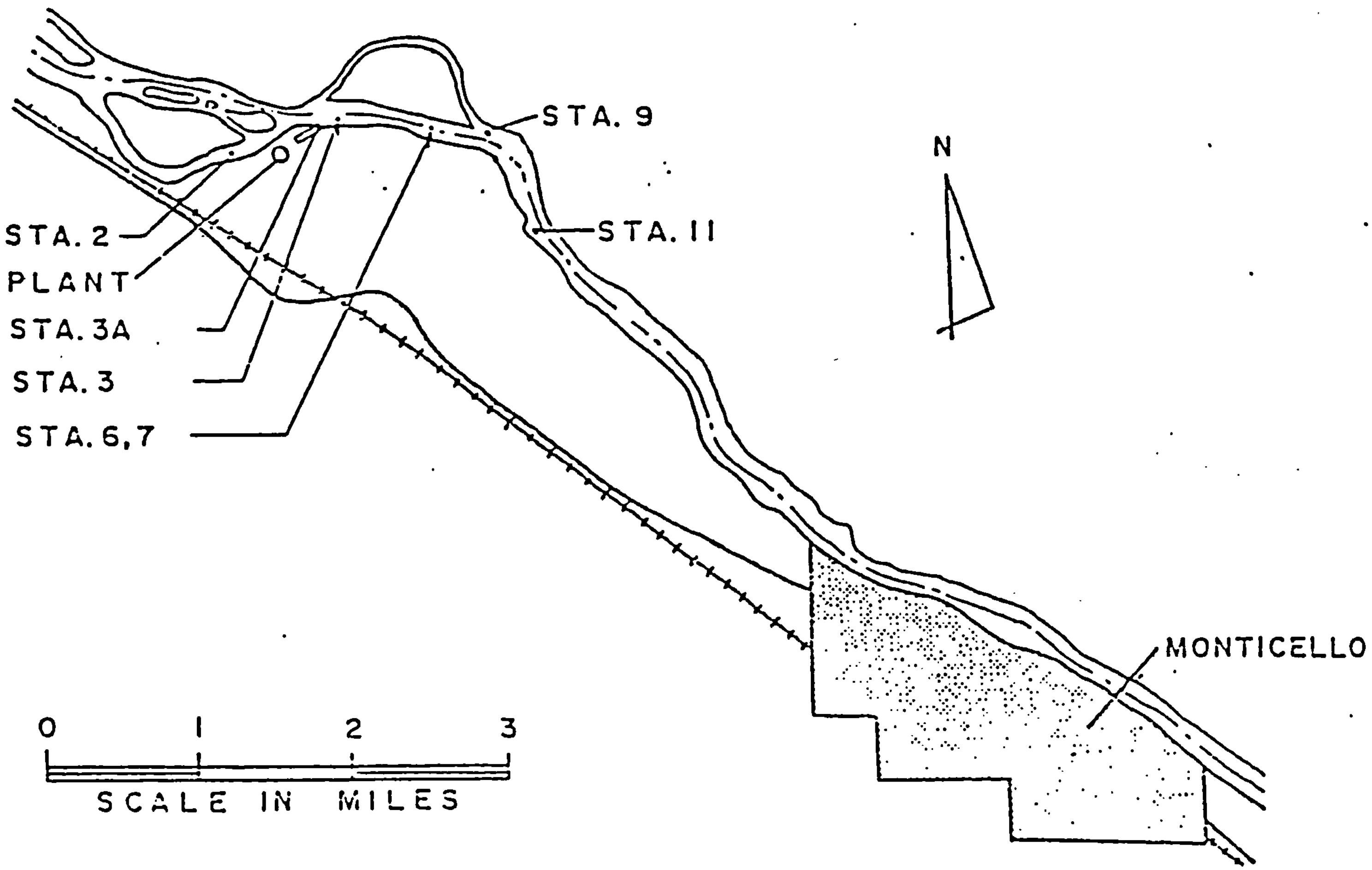

FIGURE 3.1-2

Mississippi River Periphyton Stations in 1973

(From Knutson 1974)

TABLE 3.1-1

PERIPHYTON ALGAL TAXA AT MONTICELLO SITE

CYANOPHYTA

Anabaena sp.
Calothrix membranacea
Chameosiphon sp.
Chroococcus minimus
Chroococcus minor
Chroococcus minutus
Lyngbya sp.
Merismopedia tenuissima
Oscillatoria amphibia
Oscillatoria geminata
Oscillatoria pseudogeminata
Oscillatoria splendida
Oscillatoria sp.
Phormidium favosum
Phormidium faveolarum
Phormidium tenius
Spirulina subtilissma
Xenococcus minimus

CHLOROPHYTA

Characium pringsheimii
Closterium sp.
Cosmarium cf. *rectagulare*
Oedogonium sp.
Scenedesmus sp.
Stigeoclonium farctum
Stigeoclonium nanum
Closterium leibleinii

CHRYSOPHYTA

Achnanthes clevei
Achnanthes exigua
Achnanthes hungarica
Achnanthes lanceolata var. *dubia*
Achnanthes lanceolata var. *lanceolata*
Achnanthes lanceolata var. *lanceolatoides*
Achnanthes lanceolata var. *omissa*
Achnanthes lanceolata var. *rostrata*
Achnanthes linearis
Achnanthes minutissima var. *cryptocephala*
Amphora ovalis var. *pediculus*
Diatoma hiemale
Navicula canalis
Navicula cryptocephala
Navicula decussis
Navicula gastrum
Navicula gracilis

TABLE 3.1-1 (Continued)

CHRYSOPHYTA (Continued)

Navicula hungarica
Navicula hungarica var. *capitata*
Navicula pupula var. *rectangularis*
Navicula radiosa
Navicula radiosa var. *tenella*
Navicula rhynchocephala
Navicula cf. *rhynchocephala* sp. 1
Navicula scutelloides
Navicula acicularis
Navicula sp.
Nitzschia acuta
Nitzschia amphibia
Nitzschia angustata
Nitzschia capitellata
Nitzschia dissipata
Nitzschia fasciculata
Nitzschia filiformis
Nitzschia fonticola
Nitsschia gracilis
Nitzschia holsatica
Nitzschia linearis
Nitzschia palea
Nitzschia romana
Nitzschia sigmoidea
Nitzschia sublinearis
Nitzschia vermicularis
Nitzschia sp.
Fragilaria capucina var. *acuta*
Fragilaria crotonensis
Fragilaria pinnata var. *lancettula*
Gomphonema acuminatum
Gomphonema acuminatum var. *brebissonii*
Gomphonema angustatum
Gomphonema lanceolatum
Gomphonema longiceps var. *montana*
Gomphonema longiceps var. *subclavata*
Gomphonema olivaceum
Gomphonema olivaceum var. *calcarea*
Gomphonema olivaceum var. *genuinum*
Gomphonema parvulum
Gomphonema parvulum var. *micropus*
Gomphonema sphaerophorum
Gyrosigma sp.
Melosira distans
Melosira distans var. *lirata*
Melosira granulata
Melosira granulata var. *angustissima*
Melosira varians

TABLE 3.1-1 (Continued)

CHRYSOPHYTA (Continued)
- Meridion circulare
- Asterionella formosa
- Caloneis lewissi
- Cocconeis pediculus
- Cocconeis placentula
- Cocconeis placentula var. lineata
- Cocconeis scutellum
- Cyclotella meneghiniana
- Cyclotella sp.
- Cymbella sp. 1
- Cymbella sp. 2
- Cymbella cistula
- Cymbella cuspidata
- Cymbella helvetica
- Cymbella prostata
- Cymbella sinuata
- Cymbella tumida
- Cymbella turgida
- Cymbella ventricosa
- Diatoma elongatum
- Diatoma vulgare
- Diatoma vulgare var. brevis
- Epithemia argus
- Epithemia sorex
- Epithemia zebra
- Epithemia zebra var. porcellus
- Eunotia valida
- Pinnularia dactylus
- Pinnularia gibba
- Rhoicosphenia curvata
- Rhopalodia gibba
- Rhopalodia gibba var. ventricosa
- Stephanodiscus astrea
- Stephanodiscus niagarae
- Stephanodiscus sp.
- Surirella sp.
- Synedra acus
- Synedra berolinensis
- Synedra parasitica var. subconstricta
- Synedra rumpens var. familiaris
- Synedra ulna
- Synedra ulna var. impressa
- Synedra ulna var oxyrhynchus
- Synedra ulna var. remesi
- Synedra vaucheriae var. capitellata
- Tabellaria fenestrata

TABLE 3.1-2

PERIPHYTON ALGAL CELL DENSITIES (cells/cm^2) IN THE MISSISSIPPI RIVER AT MONTICELLO SITE, 1968, 1969
(FROM COLINGSWORTH 1969, AND BROOK 1970)

Sample Collection Date	Station 2	Station 7	Station 9	Station 3	Station 6	Station 11
10- 4-68	22,993	9,685	11,677	19,395	3,510	22,890
10-17-68	721	1,093	1,809	-	-	-
8-20-69	193,055	172,240	797,786	394,280	1,081,212	26,121
9- 4-69	1,699,572	69,345	1,329,781	694,383	No Sample	810,190

TABLE 3.1-3

PERIPHYTON ALGAL CELL DENSITIES (cells/cm^2) IN THE MISSISSIPPI RIVER AT MONTICELLO SITE, 1970, 1971
(FROM KNUTSON 1971, 1972)

Sample Collection Date	Station 2	Station 7	Station 9	Station 3	Station 6	Station 11
7-28-70	7,468,468	4,894,302	Not Analyzed.	2,958,086	2,510,643	3,505,666
8-25-70	1,027,427	1,456,428	No Sample	728,230	No Sample	*

	Control	Outer Discharge		Immediate Discharge	Intermediate Discharge		
	2	7	9	3A	3	6	11
7-22-71	1,050,021	No Sample	6,014,406	245,243	1,928,610	*	6,553,998
8-19-71	356,694	4,575,238	7,757,298	4,535,805	4,764,381	33,821,705	9,535,905
10-28-71	3,184	1,393	No sample	13,532	51,191	18,886	No Sample

*Algae present; quantitative data not available

TABLE 3.1-4

PERIPHYTON ALGAL CELL DENSITIES (cells/cm^2) IN THE MISSISSIPPI RIVER AT MONTICELLO SITE, 1972
(FROM KNUTSON 1973)

	Station						
Sample Collection Date	Control	Outer Discharge		Immediate Discharge	Intermediate Discharge		
	2	7	9	3A	3	6	11
5-22-72	12,754	1,000	4,650	10,190	2,080	1,200	1,360
6- 5-72	4,075,140	31,480	71,540	23,940	1,435,980	29,199	15,650
6-19-72	12,245,875	3,219,280	23,655,370	24,700	11,279,530	6,881,972	4,508,589
7- 4-72	5,031,141	5,206,860	10,150,000	79,170	3,304,720	21,088,408	12,063,443
7-17-72	24,891,908	10,013,670	6,613,590	199,830	3,629,830	17,174,658	23,943,134
7-31-72	6,811,311	No Sample	21,308,520	10,397,750	No Sample	No Sample	No Sample
8-15-72	No Sample	No Sample	3,539,220	29,811,260	No Sample	No Sample	No Sample
9- 1-72	8,538,558	900	9,900,970	602,390	14,840	1,747,323	780
9-18-72	31,250	2,210	3,068,450	15,900	139,300	35,085	26,120
10- 3-72	32,412	37,090	16,470	2,210	4,620	139,968	23,470
10-17-72	41,846	10,030	19,620	76,230	12,630	7,130	49,250
11- 1-72	7,080	4,580	15,350	3,880	8,200	1,900	20,530
11-28-72	No Sample	19,250	7,200	900	No Sample	No Sample	No Sample

TABLE 3.1-5

PERIPHYTON ALGAL CELL DENSITIES (cells/cm^2) IN THE MISSISSIPPI RIVER AT MONTICELLO SITE, 1973
(FROM KNUTSON 1974)

Sample Collection Date	Station: Control	Outer Discharge		Immediate Discharge	Intermediate Discharge		
	2	7	9	3A	3	6	11
2-16-73	No Sample	No Sample	No Sample	3,500	No Sample	3,780	No Sample
3- 3-73	No Sample	No Sample	No Sample	7,210	No Sample	1,467	No Sample
4-24-73	92,200	350	6,748,530	9,920	349,380	2,983,000	11,150
5- 9-73	1,140,000	5,460	2,257,000	107,810	57,500	4,794,000	440,000
5-22-73	3,798,500	120	168,340	596,700	231,000	15,220	134,200
6- 5-73	10,386	14,580	101,680	661,200	12,170	481,680	121,440
6-20-73	43,421,680	11,700,840	45,901,560	602,120	54,469,800	53,100,900	51,501,746
7- 2-73	39,102,100	62,660,480	15,452,490	5,550	4,107,960	28,632,720	19,860,720
7-17-73	68,401,080	44,943,000	67,400,480	26,110	48,600,240	64,980,720	54,560,600
7-31-73	56,501,400	61,361,400	28,901,080	3,390	61,400,846	43,201,080	61,041,080
8-14-73	38,861,500	22,531,000	61,541,110	6,357,500	66,280,120	41,976,240	64,980,036
8-28-73	39,121,160	231,260	61,540,540	263,600	2,616,000	43,626,660	43,201,720
9-11-73	74,302,640	42,421,640	26,000,480	36,841,840	8,060	32,350,880	64,721,240
9-25-73	3,538,260	41,302,280	52,500,660	898,960	71,580	60,720,900	71,153,540
10- 9-73	8,570	33,650	98,550	4,960	18,080	197,460	54,500
10-26-73	3,760	No Sample	No Sample	985,920	No Sample	No Sample	No Sample
11- 9-73	240	240	0	No Sample	640	720	730
11-23-73	0	No Sample	0	0	0	0	0

TABLE 3.1-6

PERIPHYTON ALGAL CELL DENSITIES (cells/cm^2) IN THE MISSISSIPPI RIVER AT MONTICELLO SITE, 1974
(FROM KNUTSON 1975)

Sample Collection Date	Station: Control	Outer Discharge		Immediate Discharge	Intermediate Discharge		
	2	7	9	3A	3	6	11
5-22-74	1,031,978	409,626	882,406	3,307,808	533	1,636	7,612
6-10-74	8,786,350	No Sample	26,458,462	4,902,910	1,223,802	958,574	978,560
6-25-74	1,204,072	No Sample	3,552,176	623,210	5,233,415	828,618	2,462,562
7- 9-74	4,024,900	96,702,180	5,755,468	1,111,429	831,882	4,622,414	786,532
7-23-74	3,366,320	999,800	13,900,340	4,982	2,381,710	1,788,170	2,703,020
8- 5-74	1,103,100	806,300	2,937,900	2,376	873,800	809,200	3,264,300
8-20-74	4,855,200	1,281,900	1,815,590	3,712,900	1,570,900	1,970,920	1,581,200
9- 4-74	1,563,840	1,530,900	4,203,000	344,120	1,170,700	1,931,400	2,132,400
9-19-74	735,500	592,300	469,700	122,860	695,640	2,030,300	1,020,500
10- 2-74	306,300	267,520	378,200	22,941	176,432	1,938,700	623,300
10-16-74	43,040	429,900	469,500	3,011	227,200	510,300	476,500
11- 3-74	107,500	245,000	489,900	34,880	272,300	296,400	296,000

TABLE 3.1-7

DOMINANT PERIPHYTON SPECIES AT MONTICELLO SITE, 1968
(FROM COLINGSWORTH 1969)

Species	Station 2	5	7	9	12
Cocconeis placentula	151.2	3,667.8	74.4	209.3	30.2
Navicula cryptocephala	120.9	3,045.0	176.7	118.6	67.4
Navicula cf (*gracilis*)	318.6	9,757.8	744.2	1,132.6	309.3
Gomphonema parvulum	18.6	622.8	16.3	37.2	169.8
Diatoma vulgare	41.9	21,107.3	44.2	176.7	286.0
Melosira varians	14.0	6,090.0	0	11.6	20.9

TABLE 3.1-8

DOMINANT PERIPHYTON SPECIES AT MONTICELLO SITE, 1969
(FROM BROOK 1970)

Species	Station 2	7	9	3	6	11
			August 20, 1969			
Chroococcus minimus	21,632	38,775	462,853	97,550	722,035	3,673
Chroococcus minor	4,080	816	48,979	3,265	17,550	2,859
Phormidium faveolarum	4,080	1,632	36,979	131,427	184,080	
Xenococcus minimus	-	9,387	-	34,591	-	-
Cocconeis pediculus	408	-	-	-	816	-
Cocconeis placentula	152,468	118,366	148,978	115,509	126,529	18,775
Navicula spp.	-	1,224	-	-	408	408
			September 11, 1969			
Chroococcus minimus	1,037,134	51,020	560,811	426,935	No Sample	247,344
Chroococcus minor	12,652	178,774	86,121	8,163		21,224
Phormidium faveolarum	44,081	175,508	290,201	57,958		111,427
Xenococcus minimus	-	96,325	19,591	-		232,651
Cocconeis placentula	147,345	181,631	118,162	148,162		178,794
Navicula spp.	4,490	1,224	816	816		2,040

TABLE 3.1-9

DOMINANT PERIPHYTON SPECIES AT MONTICELLO SITE, 1970
(FROM KNUTSON 1971)

Species	Station 2	7	9	3	6	11
			July 28, 1970			
Chroococcus minimus	6,412,834	3,533,833	Not Analyzed	2,407,678	2,049,159	2,730,881
Chroococcus minor	406,447	530,639	Not Analyzed	62,097	80,442	330,236
Chroococcus minutus	28,226	-	Not Analyzed	19,758	8,468	-
cf *Phormidium faveolarum*	276,610	321,771	Not Analyzed	115,727	-	25,403
Cocconeis placentula	344,351	503,059	Not Analyzed	318,954	330,236	419,146
			August 25, 1970			
cf *Chamaesiphon*	14,113	165,118	No Sample	28,226	No Sample	0
Chroococcus minimus	635,085	635,070	No Sample	231,453	No Sample	0
Chroococcus minor	95,968	211,690	No Sample	53,629	No Sample	0
Cocconeis placentula	251,211	427,614	No Sample	375,406	No Sample	0
Cocconeis pediculus	5,646	8,468	No Sample	25,403	No Sample	0

TABLE 3.1-10

DOMINANT PERIPHYTON SPECIES AT MONTICELLO SITE, 1971
(FROM KNUTSON 1972)

Species	Station: Control 2	Outer Discharge 7	Outer Discharge 9	Immediate Discharge 3A	Intermediate Discharge 3	Intermediate Discharge 6	Intermediate Discharge 11
July 22, 1971							
Chroococcus minor	366,674	No Sample	5,064,387	35,715	1,400,028	Counts Not In Appreciable Numbers	6,161,118
Chroococcus minutus	100,002		171,432	-	-		-
cf Oscillatoria angustissima	-		-	59,525	-		-
Cocconeis placentula	54,763		742,872	66,668	523,820		378,594
Achnanthes exigua	-		-	4,762	-		-
August 19, 1975							
Chroococcus minor	324,870	3,761,980	6,871,566	4,335,801	4,071,510	12,435,963	9,221,613
Chroococcus minutus	-	457,152	247,624	-	114,288	378,579	-
Achnanthes exigua	-	-	-	7,143	-	-	-
Cocconeis placentula	28,509	538,106	623,822	107,145	578,583	721,443	292,863
October 28, 1971							
Cocconeis placentula	2,388	995	No Sample	398	-	1,988	No Sample
Diatoma vulgare	-	-		-	40,750	2,982	
Navicula tripunctata	-	-		7,164	5,964	7,455	

TABLE 3.1-11

DOMINANT PERIPHYTON SPECIES AT MONTICELLO SITE, 1972
(FROM KNUTSON 1973)

Species	Station: Control	Outer Discharge		Immediate Discharge	Intermediate Discharge		
	2	7	9	3A	3	6	11
May 22, 1972							
Chroococcus minimus	-	-	-	550	-	-	-
Characium pringsheimii	-	-	-	550	-	-	-
Stigeoclonium nanum	-	-	-	300	-	-	-
Cocconeis placentula	731	P	300	P	P	120	120
Gomphonema parvulum	400	-	1,100	120	100	-	P
Navicula cryptocephala	300	-	120	120	300	120	120
Achnanthes exigua	-	-	-	550	-	-	-
June 5, 1972							
Chroococcus minimus	3,700	P	-	-	-	-	550
Characium pringsheimii	-	-	-	6,000	-	-	-
Stigeoclonium nanum	-	-	300	8,200	-	-	-
Cocconeis placentula	3,891,300	550	60,000	120	565,200	19,679	3,700
Gomphonema parvulum	900	30,270	2,800	2,600	879,000	6,500	6,500
June 19, 1972							
Chroococcus minimus	4,786,608	2,300	1,500,000	400	34,600	978,260	869,515
Characium pringsheimii	-	-	-	5,400	-	-	-
Cocconeis placentula	7,434,800	3,200,000	21,000,000	1,400	10,900,000	4,391,303	1,004,348
Achnanthes exigua	-	-	-	31,000	-	-	-
Gomphonema parvulum	731	17,900	1,100,000	-	342,400	1,499,999	23,789
July 4, 1972							
Chroococcus minimus	234,414	-	97,800	71,800	97,800	168,478	217,391
Chroococcus minor	289,273	-	-	300	120	120	-
Achnanthes lanceolata	-	-	27,000	1,400	300	730	300
Cocconeis placentula	4,391,300	5,200,000	10,000,000	300	3,200,000	20,909,090	5,891,304
Gomphonema parvulum	894	2,600	400	-	2,100	1,100	59,685

TABLE 3.1-11 (Continued)

Species	Control 2	Outer Discharge 7	Outer Discharge 9	Immediate Discharge 3A	Intermediate Discharge 3	Intermediate Discharge 6	Intermediate Discharge 11
July 17, 1972							
Chroococcus minimus	244,565	9,730	598,000	300	127,200	798,912	374,999
Cocconeis pediculus	568	400	3,400	-	400	2,100	11,982,627
Cocconeis placentula	24,636,400	10,000,000	6,000,000	13,600	3,500,000	16,272,727	11,782,608
July 31, 1972							
Chroococcus minimus	1,804,347	No Sample	2,900,000	2,400,000	No Sample	No Sample	No Sample
Characium pringsheimii	-		-	478,300			
Achnanthes exigua	-		-	7,440,000			
Cocconeis placentula	500,000		18,400,000	65,700			
August 15, 1972							
Chroococcus minimus	No Sample	No Sample	34,600	P	No Sample	No Sample	No Sample
Characium pringsheimii			-	2,900,000			
Stigeoclonium nanum			-	78,700			
Cocconeis placentula			3,500,000	900			
September 1, 1972							
Chroococcus minimus	494,565	-	3,000,900	P	730	168,478	120
Characium pringsheii	-	-	-	1,400	-	-	-
Phormidium favosum	1,625	120	-	1,100	-	120	P
Stigeoclonium nanum	-	-	-	598,000	-	-	-
Cocconeis placentula	7,535,000	-	600,000	-	11,000	1,492,826	120
Gomphonema parvulum	784	120	730	-	730	103,799	120

TABLE 3.1-11 (Continued)

Species	Control 2	Outer Discharge 7	Outer Discharge 9	Immediate Discharge 3A	Intermediate Discharge 3	Intermediate Discharge 6	Intermediate Discharge 11
October 3, 1972							
Chroococcus minimus	-	3,700	300	300	-	-	300
Cocconeis placentula	18,000	2,800	3,000	400	400	31,791	3,100
Gomphonema lanceolatum	1,422	900	900	-	1,600	730	-
Gomphonema olivaceum	2,100	21,600	900	-	400	78,715	1,350
Gomphonema parvulum	5,400	2,800	730	P	1,800	14,922	5,400
October 17, 1972							
Chroococcus minimus	-	P	-	65,700	-	-	120
Phormidium faveolarum	120	300	-	-	3,400	-	-
Diatoma vulgare	21,600	550	1,350	400	-	900	7,300
Gomphonema lanceolatum	1,056	1,100	1,600	-	1,800	120	550
Gomphonema olivaceum	4,900	2,800	4,500	-	-	400	6,500
Gomphonema parvulum	-	2,100	300	120	1,800	730	550
November 1, 1972							
Diatoma vulgare	4,900	2,100	3,100	400	4,500	1,350	3,700
Gomphonema olivaceum	300	1,100	2,800	-	400	-	900
Navicula gracilis	-	-	3,700	300	300	-	1,350
Navicula rhynchocephala sp.1	-	120	1,600	300	-	-	1,600
Synedra ulna var. oxyrhynchus	1,400	900	550	-	2,100	550	2,100
November 28, 1972							
Phormidium faveolarum	No Sample	3,100	300	-	No Sample	No Sample	No Sample
Diatoma vulgare		2,300	550	120			
Gomphonema olivaceum		1,350	400	-			
Gomphonema parvulum		2,800	-	120			
Melosira granulata		1,400	-	-			
Nitzschia palea		2,800	900	-			

TABLE 3.1-12

DOMINANT PERIPHYTON SPECIES AT MONTICELLO SITE, 1973
(FROM KNUTSON 1974)

Species	Station: Control	Outer Discharge		Immediate Discharge	Intermediate Discharge		
	2	7	9	3A	3	6	11
February 16, 1973							
Characium pringsheimii	-	-	-	3,140	-	-	-
Diatoma vulgare	-	-	-	120	-	420	-
Navicula gracilis	-	-	-	120	-	1,200	-
March 3, 1973							
Characium pringsheimii	-	-	-	6,970	-	-	-
Navicula gracilis	-	-	-	-	-	120	120
Gomphonema olivaceum	-	-	-	120	-	507	-
Navicula radiosa	-	-	-	-	-	120	420
April 24, 1973							
Diatoma vulgare	2,100	-	67,600	120	1,600	455,000	1,100
Gomphonema olivaceum	-	20	-	2,300	120	120	2,000
Navicula gracilis	84,000	90	143,110	3,700	310,340	390,000	3,900
Synedra ulna	4,240	110	653,000	1,400	19,560	2,134,000	3,900
May 9, 1973							
Diatoma vulgare	796,180	2,184	901,480	45	25,755	2,156,380	197,020
Navicula gracilis	114,000	1,092	451,400	103,400	5,750	479,400	44,000
Synedra ulna	456,000	2,184	902,800	1,900	25,875	2,157,300	198,000

TABLE 3.1-12 (Continued)

Species	Station: Control 2	Outer Discharge 7	Outer Discharge 9	Immediate Discharge 3A	Intermediate Discharge 3	Intermediate Discharge 6	Intermediate Discharge 11
May 22, 1973							
Cocconeis placentula	379,850	-	32,626	120,000	21,000	-	120
Diatoma vulgare	949,625	-	24,000	115,000	52,500	1,400	46,150
Melosira varians	569,800	-	24,000	120	120	1,500	6,710
Navicula gracilis	1,519,205	120	64,270	107,400	84,000	5,800	53,650
Navicula cf. rhynchocephala	190,000	-	5,050	107,400	120	120	13,420
Synedra ulna	189,900	-	16,834	12,000	21,000	1,500	10,700
June 5, 1973							
Chroococcus minimus	1,000	1,400	20,000	-	4,500	96,000	12,000
Cocconeis placentula	1,000	5,800	50,000	480	4,000	192,000	60,000
Diatoma vulgare	2,500	1,400	120	240	120	24,000	480
Gomphonema parvulum	1,000	1,400	480	-	1,130	48,000	36,000
Navicula gracilis	2,500	1,400	20,000	120	1,000	48,000	12,000
June 20, 1973							
Chroococcus minimus	8,640,000	2,340,000	32,400,000	59,800	41,100,000	32,400,000	34,000,000
Stigeoclonium nanum	2,160,000	-	240	59,800	-	120	-
Cocconeis placentula	17,280,000	8,190,000	10,800,000	240	12,000,000	10,800,000	12,500,000
Cocconeis pediculus	-	585,000	120	120	120	2,700,000	120
Navicula cf. rhynchocephala	2,200,000	-	-	320	-	1,800,000	240
Gomphonema parvulum	4,320,000	585,000	-	120	-	-	-

TABLE 3.1-12 (Continued)

Species	Control	Outer Discharge		Immediate Discharge	Intermediate Discharge		
	2	7	9	3A	3	6	11
July 2, 1973							
Chroococcus minimus	8,640,000	13,680,000	350,000	-	350,000	3,200,000	5,100,000
Cocconeis pediculus	240	6,800,000	1,476,000	-	750,000	3,116,000	120
Cocconeis placentula	17,500,000	28,500,000	7,500,000	680	1,600,000	16,000,000	9,840,000
Cymbella tumida	8,640,000	13,680,000	1,476,000	480	120	3,116,000	2,460,000
Gomphonema parvulum	4,320,000	240	480	-	1,407,600	480	240
July 17, 1973							
Chroococcus minimus	41,040,000	29,552,400	47,360,000	-	32,400,000	41,040,000	34,000,000
Cocconeis pediculus	6,840,000	4,920,000	-	1,200	5,400,000	342,000	6,840,000
Cocconeis placentula	20,520,000	105,000,000	-	7,750	10,800,000	13,680,000	13,200,000
Gomphonema parvulum	240	120	240	120	120	120	240
July 31, 1973							
Chroococcus minimus	29,000,000	34,000,000	7,500,000	-	34,000,000	27,000,000	41,040,000
Cocconeis pediculus	120	240	3,500,000	-	240	240	120
Cocconeis placentula	27,500,000	27,360,000	14,320,000	130	27,400,000	16,200,000	20,520,000
August 14, 1973							
Chroococcus minimus	25,900,000	1,500,000	41,040,000	3,824,000	41,040,000	22,000,000	41,040,000
Chroococcus minor	420	15,000	120	-	3,420,000	1,760,000	120
Cocconeis pediculus	420	31,000	420	120,000	1,300,000	2,200,000	3,420,000
Cocconeis placentula	12,960,000	20,960,000	20,500,000	1,600,000	20,520,000	17,600,000	20,500,000

TABLE 3.1-12 (Continued)

Species	Control	Outer Discharge		Immediate Discharge	Intermediate Discharge		
	2	7	9	3A	3	6	11
August 28, 1973							
Chroococcus minimus	11,800,000	50,600	41,040,000	14,000	1,094,800	17,280,000	21,600,000
Achnanthes exigua	2,000,000	-	-	194,000	-	2,160,000	-
Cocconeis pediculus	620	540	540	-	120	540	520
Cocconeis placentula	23,760,000	180,000	20,500,000	-	1,520,000	22,000,000	21,600,000
September 11, 1973							
Chroococcus minimus	17,100,000	7,020,000	10,000,000	120	-	9,700,000	31,360,000
Achnanthes lanceolata var. omissa	4,300,000	2,700,000	1,200,000	11,800,000	-	730,000	-
Achnanthes lanceolata var. lanceolata	2,700,000	3,000,000	870,000	-	-	1,620,000	-
Cocconeis placentula	34,200,000	21,600,000	10,000,000	-	2,580	16,200,000	31,360,000
September 25, 1973							
Chroococcus minimus	593,000	4,600,000	10,000,000	146,600	-	10,800,000	120
Cocconeis pediculus	40,000	2,300,000	2,500,000	97,750	420	2,700,000	420
Cocconeis placentula	395,400	9,200,000	15,000,000	391,000	26,010	20,800,000	21,375,000
Diatoma vulgare	198,000	6,900,000	12,000,000	97,750	-	420	120
Navicula gracilis	40,000	1,800,000	1,200,000	20,000	120	2,160,000	4,275,000
Navicula cf. rhynchocephala	79,000	4,600,000	1,500,000	1,200	8,620	5,000,000	5,200,000
October 9, 1973							
Chroococcus minor	2,020	240	-	-	1,800	420	-
Cocconeis pediculus	240	240	11,670	420	420	120	7,000
Cocconeis placentula	1,030	6,000	33,000	1,200	1,800	92,000	21,000
Diatoma vulgare	1,030	16,670	23,000	420	420	23,000	14,000
Navicula gracilis	1,500	3,300	16,000	120	800	-	-

TABLE 3.1-12 (Continued)

Species	Station: Control 2	Outer Discharge 7	Outer Discharge 9	Immediate Discharge 3A	Intermediate Discharge 3	Intermediate Discharge 6	Intermediate Discharge 11
October 26, 1973							
Achanthes exigua	120	-	-	740,000	-	-	-
Cocconeis placentula	2,200	-	-	244,000	-	-	-
November 9, 1973							
Cocconeis placentula	120	120	-	-	-	-	-
Navicula gracilis	120	-	-	-	120	120	-
November 23, 1973							
No growth all stations							

TABLE 3.1-13

PERIPHYTON DIVERSITY AND NUMBER OF SPECIES AT THE MONTICELLO SITE, 1972
(FROM KNUTSON 1973)

Station	May 22	June 5	June 19	July 4	July 17	July 31	Aug 15	Sept 1	Sept 18	Oct 3	Oct 17	Nov 1	Nov 28
						DIVERSITY[1]							
2 (Control)	3.81	.28	.99	.70	.09	.85	ns	.66	1.48	2.36	2.53	1.42	ns
7 Outer	1.57	.31	.06	.02	.02	ns	ns	2.46	2.16	2.30	3.21	2.02	3.70
9 Discharge	3.64	1.06	.63	.14	.47	.58	.09	.97	.17	3.92	3.67	3.09	3.62
3A Immediate Discharge	4.05	2.68	3.30	.81	.79	1.10	.19	.08	2.76	3.16	1.04	2.37	2.46
3 Intermediate	2.95	.97	.23	.22	.23	ns	ns	1.53	1.68	2.06	3.11	3.22	ns
6 Discharge	2.66	1.60	1.31	.08	.33	ns	ns	.79	1.78	2.04	3.62	.87	ns
11	2.99	2.17	1.57	1.16	1.10	ns	ns	2.19	.71	3.44	3.64	3.18	nx
						NUMBER OF SPECIES							
2 (Control)	21	15	19	22	12	12	ns	18	14	18	20	7	ns
7 Outer	3	6	6	11	13	ns	ns	6	6	19	16	7	22
9 Discharge	17	11	15	20	13	12	5	5	24	21	18	13	14
3A Immediate Discharge	23	17	22	23	15	22	10	7	15	11	17	13	6
3 Intermediate	19	7	16	18	12	ns	ns	10	12	6	15	10	ns
6 Discharge	7	18	22	18	19	ns	ns	12	23	27	16	2	ns
11	9	11	20	17	8	ns	ns	5	5	17	26	14	ns

[1]The Shannon-Weiner Diversity Index is a function that is sensitive both to changes in number of species and to changes in the pattern of distribution of individuals among species. The index varies from a value of 0 for communities containing a single species to high values for communities containing many species, each with a small number of individuals. Greater species diversity indicates a higher degree of community stability.

ns - no sample taken.

TABLE 3.1-14

PERIPHYTON DIVERSITY AND NUMBER OF SPECIES AT MONTICELLO SITE, 1974
(ADAPTED FROM KNUTSON 1975)

Station		May 22	June 10	June 25	July 9	July 23	Aug 5	Aug 20	Sept 4	Sept 19	Oct 2	Oct 16	Nov 3
							DIVERSITY[1]						
2	(Control)	3.60	1.12	2.00	.88	.69	1.35	.53	1.59	2.58	2.24	1.76	.59
7	Outer Discharge	2.19	ns	ns	.80	1.33	1.21	1.64	.99	2.23	2.73	1.92	.83
9	Outer Discharge	3.28	.03	.90	.93	.17	.76	1.37	1.01	2.45	4.24	1.94	2.13
3A	Immediate Discharge	3.14	.01	.57	1.96	1.19	2.79	1.64	1.15	2.09	2.70	1.33	2.18
3	Intermediate Discharge	3.49	.21	1.17	1.17	.84	1.06	1.09	2.11	1.70	--	1.12	.56
6	Intermediate Discharge	3.45	.80	1.76	.72	1.19	.91	2.28	1.18	2.04	.83	4.70	2.46
11	Intermediate Discharge	3.13	.92	1.44	2.52	.77	.69	.21	.93	1.56	1.87	1.93	1.55
							NUMBER OF SPECIES						
2	(Control)	20	20	7	10	7	9	3	13	15	11	6	7
7	Outer Discharge	9	ns	ns	6	6	9	7	11	25	12	9	5
9	Outer Discharge	22	13	14	11	10	9	7	14	19	18	9	8
3A	Immediate Discharge	11	15	6	16	6	14	6	10	11	12	6	7
3	Intermediate Discharge	28	23	10	11	5	3	4	12	14	16	15	6
6	Intermediate Discharge	14	19	10	8	7	3	14	8	14	16	12	15
11	Intermediate Discharge	22	5	5	14	5	6	4	9	9	16	12	5

[1]The Shannon-Weiner Diversity Index is a function that is sensitive both to changes in number of species and to changes in the pattern of distribution of individuals among species. The index varies from a value of 0 for communities containing a single species to high values for communities containing many species, each with a small number of individuals. Greater species diversity indicates a higher degree of community stability.

ns - no sample taken.

3.2 ZOOPLANKTON

Zooplankton is the animal component of the community of organisms suspended in the water column. In rivers, zooplankton is constantly carried downstream by the current. Consequently, the zooplankton community of any collection point on a river reflects upstream conditions rather than localized conditions. The communities of large rivers such as the Mississippi are usually composed of large numbers of protozoans and rotifers and limited numbers of crustaceans.

The major components of river zooplankton tend to be temporary or tychoplanktonic. Consequently, the community lacks great stability, as it depends heavily on flow and other physical factors that affect scouring and backwater recruitment. Due to the lack of stability, few consumers have evolved that depend exclusively on zooplankton for food. There are a small number of filter-feeding benthic organisms that use zooplankton as well as phytoplankton and detritus for food. Many fish larvae are also reported to feed on zooplankton, but most adult lotic fishes do not actively consume zooplankton.

Studies of the zooplankton of the upper Mississippi show that there are relatively few crustaceans present in the system, whereas rotifers and protozoans are abundant. Of the zooplankton studied by Wiebe (1928), the most abundant taxon was an unidentified rotifer. Several other rotifer taxa were also present on most of the sampling dates. Although *Cyclops* and nauplii were the most abundant crustaceans, they were usually present in lower numbers than rotifers.

Reinhard's (1931) study confirmed the predominance of rotifers in the river system (Table 3.2-1). Although several crustacean species were recorded, the author reported finding most of these taxa just below Lake Pepin, an area ideally suited for crustacean development. Maximum rotifer densities occurred in May. Keratella cochlearis was the most abundant rotifer and was present at all stations throughout the year.

In his study of major waterways of the United States, Williams (1966) included parts of the Mississippi River. Of particular interest is his study of the area around St. Paul, Minnesota. Williams found the most abundant rotifer genera to be (in order of abundance) Keratella, Polyarthra, Brachionus, Synchaeta, and Trichocerca.

The importance of zooplankton in the Monticello region of the upper Mississippi River is probably limited. The majority of adult fish consume benthic organisms or fish that have fed on benthic organisms. Only some larval fish and a few filter-feeding benthic invertebrates (e.g., clams, some caddisflies and blackflies) feed on zooplankton. With the exception of fish, the organisms that consume plankton are generally not selective for zooplankton. The temporary nature of zooplankton in the lotic environment and its susceptibility to fluctuations in in physical and chemical factors further emphasize the limited role of zooplankton in the trophic dynamics of rivers.

3.2 REFERENCES

Reinhard, E. G. 1931. "The Plankton Ecology of the Upper Mississippi, Minneapolis to Winona." Ecol. Monogr. I: 395-464.

Wiebe, A. H. 1928. "Biological Survey of the Upper Mississippi River with Special Reference to Pollution." Bull. Bur. Fish. Wash. 43(2): 137-167.

Williams, L. G. 1966. Dominant Planktonic Rotifers of Major Waterways of the United States. USPHS. p. 83-91.

TABLE 3.2-1

ZOOPLANKTON TAXA COLLECTED IN THE UPPER MISSISSIPPI RIVER (FROM REINHARD 1931)

RHIZOPODA
- Arcella vulgaris
- Centropyxis aculeata
- Difflugia sp.
- Euglypha sp.

INFUSORIA
- Codonella cratera
- Colpoda sp.
- Halteria grandinella
- Paramecium sp.
- Tintinnidium fluviatile
- Vorticella spp.

SUCTORIA
- Acineta

ROTATORIA
- Asplanchna sp.
- Brachionus patulus
- Brachionus angularis
- Brachionus pala
- Brachionus bakeri
- Diurella stylata
- Euchlanis dilatata
- Filinia longiseta
- Keratella cochlearis
- Keratella quadrata
- Lecane luna
- Notholca striata
- Pedalia mira
- Polyarthra trigla
- Rotifer spp.
- Synchaeta stylata
- Testudinella patina
- Trichocerca spp.

TABLE 3.2-1 (Continued)

CLADOCERA
- Bosmina longirostris
- Chydorus sphaericus
- Daphnia pulex
- Daphnia longispina
- Leptodora kindtii
- Moina rectirostris

COPEPODA
- Diaptomus oregonensis
- Cyclops bicuspidatus
- Cyclops viridis
- Nauplii

3.3 MACROINVERTEBRATES

3.3.1 METHODS

Macroinvertebrate pre-operational surveys began in June 1968 at the Monticello Site. Dr. Alfred J. Hopwood from St. Cloud State College, Minnesota, and his graduate students conducted numerous benthic studies. Quantitative sampling stations and sectors for qualitative sampling were based on sounding range locations taken from U.S.G.S. map chart N4515W9345/15, revised May 29, 1968, NSP No. NR-E-5979-P19-1 & 2 (Figure 3.3-1).

A number of different types of studies were conducted; the various methods used are described below.

3.3.1.1. Qualitative Study

Pre-operational qualitative sampling was done along the five sectors described in Table 3.3-1. Sampling was accomplished by using an invertebrate sampling net which was swept among grasses and sedges of the shoreline and backwaters. Depth of water in these areas was two feet or less and substrates generally were silt and mud. Captured invertebrates were preserved in 70 percent isopropyl alcohol. Specimens were sorted by eye into phenotypic groups. These groups were identified to the lowest taxonomic level possible using standard taxonomic keys (McConville 1969, p. 21). Identification to the generic level was usually attained, with exception of the dipterans which were identified to the family level.

3.3.1.2 Quantitative Studies

The five-mile stretch of the Mississippi River under study near the Monticello Plant has been characterized by Hopwood (1969, p. 1) as a large-volume stream with a "young gravelly bottom". Because of this substrate, variable but substantial current velocities, and the depth of main channel, common quantitative samplers, such as the Ekman and Ponar dredges or Surber Sampler, are unsuitable. Artificial substrate samplers have therefore been used to monitor the survey area.

3.3.1.2.1 Bull Artificial Substrate Sampler

In 1968, a quantitative artificial substrate sampler designed by Bull (1968) was tested (Figure 3.3-2). This sampler proved to be ineffective in the Upper Mississippi River because of highly variable depths and rapid currents, although it did provide some qualitative data.

3.3.1.2.2 Modified Britt Artificial Substrate Sampler

A concrete sampler designed by Britt (1955) and modified by McConville (1969) was used from 1969 to 1975. The modified Britt sampler (Figure 3.3-3) has a surface area of approximately one-tenth square meter (31.62 cm x 31.62 cm x 8 cm).

The surface is roughened by sand blasting or by using a chemical retarder to produce an exposed aggregate. Because of its weight (40 lbs.), river currents have little effect on this sampler. Also, it does not trap large amounts of debris.

3.3.1.2.3 Major Macroinvertebrate Monitoring Program

Table 3.3-2 describes the locations of the transects used in the major macroinvertebrate monitoring program from 1969 through 1972; Figure 3.3-4 shows the transects.

Four modified Britt samplers were placed at each sampling station along a transect. Figure 3.3-5 shows the concrete block sampler arrangement and position of sampling stations on experimental transect number one. Macroinvertebrates colonized the substrates through the natural phenomena of macroinvertebrate drift, lateral movement and movement upstream. Artificial substrates were exposed for 30 days, based on the findings of Dahlquist (1970). At the end of the 30-day sampling period, the substrates were returned to the surface and the organisms were removed by washing in a preservative/cleaning solution (Britt 1955, p. 524) and then by hand cleaning the remaining invertebrates from the surface. Macroinvertebrates were preserved in 10 percent formalin.

Laboratory analysis consisted of classifying, counting and weighing the organisms to determine the average wet and dry weight per organism and the total wet and dry weight per taxonomic group. Dry weights were obtained by oven drying the organisms at 60°C (140°F) for 24 hours (McConville and Hopwood 1970, p. 30).

3.3.1.2.4 Recolonization Study of Macroinvertebrates

This study compared colonization and growth rates of macroinvertebrates below the heated power plant discharge to those of a control station above the intake. The study began in July 1971 and continued into July 1972. Figure 3.3-6 shows the location of the control and experimental sampling stations used. Station C (control) was 1,320 feet (0.25 mi.) above the intake structure. The experimental station (E) was located immediately below the end of the discharge canal where modified Britt samplers were exposed to increased temperatures during plant operation. Both sites were approximately 20 feet from the shore. Five substations of four modified Britt samplers with one float each were placed at Station C and Station E. The substations were placed in a "W" pattern to expose each set of blocks to an unobstructed current flow. Every seven days following the placement of the samplers, one substation of four blocks was recovered. One cycle thus consisted of 35 days of exposure. Once the artificial substrates were lifted to the boat, the same field procedures described in 3.3.1.2.3 on p. 111 were followed.

Identifying, counting and weighing of sample organisms were based on the use of subsamples. Each preserved sample was emptied into a square graduated pan and spread evenly over the bottom. The pan was marked into 16 numbered squares, which in turn were divided into four equal, numbered squares (Figure 3.3-7). Observation determined what fraction of sample would contain a sufficient number of organisms in the major orders. A die was used to achieve randomness in the order in which the squares were collected for the subsample. Organisms in the squares used for the subsamples were sorted into four groups: Trichoptera, Ephemeroptera, Diptera, and miscellaneous. Each group was transferred to separate vials, labeled, and preserved. The grouped organisms were identified and enumerated with the aid of dissecting microscopes, separated (usually to genera) and preserved in five percent formalin. Actual subsample numbers were recorded. Projected numbers were calculated by multiplying the number of organisms in a subsample by the reciprocal of the fraction subsampled.

Identified organisms were dried for one minute in a Buchner funnel and weighed to the nearest 0.1 milligram in dry vials of preweighed tare on a Torbal torsion balance (Hopwood 1974a, p. 33). Weighed specimens were stored in a 50-50 solution of glycerine and 10 percent formalin. The weight per organism was calculated by dividing the weight of organisms in a vial by the actual number of organisms in the vial. The weight for each group of the station was then calculated by multiplying the weight per organism by the calculated number in the group. Weights per group were summed to obtain a weight for an entire station.

3.3.1.2.5 Invertebrate Drift Study

The phenomenon of drift is essential in the recolonization process. When drifting, an organism is dislodged from or leaves its substrate and is carried by the current downstream where it may recolonize on a suitable substrate. Very few studies on large river invertebrate drift are available due to the difficulties of sampling.

W. Matter (1975) investigated invertebrate drift in the Mississippi River near the Monticello Site. He chose two sampling sites within the ecological monitoring program study area of the Monticello Site (Figure 3.3-8). The control site (C) was 1,312 feet (0.25 mi.) above the power plant water intake canal at the end of a short rapids, 15-30 feet out from the south bank of Cedar Island. The substrate was primarily rubble. The sampling apparatus was set 1.4 to 4.2 feet deep. The second site (E) was 984 feet (0.18 mi.) below the end of the discharge canal at the end of a short riffle. This site was 45-60 feet from the north bank of the river; the bottom substrate was primarily gravel and small rubble. The sampling apparatus was set 1.3 to 4.1 feet deep. Field data were collected from July 1973 through July 1974.

The sampling apparatus used by W. Matter (1975) employed nets patterned after Waters (1962, p. 316-319) but the frame was constructed to withstand the stress of a lotic environment (Figure 3.3-9).

Drift sampling nets (15 cm x 15 cm x 145 cm) were constructed of 452 mesh Nitex (openings approximately 452 μ). The mouth of each net was secured to a brass rod frame. Fifteen-centimeter lengths of steel conduit attached to the sides of the brass frame held the nets in place in the "net-stack frame."

Four "net-stack frames" were constructed of 2.5 centimeter square iron tubing with two iron rods in the center to receive the conduit tubes of the net frames. Additional 15-centimeter lengths of conduit were used to separate one net in a stack from another.

Two "river frames" were constructed of 2.5 centimeter-square iron tubing with a vertical channel at the anterior face, within which a stack frame and its nets could be lowered and thus held in place facing into the river flow. The river frames were anchored to the river bottom with iron reinforcing rods driven into the substrate. The nets could then be set in place or removed for cleaning by sliding the stack frame in and out of the fixed river frame (W. Matter 1975, p. 11).

Samples were collected over a 24-hour period. Prior to each sampling period, the river frames were secured to the substrates at the two sites. The frames faced into the river flow. Two net-stack frames were loaded with nets separated by spacers made of 15-centimeter sections of conduit. The loaded net-stack frames were lowered into the river frames from an anchored boat and left in position for four hours. During several sampling periods, the nets were left for only two to three hours to avoid clogging. All sampling periods were initiated so that one set began prior to sunset and another ended near sunrise the following day.

At the end of the set, the net was cleaned by rinsing the sample to the caudal end where the sample was removed by everting the net (W. Matter 1975, p. 16). Samples were preserved in 10 percent formalin.

Each sample was then subsampled as described in 3.3.1.2.4, p. 111. Organisms in subsamples were then sorted into the four major groups: Trichoptera, Ephemeroptera, Diptera, and miscellaneous.

Each group was placed in a vial containing 5 percent formalin (W. Matter 1975, p. 16). Analytical procedures were the same as in the recolonization study 3.3.1.2.4, p. 111.

3.3.1.2.6 Natural Substrate Study

This study investigated the natural substrate community for comparison with the artificial substrate community. A standard square-foot Surber sampler was used to collect 80 samples from 4 transects on August 19-20, 1970. The transects were both above the power plant (C1 and C2) and downstream (E1 and E4). Each transect was divided into 20 sample plots. The invertebrates captured were preserved and were later identified and counted in the laboratory (Hopwood 1971, p. 59).

3.3.1.2.7 Aquatic Insect Adult Light - Trap Study

A 15-watt fluorescent lamp with a pan of 50 percent isopropanol was located at each of three sampling stations. Propylene glycol anti-freeze was used in place of the isopropanol in freezing weather. The stations were located approximately six feet from shore along the river. Station 1 was 1,312 feet (0.25 mi.) above the plant intake, Station 2 was near the discharge canal, and Station 3 was 1,640 feet (0.4 mi.) below the end of the discharge canal (Hopwood 1974b, p. 233). Daily collections were made of samples accumulated the previous night. Collecting began in July 1973 and continued through July 1974. Preserved samples were subsampled (as described in 3.3.1.2.4 on p. 111) in the laboratory and separated according to order. Data from each month were analyzed separately. Identifications were made to the lowest taxon possible. Numbers and weights for each group in the subsample were projected to estimate total taxonomic biomass in the raw sample.

3.3.2 RESULTS

In order to clarify the results of the macroinvertebrate studies at the Monticello Site, the following discussion of the position of collection stations relative to thermal profiles is supplied.

During the operational period from 1971-1973, thermal profiles of the Monticello discharge and a control station 300 feet upstream of the discharge were mapped on 34 occasions. As shown by the vertical profile maps (Appendix F), the water body segment above the intake is thermally homogeneous. Surface temperatures at the discharge often exceeded the +9°F (+5°C) Δ T, although bottom temperatures near the discharge were not as warm due to incomplete mixing. None of the stations in Figure 3.3-4 (Major Monitoring Program) met the criteria for the immediate discharge area as defined by the MPCA (1975, p. 56). Stations E2E, E2R, E4R, and E5R were in the intermediate discharge area. Stations E1E, E1R, E1C, E1L, E2L, E3C, E4C, E4L, E5C, E5L, and E6C were generally in the outer discharge. However, station E1E fell in the +3°F to +9°F (+2°C to +5°C) isotherm up to 50 percent of the time. Stations E1C, E1L (in particular) and E4L, and E5L often had temperatures which were the same as ambient temperatures. Vertical mixing of the thermal effluent was quite rapid and in most cases thermal equilibrium of the vertical column occurred less than 1,400 feet (0.26 mi.) below the discharge.

3.3.2.1 Qualitative Study Results

Two basic types of habitats were observed in the early benthic investigations near the Monticello Site. The first was the back-water and protected shore areas where grasses and sedges provided additional features to the habitats. Substrates in this area were mainly silt and mud. Table 3.3-3 lists the taxa collected. These taxa were collected between July 1, 1968 and November 15, 1968 (McConville 1969, p. 16). Eleven orders, 32 families, and 66 genera were collected, and Coleoptera, Ephemeroptera, and Hemiptera were the dominant orders.

The second type of habitat was the main channel. Substrates were gravel, rubble and some boulders. Currents were substantial and water was generally two to 20 feet deep. This environment was more rigorous than that of the backwaters, and thus there were fewer taxa. Qualitative analysis of four quantitative samplers produced representatives of 8 orders, 15 families, and 25 genera (Table 3.3-4). Caddisflies and mayflies were the major macro-invertebrates in the main channel, but five genera of Plecoptera were also represented. In most cases these three orders are pollution sensitive and their presence suggests good water quality in this part of the Mississippi River.

3.3.2.2 Quantitative Study Results

3.3.2.2.1 Major Macroinvertebrate Monitoring Program

The major macroinvertebrate monitoring program, which commenced in 1969 and continued through 1972, was based on two control stations above and six experimental stations below the discharge (Figure 3.3-4). Total numbers of the major taxa collected in the two pre-operational years (1969-1970) and one operational year (1971) are presented in Tables 3.3-5 through 3.3-11. The percentage compositions of the four major groups (caddisflies, mayflies, true flies, and miscellaneous) for the two pre-operational years (1969-1970) and three operational years (1971-1973) are presented in Table 3.3-12.

Group percentages changed little in 1971. In the operational year of 1972 there were substantial increases in caddisflies (Table 3.3-12). Preliminary results from artificial substrates placed on September 6, 1973 and retrieved October 3, 1973 are shown in Table 3.3-13. Percentage composition of the four major groups based on this information is presented at the bottom of Table 3.3-12. Caddisflies had declined over the previous year to approximately 60 percent of the community by number.

The caddisflies, mayflies, and true flies showed definite seasonal cycles. The caddisflies (Trichoptera) have been the dominant order in pre-operational and operational years. Hydropsyche and Cheumatopsyche have been the dominant genera within the order. Macronemum, another net-builder in the family Hydropsychidae, followed the above two genera in abundance. Tables 3.3-5 and 3.3-6 show the seasonality of these taxa. At certain times of the year, it was impossible to collect samples because of unnavigable waters due to floating or unstable ice, or due to flooding. During these months no data appear. *Hydropsyche* and *Cheumatopsyche* were collected in relatively low numbers in the spring, peaked in numbers from mid- to late summer and then, due to emergence, decreased during the fall. Actual emergence times of these genera will be discussed in Section 3.3.2.2.6, p. 127. Based on numbers and biomass, McConville (1972, p. 120) concluded that *Hydropsyche*, *Cheumatopsyche*, and *Macronemum* had univoltine life cycles (one generation per year). In the laboratory, McConville found what he believed to be an extended period of ecdysis (moulting) and eclosion (egg hatching), because on almost all collecting dates many different instar stages were represented. *Hydropsyche* and *Cheumatopsyche* comprised 95 percent of the total number of Trichoptera during the pre-operational years (McConville 1972, p. 120). *Macronemum*, the next most abundant taxon, was a minor component of the community compared to *Hydropsyche* and *Cheumatopsyche*. Numbers of *Macronemum* were low in the spring and peaked in mid-August. Maximum weight per organism occurred in late May and June (McConville 1972, p. 127,129); emergence began in mid-June.

Seasonal patterns for the major taxa of mayflies, except for *Ephemerella*, were somewhate similar to those of the caddisflies. *Pseudocloeon* and *Stenonema* were dominant in summer. *Ephemerella* became dominant during fall and winter. According to McConville (1972, p. 139), *Stenonema* and *Pseudocloeon* have low or no nymphal populations in early spring, reach peak abundance in mid- to late summer and then decrease rapidly in numbers into November when populations are again very small (Tables 3.3-7, 3.3-8, 3.3-9).

McConville (1972, p. 139) states that Pseudocloeon may be a multivoltine taxon, i.e., having more than one generation per year. The fact that there was a definite bimodal size frequency distribution present during mid-summer suggests that Pseudocloeon is a bivoltine species having two short summer cycles with two separate emergence periods, the first emergence occurring in mid-summer and the second emergence occurring in late fall. Stenonema appeared to have one generation per year. McConville (1972, p. 144) describes Ephemerella as a univoltine species.

Eclosion begins in late summer with the peak population numbers occurring in the fall. As with many aquatic insects, from this point of maximum recruitment from the first instar in Ephemerella there is a continual decrease in population numbers due to death caused by predation or natural causes.

The dipterans were the most abundant part of the community during late winter and early spring. The black flies (Simuliidae) were responsible for the early spring abundance of dipterans, and the non-biting midges (Chironomidae) were responsible for the winter abundance of dipterans (Tables 3.3-10, 3.3-11).

3.3.2.2.2 Recolonization Exposure Time Pilot Study

The recolonization period of one month used in the major macroinvertebrate monitoring (3.3.2.2.1) program was based on the following pilot study by Dahlquist (unpubl.). Dahlquist, under the direction of Dr. Hopwood, used the modified Britt sampler (Figure 3.3-3) to sample station E1C between August 14, 1969 and October 9, 1969. The primary purpose of the study was to test invertebrate colonization time for artificial substrates. There were two recolonization periods of four weeks each. Sixteen sampling blocks were positioned each study period, and four blocks were recovered each succeeding week to give block exposure from one to four weeks. In this way Dahlquist could tell by looking at the total numbers of a particular taxon if its population was still increasing or had stabilized. In the first four-week study, from August 21, 1969 to September 3, 1969, Trichoptera peaked by the third week and leveled off by the fourth week. This also occurred in the second four-week period from September 11, 1969 to October 9, 1969. Trichopterans were significant in both numbers and biomass, representing 36 to 83 percent by number and 55 to 92 percent by biomass of the total sample community during the eight weeks of study. The major contributor, Hydropsyche, constituted 34 to 80 percent of the whole sample community and 50 to 89 percent of the community biomass. The population growth curve of Hydropsyche was almost identical to that of Trichoptera. In both cases, the population peaked in the third week and leveled off by the fourth week (Dahlquist unpubl., p. 6).

Mayflies (Ephemeroptera) were estimated to constitute 7 to 13 percent of the total sample community. Populations fluctuated in the two studies. In the first study, numbers of mayflies dropped after the second week, rose the third week, and leveled off from the third to fourth week. In the second study period, populations peaked during the second and third week and then decreased (Dahlquist unpubl., p. 7).

In both sampling periods, the black flies (Simuliidae) peaked in the first week and decreased thereafter. During the first study period, the Chironomini (Tendipedini) populations appeared to level off after three weeks. However, in the second study period, numbers steadily increased, with no leveling off. However, there was a steady decrease in body weights, suggesting that the population increase was due to recruitment by eclosion.

3.3.2.2.3 Macroinvertebrate Recolonization Study

The recolonization study was carried out between July 1971 and July 1972. Field and laboratory methods for this study are described in Section 3.3.1.2.4 on p. 111. One control station [1,320 ft (0.25 mi.) above the intake] and one experimental station (E) (immediately below the discharge canal) were studied (Figure 3.3-6). Stations C and E had rubble and gravel substrates. However, particle size was smaller at Station E. Current velocity averaged 3.1 feet per second at both stations. Depth averaged 6.9 feet at Station E, and 4.3 feet at Station C. Although Station E fell in the +3°F (+2°C) isotherm much of the time (see Table

3.3-15) it did not fall within this isotherm 70 percent of the time and thus is considered to occur in the outer discharge area.

Surface temperatures were taken weekly with a telethermometer and thermistor; bottom temperatures were measured with a continuous-recording thermometer in both control and experimental stations (Tables 3.3-14 and 3.3-15). The surface temperature comparisons of Station C to Station E show some substantial differences. However, because of the way the heated effluent is discharged, the bottom area at the experimental station shows, in general, smaller differences in temperature changes than the surface water. Thus, the benthos at the experimental station do not experience the maximum change in temperature.

Five substations with four block samplers each (a total of 20 samplers) were placed in a "W" pattern at Stations C and E (Figure 3.3-6). Every seven days, a substation of 4 samplers was removed. Thus, at the end of 35 days, the cycle was completed. Eight cycles were completed in the one-year study (Table 3.3-16).

Composition percentage of the total numbers of organisms and total weight in the four major groups is shown in Figures 3.3-10 and 3.3-11. Trichoptera were more abundant in the experimental station below the discharge, whereas Ephemeroptera and Diptera were more abundant in the control station above the discharge (Figure 3.3-10). Biomass of the trichopterans was consistently higher in the experimental station throughout the eight cycles (Figure 3.3-11).

Generally, the total weight of the ephemeropterans as well as the dipterans was greater in the control station (Table 3.3-17).

Data used to develop the percent composition above were analyzed statistically using the Mann-Whitney U rank correlation at the 95 percent significance level. This was done to determine if significant differences occurred between Stations C and E of each cycle (Table 3.3-18). Caddisfly larvae were significantly higher in numbers at Station E in cycles I, III and IV (Hopwood 1974a, p. 44). Differences in Ephemeroptera occurred in cycles I, VII, and VIII, with higher percentages at Station C; significantly higher percentages of dipterans occurred at Station C in cycles III and IV.

Differences in percent composition of the fauna above the intake and below the discharge are likely caused by temperature differences, since substrates, current velocity, and depth are similar at both sites. The maximum standing crop (in numbers of organisms) at both the control and experimental stations occurred in late August 1971. In 1972, the benthos at the control station reached a maximum standing crop in midsummer (June 28-July 17) whereas the benthos at the experimental transect reached a maximum standing crop in late spring (May 19-June 23). This earlier attainment of maximum standing crop at the downstream station in the outer discharge area may be a result of the constant elevated temperatures at this point.

Dahlquist (1970) found that colonization stability for major taxa generally occurred between the third and fourth week. However, in the 35-day macroinvertebrate recolonization studies, no plateaus occurred in eight cycles at either the upstream or downstream stations (Figures 3.3-13 through 3.3-26). The small differences in slope between growth rates (Figures 3.3-13 through 3.3-26) at the two stations were not deemed significant because of the high degree of variability in growth (Hopwood 1974a, p. 61).

3.3.2.2.4 Invertebrate Drift Study

W. Matter (1975) studied the phenomenon of drift at the Monticello Site between July 1973 and July 1974 (Tables 3.3-19, 3.3-20; Figure 3.3-9). Since substrate, depth, and current velocity at Stations C and E were consistently similar throughout the study, the dominant variable was water temperature. The experimental station always had higher temperatures than the control (Table 3.3-19). The range of difference between the two stations was 1.4-6.0°C (2.5-10.8°F) at the surface and 1.4-5.8°C (2.5-10.2°F) at the bottom. Temperatures at the experimental station, which is 984 feet (0.19 mi.) below the discharge, placed it within the defined intermediate discharge area.

W. Matter found that invertebrate drift composition at the two stations was not significantly different at the order level nor was the relative magnitude of major taxa within each order significantly different at the two stations. The elevated water temperatures at site E (intermediate discharge area) produced no measurable increase in drift density as compared to the upstream station (W. Matter 1975, p. 61).

3.3.2.2.5 Natural Substrate Study

During low flow of August 1970, the communities of the artificial substrates and the natural substrates were compared. Eighty Surber samples were taken from natural substrates along transects C1, C2, E1 and E4. The organisms taken from the natural substrates represented approximately the same taxonomic groups as those found on the artificial substrates (Hopwood 1974a, p. 48).

3.3.2.2.6 Aquatic Insect Adult Light-Trap Study

In many groups of aquatic insects, identification to species is based on copulatory structures that are present only in flying adult stages. Additional information on aquatic insect populations was obtained by collecting adult stages with light-trap samplers. The primary objective of this study was to establish a taxonomic list of aquatic insects, identified to the specific level, which inhabit the Mississippi River near the Monticello plant. Secondarily, nocturnal insect flights were observed quantitatively at three riverside sampling stations every day for one year. Emergent Trichoptera, Ephemeroptera and Diptera collected in this study are listed in Table 3.3-21.

Stations 1 (1,312 ft. above the intake) and 3 (1,640 ft. below the discharge) gave comparable results as river habitats were similar at both locations; Station 2 collections were recorded in much lower numbers than at Stations 1 and 3. The differences in numbers are probably due to the facts that Station 2 is not open to full width of river, and that the discharge substrate is mostly sand and gravel, instaed of the rubble and gravel of the main channel. Interference from lights of the power plant may also have some effects on the numbers collected at Station 2 (Hopwood 1974, p. C-242).

Preliminary results show emergence periods to be fairly similar at Stations 1 and 3. _Macronemum zebratum_ emergence was in progress on the first night of the annual light trap program (July 17, 1973). At Station 1, emergence continued through July 28. A second emergence period began on August 4 and continued through August 20. At Station 3 (thermal plume area), _Macronemum zebratum_ emerged only until July 27. There was no second emergence period as at Station 1. In 1974, emergence began first at the thermal plume area on June 3 and continued to June 8. There was a second emergence which began on June 18. At the control station, emergence of _Macronemum zebratum_ did not occur until June 18. Preliminary results for this species suggests that the heated effluent has caused emergence to occur approximately two weeks earlier. Two species of _Cheumatopsyche_, _Cheumatopsyche campyla_ and _Cheumatopsyche speciosa_, were collected in the light traps. Emergence periods for _Cheumatopsyche_ spp. do not appear to be significantly different at Station 1 and 3. Emergence of _Cheumatopsyche_ began on June 1, 1974 at both stations and continued through July 14, 1974 with little interruption. In the 1973 collections, _Cheumatopsyche_ was collected at Station 3 from July 18 through July 27 and then from August 1 to September 8. At Station 1 in 1973, _Cheumatopsyche_ was collected in light traps from July 20 to September 4, with only minor interruptions. Seven species of

Hydropsyche have been identified from the adult collections. Emergence of *Hydropsyche* at Stations 1 and 3 was very similar. Emergence occurred from June through September with four or five distinct breaks in emergence within this period.

Mayfly emergence began in May, increased to a maximum level in August and then decreased rapidly. No mayfly specimens were collected in the light traps from November through April.

Dipteran emergence began in March, increased in April, was heavy in June, and was at a moderate level in July, August, and September. In October and November, small numbers emerged.

3.3.2.2.7 Summary

No stations were within the immediate discharge zone, as defined by the MPCA (1975). In the major monitoring program, four stations occurred in the intermediate discharge zone, and 11 stations in the outer discharge zone.

Comparison of the taxa in the heated discharge to those in the control station above the intake showed no appreciable changes in the indigenous benthic communities. However, there was a percent composition change in the fauna below the discharge: caddisflies became more abundant whereas mayflies and true flies decreased as compared to the control station. In 1972, the maximum standing crop occurred at the experimental station one month earlier than at the control station, probably the result of the constantly elevated temperatures in the plume. The total impact of the Monticello Plant effluent does not appear to adversely affect the balanced indigenous macroinvertebrate populations of the Mississippi River.

3.3.3 REFERENCES

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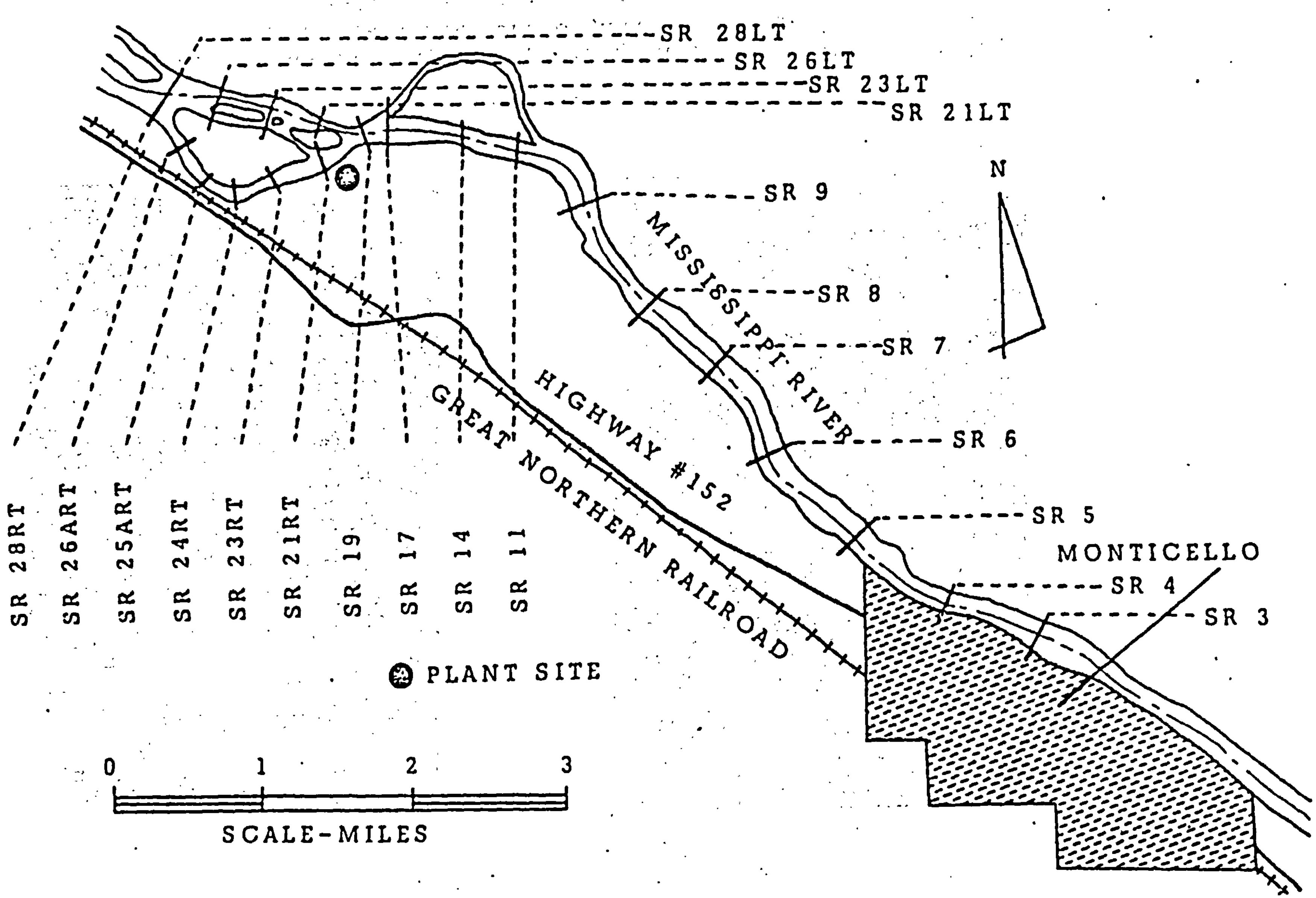
FIGL 3.3-1

Survey map of the study area showing sounding ranges near the Monticello Site (from U.S.G.S. Survey Map Chart N4515W9345/15, NSP No. NR-E-5979-P19-1 & 2)

(From McConville 1972, p. 32.)



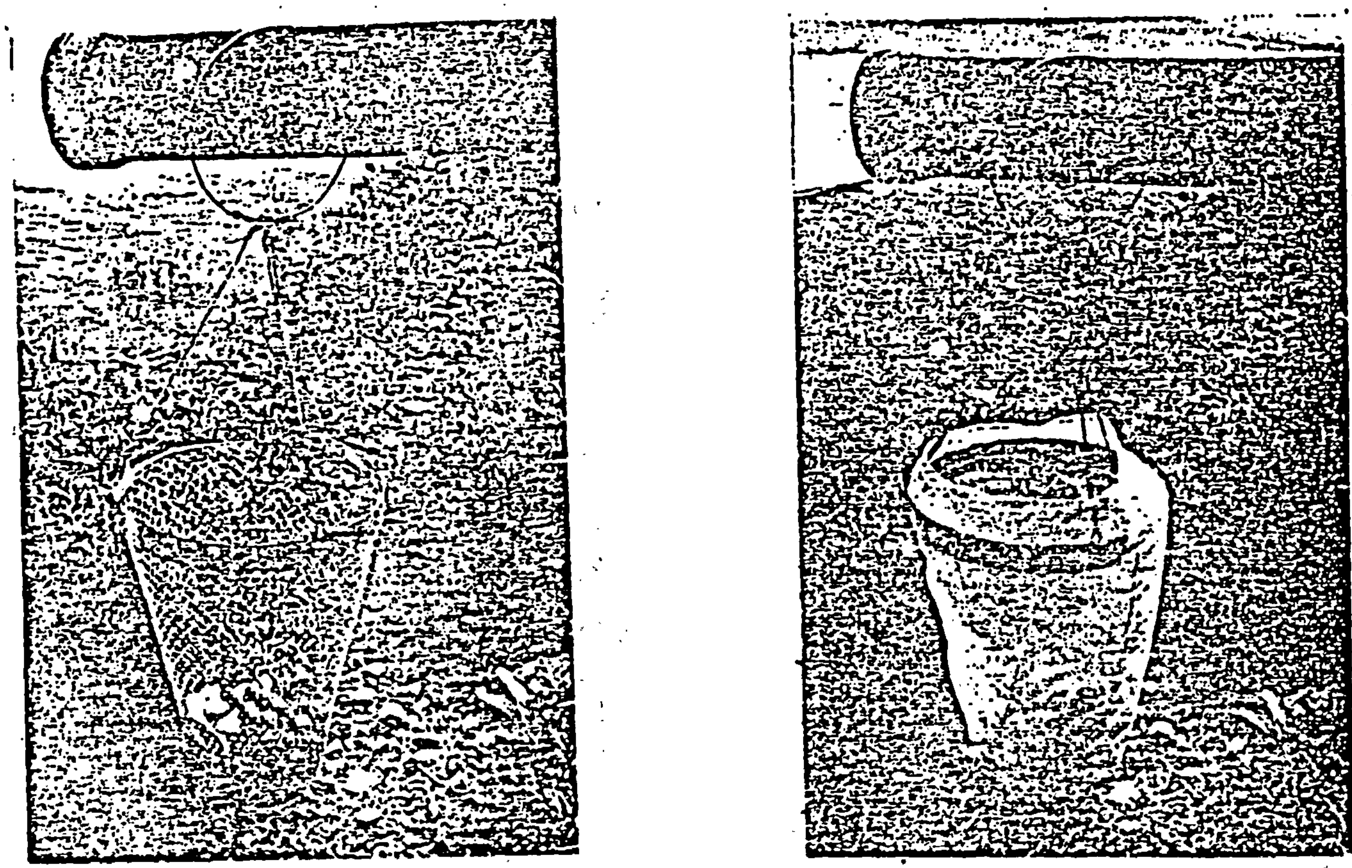


FIGURE 3.3-2

Artificial substrate sampler as designed by Bull (1968) showing framework (left) and organdy bag (right)

(From McConville 1969, p. 69)

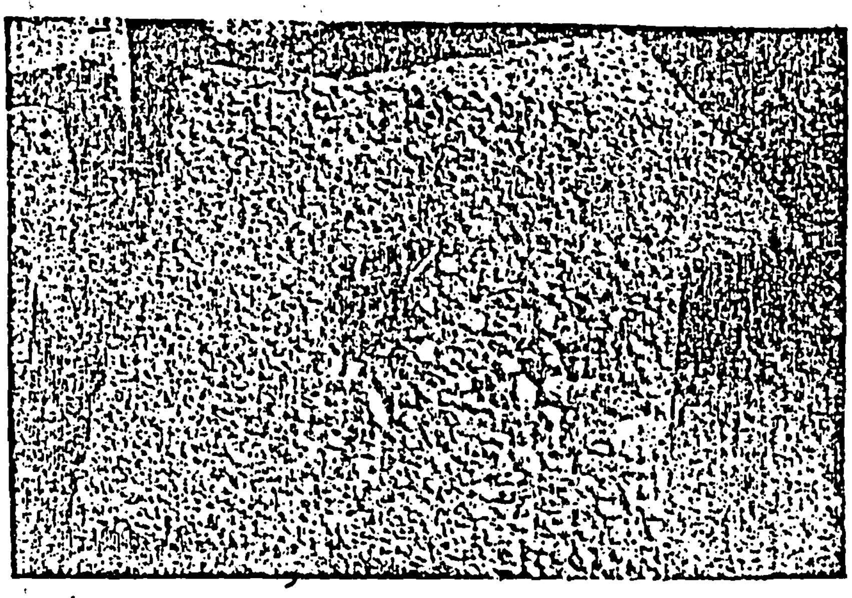


FIGURE 3.3-3

Artificial substrate sampler as designed by Britt (1955).
(From McConville 1969, p. 70)

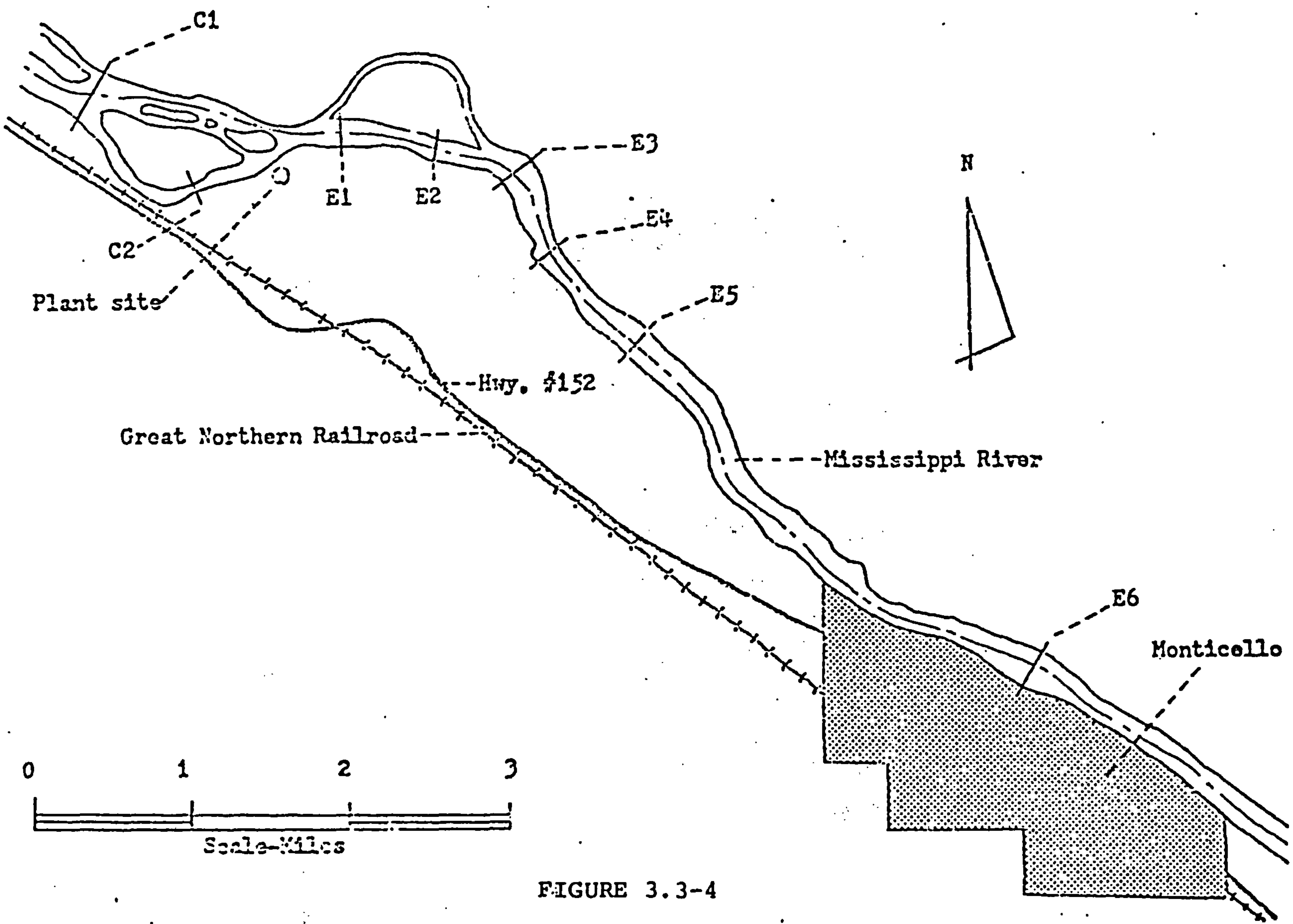


FIGURE 3.3-4

Position of block sampling transects in the major macroinvertebrate monitoring program at the Monticello Site

(From Hopwood 1969, p. 28)

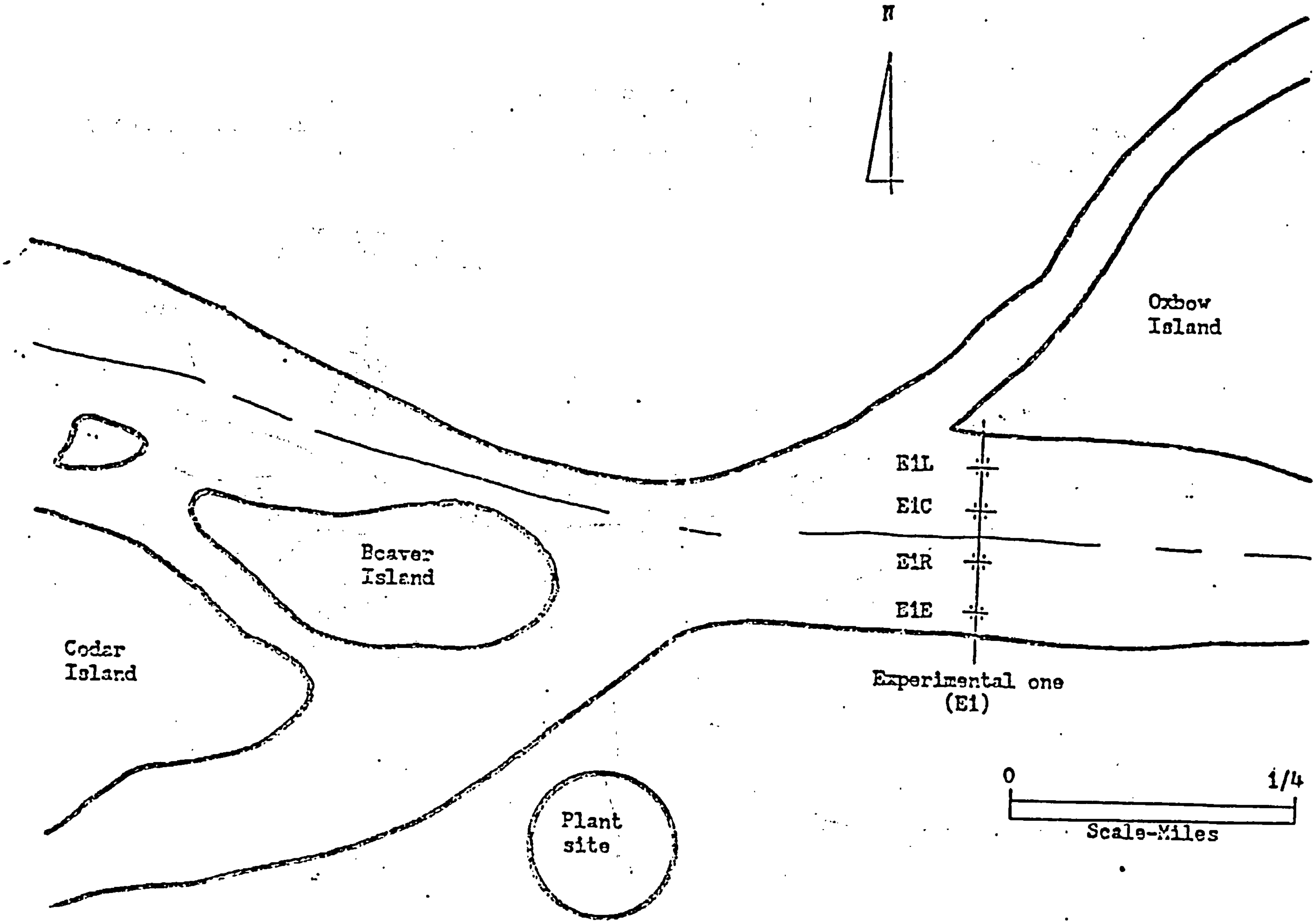


FIGURE 3.3-5

Block sampler arrangement and position of sampling stations on experimental transect number one in major macroinvertebrate monitoring program at the Monticello Site.

(From McConville 1972, p. 37)

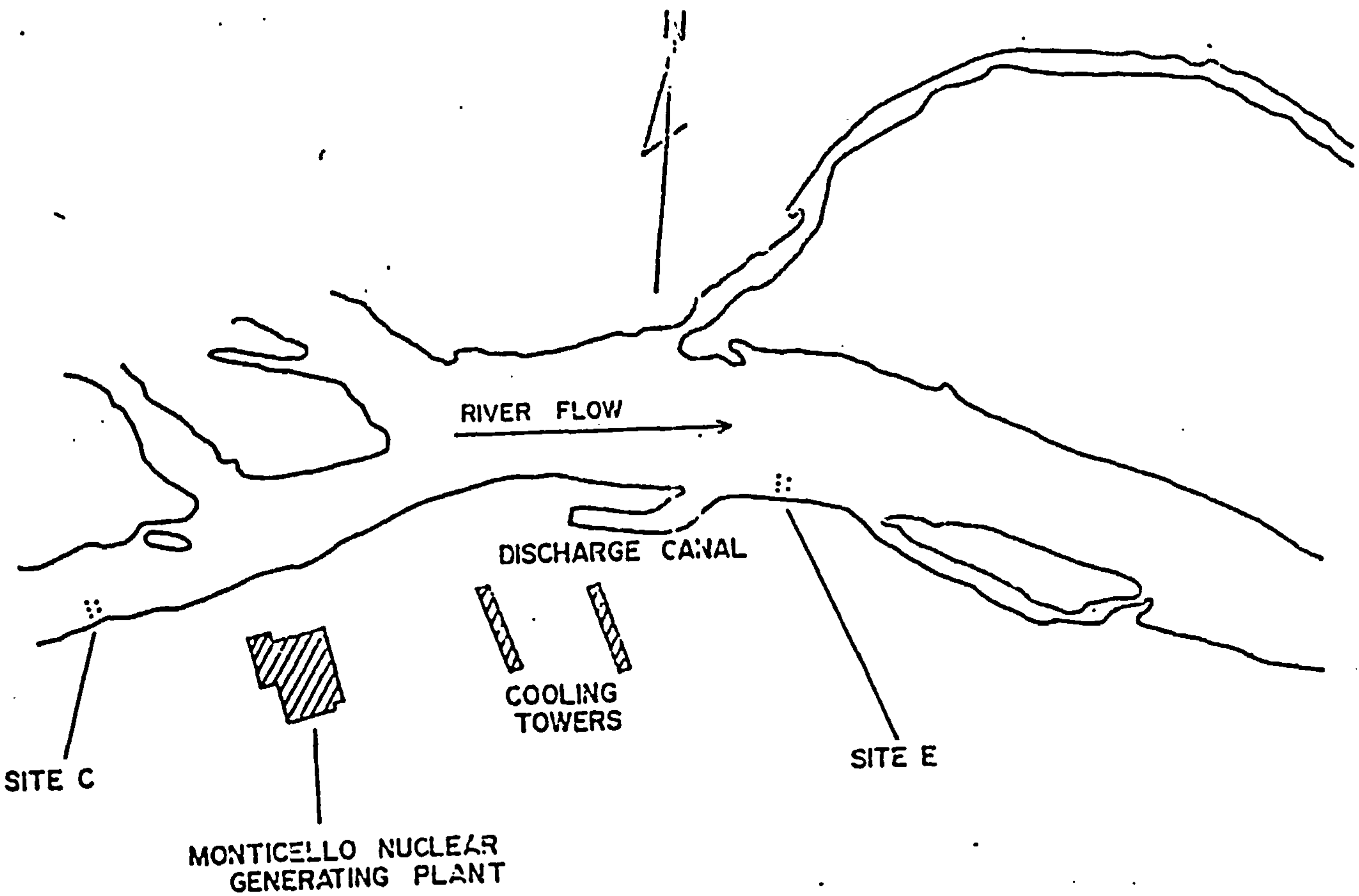


FIGURE 3.3-6

Sampling sites for the recolonization study at the Monticello Site. Sites C and E are shown in relation to the power plant and the discharge canal.

(From Hopwood 1972, p. 41)

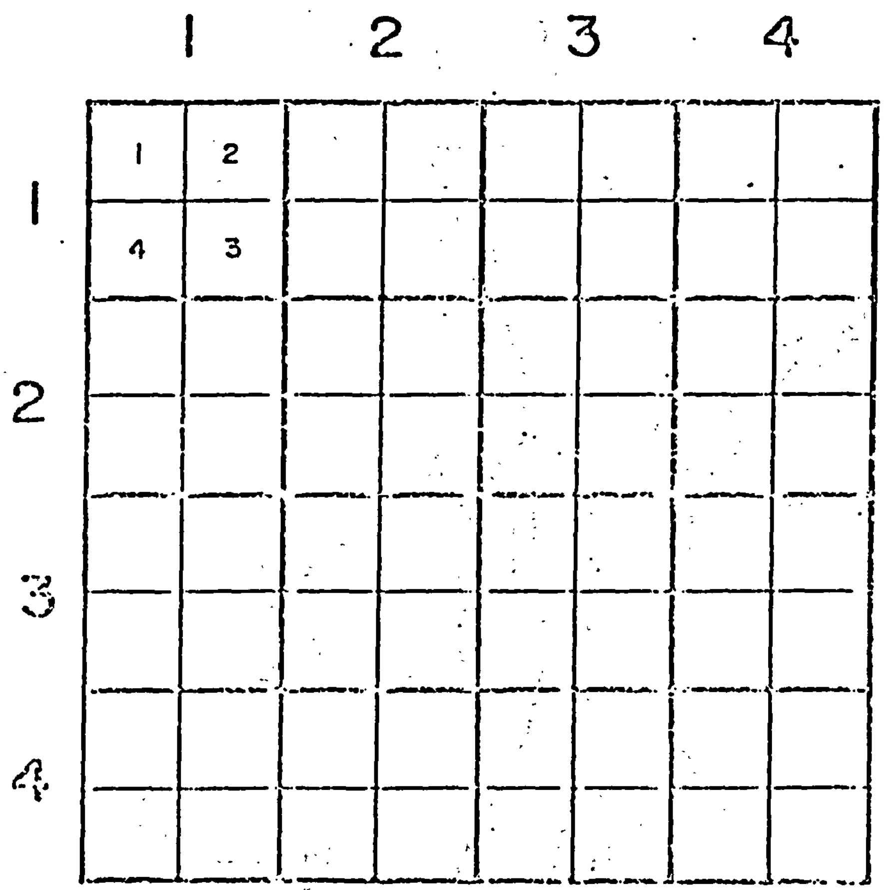


FIGURE 3.3-7

Diagram of 8" x 8" pan used to take subsamples for the recolonization and drift studies.

(From Hopwood 1974a, p. 32)

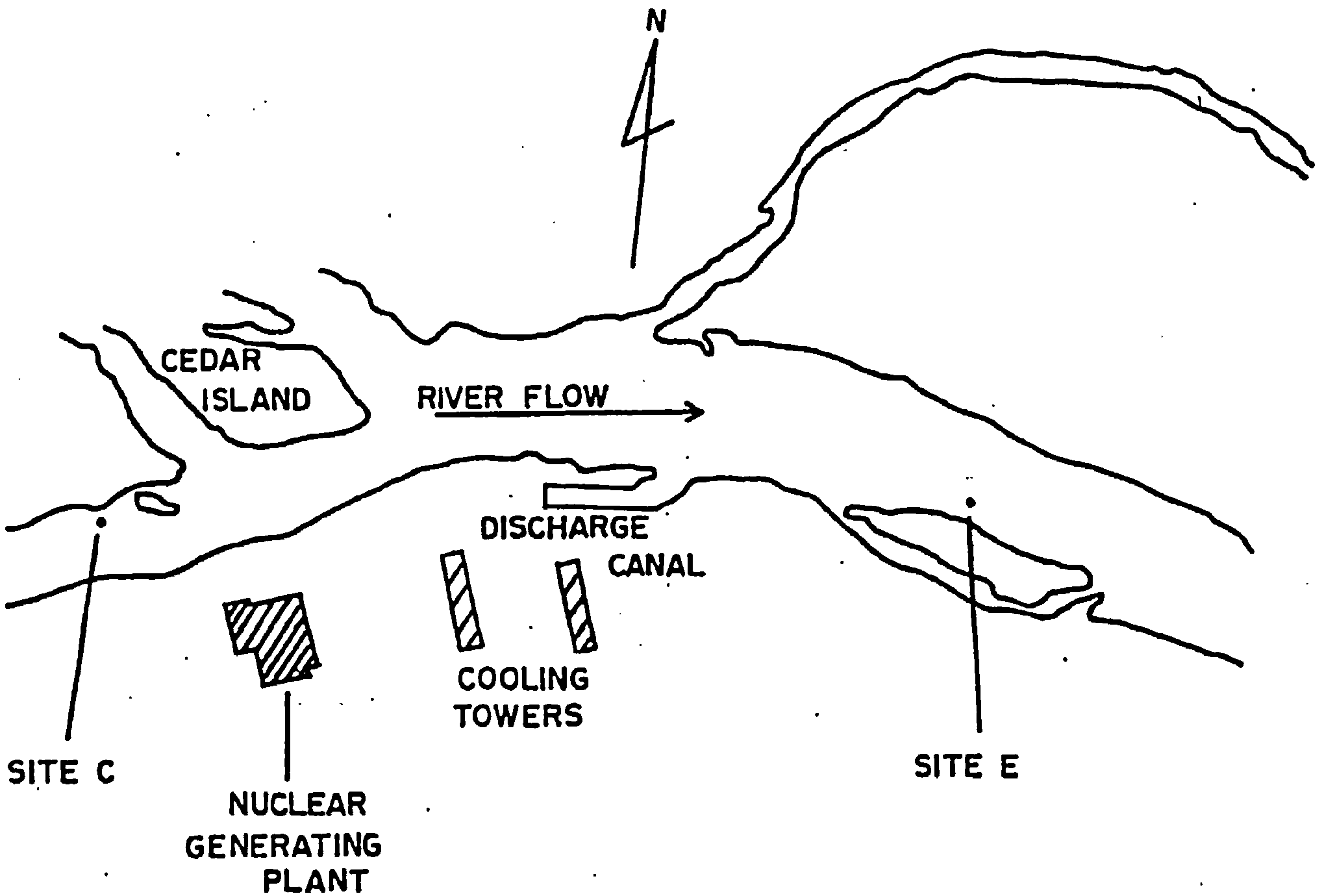


FIGURE 3.3-8

Drift sampling sites C and E, in relation to the Monticello plant and discharge canal.

(From Matter 1975, p. 9)

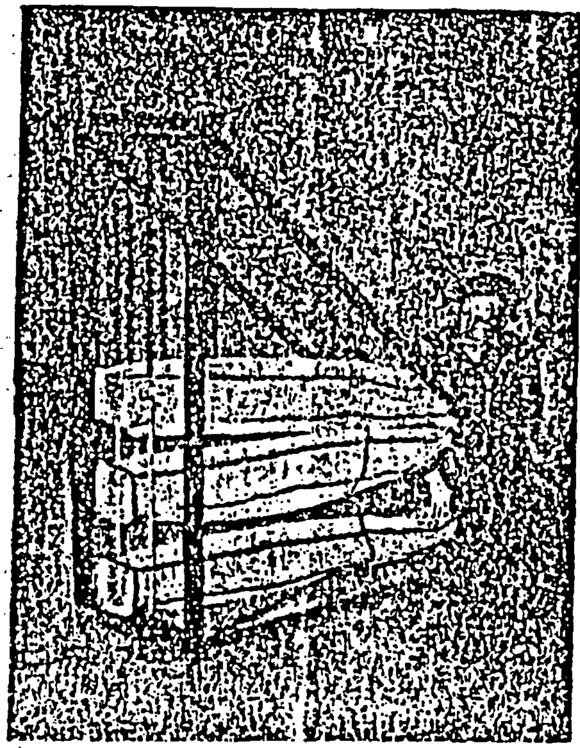


FIGURE 3.3-9

Drift sampling apparatus used at the Monticello Site. Frame holds nets separated by 15 cm lengths of steel conduit.

(From Matter 1975, p. 15)

FIGURE 3.3-10

Percentage composition of the total number or organisms sampled at Sites C and E for each cycle in the recolonization study at the Monticello Site. The letters C and E indicate sampling sites. Roman numerals indicate the separate cycles. Areas not shaded in are keyed as the group of miscellaneous organisms.

(From Hopwood 1973, p. 360)

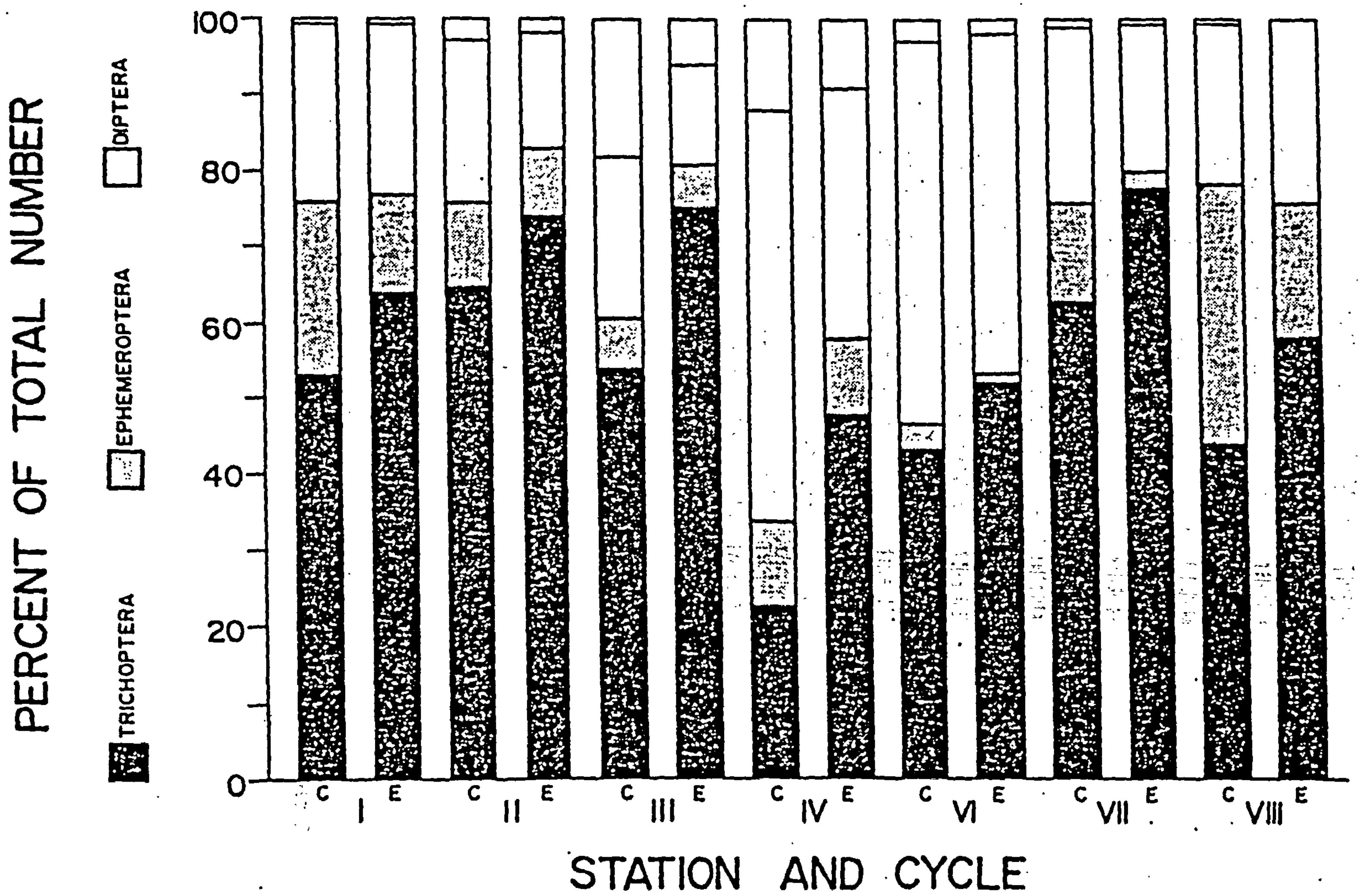
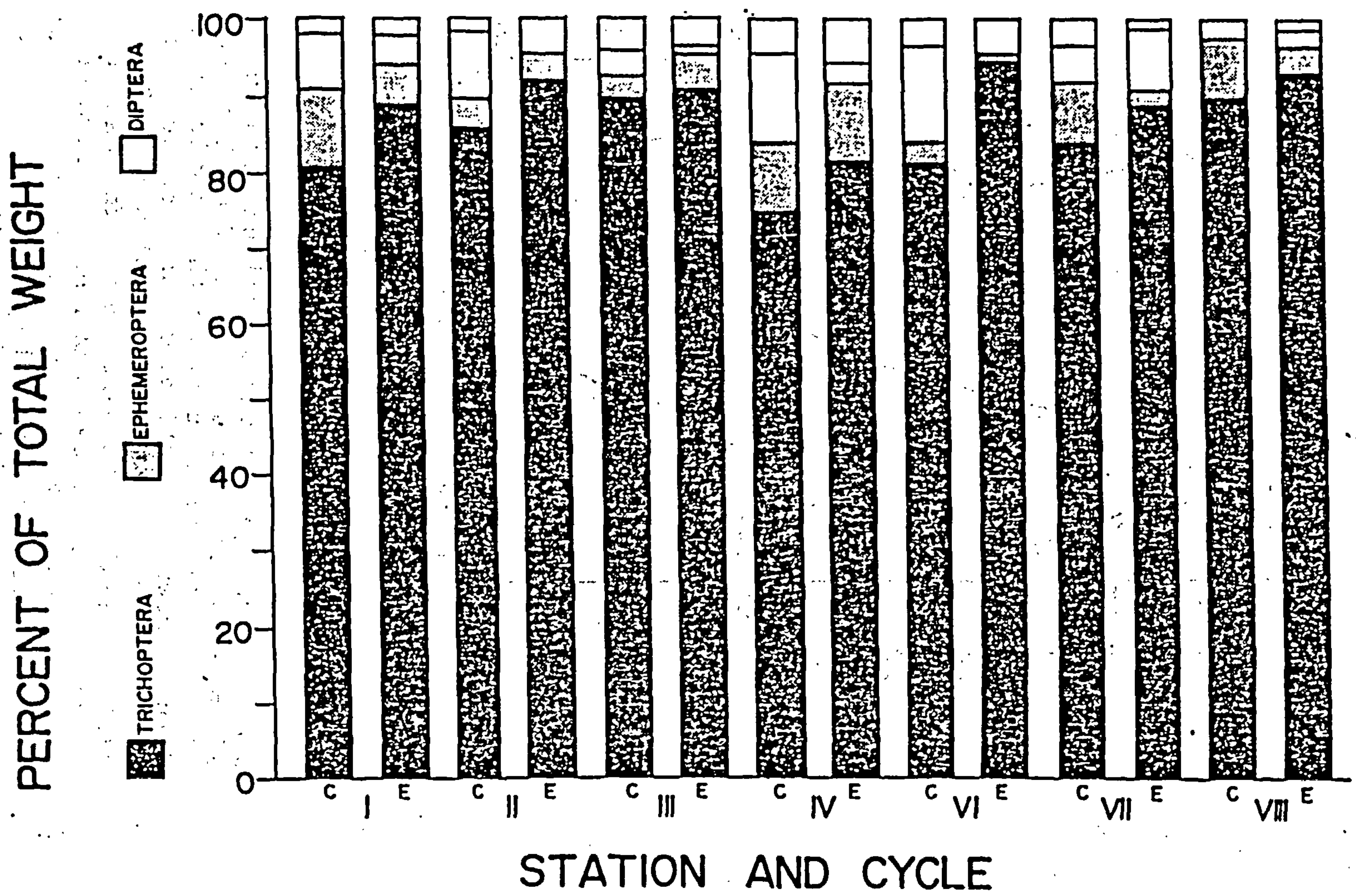


FIGURE 3.3-11

Percentage composition of the total weight collected at Sites C and E for each cycle in the recolonization study at the Monticello Site. The letters C and E indicate sampling sites. Roman numerals indicate the separate cycles. Areas not shaded in are keyed as the group of miscellaneous organisms.

(From Hopwood 1973, p. 361)



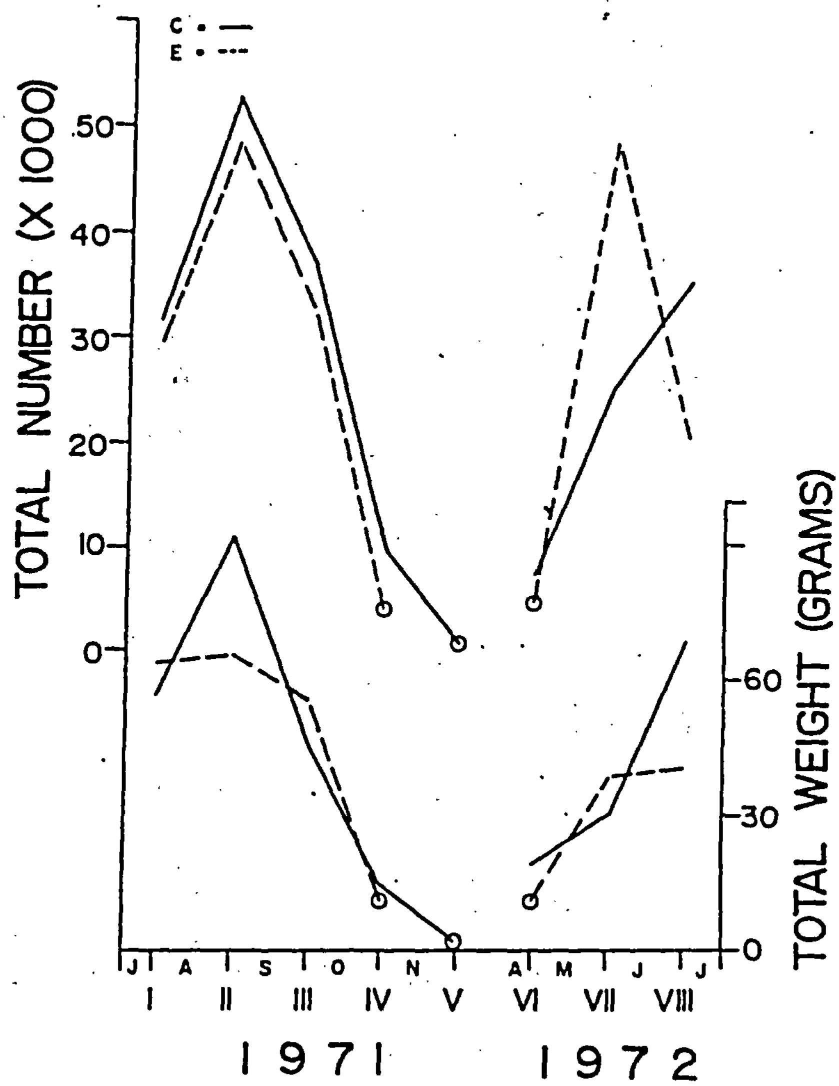


FIGURE 3.3-12

Seasonal changes in sample weights and numbers of insects from sites C and E of cycles I-VIII in the recolonization study at the Monticello Site. Values shown are estimates based on subsamples taken from the series of samples in a 35-day cycle. Weekly data were summed for each cycle to give the values shown here. Circled points indicate there were less than five samples taken at that site for that particular cycle. Roman numerals indicate cycles.

(From Hopwood 1974a, p. 63)

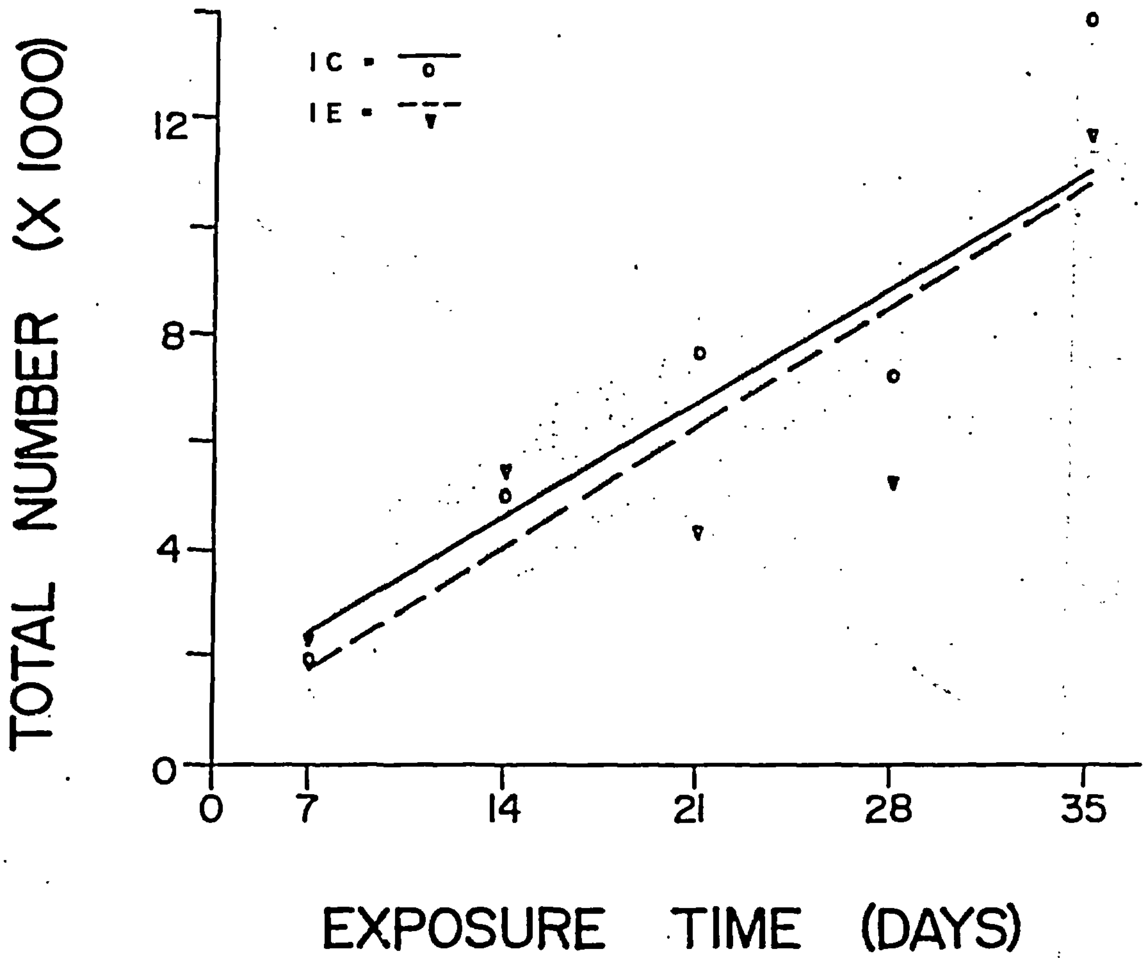


FIGURE 3.3-13

Monticello site recolonization study - growth rate as shown by the total number of organisms in each of five samples taken at sites C and E. Cycle I, 12 July to 16 August, 1971. Lines represent the growth rate, shapes mark the actual total numbers for sample site, shaded area indicates 95% confidence limits on the line for Site C.

(From Hopwood 1973, p. 364)

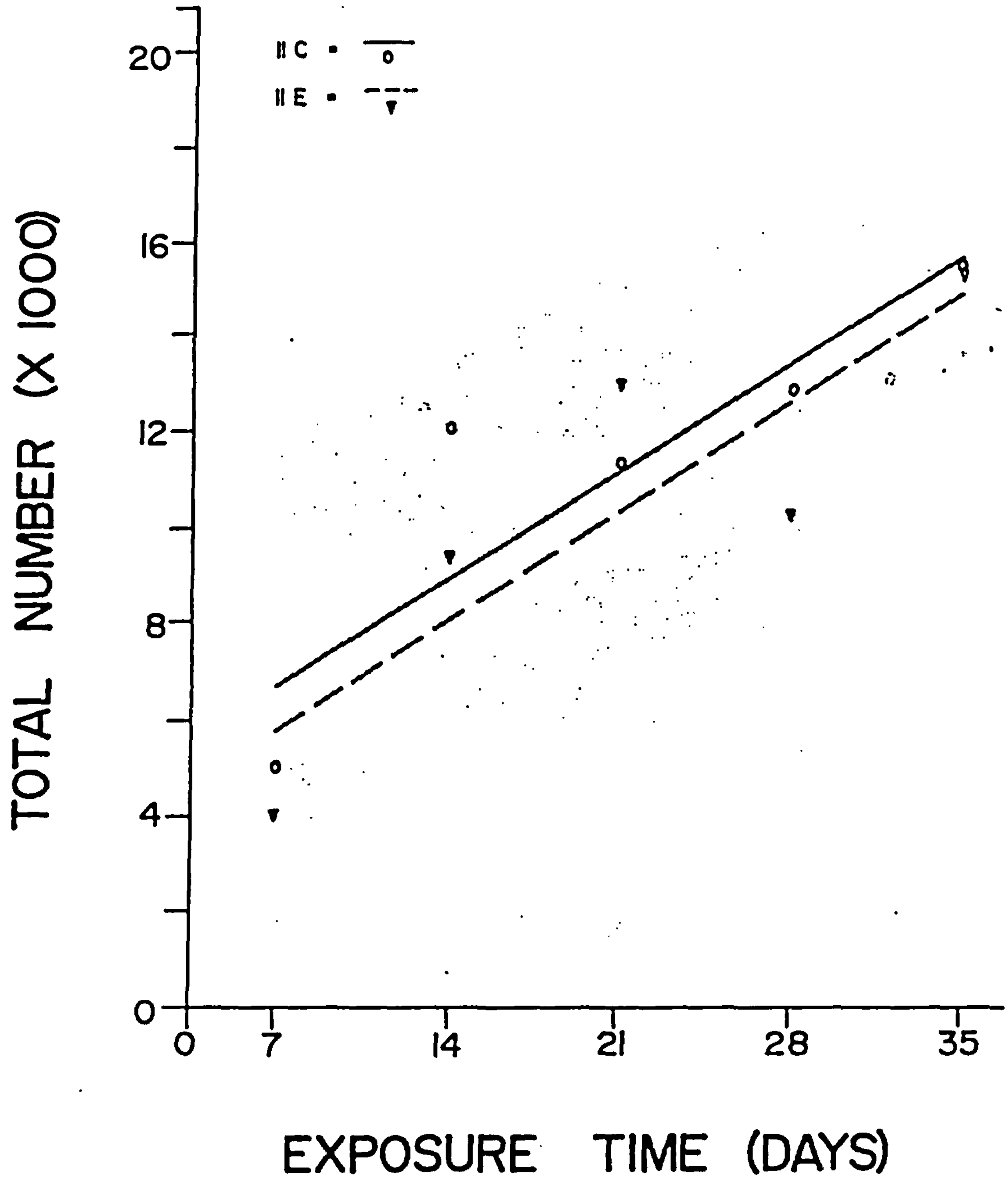


FIGURE 3.3-14

Monticello site recolonization study - growth rate as shown by the total number of organisms in each of five samples taken at sites C and E. Cycle II, 9 August to 13 September, 1971. Lines represent the growth rate, shapes mark the actual total number for a sample site, shaded area indicates 95% confidence limits on the line for site C.

(From Hopwood, 1973, p. 365)

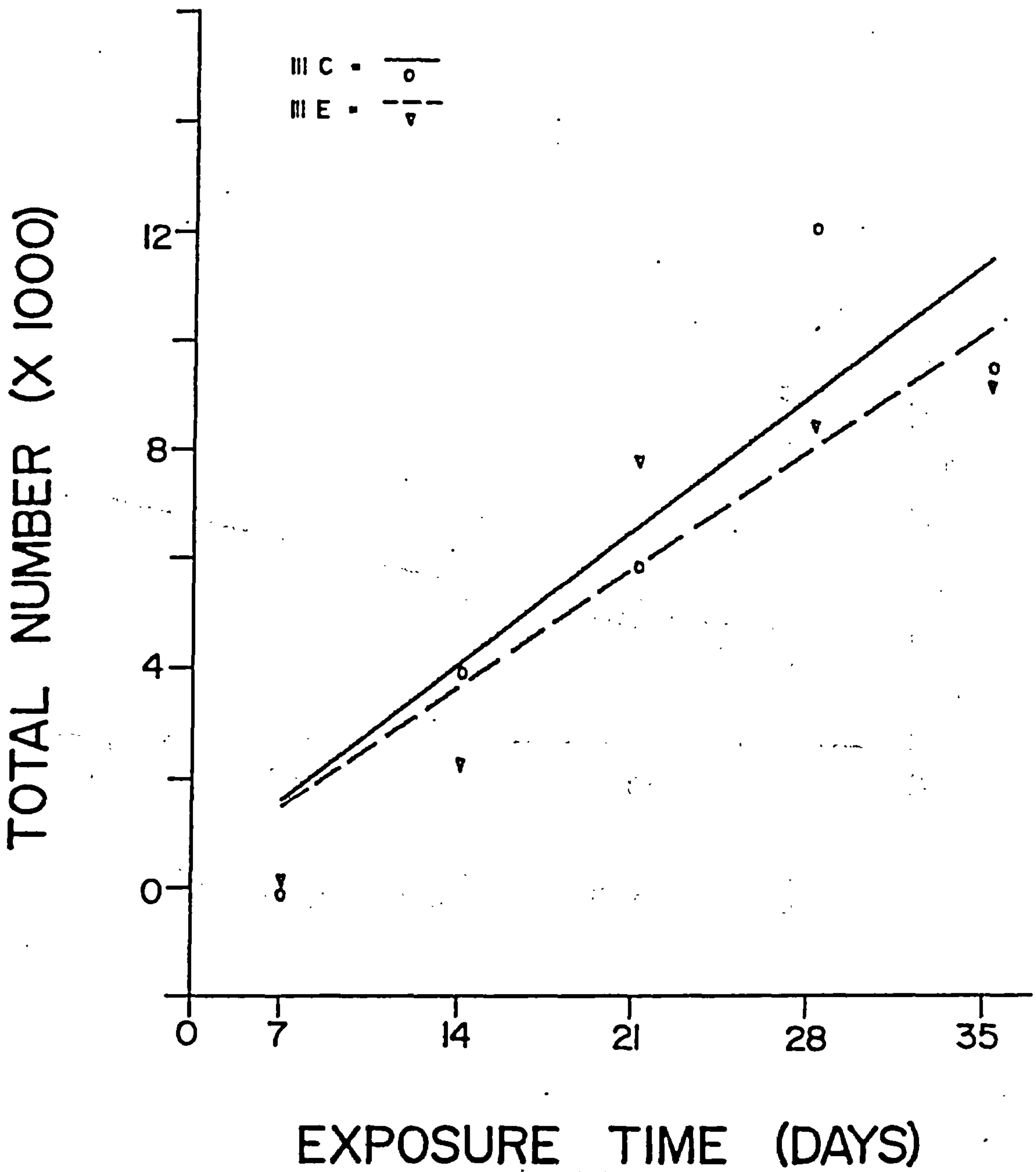


FIGURE 3.3-15

Monticello site recolonization study - growth rate as shown by the total number of organisms in each of five samples taken at sites C and E. Cycle III, 6 September to 14 October, 1971. Lines represent the growth rate, shapes mark the actual total number for a sample site, shaded area indicates 95% confidence limits on the line for site C.

(From Hopwood, 1973, p. 366)

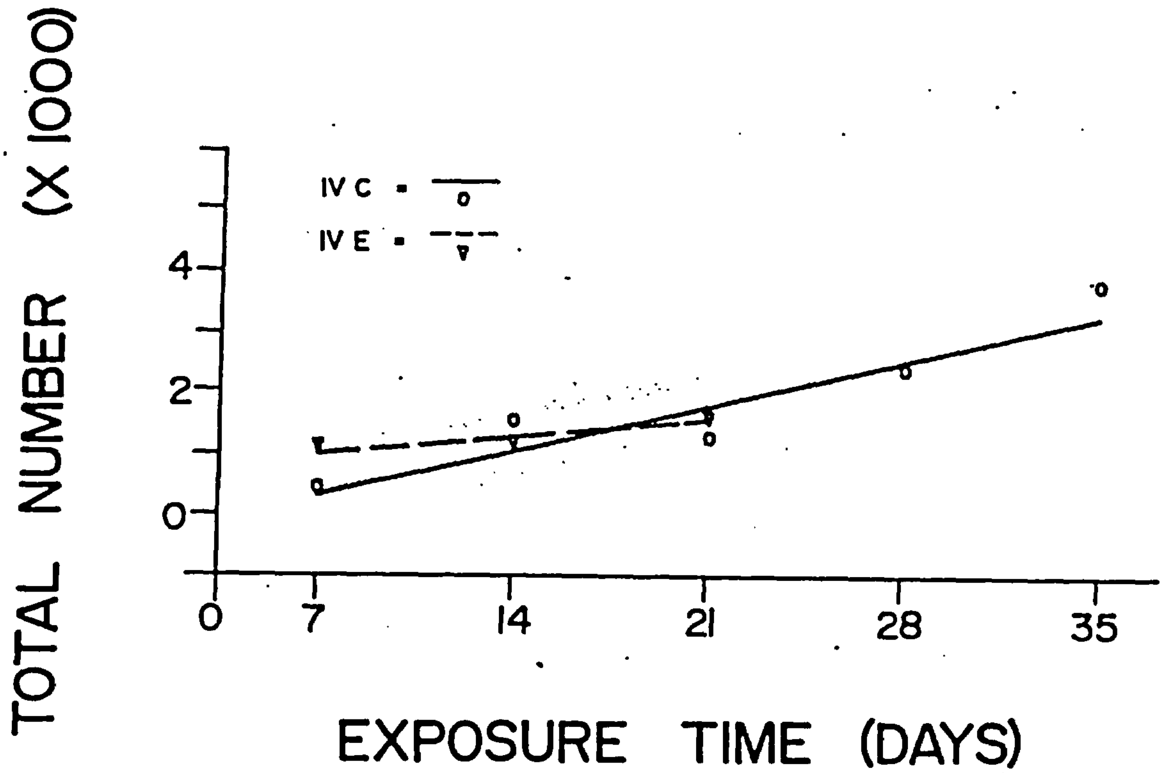


FIGURE 3.3-16

Monticello site recolonization study - growth rate as shown by the total number of organisms in each of five samples taken at sites C and E. Cycle IV, 6 October to 10 November, 1971. Lines represent the growth rate, shapes mark the actual total number for a sample site, shaded area indicates 95% confidence limits on the line for site C.

(From Hopwood, 1973, p. 367)

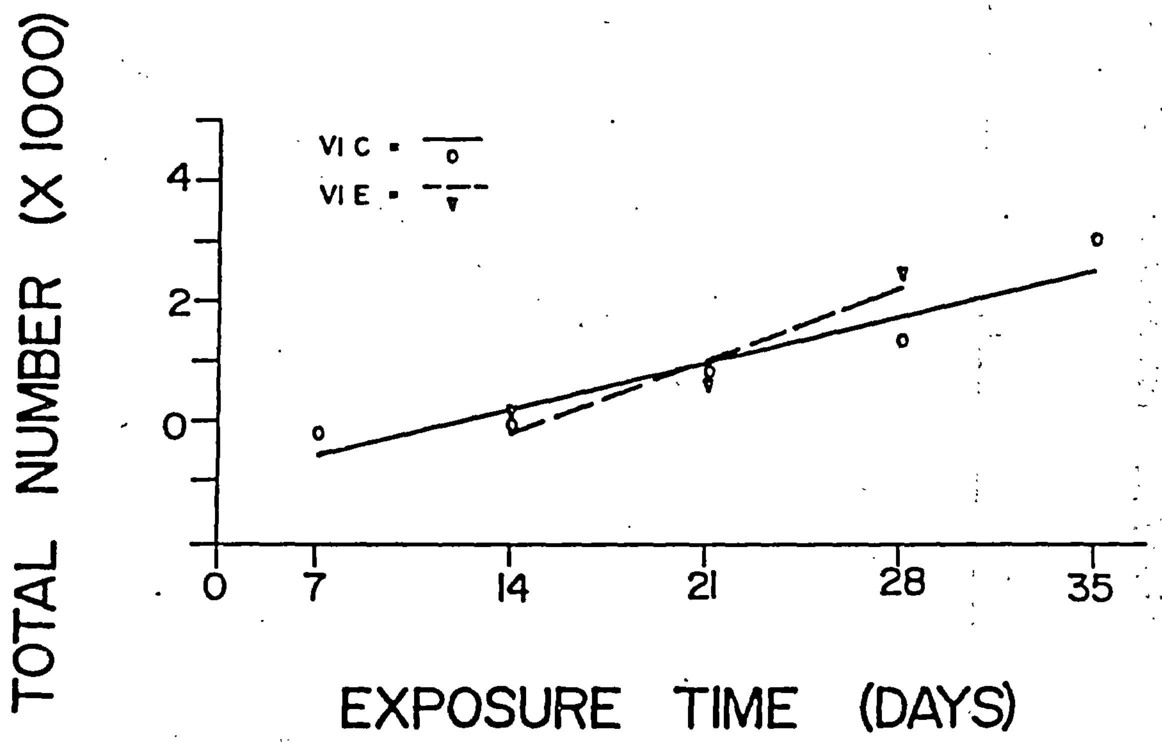


FIGURE 3.3-17

Monticello site recolonization study - growth rate as shown by the total number of organisms in each of five samples taken at sites C and E. Cycle VI, 15 April to 19 May, 1972. Lines represent the growth rate, shapes mark the actual total number for a sample site, shaded area indicates 95% confidence limits on the line for site C.

(From Hopwood, 1973, p. 368)

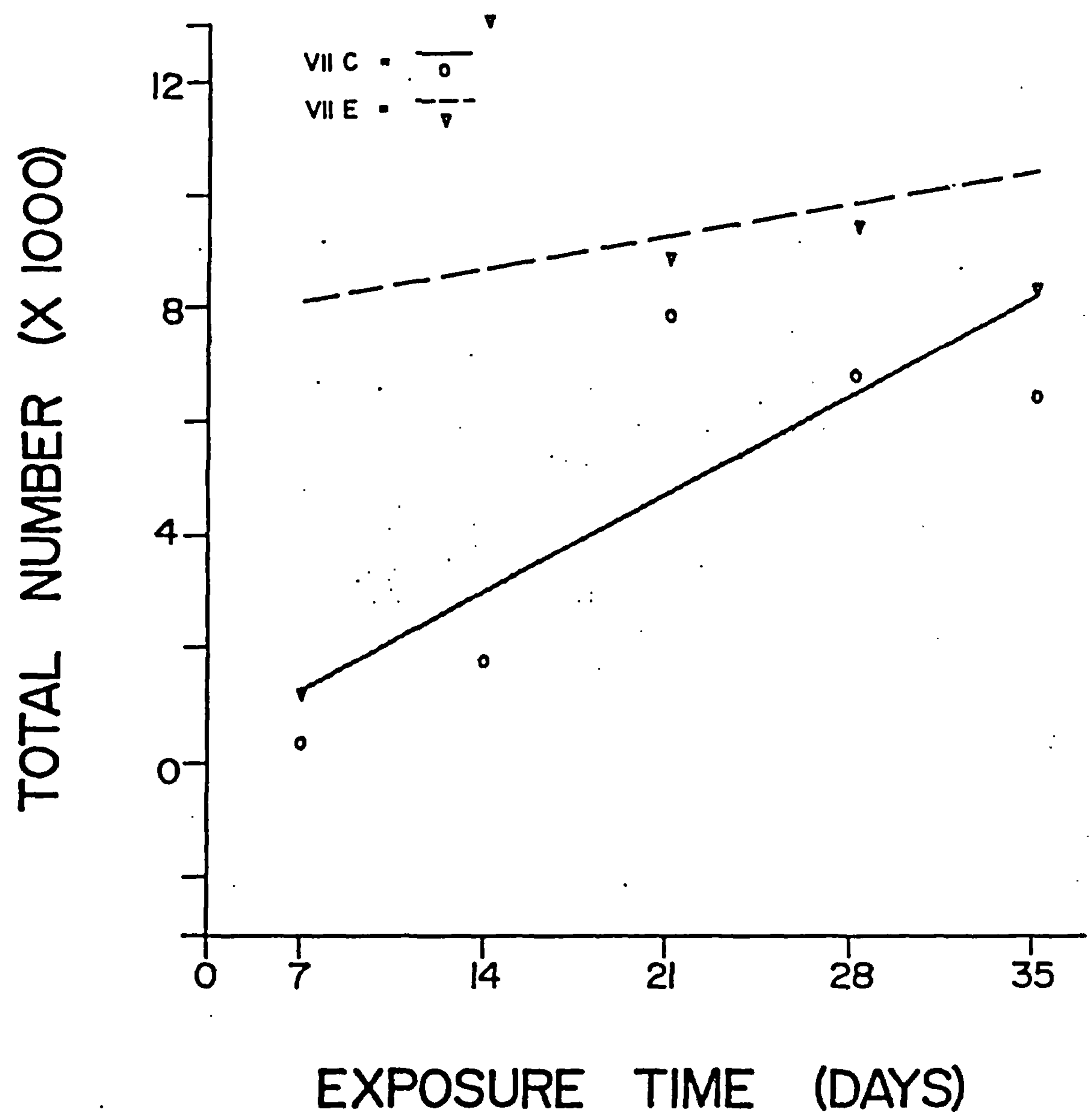


FIGURE 3.3-18

Monticello site recolonization study - growth rate as shown by the total number of organisms in each of five samples taken at sites C and E. Cycle VII, 19 May to 23 June, 1972. Lines represent the growth rate, shapes mark the actual total number for a sample site, shaded area indicates 95% confidence limits on the line for site C.

(From Hopwood, 1973, p. 369)

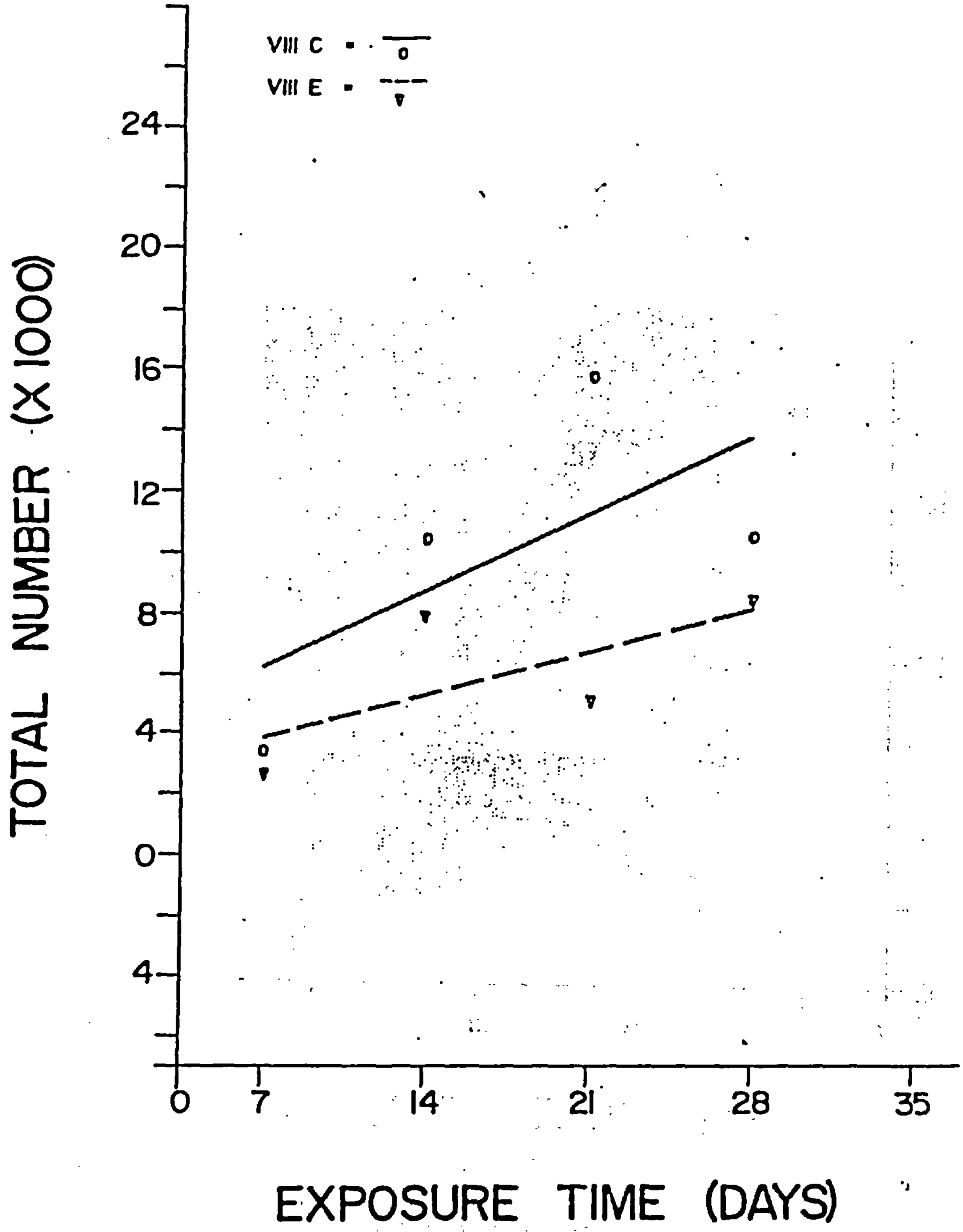


FIGURE 3.3-19

Monticello site recolonization study - growth rate as shown by the total number of organisms in each of five samples taken at sites C and E. Cycle VIII, 23 June to 21 July, 1972. Lines represent the growth rate, shapes mark the actual total number for a sample site, shaded area indicates 95% confidence limits on the line for site C.

(From Hopwood, 1973, p. 370)

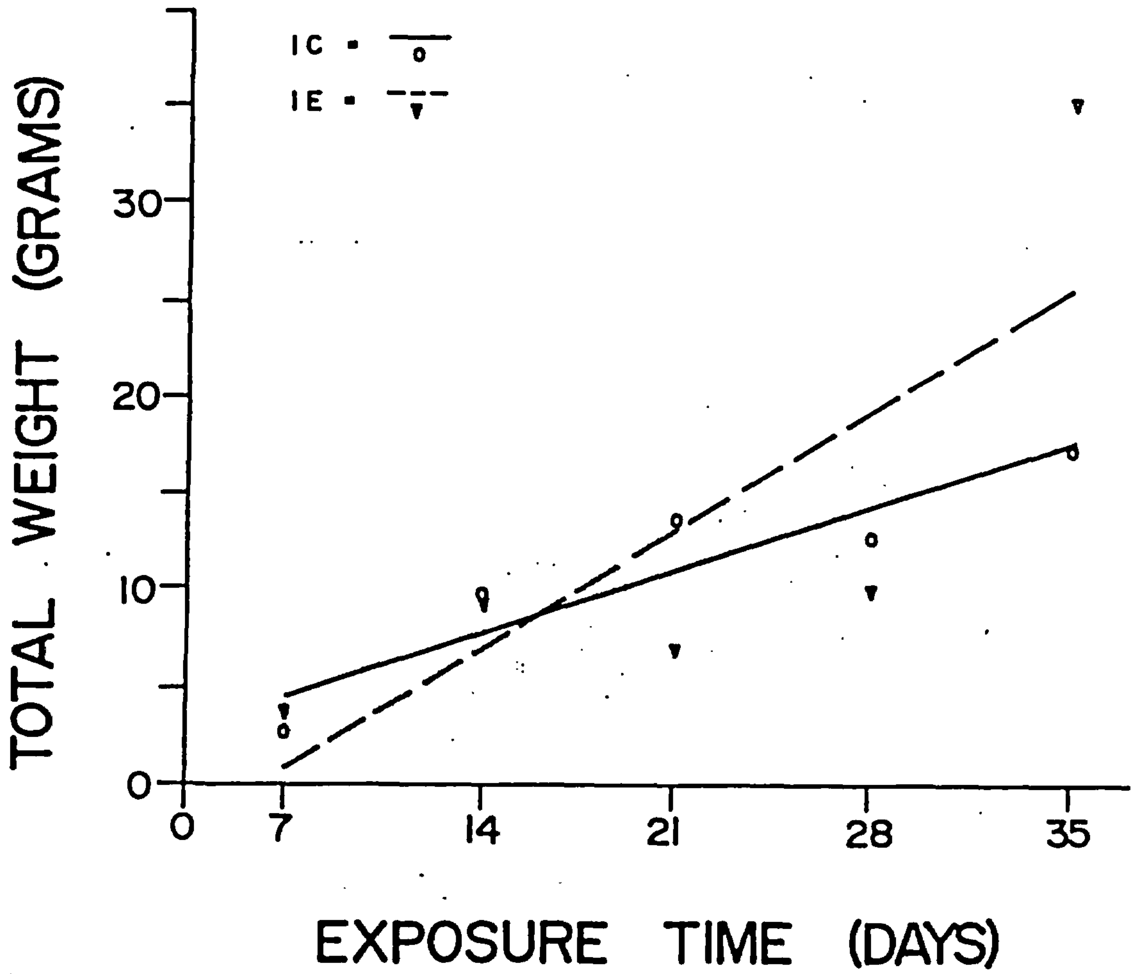


FIGURE 3.3-20

Monticello site recolonization study - growth rates as shown by the total weight of each of five samples taken at sites C and E. Cycle I, 12 July to 16 August, 1971. Lines represent the growth rate, shapes mark the actual total weight for a sample site, shaded area indicates 95% confidence limits on the line for site C.

(From Hopwood, 1973, p. 371)

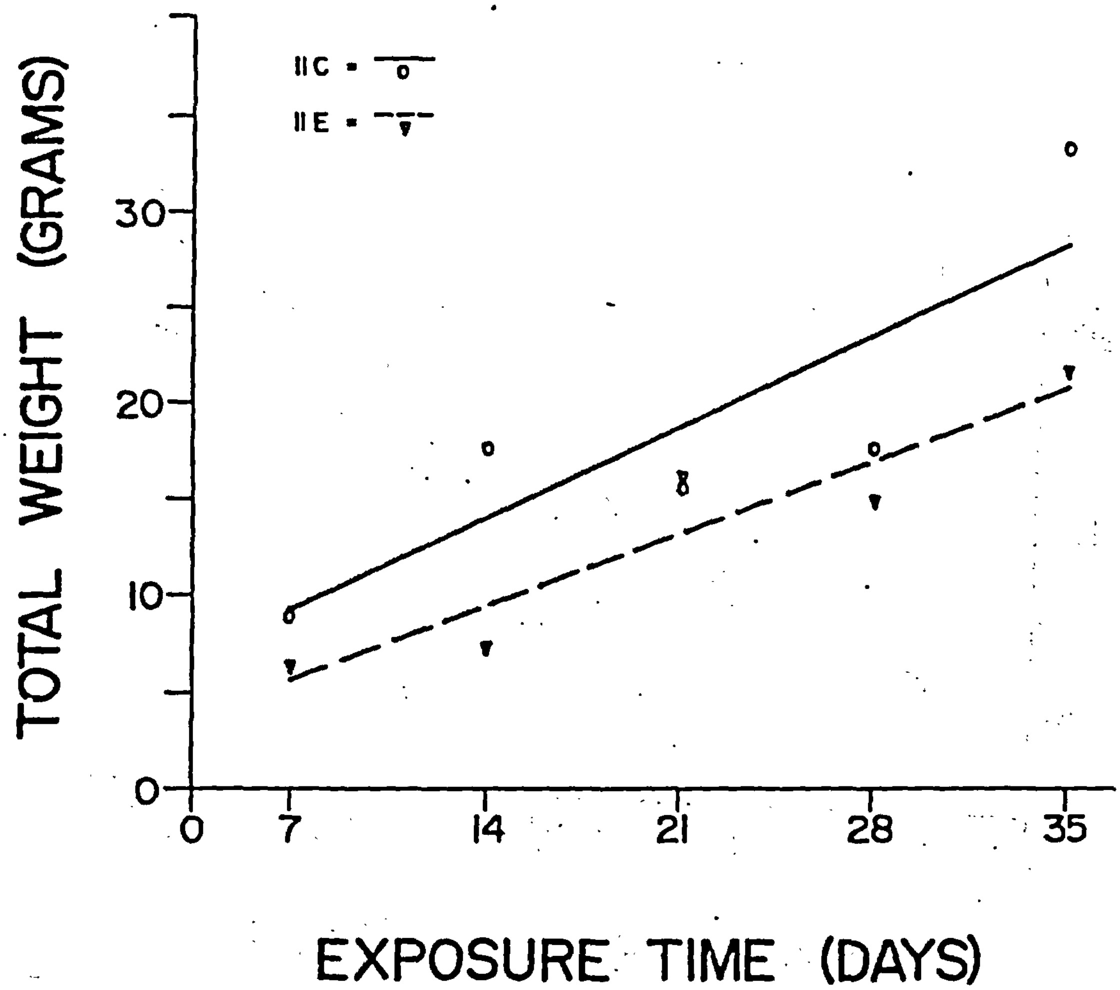


FIGURE 3.3.21

Monticello site recolonization study - growth rates as shown by the total weight of each of five samples taken at sites C and E. Cycle II, 9 August to 13 September, 1971. Lines represent the growth rate, shapes mark the actual total weight for a sample site, shaded area indicates 95% confidence limits on the line for site C.

(From Hopwood, 1973, p. 372)

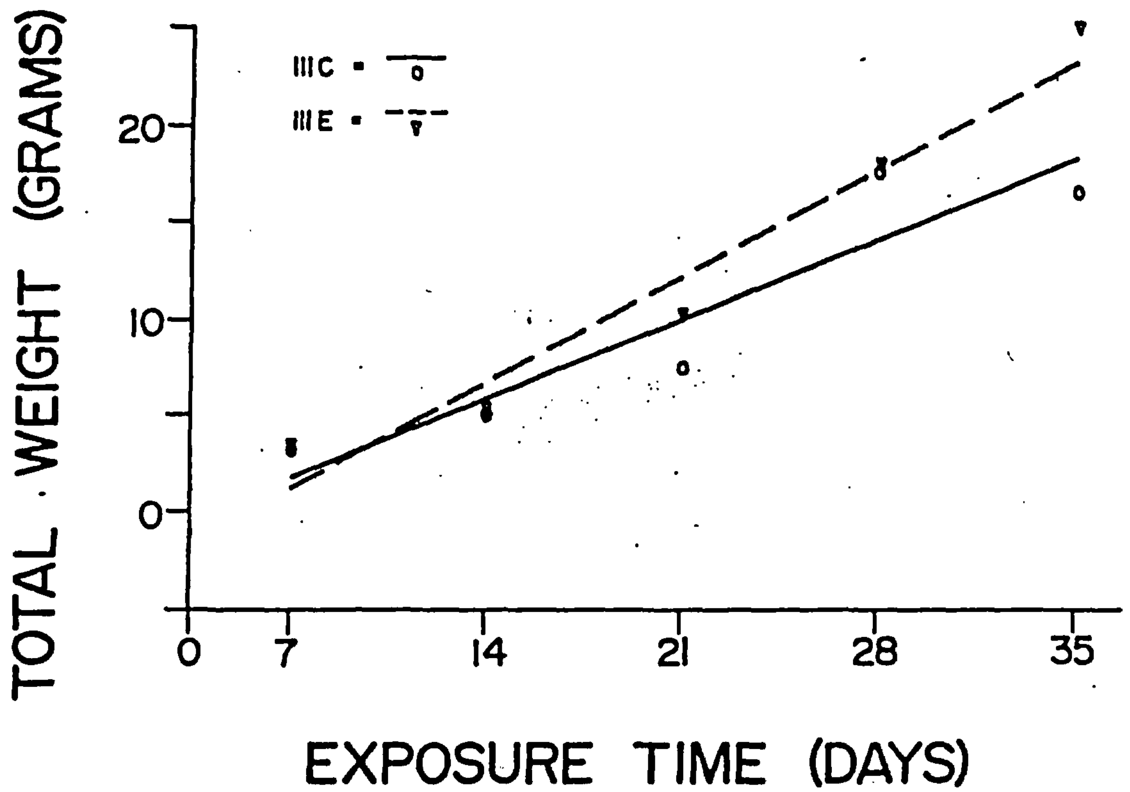


FIGURE 3.3-22

Monticello site recolonization study - growth rates as shown by the total weight of each of five samples taken at sites C and E. Cycle III, 6 September to 14 October, 1971. Lines represent the growth rate, shapes mark the actual total weight for a sample site, shaded area indicates 95% confidence limits on the line for site C.

(From Hopwood, 1973, p. 373)

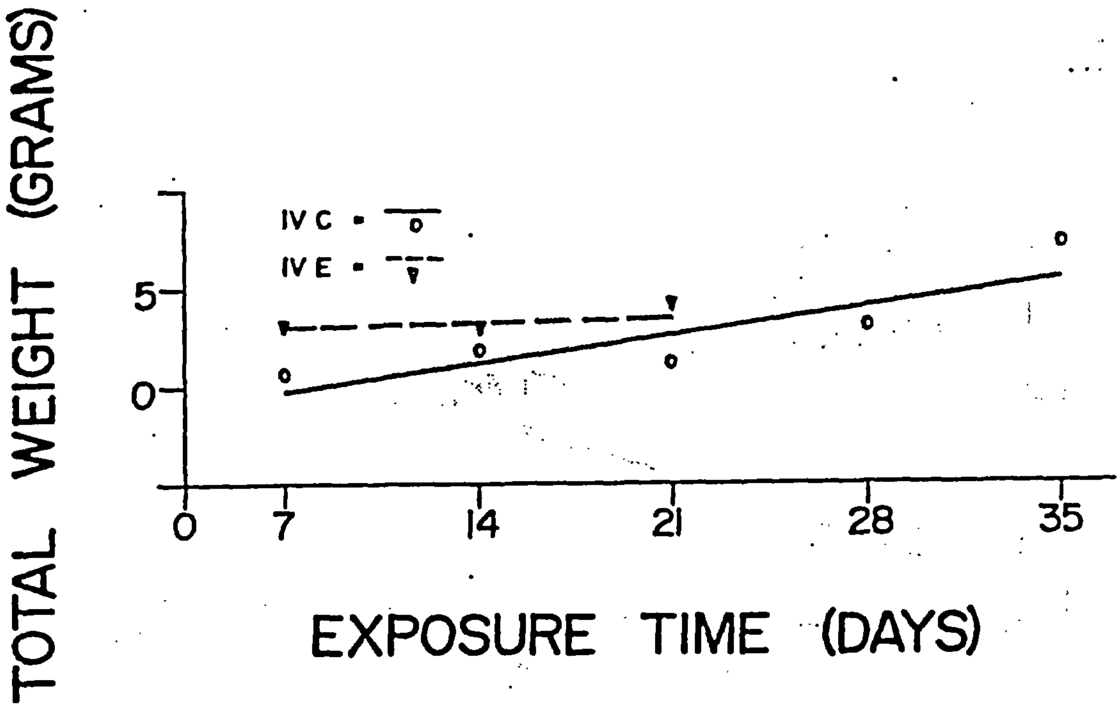


FIGURE 3.3-23

Monticello site recolonization study - growth rates as shown by the total weight of each of five samples taken at sites C and E. Cycles IV, 6 October to 10 November, 1971. Lines represent the growth rate, shapes mark the actual total weight for a sample site, shaded area indicates 95% confidence limits on the line for site C.

(From Hopwood, 1973, p. 374)

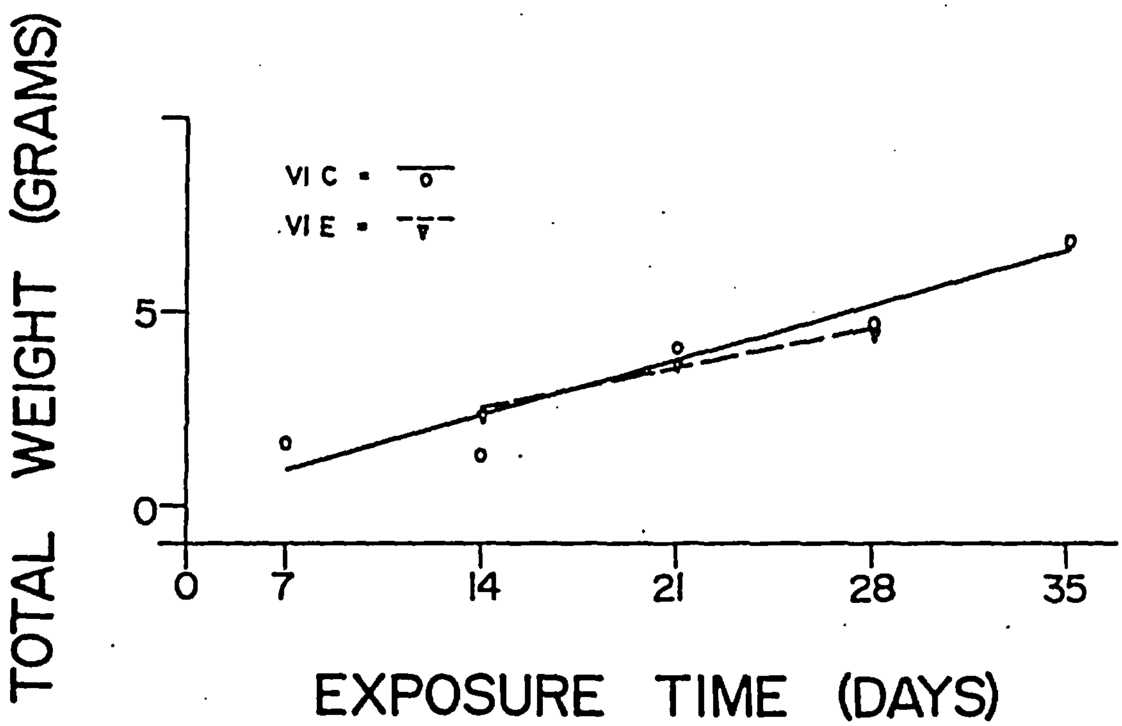


FIGURE 3.3-24

Montícello site recolonization study - growth rates as shown by the total weight of each of five samples taken at sites C and E. Cycles VI, 15 April to 19 May, 1972. Lines represent the growth rate, shapes mark the actual total weight for a sample site, shaded area indicates 95% confidence limits on the line for site C.

(From Hopwood, 1973, p. 375)

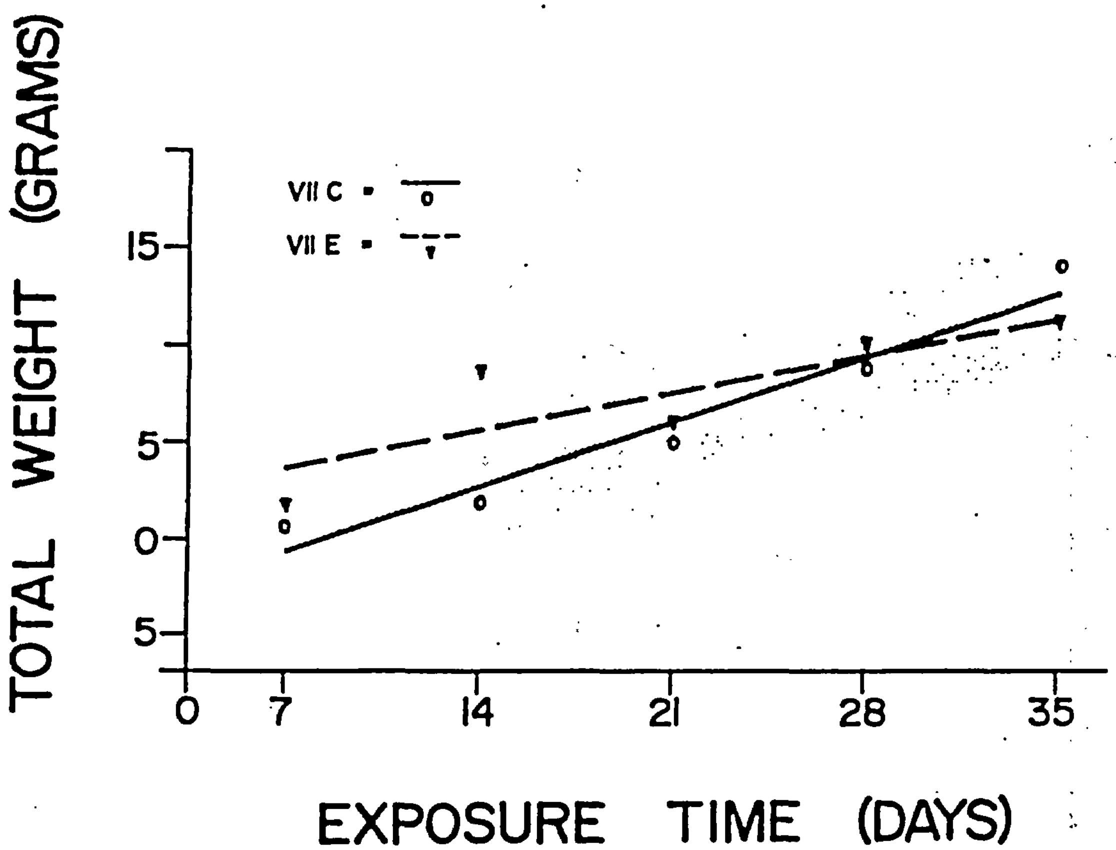


FIGURE 3.3-25

Monticello site recolonization study - growth rates as shown by the total weight of each of five samples taken at sites C and E. Cycle VII, 19 May to 23 June, 1972. Lines represent the growth rate, shapes mark the actual total weight for sample site, shaded area indicates 95% confidence limits on the line for site C.

(From Hopwood, 1973, p. 376)

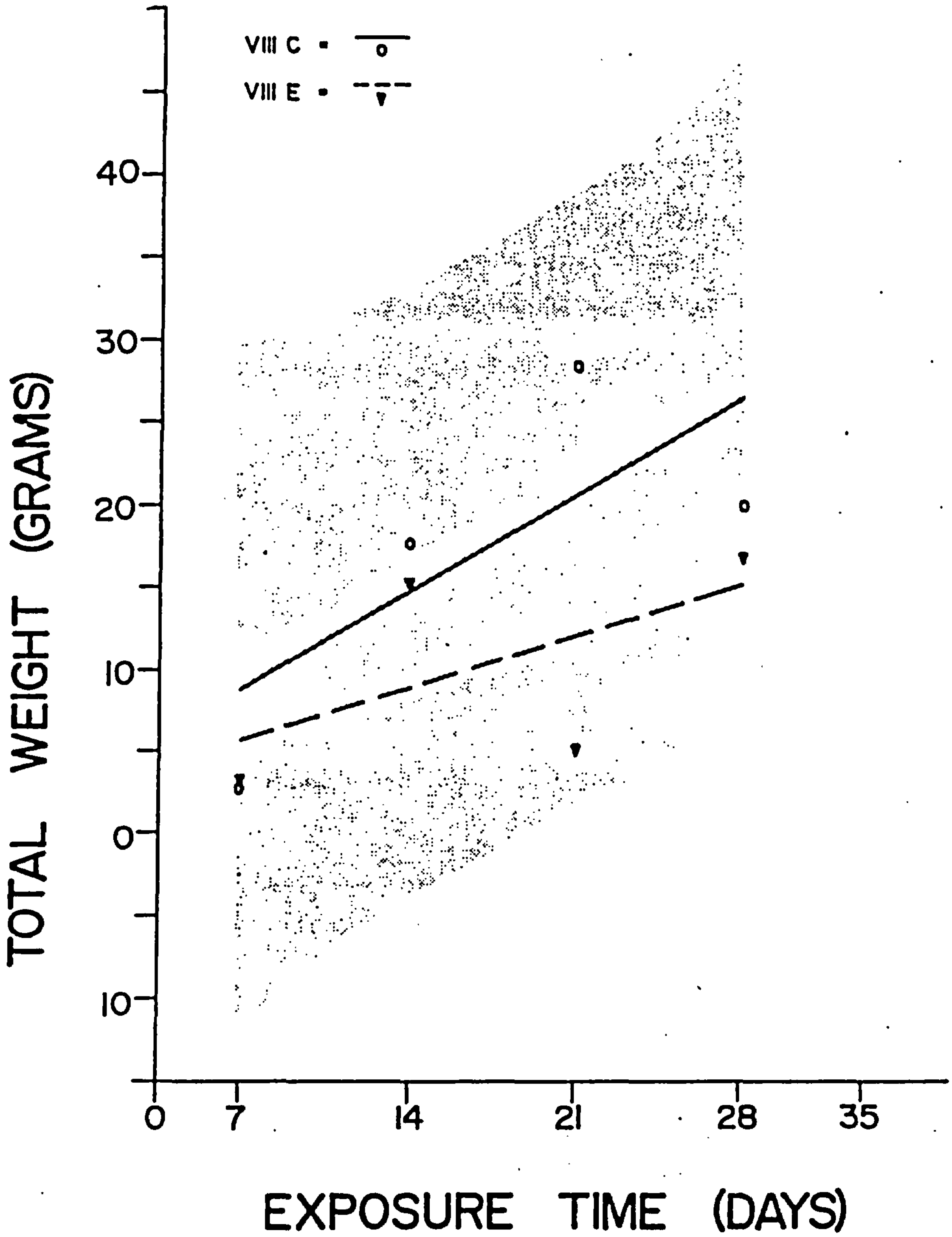


FIGURE 3.3-26

Monticello site recolonization study - growth rates as shown by the total weight of each of five samples taken at sites C and E. Cycle VIII, 23 June to 21 July, 1972. Lines represent the growth rate, shapes mark the actual total weight for a sample site, shaded area indicates 95% confidence limits on the line for site C.

(From Hopwood, 1973, p. 377)

TABLE 3.3-1.

GENERAL PHYSICAL DESCRIPTION OF EACH SECTOR NEAR THE MONTICELLO NUCLEAR GENERATING PLANT (FROM HOPWOOD 1974a, P. 7, 9) SEE FIGURE 3.3-1, p. 133, FOR LOCATION OF SOUNDING RANGES

Sector A

Extends from one mile above the power plant discharge to sounding range 17, a distance of about 1.1 river miles. This sector includes two flows separated by Cedar Island. On the right side of the island the river flows through two deep pools at approximately SR26R to 23R, and SR22R to SR17, and two rapids at SR27R to 26R and at SR22A-R. The left flow is subdivided by several small islands. Much of this flow is less than three feet deep, however, there are pools at SR25L to 24L in the middle channel and SR21L to 20L in the left channel.

Bottom types in Sector A range from silt and mud in the pools to rubble and boulders in the rapids. The right and left channel substrates consist mostly of stones and gravel. That of the middle flow between the islands is composed of silt, fine sand and gravel.

Sector B

Extends from sounding range 17 (the end of the upstream side of the discharge canal) to sounding range 8 (Montissippi Park), 1.5 river miles. Below the confluence of the flows around the islands the river bed broadens (SR17 to SR9). The bottom is fairly uniform, composed mainly of gravel and sand. Some silt deposits occur at the

TABLE 3.3-1 (Continued)

bend area between the rapids at SR9 and the discharge of the left side channel. Large boulders are strewn in the rapids at SR9 where the flow is constricted into a narrow bed. The river then flows through a pool about 200 yards long before broadening into a shallow area of less than three feet deep.

Sector C

Extends from sounding range 8 to sounding range 5 (discharge of Otter Creek), 1.2 river miles. At SR7 the channel deepens, forming a relatively slow-flowing, lake-like area below SR6. This section contains some fallen trees, stumps and roots suitable for fish cover.

Sector D

Extends from sounding range 5 to sounding range 3 (State Highway 25 bridge), 0.8 river miles. A rapids about 50 yards above SR5 marks the upstream end of Sector D. This area is very shallow on the left, deep and swift on the right. There are large boulders among the rubble under the swift water near the right bank. The highest flow velocity in the study area was recorded midway between SR5 and SR4 on the right side. Below SR4 the deep flow changes abruptly from right to left.

TABLE 3.3-1 (Continued)

Sector E

Extends from sounding range 3 to .25 miles below Ellison Park on the south end of Monticello, one river mile. The river flow under the bridge is swift over a shallow riffle extending over most of the width from the right side. A deeper channel lies between the right bank and the north bridge support. Substrates in this area range from boulders and rubble in the swift areas near the bridge to sand and gravel elsewhere. Silt is restricted to areas between the right bank and the islands on the right side of the river.

TABLE 3.3-2

BENTHOS SAMPLING STATIONS, MAJOR MACROINVERTEBRATE MONITORING PROGRAM AT THE MONTICELLO SITE, 1969-1972.
(FROM McCONVILLE, 1972, P. 34, 35, 38)
(FIGURE 3.3-4)

Transect C1 - SR 28RT, 1.3 miles above the nuclear generator intake canal; composed of 3 sampling stations, C1C located in the middle of the river, C1L located midway between C1C and the east bank of the river, and C1R located midway between C1C and the west bank of the river. 12 artificial substrate sampling blocks; (The notation --C, --L, and --R was uniform throughoug the study area and will have the same meaning as outlined above regardless of the transect involved.

Transect C2 - SR 23RT, 0.3 river miles above the nuclear generator intake canal; composed to 2 sampling stations, C2C and C2R. 8 artificial substrate sampling units;

Transect E1 - SR 17, located about 100 feet below the nuclear generator discharge canal; composed of 4 sampling stations, E1L, E1C, E1R, and E1E which was located midway between E1R and the west bank of the river (Fig. 5). 16 artificial substrate sampling units;

Transect E2 - SR 14, 0.3 river miles below the nuclear generator discharge canal; composed of 3 sampling stations, E2L, E2R, and E2E. 12 artificial substrate sampling blocks;

TABLE 3.3-2 (Continued)

Transect E3 - SR 10, 0.8 river miles below the nuclear generator discharge canal; composed of 1 sampling station, E3C. 4 artificial substrate sampling units;

Transect E4 - Midway between SR 9 and SR 8, 1.2 river miles below the nuclear generator discharge canal. Composed of 3 sampling stations, E4L, E4C, and E4R. 12 artificial substrate sampling blocks;

Transect E5 - Midway between SR 8 and SR 7, 2.2 river miles below the nuclear generator discharge canal. Composed of 3 sampling stations, E5L, E5C, and E5R. 12 artificial substrate sampling units;

Transect E6 - SR 3, 4 river miles below the nuclear generator discharge canal. Composed of 1 sampling station, E6C, with 4 artificial substrate sampling blocks.

TABLE 3.3-3

ORGANISMS CAPTURED BY QUALITATIVE SAMPLING AT THE MONTICELLO SITE, 1968 (ADAPTED FROM HOPWOOD, 1969, P. 15-18)

Gastropoda - Snails
- Basommatophora
  - Physidae
    - *Physa* Draparnaud
    - *Lymnaea* Lamarck
  - Planoribdae
    - *Gyraulus* Charpentier

Crustacea
- Amphipoda
  - Gammaridae
    - *Gammarus*
  - Talitridae
    - *Hyalella azteca* Saussure
- Isopoda
  - Asellidae
    - *Asellus intermedius* Forbes
    - *Asellus militaris* Hay
- Decapoda
  - Astacidae
    - *Astacus trowbridgi* Stimpson

Insecta
- Ephemeroptera
  - Baetidae
    - *Baetis* Leach
    - *Centroptilum* Eaton
  - Heptageniidae
    - *Heptagenia*
    - *Epeorus* (*Iron*)
    - *Stenonema*
  - Tricorythidae
    - *Tricorythodes* Ulmer
  - Caenidae
    - *Caenis*
    - *Brachycercus* Curtis
  - Polymitarcidae
    - *Ephoron* Williamson
  - Ephemeridae
    - *Hexagenia* Walsh
  - Siphlonuridae
    - *Isonychia*
    - *Ameletus*
- Odonata
  - Calopterygidae
    - *Calopteryx* Leach
  - Coenagrionidae
    - *Anomalagrion hastatum* Say
    - *Enallagma* Charpentier

TABLE 3.3-3 (Continued)

Insecta (Continued)
- Plecoptera
  - Perlodidae
    - *Isoperla* Banks
  - Perlidae
    - *Acroneuria*
- Hemiptera
  - Gerridae
    - *Gerris*
    - *Microvelia*
    - *Trepobates*
    - *Rheumatobates* Bergr. 1892
    - *Platygerris* B-White
  - Veliidae
    - *Rhagovelia* Mayr
  - Mesoveliidae
    - *Mesovelia mulsanti*
  - Nepidae
    - *Ranatra Fabricius*
  - Notonectidae
    - *Notonecta*
  - Belostomatidae
    - *Lethocerus americanus* Leidy
  - Corixidae
    - *Trichocorixa* Kirkaldy
    - *Neocorixa* Hungerford
  - Pleidae
    - *Plea striola* Fieber
- Coleoptera
  - Haliplidae
    - *Haliplus*
    - *Peltodytes*
  - Dytiscidae
    - *Hydrovatus*
    - *Bidessus*
    - *Desmopachria*
    - *Hygrotus*
    - *Copototomus*
    - *Acilius*
    - *Laccophilus*
  - Hydrophilidae
    - *Enochrus*
    - *Laccobius hamiltoni*
    - *Tropisternus*
    - *Berosus*
    - *Paracymus*
    - *Hydrochus*
  - Gyrinidae
    - *Dineutus*
    - *Gyrinus* Muller
  - Chrysomelidae
    - *Donacia*

TABLE 3.3-3 (Continued)

Insecta (Continued)
- Coleoptera (Continued)
  - Elmidae
    - *Narpus*
    - *Stenelmis*
  - Curculionidae
- Trichoptera
  - Philopotamidae
    - *Chimarra* Stephens
  - Hydropsychidae
    - *Hydropsyche*
    - *Cheumatopsyche*
- Diptera
  - Tendipedidae
    - *Calopsectra*
    - *Tendipes* (Chironomus)
    - *Glyptotendipes*
  - Pelopiinae
    - *Pentaneura*
  - Simuliidae
    - *Simulium venustum* Say

TABLE 3.3-4

RIVER BOTTOM FAUNA BASED ON QUALITATIVE ANALYSIS OF FOUR QUANTITATIVE SAMPLERS (ADAPTED FROM McCONVILLE AND HOPWOOD 1970, P. 40)

- Arthropoda
  - Crustacea
    - Amphipoda
      - Gammaridae
        - Gammarus sp.
    - Isopoda
      - Talitridae
        - Asellus sp.
  - Insecta
    - Ephemeroptera
      - Baetidae
        - Baetis sp.
      - Heptageniidae
        - Epeorus (Iron) sp.
        - Stenonema sp.
      - Polymitarcidae
        - Ephoron sp.
      - Ephemeridae
        - Hexagenia sp.
      - Siphlonuridae
        - Ameletus sp.
        - Isonychia sp.
    - Odonota
      - Coenagrionidae
        - Enallagma sp.
      - Gomphidae
        - Gomphus sp.
    - Plecoptera
      - Perlodidae
        - Isoperla sp.
      - Perlidae
        - Neoperla sp.
        - Paragnetina sp.
        - Perlesta sp.
        - Phasganophora sp.
    - Coleoptera
      - Elmidae
        - Narpus sp.
        - Stenelmis sp.
    - Trichoptera
      - Hydropsychidae
        - Cheumatopsyche sp.
        - Hydropsyche sp.
        - Macronemum sp.
      - Philopotamidae
        - Chimarra sp.
      - Psychomyiidae
        - Psychomyia sp.

TABLE 3.3-4 (Continued)

Insecta (Continued)
    Diptera
        Simuliidae
            Simulium sp.
        Tendipedidae
            Tribe Tendipedini

TABLE 3.3-5

TOTAL NUMBERS OF HYDROPSYCHE AND CHEUMATOPSYCHE CAPTURED ON CONCRETE BLOCK SAMPLERS (MAJOR MONITORING PROGRAM) IN THE MISSISSIPPI RIVER, MONTICELLO SITE (ADAPTED FROM HOPWOOD, 1972, P. 23)

Dates	C1R	C1C	C1L	C2R	C2C
Control - Preoperational					
2-69	-	-	37	9	-
5-69	-	-	-	1456	2143
6-69	1368	992	436	2172	1500
2-70	-	229	-	22	562
5-70	-	2160	-	2000	2440
6-70	3256	2152	2016	7200	4976
Control - Operational					
1-71	-	-	-	36	62
5-71	-	-	-	316	488
6-71	1552	1896	1728	2408	3344
7-71	2944	6656	5552	5136	8496
8-71	2192	2176	2688	3312	5024
9-71	784	3936	2272	6224	7840
10-71	1680	1952	1792	4592	3264
11-71		4096	3472	712	63

Dates	E2E	E2R	E4R	E5R
Intermediate Discharge Area - Preoperational				
2-69	-	-	-	-
5-69	-	576	672	-
6-69	-	1420	2384	1296
2-70	-	1532	57	-
5-70	-	-	2260	-
6-70	4680	6768	7640	-
Intermediate Discharge Area - Operational				
1-71	-	700	-	-
5-71	-	440	-	-
6-71	2544	3292	5104	3744
7-71	3040	7424	5936	6128
8-71	904	3584	4352	1704
9-71	88	2240	2336	5568
10-71	136	3200	1824	1760
11-71				

Dates	E1E	E1R	E1C	E1L	E2L	E3C	E4C	E4L	E5C	E5L	E6C
Outer Discharge Area - Preoperational											
2-69	-	-	67	996	-	-	-	58	-	-	-
5-69	-	-	156	960	-	488	-	-	-	-	-
6-69	-	-	1088	-	1476	2052	-	-	-	-	824
2-70	356	752	-	2552	-	311	-	174	-	-	-
5-70	-	3274	-	5240	-	2544	-	5172	-	-	-
6-70	8784	7776	5344	7344	4520	2304	-	7040	1432	-	2376
Outer Discharge Area - Operational											
1-71	75	797	-	-	-	208	-	-	-	-	-
5-71	492	-	880	-	-	-	-	-	-	-	-
6-71	7920	6368	2096	3680	4608	4528	4283	5376	2896	3632	-
7-71	5872	4056	4872	4496	9664	6336	6192	5232	7616	-	6512
8-71	4432	5168	4608	6208	5184	4096	2368	2016	2480	2384	2272
9-71	4864	6592	6560	9088	6272	6400	7520	3248	7536	8576	4848
10-71	4136	4016	6528	6032	3872	3440	2752	5216	3984	1872	2640
11-71	-	-	-	-	-	3168	3616	2224	-	-	-

TABLE 3.3-6

TOTAL NUMBERS OF MACRONEMUM CAPTURED ON CONCRETE BLOCK SAMPLERS (MAJOR MONITORING PROGRAM) IN THE MISSISSIPPI RIVER, MONTICELLO SITE (ADAPTED FROM HOPWOOD, 1972, p. 24).

Dates	C1R	C1C	C1L	C2R	C2C
Control - Preoperational					
2-69	-	-	-	-	-
5-69	-	-	-	44	52
6-69	-	37	5	38	18
2-70	-	2	-	-	9
5-70	-	4	-	-	8
6-70	-	56	96	176	72
Control - Operational					
1-71	-	-	-	-	-
5-71	-	-	-	-	-
6-71	-	-	16	-	-
7-71	16	16	32	80	32
8-71	16	64	576	32	48
9-71	4	352	96	-	96
10-71	-	16	-	16	-
11-71	-	0	0	0	0

Dates	E2E	E2R	E4R	E5R
Intermediate Discharge Area - Preoperational				
2-69	-	-	-	-
5-69	-	16	17	-
6-69	-	28	24	32
2-70	-	-	-	-
5-70	-	-	8	-
6-70	104	80	240	-
Intermediate Discharge Area - Operational				
1-71	-	-	-	-
5-71	-	8	-	-
6-71	-	-	64	8
7-71	32	64	160	192
8-71	80	96	320	72
9-71	-	0	32	8
10-71	-	0	0	16
11-71	-	-	-	-

Dates	E1E	E1R	E1C	E1L	E2L	E3C	E4C	E4L	E5C	E5L	E6C
Outer Discharge Area - Preoperational											
2-69	-	-	-	-	-	-	-	-	-	-	-
5-69	-	-	4	32	-	28	-	-	-	-	-
6-69	-	-	36	116	36	40	-	-	-	-	48
2-70	-	-	-	-	-	-	-	-	-	-	-
5-70	-	-	-	12	-	16	-	4	-	-	-
6-70	128	80	136	384	232	80	-	136	108	-	12
Outer Discharge Area - Operational											
1-71	-	-	-	-	-	0	-	-	-	-	-
5-71	-	-	-	-	-	-	-	-	-	-	-
6-71	-	16	-	-	-	0	0	0	32	0	-
7-71	280	24	96	80	256	64	96	80	80	-	128
8-71	272	288	576	224	384	448	144	192	272	64	320
9-71	192	32	160	32	160	352	96	48	16	128	176
10-71	-	-	-	-	0	16	8	0	0	0	0
11-71	-	-	-	-	-	0	0	0	-	-	-

TABLE 3.3-7

TOTAL NUMBERS OF PSEUDOCLOEON CAPTURED ON CONCRETE BLOCK SAMPLERS (MAJOR MONITORING PROGRAM) IN THE MISSISSIPPI RIVER, MONTICELLO SITE (ADAPTED FROM HOPWOOD, 1972, P. 25)

Control - Preoperational					
Dates	C1R	C1C	C1L	C2R	C2C
2-69	-	-	-	-	-
5-69	-	-	-	-	-
6-69	1268	994	920	1184	652
2-70	-	-	-	-	-
5-70	-	-	-	8	-
6-70	3008	1408	1552	1824	2648
Control - Operational					
1-71	-	-	-	2	-
5-71	-	-	-	-	-
6-71	864	3552	2048	1096	1776
7-71	1736	2432	1480	2416	2080
8-71	2640	2768	14304	3440	3792
9-71	356	1008	2656	1264	448
10-71	384	688	1504	240	272
11-71	-	0	0	0	0

Intermediate Discharge Area - Preoperational				
Dates	E2E	E2R	E4R	E5R
2-69	-	-	-	-
5-69	-	-	-	-
6-69	-	300	96	600
2-70	-	-	-	-
5-70	-	-	-	-
6-70	1160	480	860	-
Intermediate Discharge Area - Operational				
1-71	-	-	-	-
5-71	-	-	-	-
6-71	880	256	16	368
7-71	1328	880	176	800
8-71	1192	2016	832	1328
9-71	160	320	288	480
10-71	52	160	256	384
11-71	-	-	-	-

Outer Discharge Area - Preoperational											
Dates	E1E	E1R	E1C	E1L	E2L	E3C	E4C	E4L	E5C	E5L	E6C
2-69	-	-	-	-	-	-	-	-	-	-	-
5-69	-	-	-	-	-	-	-	-	-	-	-
6-69	-	-	140	156	76	236	-	-	-	-	728
2-70	-	-	-	-	-	-	-	-	-	-	-
5-70	-	-	-	-	-	-	-	-	-	-	-
6-70	624	544	780	608	408	644	-	96	20	-	648
Outer Discharge Area - Operational											
1-71	-	-	-	-	-	0	-	-	-	-	-
5-71	-	-	-	-	-	-	-	-	-	-	-
6-71	832	1360	112	736	272	576	224	536	128	536	-
7-71	416	240	168	576	368	1120	224	976	368	-	1088
8-71	1984	2384	3312	5664	5280	3024	1488	2736	1424	1520	4192
9-71	288	608	416	864	960	640	512	1056	256	608	384
10-71	240	432	704	752	816	592	248	320	256	208	608
11-71	-	-	-	-	-	32	0	32	-	-	-

TABLE 3.3-8

TOTAL NUMBER OF STENONEMA CAPTURED ON CONCRETE BLOCK SAMPLERS (MAJOR MONITORING PROGRAM) IN THE MISSISSIPPI RIVER, MONTICELLO SITE (ADAPTED FROM HOPWOOD, 1972, P. 26)

Dates	C1R	C1C	C1L	C2R	C2C
Control - Preoperational					
2-69	-	-	-	10	4
5-69	-	-	-	72	40
6-69	52	48	76	96	64
2-70	-	4	-	2	11
5-70	-	8	-	128	24
6-70	84	16	32	240	216
Control - Operational					
1-71	-	-	-	17	14
5-71	-	-	-	10	28
6-71	176	16	48	32	48
7-71	732	64	208	96	80
8-71	208	112	96	64	64
9-71	84	304	448	352	240
10-71	400	256	480	96	32
11-71	-	112	0	0	9

Dates	E2E	E2R	E4R	E5R
Intermediate Discharge Area - Preoperational				
2-69	-	-	-	-
5-69	-	32	-	-
6-69	-	48	32	60
2-70	-	6	5	-
5-70	-	-	60	-
6-70	52	112	232	-
Intermediate Discharge Area - Operational				
1-71	-	38	-	-
5-71	-	24	-	-
6-71	64	20	96	24
7-71	80	160	104	0
8-71	168	256	112	64
9-71	272	128	160	136
10-71	200	112	312	64
11-71	-	-	-	-

Dates	E1E	E1R	E1C	E1L	E2L	E3C	E4C	E4L	E5C	E5L	E6C
Outer Discharge Area - Preoperational											
2-69	-	-	-	-	-	-	-	-	-	-	-
5-69	-	-	1	16	-	-	-	-	-	-	-
6-69	-	-	8	4	-	24	-	-	-	-	12
2-70	-	6	-	16	-	1	-	-	-	-	-
5-70	-	4	-	-	-	32	-	48	-	-	-
6-70	96	80	28	128	40	64	-	104	16	-	12
Outer Discharge Area - Operational											
1-71	5	-	-	-	-	23	-	-	-	-	-
5-71	28	-	-	-	-	-	-	-	-	-	-
6-71	16	64	4	32	48	48	32	104	0	8	-
7-71	112	96	64	112	144	112	48	256	16	-	96
8-71	272	320	448	96	160	192	160	96	48	16	256
9-71	352	64	320	544	384	160	256	560	16	208	192
10-71	144	64	256	240	304	208	88	304	32	144	304
11-71	-	-	-	-	-	32	272	80	-	-	-

TABLE 5.3-9

TOTAL NUMBERS OF EPHEMERELLA CAPTURED ON CONCRETE BLOCK SAMPLERS (MAJOR MACROINVERTEBRATE PROGRAM) IN THE MISSISSIPPI RIVER, MONTICELLO SITE (ADAPTED FROM HOPWOOD, 1972, p. 27)

Control - Preoperational					
Dates	C1R	C1C	C1L	C2R	C2C
2-69	-	-	24	13	26
5-69	-	-	-	40	48
6-69	-	-	12	8	12
2-70	-	6	-	7	14
5-70	-	124	-	64	72
6-70	60	0	16	48	16
Control - Operational					
1-71	-	-	-	22	19
5-71	-	-	-	40	44
6-71	16	16	-	-	-
7-71	0	0	0	0	0
8-71	0	0	0	80	0
9-71	12	32	32	32	0
10-71	416	160	1760	400	192
11-71	-	224	128	56	8

Intermediate Discharge Area - Preoperational				
Dates	E2E	E2R	E4R	E5R
2-69	-	-	-	-
5-69	-	16	-	-
6-69	-	-	4	4
2-70	-	19	3	-
5-70	-	-	52	-
6-70	28	32	24	-
Intermediate Discharge Area - Operational				
1-71	-	36	-	-
5-71	-	8	-	-
6-71	-	-	16	0
7-71	0	0	0	0
8-71	0	32	0	8
9-71	0	0	0	0
10-71	0	16	8	16
11-71	-	-	-	-

Outer Discharge Area - Preoperational											
Dates	E1E	E1R	E1C	E1L	E2L	E3C	E4C	E4L	E5C	E5L	E6C
2-69	-	-	28	-	-	-	-	15	-	-	-
5-69	-	-	13	-	-	-	-	-	-	-	-
6-69	-	-	-	4	-	-	-	-	-	-	4
2-70	18	142	-	512	-	29	-	8	-	-	-
5-70	-	37	-	16	-	4	-	48	-	-	-
6-70	-	-	-	-	16	32	-	16	4	-	4
Outer Discharge Area - Operational											
1-71	24	32	-	-	-	66	-	-	-	-	-
5-71	40	-	16	-	-	-	-	-	-	-	-
6-71	-	16	-	-	-	16	0	48	0	0	-
7-71	0	0	0	0	32	0	0	64	0	-	0
8-71	0	16	16	64	96	16	0	48	0	0	64
9-71	0	32	0	32	0	128	64	0	0	64	0
10-71	176	112	592	736	384	80	48	128	32	96	112
11-71	-	-	-	-	-	160	128	80	-	-	-

TABLE 3.3-10

TOTAL NUMBERS OF SIMULIIDAE CAPTURED ON CONCRETE BLOCK SAMPLERS (MAJOR MONITORING PROGRAM) IN THE MISSISSIPPI RIVER, MONTICELLO SITE (ADAPTED FROM HOPWOOD, 1972, p. 28)

Control - Preoperational					
Dates	C1R	C1C	C1L	C2R	C2C
2-69	-	-	-	3	2
5-69	-	-	-	4	80
6-69	812	17888	15136	-	44
2-70	-	2	-	-	-
5-70	-	148	-	56	16
6-70	572	3432	6972	224	96
Control - Operational					
1-71	-	-	-	-	-
5-71	-	-	-	160	944
6-71	592	1672	1668	128	304
7-71	100	352	608	16	112
8-71	48	96	1376	208	416
9-71	20	96	0	0	64
10-71	0	64	64	0	176
11-71	-	0	0	0	0

Intermediate Discharge Area - Preoperational				
Dates	E2E	E2R	E4R	E5R
2-69	-	-	-	-
5-69	-	28308	22860	-
6-69	-	996	476	5252
2-70	-	-	-	-
5-70	-	-	2304	-
6-70	152	576	760	-
Intermediate Discharge Area - Operational				
1-71	-	6128	-	-
5-71	-	60	128	120
6-71	48	128	80	128
7-71	56	176	0	80
8-71	0	16	0	0
9-71	0	0	0	0
10-71	0	-	-	-
11-71	-	-	-	-

Outer Discharge Area - Preoperational											
Dates	E1E	E1R	E1C	E1L	E2L	E3C	E4C	E4L	E5C	E5L	E6C
2-69	-	-	-	-	-	-	-	-	-	-	-
5-69	-	-	992	30142	-	13348	-	-	-	-	-
6-69	-	-	764	2148	1628	1348	-	-	-	-	2980
2-70	1	4	-	-	-	3	-	4	-	-	-
5-70	-	181	-	68	-	896	-	7236	-	-	-
6-70	272	1136	1016	1264	856	3048	-	24	784	-	216
Outer Discharce Area - Operational											
1-71	3	-	-	-	-	1	-	-	-	-	-
5-71	4412	-	8408	-	1472	-	-	-	-	-	-
6-71	128	224	640	1008	1056	704	6768	912	7248	2312	-
7-71	176	192	1888	1392	3872	2720	3152	224	880	-	224
8-71	48	224	2192	3232	192	2224	1104	304	432	496	352
9-71	0	64	96	32	112	32	0	192	0	96	0
10-71	0	0	16	32	-	80	120	48	160	144	80
11-71	-	-	-	-	-	0	16	16	-	-	-

TABLE 3.3-11

TOTAL NUMBERS OF CHIRONOMINI CAPTURED ON CONCRETE BLOCK SAMPLERS (MAJOR MONITORING PROGRAM) IN THE MISSISSIPPI RIVER, MONTICELLO SITE (ADAPTED FROM HOPWOOD, 1972, p. 29)

Control- Preoperational

Dates	C1R	C1C	C1L	C2R	C2C
2-69	-	-	5	11	4
5-69	-	-	-	120	168
6-69	976	2188	996	540	456
2-70	-	329	-	145	591
5-70	-	1660	-	2040	1792
6-70	2004	3896	5856	2384	3168
Control - Operational					
1-71	-	-	-	54	113
5-71	-	-	-	478	896
6-71	2544	1464	2224	1024	1184
7-71	948	624	1232	496	1280
8-71	2288	1232	6688	2384	3248
9-71	492	352	1216	448	160
10-71	2176	2272	2080	1232	1040
11-71	-	4704	3776	1720	197

Intermediate Discharge Area - Preoperational

Dates	E2E	E2R	E4R	E5R
2-69	-	-	-	-
5-69	-	-	80	-
6-69	-	364	480	448
2-70	-	811	241	-
5-70	-	-	888	-
6-70	552	1392	2024	-
Intermediate Discharge Area - Operational				
1-71	-	252	-	-
5-71	-	272	-	-
6-71	560	572	1616	600
7-71	384	464	296	368
8-71	1824	2688	1776	1152
9-71	808	784	688	664
10-71	3100	1824	792	720
11-71	-	-	-	-

Outer Discharge Area - Preoperational

Dates	E1E	E1R	E1C	E1L	E2L	E3C	E4C	E4L	E5C	E5L	E6C
2-69	-	-	5	-	-	-	-	3	-	-	-
5-69	-	-	24	20	-	12	-	-	-	-	-
6-69	-	-	484	386	360	692	-	-	-	-	292
2-70	248	428	-	1384	-	381	-	122	-	-	-
5-70	-	1369	-	1960	-	612	-	1228	-	-	-
6-70	1664	1728	1192	2704	960	1944	-	1600	904	-	1680
Outer Discharge Area - Operational											
1-71	56	347	-	-	-	127	-	-	-	-	-
5-71	332	-	352	-	-	-	-	-	-	-	-
6-71	1648	1232	516	1824	1504	896	2736	2080	552	1040	-
7-71	672	232	400	592	2016	800	080	624	752	-	432
8-71	1888	2800	2432	6592	3872	3168	1424	3104	1168	960	4640
9-71	352	544	384	1712	1504	1344	832	1120	720	640	576
10-71	1280	1392	1888	3024	1504	1968	984	1040	1248	1008	1760
11-71	-	-	-	-	-	3488	2656	5424	-	-	-

TABLE 3.3-12

NUMBER OF BENTHIC ORGANISMS CAPTURED ON CONCRETE BLOCK SAMPLERS, PERCENTAGE CONTRIBUTION OF DOMINANT GROUPS TO THE TOTAL IN 1972, AND PERCENTAGE COMPOSITION OF BENTHIC FAUNA IN 1969, 1970, AND 1971 (FROM HOPWOOD, 1973, P. C-382)

Date	Total	Caddisflies	Mayflies	Dipterans	Misc. Groups
June 1972	138,432	96,640	11,216	29,904	672
July	4,928	3,792	352	672	112
October	35,352	29,384	1,040	3,528	1,400
November	7,487	4,611	194	1,935	747
1972 Total	186,199	134,427	12,802	36,039	2,931
1972 %		72.19	6.87	19.37	1.57
1969 %		41.75	12.14	38.94	7.18
1970 %		52.10	11.71	31.10	5.10
1971 %		49.00	15.90	24.60	10.50
1973 %		56.43	12.32	26.99	3.75

TABLE 3.3-13

NUMBER OF ORGANISMS PER 4-BLOCK STATION COLLECTED FROM ARTIFICIAL SUBSTRATES PLACED ON SEPTEMBER 6, 1973 AND RETRIEVED OCTOBER 3, 1973 MISSISSIPPI RIVER NEAR THE MONTICELLO PLANT (ADAPTED FROM HOPWOOD 1974b, p. C-250)

Stations	Hydropsyche and Cheumatopsyche	Chimarra	Psychomyia	Protoptila	Oecetis	Hydroptilidae	Pseudocloeon	Stenonema	Rhithrogena	Potamanthus	Isonychia	Ephemerella	Tricorythodes	Heptagenia
C2L	1111	11		958			850	21	3		4	149		2
C2C	1992	12		404	24	8	376	72				76	4	4
C2R	1796	4	8	516	60	24	316	16				104		16
E1L	3098	132	24	2908	8	6	488	96	8		16	516	8	6
E1C	3320	64	16	4264	56		248	104		16	16	520		
E1R'	4072	112		1312	64	40	264	648	8	16	16	704	8	

Stations	Neoperla	Paragnetina	Phasganophora	Tribe Chironomini Larvae	Pupae	Simuliidae Larvae	Ferrissia	Planaria	Small and Damaged Trichoptera	Small and Damaged Ephemeroptera	Small and Damaged Plecoptera	Small and Damaged Diptera	Hydropsyche Cheumatopsyche Damaged
C2L				2258	109	61		6	94	109		13	
C2C				2584	84	24	8	12	116	52	4	16	
C2R				2496	52	8	12	32	132	36		8	
E1L				2020	28	52			338	62	52		
E1C	8	8		1344	8	8		16	80	32	32		112
E1R			8	1352	40				128	32	88		96

TABLE 3.3-14

SURFACE WATER TEMPERATURES IN DEGREES CENTIGRADE TAKEN AT SAMPLING SITES C AND E ON SAMPLE RECOVERY DAYS. TEMPERATURES WERE TAKEN WITH A YELLOW SPRINGS INSTRUMENT COMPANY TELE-THERMOMETER AND THERMISTOR. (FROM NEMANICK, 1973, P. 98)

Date	Temperature (C) Site C	Site E	Date	Temperature (C) Site C	Site E
19 July 1971	21.7	21.2	22 Apr. 1972	4.4	--
26 July	21.1	21.1	29 Apr	9.4	10.6
2 Aug	15.6	26.4	6 May	10.6	12.2
9 Aug	23.9	32.2	13 May	12.8	12.8
16 Aug	22.8	28.9	20 May	20.6	--
23 Aug	22.2	26.1	26 May	22.8	23.9
30 Aug	21.7	21.7	2 June	21.1	23.2
6 Sept	20.6	25.0	9 June	22.2	25.0
13 Sept	20.6	26.1	16 June	20.0	21.1
21 Sept	16.7	20.6	23 June	21.1	25.6
28 Sept	16.1	16.1	30 June	22.8	27.2
5 Oct	15.8	21.1	7 July	22.2	25.0
12 Oct	--	--	14 July	25.6	25.0
19 Oct	13.3	17.8	21 July	23.2	26.1
26 Oct	--	17.2			
2 Nov	5.0	--			
9 Nov	2.2	--			
16 Nov	2.8	--			

TABLE 3.3-15

BOTTOM WATER TEMPERATURES IN DEGREES CENTIGRADE TAKEN AT SAMPLING SITES C AND E ON SAMPLE RECOVERY DAYS. TEMPERATURES WERE RECORDED ON A PALMER CONTINUOUS RECORDER.
(FROM NEMANICK, 1973, P. 99)

Date	Temperature (C)		Date	Temperature (C)	
	Site C	Site E		Site C	Site E
19 July 1971	22.3	22.5	22 Apr 1972	4.8	8.1
26 July	21.5	22.8	29 Apr	7.8	10.0
2 Aug	19.4	21.2	6 May	8.6	11.4
9 Aug	24.4	25.3	13 May	11.4	12.2
16 Aug	23.2	24.3	20 May	18.3	20.6
23 Aug	22.0	24.4	26 May	20.0	22.2
30 Aug	20.6	20.9	2 June	18.5	21.1
6 Sept	--	21.4	9 June	21.4	23.9
13 Sept	20.6	22.2	16 June	18.3	21.1
21 Sept	15.7	19.4	23 June	18.3	22.5
28 Sept	15.8	16.4	30 June	21.7	25.0
5 Oct	16.0	18.0	7 July	19.1	21.9
12 Oct	11.5	13.5	14 July	21.4	23.0
19 Oct	13.6	15.1	21 July	21.9	23.9
26 Oct	12.6	13.9			
2 Nov	5.6	8.3			
9 Nov	1.7	5.0			
16 Nov	3.3	4.4			

TABLE 3.3-16

A LIST OF THE SAMPLING CYCLES AND THE PLACEMENT AND RECOVERY DATES FOR EACH. ROMAN NUMERALS DESIGNATE SPECIFIC CYCLES. (FROM HOPWOOD, 1973. P. C-359)

Cycle	Dates (placed-station 5 recovery)
I	12 July - 16 August 1971
II	9 August - 13 September 1971
III	6 September - 14 October 1971
IV	6 October - 10 November 1971 (site E - 3 samples collected) 6 October - 27 October
V	2 November - 23 November 1971 (site C only, 3 samples)
VI	15 April - 19 May 1972 (Site E - collections on 29 April, 5 & 12 May)
VII	19 May - 23 June 1972
VIII	23 June - 21 July 1972 (4 samples 1-4)

TABLE 3.3-17

DIFFERENCE IN TAXONOMIC COMPOSITION BY WEIGHTS AND NUMBERS BETWEEN SAMPLES FROM THE CONTROL (C) STATION AND THE EXPERIMENTAL (E) STATION. LETTERS INDICATE WHICH STATION HAD THE GREATER VALUE. MEAN IS THE AVERAGE DIFFERENCE DETERMINED BY THE SUM OF DIFFERENCES FOR EACH CYCLE. SD = STANDARD DEVIATION OF THE DIFFERENCES BETWEEN THE TWO STATIONS. (FROM HOPWOOD, 1973, P. C-362)

Numbers

Cycle	Trichoptera percent difference	High	Ephemeroptera percent difference	High	Diptera percent difference	High
I	18.2	E	43.5	C	6.1	C
II	12.2	E	16.7	C	28.0	C
III	28.8	E	7.3	C	39.6	C
IV	52.1	E	4.4	C	40.0	C
VI	18.1	E	62.8	C	10.2	C
VII	19.0	E	82.0	C	16.7	C
VIII	25.0	E	48.3	C	10.8	E
Mean =	24.8	Mean =	37.9	Mean =	21.6	
SD =	12.2	SD =	27.29	SD =	17.25	

Weights

Cycle	Trichoptera percent difference	High	Ephemeroptera percent difference	High	Diptera percent difference	High
I	9.5	E	46.6	C	37.1	C
II	6.6	E	11.4	C	55.9	C
III	0.6	E	49.8	E	76.3	C
IV	8.9	E	11.8	E	80.4	C
VI	16.0	E	65.8	C	76.5	C
VII	6.0	E	79.9	C	29.2	E
VIII	3.9	E	45.8	C	27.4	C
Mean =	7.4	Mean =	44.4	Mean =	54.7	
SD =	4.5	SD =	42.58	SD =	36.27	

TABLE 3.3-18

OCCURRENCES OF A SIGNIFICANT DIFFERENCE (5% LEVEL) BETWEEN THE PERCENTAGE COMPOSITION BY NUMBER AND WEIGHT AT SITES C AND E. ROMAN NUMERALS DESIGNATE THE CYCLES. THE LETTERS SIGNIFY IF THE DIFFERENCE OCCURRED IN NUMBERS (N), OR WEIGHT (W) FOR THE SPECIFIC ORGANISM. THE (C) OR (E) FOLLOWING EACH LETTER SHOWS WHICH SITE HAD THE HIGHER VALUE. (FROM HOPWOOD, 1973, P. C-363)

	I	II	III	IV	VI	VII	VIII
Trichoptera	N(E)W(E)		N(E)	N(E)			
Ephemeroptera	N(C)W(C)					N(C)W(C)	N(C)
Diptera			N(C)W(C)	N(C)W(C)			

TABLE 3.3-19

SAMPLING PERIOD DESIGNATIONS, TIMES, AND DATES OF INITIATION AND COMPLETION. (FROM MATTER, 1975, P. 10)

Sampling Period	Start		End	
	Hour	Date	Hour	Date
I	0830	27 July	0830	28 July 1973
II	0800	13 August	0800	14 August 1973
III	0830	28 August	0830	29 August 1973
IV	0800	11 September	0800	12 September 1973
V	1030	28 September	0930	29 September 1973
VI	0830	9 November	0830	10 November 1973
VII	1230	30 November	0830	1 December 1973
VIII	0800	26 February	0830	27 February 1974
IX	1300	14 March	0330	15 March 1974
X	1300	31 May	1200	1 June 1974
XI	1430	21 June	1130	22 June 1974
XII	1300	12 July	1100	13 July 1974
XIII	0800	23 July	0800	24 July 1974

TABLE 3.3-20

SURFACE AND BOTTOM WATER TEMPERATURE IN DEGREES CELSIUS (C) RECORDED AT SAMPLING SITES C AND E. ROMAN NUMERALS REPRESENT SAMPLING PERIODS. (FROM MATTER, 1975, P. 23)

Sampling Period	Surface Temperature (C)		Bottom Temperature (C)	
	Site C	Site E	Site C	Site E
I	21.5	24.0	21.4	24.3
II	24.0	26.5	24.2	26.6
III	24.0	26.0	24.4	25.8
IV	19.0	23.0	19.7	23.8
V	15.0	16.6	15.0	16.7
VI	1.0	7.0	2.2	7.5
VII	0.5	6.0	1.9	7.7
VIII	--	6.3	--	7.2
IX	--	5.0	--	4.4
X	16.8	21.0	16.9	21.7
XI	20.8	23.8	20.6	24.0
XII	25.0	27.2	25.6	28.0
XIII	25.7	27.1	25.6	27.7

TABLE 3.3-21

CADDISFLIES, MAYFLIES AND TRUE FLIES COLLECTED IN LIGHT TRAPS NEAR THE MISSISSIPPI RIVER AT THE MONTICELLO SITE, 1973-1974* (ADAPTED FROM J. MATTER, 1975, P. 102-103)

TRICHOPTERA

Hydropsychidae

Macronemum zebratum
Cheumatopsyche sp. (females)
C. campyla
C. speciosa

Hydropsyche sp. (females)
H. betteni
H. recurvata
H. phalerata
H. bifida
H. scalaris
H. vexa
H. morosa

Potamyia flava
Arctopsyche sp.

Leptoceridae

Athripsodes sp. (females)
A. punctatus
A. transversus
A. mentieus
A. cancellatus
A. flavus
A. dilutus
A. ancylus
A. tarsi-punctatus
A. angustus

Oecetis sp. (females)
O. avara
O. inconspicua

Leptocella sp.
Leptocerus americanus
Setodes oligia
Triaenodes sp. (females)
T. tarda

TABLE 3.3-21 (Continued)

Limnephilidae
- *Pycnopsyche subfasciata*
- *Limnephilus submonilifer*

Psychomyiidae
- *Psychomyia flavida*
- *Nyctiophylax* sp. (females)
- *N. vestitus*
- *Cerotina* sp.
- *Neureclipsis crepuscularis*

Rhyacophilidae
- *Protoptila* sp. (females)
- *P. erotica*
- *P. maculata*

Philopotamidae
- *Chimarra* sp. (females)
- *C. obscura*

Hydroptilidae
- *Hydroptila* sp.

Helicopsyche
- *Helicopsyche borealis*

EPHEMEROPTERA

Baetidae

Baetinae
- *Baetis* sp.
- *Pseudocloeon* sp.
- *Callibaetis* sp.
- *Centroptilum* sp.

Caeninae
- *Caenis* sp.
- *Brachycercus lacustris*
- *Tricorythodes* sp.
- *T. attratus*

TABLE 3.3-21 (Continued)

Ephemerellinae
Ephemerella sp.
E. *deficiens*

Siphlonurinae
Isonychia sp.
Ameletus sp.

Metretopodinae

Heptageniidae
Heptageninae
Stenonema sp.
S. *nepotellum*

Anepeorus sp.

Ephemeridae
Ephoroninae
Ephoron sp.

Potamanthinae
Potamanthus sp.
P. *verticis*

Ephemerinae
Ephemera simulans
Hexagenia sp.

DIPTERA

Simuliidae
Simulium sp.
S. *jenningsi*

Cecidomyiidae

TABLE 3.3-21 (Continued)

Chironomidae
- Hydrobaeninae
  - _Hydrobaenus_ sp.
  - _Cardiocladius_ sp.

- Pelopiinae
  - _Procladius_ sp.
  - _Cardiocladius_ sp.

- Tendipedinae
  - _Calopsectra_ sp.
  - _Tendipedini_

Heleidae (Ceratopogonidae)

Culicidae
Muscidae
Empididae
Sciomyzidae
Tipulidae
Phoridae
Syrphidae
Anthomyiidae
Asilidae
Calliphoridae
Canaceidae
Scopeumatidae
Dolichopodidae
Psychodidae
Tabanidae
Pyrgotidae

3.4 FISH

3.4.1 METHODS

The fisheries investigations at the Monticello Nuclear Generating Plant are divided into two phases: pre-operational and operational. The pre-operational phase includes baseline data gathered from 1968 through June 1971; the operational phase includes data from June 1971 through 1974. The fishery studies were conducted under the direction of Dr. Alfred J. Hopwood, St. Cloud College. The study extended over approximately 5 miles of river from just north of the Monticello plant site downstream to the town of Monticello.

This 5-mile reach of river was divided into five sectors during electrofishing operations (Figure 3.4-1). Sector A was located above the discharge and represents the upstream control area. Sector B contained the discharge canal and thermal discharge zones as per MPCA 316(a) Type I Section 4(A)(i)(ii)(iii)(iv). Sectors C through E were downstream sampling stations. A description of flow characteristics and substrate types appears in Table 3.4-1. Sounding range locations are shown in Figure 3.4-2.

Electrofishing methods are described in Hopwood (1974a, p. 68):

> "Electrofishing was practiced along the river's edge over depths ranging from less than one foot to more than ten feet, and in current velocities ranging from near zero to over 8 feet per second. The electrofishing gear included a 3000 Watt, 230 Volt A.C. Homelite generator, Model 9HY-1A, operated on a 16 foot flat bottom boat. A boom frame of galvanized steel tubing was extended out from the front of the boat, and three electrodes hung down into the water from the frame. The current flowed from the generator through a control panel and switchbox to the electrodes. For safety

the circuit was designed to allow current to flow to the electrodes only when an operator stood on a switch mat in the front of the boat.

The procedure for collecting fish was to orient the boat parallel to the shoreline and move downstream with the electrodes leading. The speed of the boat was adjusted so the majority of the fish surfaced near the front deck. The stunned fish were taken from the water with the aid of long-handled nets and placed in tubs of water. Electrofishing runs were timed to the nearest minute, with the length of the run being terminated at predetermined landmarks along the shore, or when the tubs of water became filled with captured fish. Fish were released at the location of the beginning of each run, since dispersal takes place in a downstream direction...A sample of scales for laboratory analysis was taken from each fish. All data were recorded on tape cassettes in the field for later transcription in the laboratory."

Most electrofishing fishing took place during the summer with some sampling during the spring and fall. Catch-per-unit-effort (numbers of fish per electrofishing hour) was used as the measure of relative abundance. Percent composition was also calculated based on fish per electrofishing hour. Electrofishing is generally selective for larger fish.

Seining studies, designed principally for the collection of cyprinid minnows, were conducted in both pre- and operational years using a 20-foot seine with either 1/4 or 1/8 inch mesh. Bottom types in the seining areas were principally a combination of sand, gravel and rubble. Station locations are indicated in Figure 3.4-3 for the pre-operational study in 1970. Station descriptions for this study are found in Table 3.4-2. Seining was conducted from May through November 1970, although attempts on November 25 were unsuccessful due tc floating ice. Winter sampling with minnow traps, fished through holes in the ice, was also unsuccessful.

The operational seining study was conducted from June 1972 to July 1973. Eight stations were sampled, four above the discharge (Figure 3.4-4) and four below the discharge (Figure 3.4-5). Station descriptions are found in Table 3.4-3. Pre-operational stations Upstream 1, Downstream 1 and Downstream 2 were identical to operational stations Upstream 1, Downstream 2 and Downstream 3, respectively.

Additional seining studies were conducted in the summers of 1973 and 1974 to assess young-of-the-year fish growth and abundance in thermally-affected and control areas. Two sizes of seine were used: 15-foot with 1/8 inch mesh and 20-foot with 1/4 inch mesh. Three sections were sampled: one upstream from the discharge, one downstream from the discharge and one within the thermal plume (Figure 3.4-6). Four seining sites were sampled per section (two pool and two riffle habitats). Since the habitats were comparable, the major difference between sections was temperature.

A creel census was conducted during the summer and fall of 1972 and 1973. The stratified-random creel survey method of Neubold and Lu (1957) was used. In 1972, the sampling sites corresponded to electrofishing river sections (Figure 3.4-1). In 1973, the geographical boundaries of the creel study remained the same as in 1972 but the actual census areas were more precisely defined (Figure 3.4-7).

Studies were conducted to determine the spawning grounds of various fish species in the area around the Monticello plant.

Adult fish were collected by electroshocking and examined for gonadal development. This method was deemed most appropriate under existing conditions. Spawning activity is often determined by visual observation, but the turbidity in the reach of river near the plant precluded mapping of spawning grounds by sighting. Another method is to collect fish eggs and larvae with fine mesh ichthyoplankton nets. Most cyprinids, catostomids, centrarchids, etc. build nests or lay demersal eggs, reducing the effectiveness of this technique. Electrofishing allows large areas of water to be covered in a relatively short time. The capture of concentrations of mature and/or running fish can be pinpointed and the potential location of spawning grounds verified by replication. The criteria used to identify specimens ready to spawn are listed in Table 3.4-4. The presence of ripe fish and concentrations of mature fish were used to locate spawning grounds. The timing of spawning was determined by computing condition factors (condition factor declines due to loss of gametes and energy loss associated with spawning activity).

Winter fish studies in the discharge canal consisted of 24-hour trap net collections (mesh size: 1 inch bar). Fish were tagged by distinct fin clips representing capture on a particular date (NSP undated).

3.4.2 RESULTS

3.4.2.1 Fishes of the Study Area

Several studies have censused the ichthyofauna of the Mississippi River drainage above St. Anthony Falls. A total of 68 species has been recorded (Table 3.4-5). A list of the common and scientific names for these species is presented in Table 3.4-6. The 40 species taken in the present study are identified in Table 3.4-5.

The MPCA 1975 316(a) guidelines list 64 species as being indigenous above St. Anthony Falls (Table 3.4-7). All of the species caught in the present study occur in the MPCA list. Table 3.4-8 is a list of representative important species as determined by the MPCA. Ten of the 25 species listed are not known to occur above St. Anthony Falls. Nine of the remaining 15 species have been captured in the present study.

According to the United States Fish and Wildlife Service (USFWS) (1974, p. 4-6), there are no endangered fish species in the Upper Mississippi River. The crystal darter, Ammocrypta asprella, may be placed on the 1976 list of endangered species (Williams 1975). Other species which will be considered for the 1976 list include those species listed by Miller (1972, p. 247-248) as rare in Minnesota (lake sturgeon, shovelnose sturgeon and paddlefish) (Williams 1975). According to Mr. Floyd Henneger of the Minnesota DNR, the 1975 federal list is the current official list for Minnesota. None of the aforementioned species have been caught in the Mississippi above St. Anthony Falls.

Details of the fish species in the study area and their relation to the thermal discharge follow.

3.4.2.2 Electrofishing

Pre-Operational Electrofishing

A review of the electrofishing data by sector during the pre-operational phase of the study provides insight into 1)natural variations within areas with time and 2) sector preference without thermal addition. The pre-operational electrofishing data are presented in Table 3.4-9. In terms of the number of individuals caught shorthead redhorse and carp ranked first and second, respectively. Shorthead redhorse were always more abundant than carp, except in Sector A in 1968 when the reverse was true. In all years for all sectors (except Sector C in 1969), shorthead redhorse and carp accounted for more than 75 percent by number of the species captured (range: 75.5 to 93.2 percent). The relative abundance of these two species for all sectors combined remained stable during the two-year pre-operational study, changing by less than 10 percent. Other species captured included silver redhorse, black crappie, white sucker, smallmouth bass, walleye, northern pike, bullheads, rock bass, burbot, logperch and bluegill.

Operational Electrofishing

Immediate Discharge Area

The power plant discharge canal is within the immediate discharge zone (refer Table 2.6-2) and will be designated as such for purposes of this demonstration. Canal and ambient temperatures for a given sampling date are the maximum and minimum temperatures, respectively, recorded for that particular sampling date. This will allow for display of maximum temperatures and ΔT's. It is unlikely, however, that all fish were caught at the maximum temperature recorded.

Electrofishing was conducted on June 22 and June 28 in the discharge canal during 1972. On June 22, canal temperatures were about 27°F (15.0°C) above the ambient of 69.8°F (21.0°C). Carp, smallmouth bass, northern redhorse and silver redhorse were captured on June 22. Carp were most abundant. Only one smallmouth bass was taken in 17 minutes of electrofishing.

Carp, brown bullhead, smallmouth bass, walleye, and silver redhorse were caught in the discharge on June 28. Again, carp were most abundant. Two walleye and two smallmouth bass were caught in 18 minutes of electrofishing. Canal temperatures (85.5°F [29.7°C]) were about 16.2°F (9.0°C) above ambient.

Sampling was conducted from January through September during 1973. The data of Hopwood (March through September) were plotted as catch/electrofishing-hour against time (Figures 3.4-8 through 3.4-11). April data were not used as time of shocking was not recorded.

January and February data were not graphed as the work was not done by Hopwood.

In all, six fish were taken during January and February electro-shocking (1 northern pike, 3 carp, 1 shorthead redhorse and 1 silver redhorse). No fish were taken in the discharge in March. On April 5 and 16 when the plant was not operating, carp, shorthead redhorse and one northern pike were captured.

In the late spring, the plant was not operating. Many more rough fish than game fish were caught in the discharge, probably a reflection of the general relative abundance of rough and sport species (Figure 3.4-8 and 3.4-9). When the plant went on line at the end of May, conditions were similar. Large numbers of rough fish, principally carp (Figure 3.4-10), were found in the discharge canal with the catch/electrofishing-hour for rough fish ranging from 4 to 150. Sport fish catch was usually below 20 for this time period (late May to September). Carp were a major constituent of the rough fish canal catch throughout the summer. Shorthead redhorse, while abundant in the main stream of the river, generally avoided the heated discharge.

Smallmouth bass catch was plotted (Figure 3.4-11) because of their importance in the fall canal sport fishery in 1973. Catch of smallmouth bass was usually below 10 fish per electrofishing-hour. Walleye, another fall canal sport fish, generally avoided the canal in the summer.

Data were graphed for 1974 electrofishing catch in the discharge canal (Figures 3.4-12 to 3.4-16). Rough fish frequented the canal quite extensively throughout the spring and early summer with little regard to thermal regime (Figure 3.4-12). A general decline was noted in July and all fish were gone from the discharge by July 22. Carp (Figure 3.4-13) and shorthead redhorse (Figure 3.4-14) dominated the rough fish catch. Discharge temperatures appeared to drive out the shorthead, as none were caught after mid-June. The large catch of rough fish noted on May 22 was composed mostly of carp, shorthead redhorse and silver redhorse.

Smallmouth bass and other gamefish were found in the discharge but in very low numbers (Figures 3.4-15 and 3.4-16) and, as in 1973, in much lower numbers than rough fish. It is of interest that they were found in the canal at 44.6°F (7.0°C) and 93.2°F (34.0°C). In general, fewer than 10 fish/electrofishing-hour were caught.

<u>Intermediate Discharge Area</u>

The intermediate discharge area is that portion of the river encompassing the 3°F (2°C) isotherm. One of the difficulties in defining this area for electroshocking data is that the natural, daily temperature variation may be close to 3°F during the late spring, summer and early fall. Also, cross-sectional surface temperatures vary at any given time. Thermal survey data (refer Table 2.6-2) were used to designate the area bounded by the 3°F (2°C) isotherm. A riffle area, beginning about 3/4 mile from the discharge and extending downstream for about 1/2 mile on the south shore of the river, was chosen as representative of the intermediate discharge area.

The intermediate discharge zone was sampled on two dates in 1972. On June 22, six species were captured, including walleye, carp, black crappie, smallmouth bass, shorthead redhorse and silver redhorse. Rough fish dominated the catch (102 fish/electrofishing-hour compared to 18 game fish/electrofishing-hour). The temperature was 75.2°F (24.0°C), which was 2.7°F (1.5°C) above ambient. On June 28, shorthead redhorse, carp, black bullhead, smallmouth bass and silver redhorse were captured. The rough fish to game fish ratio was 18:1. Total fish catch averaged 190 fish/electrofishing-hour.

During 1973, the intermediate discharge area was sampled on 16 dates. Data on the abundance of rough and game fish are presented in Figures 3.4-17 and 3.4-18. Rough fish (shorthead redhorse, silver redhorse, white sucker and carp) were most abundant in late May - early June and again in early September. Numbers were relatively high throughout the summer. Game fish caught included northern pike, walleye, black crappie and smallmouth bass. Their abundance was relatively low, as they were captured on only about 30 percent of the sampling days. Peak abundance occurred in mid-June when temperatures ranged from 68.9°F (20.5°C) to 77.0°F (25.0°C). Temperatures were running from 0 to 6.3°F (3.5°C) above ambient at that time.

Fish were sampled on 12 dates in 1974. As in 1973, the greatest numbers were caught in late May - early June, falling off in early July (Figure 3.4-19). Species composition of rough fish was the same as in 1973. Game fish abundance was highest in late May and late June (Figure 3.4-20). The species caught included northern pike, walleye, smallmouth bass, black crappie and rock bass. Rock bass were not caught in 1973.

<u>Outer Discharge Area</u>

The portion of the river representative of the outer discharge zone was along the southern shore of a large oxbow island across the river from the discharge canal. Electrofishing runs in this area paralleled the heated discharge.

The outer discharge area was sampled twice in 1972. Five species were captured on June 22 when the water temperature was 69.8°F (21.0°C). Catch/electrofishing-hour was 30 silver redhorse, 24 white sucker, 18 smallmouth bass, 18 black crappie and 8 shorthead redhorse. On June 28, six species were caught, representing a total catch rate of 100 fish/electrofishing-hour. Water temperature was 70.5°F (21.4°C). Smallmouth bass was second in abundance; only silver redhorse was caught more frequently. Carp, shorthead redhorse, northern pike and white sucker, in decreasing order of abundance, were also captured.

The outer discharge area was sampled on 28 days in 1973. Relative abundance of rough fish is plotted in Figure 3.4-21. The five species of rough fish captured were shorthead redhorse, carp, silver redhorse, white sucker and black bullhead. Catch/electrofishing-hour was highest in May and lowest in August. On three dates (September 4, 12 and 17), the thermal plume was detected in the outer discharge area. Game fish catch was low with a noticeable peak on June 11 (Figure 3.4-22), due mainly to abundance of black crappie. Other species of game fish captured in this area in 1973 were smallmouth bass and northern pike.

Rough fish catch data for the outer discharge area in 1974 are presented in Figure 3.4-23. As in 1973, good catches were made in May. These high early season catches in both years may be associated with white sucker and redhorse in the riffles during the spawning season. Catch remained relatively high until mid-June. Catches of game fish were low in 1974 except on June 11, when, as in 1973, the relative abundance of black crappie was very high (Figure 3.4-24). On June 11, the temperature was about 10°F (18.0°C) lower in 1974 than in 1973.

Adjacent Water Body Segment

The section of river designated as the adjacent water body segment is located in Sector A in a riffle area on the north side of Cedar Island. Because the Mississippi River near the Monticello Site is relatively free from pollution, the waters above the plant site are considered to represent waters without poi: sources of stress. This area is about one mile above the discharge canal. The riffle habitat allows comparison to similar habitats in the intermediate discharge area and the outer discharge area.

In 1972, fish were sampled on two dates in the adjacent water body segment. On July 21, two runs were made at an ambient temperature of about 66°F (18.9°C). Nine species were caught: northern pike, walleye, black crappie, smallmouth bass, shorthead redhorse, silver redhorse, carp, black bullhead and white sucker. Black crappie and smallmouth bass were the most frequently caught game fish, at 21 and 20 fish/electrofishing-hour, respectively. Carp, shorthead redhorse and silver redhorse were the most common rough fish at 95, 45 and 31 fish/electrofishing-hour, respectively.

On July 7, 1972, two runs were made at about 72°F (22.2°C). Six species were caught: walleye, smallmouth bass, shorthead redhorse, silver redhorse, carp and white sucker. Smallmouth bass and walleye were caught at the rate of 10 and 2/electrofishing-hour. Carp was the most common rough fish at 30 fish/electrofishing-hour. Rough fish again accounted for the majority of the catch at 78 fish/ electrofishing-hour as compared to 12 game fish/electrofishing-hour.

During 1973, sampling was performed on four dates (June 26, July 27, August 24 and September 4). Temperatures ranged from 68.5°F (20.3°C) to 74.3°F (23.5°C). Although no game fish were caught during July and September, northern pike and smallmouth bass were relatively abundant in June (29 percent of the total catch) at 3 and 7/ electrofishing-hour, respectively. In August, many game fish were caught (8 black crappie and 8 smallmouth bass/electrofishing-hour) but the catch was low compared to that of rough fish. In June, carp, shorthead redhorse and silver redhorse were caught at a rate of 14, 7 and 4 fish/electrofishing-hour, respectively. No rough fish were caught in July. Catches of rough fish went up dramatically in August and September to totals of 185 and 102/electrofishing-hour, respectively.

Five dates were sampled in 1974 (April 17, May 3, May 24, June 7 and August 6). Ambient temperatures ranged from 40.1°F (4.5°C) to 71.6°F (22.0°C). No game fish were caught on any of the sampling dates in that portion of Sector A designated as the adjacent water body segment. Game fish were caught in other portions of Sector A on April 25, when temperatures reached 50°F (10.0°C), until the last sampling date. Rough fish caught included shorthead redhorse, silver redhorse, carp, black bullhead and white sucker. Silver redhorse was the most common fish caught on three of five sampling dates. Rough fish catches/electrofishing-hour for the five dates were 64, 60, 240, 240 and 180, respectively.

3.4.2.3 Seining

Pre-operational Seining

During the pre-operational seining study, a total of 7,248 fish were collected. Their relative abundance is presented in Table 3.4-10. According to Morgenweck (1971, p 13):

> "The bigmouth shiner, bluntnose minnow, common shiner, hornyhead chub, johnny darter, sand shiner, smallmouth bass, spotfin shiner, and white sucker had the most widespread distribution. They were found at each station. The longnose dace and redhorse sucker were collected at five of six stations. The blacknose dace was collected at four stations; the creek chub at three; the black bullhead at two; the black crappie, golden shiner, and rock bass were each collected at one station."

The species composition at the stations was established after two weeks of seining and only minor fluctuations were observed after that.

Operational Seining

A total of 7,599 fish were seined during the operational study. Data on species totals (Table 3.4-11), although not expressed in catch-per-unit-effort, were transformed to catch-per-unit-effort for comparison with the pre-operational data. According to Ott (1973, p. 13 and 17):

> The most widely distributed fish (occurring at the most stations) were: spotfin shiner, bigmouth shiner, sand shiner, bluntnose minnow, common shiner, johnny darter, hornyhead chub, spottail shiner, redhorse sucker spp., white sucker, fathead minnow, smallmouth bass, trout-perch, blacknose dace, longnose dace, brassy minnow, logperch, largemouth bass, creek chub, and northern redbelly dace."

Comparison of Pre-operational and Operational Seining

The following stations were the same in the pre-operational and operational studies: pre-operational Upstream 1, operational Upstream 3; pre-operational Downstream 1, operational Downstream 1; Pre-operational Downstream 2, operational Downstream 3. Hopwood (1974b, p. C-267) concluded the following:

> "The species composition (by percentage) of pre-operational and post-operational samples are compared in Table (3.4-12). A rank correlation calculation was performed on these two sets of data, resulting in the values shown in Table (3.4-13). The correlation coefficients were: Upstream Station 3 = 0.873, Downstream Station 1 = 0.926, and Downstream Station 3 = 0.930."

Pre-operational Upstream 1 and operational Upstream 3 represent the unaffected water body segment. Pre-operational Downstream 1 and operational Downstream 1 were usually within the 3°F (2°C) isotherm of the discharge as were pre-operational Downstream 2 and operational Downstream 3.

Young-of-the-year Seining Study

Heberling (1975) conducted summer seining studies of abundance and growth of young-of-the-year smallmouth bass and white suckers in ambient waters both above and below the discharge and in the area of the discharge [discharge station average ΔT 3.3°F (1.8°C) in 1973 and 5.1°F (2.9°C) in 1974]. Relative abundance data are presented in Tables 3.4-14 and 3.4-15. Estimates of abundance for white suckers in June of 1974 were not attempted because the fish were too small to be distinguished from species of redhorse in the field. Two-way analysis of variance for each fish group revealed that there were no statistically significant differences (at the 0.05 level) in abundance between heated and control stations. Heberling noted, however, that abundance indices for 1973 were generally higher than 1974 and that, early in the summer, control areas showed higher levels of abundance (except 1974 smallmouth bass).

Growth of smallmouth bass was significantly faster in the heated water (at the 0.001 probability level for length and 0.025 level for weight). Similarly, white suckers grew significantly (at the 0.001 level) faster in the heated waters in 1973. The low numbers caught in 1974 did not warrant statistical testing.

3.4.2.4 Spawning

Spawning Areas

Eberley (1975, p. 14) sampled weekly from April 6 to August 14, 1974 along a 4-mile reach of river centered at the Monticello plant. The object of his investigation was to determine the spawning grounds of the carp, shorthead redhorse, silver redhorse and white sucker. Spawning areas are depicted in Figure 3.4-25. Eberley (1975, p. 54, 57, 61 and 63) concluded:

> "Male and female carp in spawning condition were captured in all types of habitat within the study area. A definite preference was shown for shallow backwater and marginal inundated areas where current was minimal. Along the river banks flooded areas containing debris or emergent vegetation were preferred. In many cases, it was impossible to capture more than a few specimens from these areas because of the dense vegetation or shallow depth. Bottom types in these areas could best be described as muck or silt; however, no substrate samples were collected.
>
> Shorthead and silver redhorse in spawning condition were generally captured on the upper stretches of shallow riffles. The two species were often collected at the same time and appeared to be utilizing similar areas for spawning activities. Current velocities on the spawning grounds ranged from 0.45 to 1.00 m/sec. Depths ranged from 90 to 150 cm, the mode occurring in the 100-120 cm range.
>
> Several spawning areas were identified within the study area. Substrate samples were collected from the four sites where the greatest number of specimens in spawning condition were collected. Site 1 was near the top of Cedar Island along the south side; site 2 was located between Cedar and Beaver Islands, along the south side of Beaver Island; site 3 was in the small oxbow just downstream from the discharge canal; site 4 was located upstream from Montissippi Park on the south side of the river.

The mean percent composition of different particle sizes, by weight for samples collected from each site is listed in Table (3.4-16). Particles classified as cobble or rubble comprised at least 59% of the mean total weight at all sites. Gravel was less abundant and consisted of 13.0, 14.1, 38.9, and 12.8 percent of the total weight for sites 1-4, respectively. Silt was a small fraction of the total weight at each site and comprised less than 0.1% in each case.

Males were more abundant on the riffles than females. Most of the females captured that were in spawning condition were collected from deeper water areas adjacent to the riffles.

White suckers in spawning condition were also captured on riffles; not on the upper portions, but farther downstream in shallower, faster flowing water than either species of redhorse. Of the spawning areas shown in Figure (3.4-25), white suckers in spawning condition were collected from all but two; the area between Cedar and Beaver Islands, and the area upstream from Montissippi Park on the south side of the river.

Current velocities from 0.85 to 1.65 m/sec were recorded in the spawning areas. Depths varies between 50 and 105 cm, the mode occurring in the 80-100 cm range.

Substrate samples were collected from the four sites where the greatest number of specimens in spawning condition were collected. Site 1 was located on the south side of Cedar Island; site 2 was along the north side of the river directly across from the plant site; site 3 was in the small oxbow downstream from the discharge canal, and site 4 was adjacent to the small island downstream from the discharge canal.

The mean percent composition of samples collected at each site is listed in Table (3.4-17) by weight for each particle size. Pebbles comprised 44.0, 46.5, 37.2, and 70.8 percent of the total weight for sites 1-4, respectively. Gravel was more abundant than pebbles at each site except site 4 and comprised 52.9, 52.2, 56.6 and 20.7 percent of the total weight for sites 1-4, respectively. Particles classified as cobbles comprised less than 8.0% of the total weight at each site. Silt was less than 0.2% of the total weight for each site.

As with the redhorse, males were more common on the spawning grounds, with females most often collected in adjacent waters. In many instances males only were captured on the riffles."

During the study of spawning areas, it became apparent that more ripe males were being captured than ripe females. It appears that both physiological and behavioral processes are responsible for this disparity. It is likely that males mature sooner than females both in a given year and at an earlier age. This would place males on the spawning grounds longer in any given year and in greater numbers than females. Also, for the redhorse and white suckers, females only venture onto the spawning grounds when they are ready to spawn, departing upon completion (Eberley 1975, p. 69). Additionally, if significant spawning occurred at night (Eberley 1975, p. 7-9), more males would be captured on the spawning grounds during the daytime sampling.

Some preliminary work by Hopwood (1974b, C-255 to C-256) in 1973 suggested that black crappie spawn in the study area.

Information from the literature on the reproductive habits of 26 species captured during the present study is presented in Table 3.4-18. In addition to the five species that are known to spawn in the study area (carp, white sucker, shorthead redhorse, silver redhorse and black crappie), the data gathered in Table 3.4-18 would indicate that other species (spottail shiner, spotfin shiner, bigmouth shiner, long-nose dace, creek chub, smallmouth bass, bluegill, white crappie, johnny darter and walleye) may spawn in the study area. Other species have more restricted spawning areas, such as flooded plains, still backwaters, weed cover so that they may or may not spawn in the study area. These species include bowfin, northern pike, bluntnose minnow, black and brown bullhead, trout-perch, burbot, rock bass, largemouth bass, yellow perch, and logperch.

Time of Spawning

According to Heberling (1975), both male and female carp in spawning condition were caught throughout the spring and summer. Shorthead redhorse spawned from about the end of April to the beginning of June, commencing at about 52°F (11.1°C). Silver redhorse spawned at about the same time. White sucker spawned in late April or early May at about 50 to 53.6°F (10.0 to 12.0°C).

Additional Information on Reproduction of Fishes Inhabiting the Monticello Area

The plant was not generating during April and most of May 1974 when the redhorse and white sucker were spawning. The discharge canal temperature was about 84°F (28.9°C) at the end of May 1974. Most spawning presumably would occur at lower temperatures. At higher temperatures, some eggs may not incubate properly.

Development of young-of-the-year smallmouth bass and white sucker occurred both in heated and unheated waters (see section on young-of-the-year seining). The capture of young-of-the-year smallmouth bass would indicate spawning of this species in the reach of river near the power plant.

The reproductive capacity of fish living below the plant site should not be adversely affected by plant operation, as the ΔT

would be 3°F (2°C) or less. Most spawning occurs during the spring freshet or in early summer when discharges are expected to be high. At these times, the proportion of river water heated by the plant would be lowered.

Larvae drifting by the plant may be entrained by the heated discharge. The time that larvae will be entrained will vary. In a worst case situation, larvae could drift in heated water [3°F (1.7°C)] for at least 3.5 miles downstream from the discharge under summer, low flow conditions. It is anticipated that the majority of spawning will be completed before summer low-flow conditions are reached and that a ΔT of 3°F (1.7°C) would have little effect on development.

3.4.2.5 Creel Census

The creel census near the Monticello site was conducted during two operational years (1972 and 1973), therefore no comparisons with pre-operational conditions are possible.

Two types of information regarding recreational fishing can be gathered from the creel census data: the current (operational) fishing pressure applied in the area by sport fishermen and the catch rates in the discharge canal compared to non-heated adjacent waters.

During 1972 and 1973, estimated man-hours of fishing over the entire study area amounted to 2,569 and 2,418 hours, respectively (NSP 1974b, p. C-281). There was very little boat activity in this section of the river due to its shallowness. The great majority of the anglers were bank fishermen who still-fished with natural bait for no specific species.

A fall creel census was conducted in November of 1973 in the discharge canal. The catch rates were 2.7 fish/hour and 4.56 pound/hour for smallmouth bass and 3.45 fish/hour and 3.45 pound/hour for walleye (NSP 1974a, p. C-291). The mean catch rate for smallmouth bass during the regular 1973 creel census from May to October was 0.24 fish/hour and 0.10 fish/hour for walleye (NSP 1974b, p. C-283). These high catch rates would indicate that smallmouth bass and walleye are concentrating in the discharge canal in the fall and represent a new potential sport fishery.

3.4.2.6 Attraction and/or Avoidance of the Discharge Canal and Resultant Condition Factors

As discussed by NSP (1975):

> "Fish can be expected to be attracted to the discharge canal in a sequential pattern beginning as early as September. As ambient river temperature declines, those fish with higher temperature preferenda can be expected to enter the canal sooner than those with lower preferenda. When ambient river temperature drops below 50°F (10°C) species that find the canal temperature and habitat conditions favorable will be present. Species composition can indicate preference of a species for temperature regimes encountered or unique habitat condition found in the canal (they are found in the canal without thermal discharge). Table (3.4-19) shows species composition resulting from a combination of all sampling gear (trapnet, electrofishing, SCUBA, visual observation) for months of cold shock susceptibility. Comparison of Table (3.4-19) with relative abundance data gathered in a four-mile stretch of river near the plant from 1968 to 1972 provides a basis to determine selective attraction or repulsion of fish in the discharge canal. Black bullhead (Ictalurus melas), rockbass (Ambloplites rupestris), bluegill sunfish (Lepomis macrochirus), yellow bullhead (Ictalurus natalis) and walleye (Stizostedion vitreum) comprise a

higher percent composition in the canal than river, while smallmouth bass (Micropterus dolomieui), carp (Cyprinus carpio), shorthead redhorse (Moxostoma macrolepidotum), white sucker (Catostomus commersoni), and silver redhorse (Moxostoma anisurum) comprise a lower percent composition.

Perhaps two major factors influencing species compositon of the discharge canal are current velocity and bottom substrate type as it relates to food availability. Species displaying attraction during the winter are more suited to slower currents encountered in the canal while those repulsed generally prefer current velocities typical of the river. Trophic niche of attracted or repulsed species must also interrelate to canal food availability. Species attracted to the canal are generally carnivorous and derive their food source from entrained animal matter, small forage species, or to a lesser extent resident benthic macroinvertebrates. Because suitable substrate for attachment and growth of periphytic organisms is limited, herbivourous fish species would find little available food. Four or five species favoring the river rather than canal are considered dominantly herbivorous.

Fish density is best expressed as number per unit area, however, standing crop (kg/ha) is a more realistic parameter when considering possibility of overcrowding in the discharge canal. A unit area of water can support higher fish densities if fish are of a small average size. Carrying capacity (kg/ha) of a water body or a segment of a water body is density independent. High densities alone do not indicate standing crop levels in excess of carrying capacity. Population and standing crop levels for selected species are shown in Table (3.4-20). Estimates were derived from mark-recapture experiments performed during the winter of 1974-1975.

Standing crop levels of all species except rockbass are very low and reflect low canal carrying capacity for these species. Standing crop levels of the rockbass are higher, but are still in the low range when compared to productive warm-water lakes. None of the standing crop estimates shows high congregations of fishes indicating "forced" residence in the discharge canal resulting from temperature preference. Higher rockbass abundance is more likely determined by a combination of preferred temperature and habitat suitability (food, substrate, current) rather than temperature alone.

The best indication of overall well-being of fish is a condition factor index. This index is useful in describing the "plumpness" of fish. Low condition factors indicate the presence of natural or man-induced sources of stress. In the case of fish in the discharge canal, it can be used to indicate standing crop levels in excess of carrying capacity. Low condition indices ("skinny" fish) can indicate elevated metabolic demand and lack of adequate food. Table (3.4-21) presents calculated condition factors for fish sampled in the discharge canal during the winter of 1974-1975. The coefficient of condition was computed using the formula presented below:

$$K = \frac{W \times 10^5}{L^3}$$

Where: W = weight in grams
L = length in millimeters
and 10^5 is a factor to bring K near unity

All values for condition of fish in the discharge canal are within the normal range of variation for each species. Variation in coefficient of condition can result from habitat, sex, age, season and time of day. Condition factor as presented lends support to the previously made statement concerning lack of overcrowding. Low condition factors indicating abnormally high standing crop levels (overcrowding) are not found for fish in the canal."

During the spring and summer months, rough fish dominated the canal populations (Figures 3.4-8 to 3.4-16). In both 1973 and 1974, some fish remained in the canal when temperatures were 91-95°F (32.8-35°C) but most avoided the canal when temperatures reached 104°F (40.0°C) in late June 1973.

3.4.2.7 Fish Kills

As explained by NSP (1975):

"Mortality of fishes resulting from winter shutdowns has been systematically studied since March, 1974. Fish mortality experiments using caged fish have been performed in duplicate to determine rapid and scheduled shutdown effects. Several generalizations can be made based on these experiments and field observations during and after shutdowns. These are:

1. For some species, rapid shutdowns (return to ambient in less than two hours) present more severe consequences for fully acclimated fish than do schedule shutdowns (return to ambient in six hours or more). This may result from species specific rate sensitivity.

2. Discharge canal temperatures in relation to ambient temperatures and the exact temperature reduction regime influence the extent of "cold shock" kills.

3. "Cold shock" mortality can be expected to begin when canal temperatures exceed 50°F and ambient river temperatures are 33°F or lower. As canal temperatures rise above 50°F more species are affected.

4. Species potentially affected are those that display a preference for the unique habitat conditions found in the canal. Included in this group are black bullhead, rockbass, bluegill sunfish, yellow bullhead and walleye. Of this group bluegill sunfish, rockbass and walleye are most sensitive because of elevated lower incipient lethal temperatures for a given acclimation temperature.

5. Total number of fish killed is influenced by canal population density while total pound loss due to kill is a function of standing crop.

6. Canal population densities and standing crop levels affected by winter shutdowns are established in October and early November. The majority of these fish will be lost if three shutdowns occur during the "cold shock" susceptibility period. Large scale replacement of fish killed after each shutdown by immigrating fish is not likely to occur because of the sedentary nature of riverine fish species during winter months. Based on this premise, the predicted mortality for several species during November through March is as follows: rockbass 945 ± 301, bluegill sunfish 216 ± 138, black bullhead 264 ± 247.

7. Winter "cold shock" mortality has not adversely affected fish population in the river based on catch per unit effort data."

For additional information concerning fish reaction to shutdowns, refer to NSP (1975).

Entrainment Losses

Entrainment losses due to mechanical damage or ΔT will be addressed in the 316b demonstration document to be submitted by NSP.

3.4.3 DISCUSSION

3.4.3.1 Electrofishing

The dominant species sampled by electrofishing techniques were carp and shorthead redhorse. These two species constituted 75 to 93 percent of the catch in pre-operational years. Most of the river near the Monticello Site is considered "rough" fish habitat (Hopwood 1969, p. 22; 1970, p. 101). He mentions that, in 1968, shorthead redhorse were frequently the only species found in shallow riffles over gravel and small stones. Carp were most numerous in the pools, however they were not confined to deep, slow flowing areas. In 1969, Hopwood came to the same conclusions. He concluded that game fish catches were low because game fish inhabited small microhabitats within each sector. Although these microhabitats (brush piles, stumps, large boulders, etc.) are small compared to the overall area of each sector, they yield fairly high densities of game fish.

When the plant began generating, fish were found in the discharge canal. Carp were usually found in the discharge, as were smallmouth bass (but in much lower numbers than carp). Shorthead redhorse and walleye generally avoided the canal during periods of high temperature. Rough fish frequented the canal more extensively than game fish. This higher abundance of rough fish is a reflection of pre-operational relative abundance.

Rough fish dominated the catch in the intermediate discharge zone. Four rough fish (shorthead redhorse, carp, silver redhorse and white sucker) dominated the catches in the intermediate discharge area as they did the immediate discharge area. The catch/electro-fishing-hour was consistently higher in the intermediate discharge area than in the immediate discharge area in both 1973 and 1974. This was true whether or not the plant was generating.

The same general trends apply to the outer discharge area. Rough fish (shorthead redhorse, silver redhorse, carp and white sucker) dominated the catch. Catches were generally higher earlier in the season, possibly due to concentrations of redhorse and white sucker on the spawning beds.

The fewest game fish were caught in the adjacent water body segment. The low catch of game fish may reflect habitat preference or the lesser fishing effort in the adjacent water body segment. Game fish captured were northern pike, black crappie, walleye and smallmouth bass. Rough fish caught included shorthead redhorse, carp, silver redhorse, white sucker, black bullhead. The preponderance of rough fish in the riffle habitat in the adjacent water body segment supports the theory that the riffles are extensively used by rough fish and that the game fish are restricted to rather limited microhabitats.

3.4.3.2 Seining

Hopwood (1974b, p. C-267, 270) stated:

> "The high correlation of the data from preoperational and operational seining studies shows that the changes in species composition have been minor. The lower correlation of the data from Upstream Station 3 indicates that more change occurred at this station than at Downstream Station 1, which shows a higher correlation, despite the fact that Downstream Station was subject to the heated water. Other than added heat, possible causes of the minor changes in species composition observed at the three stations compared could be natural population fluctuation, sampling error, or alterations in the habitat. From these data it is possible to conclude that the addition of the heated water effluent had no significant effect on minnow population in the study area."

Young-of-the-Year Seining Study

Heberling (1975) summarized his study as follows:

> "The results of this study favorably agree with those that have been demonstrated by laboratory investigations. Based on abundance indices, there did appear to be some inhibitory action on spawning and/or egg hatching success in the thermally enriched section. However, temperature cannot be singled out as the only factor creating this phenomenon. Shortly after hatching, compensitory activities began to transpire in the heated zone. It is assumed that the lower density levels in the heated section caused reduced intra- and interspecific competition for food and space. This situation made the area more conducive to immigration by other YoY fish, and also enhanced the growth rate of the "resident" fish. Growth rate may have been stimulated by the warmer water which may have more closedly approximated temperatures that were optimal for growth. Because of this accelerated growth rate, a shorter period of time was spent in the smaller sizes and these fish were therefore less susceptible to early natural mortality losses. This combination of recruitment and elevated growth rate gave the impression of reduced mortality rates in the heated section (i.e., the downward slope of abundance with the time was not as steep as those of the control areas) so that by August, the fish densities in the heated section were essentially the same as those of the ambient zones.
>
> In terms of growth, the YoY fish in the heated section were generally one week ahead of the fish in the ambient zones. As the summer progressed, this size differential diminished, and by late August, fish in the three different areas were basically the same size.

In conclusion, this study has demonstrated that differences in both abundance and growth rate of YoY smallmouth bass and white sucker in heated and ambient sections did exist. However, these differences were ephemeral, because of the compensitory mechanisms of fishery populations.

The complex interaction of immigration, growth, and mortality rate functioned so that both the size and the density of these YoY fish equilibrated, and by the end of the first growing season there were no detectable differences."

3.4.3.3 Spawning and Reproduction

Spawning sites aroung the power plant site have been described for the carp, white sucker, shorthead redhorse, silver redhorse and black crappie. Capture of large numbers of young-of-the-year smallmouth bass indicates that this species spawns near the plant also. A review of the literature would indicate that additional species may find suitable habitat for spawning and consequently may spawn in the reach of river near the plant.

Spawning times for most species (except the burbot which is a winter spawner and carp which may spawn throughout the summer) are during the spring and early summer. The spring freshet would dilute the additional heat loading from the power plant, therefore reducing impact. The 3°F (2°C) isotherm may extend for a considerable distance below the plant but this small increase in temperature would probably have little impact except in the region of lethal temperature. At the time of year (low flow) when the 3°F (2°C) isotherm is most evident, most spawning would have already occurred and many of the larvae would have developed into fry or juveniles.

Recent investigations (Smith and Koenst 1975, p. 1) have elucidated the thermal requirements of walleye eggs and larvae. Optimum fertilization temperatures were 43-54°F (6-12°C) and optimum incubation temperatures were 48-59°F (9-15°C). Survival through yolk sac absorption was best at 48-70°F (9-21°C); survival to juvenile was greatest at 70°F (21°C). Growth of juvenile walleye was optimum at 72°F (22°C). Sudden temperature changes are not a significant lethal factor, except near the upper lethal temperatures [80.6-88.9°F (27.0-31.6°C)] or at very low temperatures [43°F (6°C)].

Smith and Koenst (1975, p. 35) conducted tests with walleye fry reared at one temperature and placed in a higher or lower temperature for 72 hrs. Five-day old fry reared at 43°F (6°C) were tested at 52°F (11°C), 61°F (16°C) and 70°F (21°C). Fry mortality (44 percent) occurred only at 70°F (21°C) [equivalent to a ΔT of 27°F (15°C)]. In tests with two-day old fry reared at 52°F (11°C) and tested at 43°F (6°C), 61°F (16°C) and 70°F (21°C), the lowest survival (58 percent) occurred at 43°F (6°C). This corresponds to a ΔT of -9°F (-5°C). At 61°F (16°C) there was no mortality and at 70°F (21°C), 78 percent of the fry survived. Seven-day old walleye fry reared at 70°F (21°C) were tested at 43°F (6°C), 52°F (11°C) and 61°F (16°C). Survival was 100 percent at 61°F (16°C), 91 percent at 52°F (11°C) and 0 percent at 43°F (6°C).

Survival is expected to be much greater in the Monticello thermal plume for two reasons. First, residence times in the thermal plume are expected to be much shorter than the 72 hours of the

Smith and Koenst (1975) study. The combined length of the immediate and intermediate discharge areas (about 3 miles) when calculated using low flow velocities (0.5 ft/sec) would lead to a residence time of about 8.7 hours. Second, the greatest mortalities of walleye fry were generally associated with large ΔT s. The area of the Mississippi River affected by the plant with ΔT's greater than 8°F is relatively small. During electrofishing runs in 1972, 1973 and 1974 in the intermediate discharge area (see section 3.4.2.2 and Figures 3.4-17 to 3.4-20), temperatures exceeding a ΔT of 8°F were recorded only once.

Webster (1954, p. 33) conducted studies with smallmouth bass in Cayuga Lake, New York. He found that ova in various stages of development were not affected by relatively rapid temperature changes within a range of 50°F (10.0°C) to 77°F (25.0°C). A time frame within which the experiments were conducted was not given, so the data cannot be directly applied to the Monticello thermal plume; however, it does not appear that short term residence would have any affect on smallmouth bass egg development.

Gamete production and subsequent spawning are actuated through the brain-pituitary-gonadal complex. Environmental and behavioral cues stimulate this mechanism. For example, aquarists commonly lower water temperature to induce cyprinids to breed in captivity (Liley 1969, p. 103). Courtship rituals or development of secondary sex characteristics are important components for successful spawning in some species. Edsall and Yocum (1972, p. 56) reported that yellow perch held at 39°F (3.9°C) for about six months had twice the reproductive success as perch held at 43°F (6.1°C). It appears that the reproductive strategy of the yellow perch involves a winter chill period. However, yellow perch are not likely to be abundant in the discharge canal, based on past collections from the canal. It is possible that spawning of yellow perch and walleye residing in the discharge canal may be reduced or eliminated (Edsall and Yocom 1972, p. 57). Some species, such as the carp and northern pike, which reside in the canal would not spawn in the canal due to undesirable habitat type. The effect of temperature on gonadal development is not known for most species.

3.4.3.4 Creel Census

The sport fishery in the Mississippi River near the Monticello plant is relatively small and is usually of secondary interest to other activities such as camping. Very little boat sport fishing was observed. The great majority of the anglers were bank fishermen who still-fished with natural bait for no specific species.

A creel census in November 1973 revealed that the canal provided an excellent sport fishery for smallmouth bass and walleye.

3.4.3.5 Attraction and/or Avoidance of the Discharge Canal

Some species of fish will be attracted to the discharge canal when river temperatures begin to decline in the fall. Species caught in the canal in the winter (November to February) include black bullhead, rock bass, bluegill, yellow bullhead, walleye, smallmouth bass, carp, shorthead redhorse, white sucker, silver redhorse, northern pike, burbot and black crappie. During the summer months, approximately the same species were caught in the discharge canal, but relative abundance declined as temperatures became stressful. Rough fish were much more abundant than game fish.

Heat is a basic stimulus for fish attraction to the discharge canal. However, because fish are also found in the canal without thermal addition, other factors, such as current velocity and food availability, must be considered important.

Standing crop estimates and condition factors of selected canal species did not indicate crowding or lack of food for these species in the discharge canal during the winter.

3.4.3.6 Fish Kills

Fish kills are most likely to occur in the winter when canal temperatures are above 50°F (10.0°C) and ambient temperatures are 33°F (0.5°C) or lower. Cold shock mortalities result when water temperatures decrease rapidly at a rate exceeding the compensatory mechanisms of the species. Bluegill, rock bass and walleye would be especially susceptible to cold shock due to elevated lower incipient lethal temperatures as discharge canal temperature increases.

In a worst cast situation, all fish in the discharge canal would die if several winter shutdowns occurred. The relatively small number of fish inhabiting the discharge, in addition to the natural mortality that occurs during each winter, would tend to minimize the impact of total mortality.

3.4.3.7 Matrix of Fish Data

Guidelines for a 316(a) Type I demonstration call for an accounting of fish distribution relative to various topics. These topics include occurrence in the immediate discharge area, intermediate discharge area, outer discharge area and adjacent water body segment under temperature regimes posed by the summer maximum, fall transitional, winter minimum and spring transitional. Information is also needed on threatened, endangered or unique species; species indicative of high or low water quality; nuisance potential; energy transfer; and historical significance.

A matrix is used to summarize these data (Table 3.4-22). Specific information, such as relative abundance and temperature, are found under the appropriate sub-sections within the text.

Only one fish, the bowfin, was deemed historically significant, however it is significant probably only to the professional ichthyologist. The bowfin is a transitional species related to the gars but with characteristics leading to the higher teleosts. It is the only living member of the order Amiiformes. It is widely distributed in the freshwaters of eastern North America.

All fishes are intimately involved in energy transfer within the aquatic ecosystem near the Monticello plant. The matrix defines forage species and predators. Since energy transfer involves complex food webs, the species are subjectively categorized into one of the two groups.

Several fishes are considered potential nuisance species. Bowfin are considered voracious, piscivorous predators, and, in sufficiently large numbers, may reduce populations of more desirable species. Bowfin do not appear to occur in great numbers in the study area. Carp is a prolific species and grows under a wide variety of environmental conditions. Although carp are harvested commercially in some parts of the United States, they are generally considered a nuisance. Their habit of stirring up sediment and eating aquatic vegetation creates turbidity, covers spawn and removes cover needed by other species. The catostomids and ictalurids may, under appropriate conditions, constitute nuisance species. Their bottom feeding habit may reduce game fish populations by removal of eggs and non-swimming larvae of favored species. They are also relatively prolific. Burbot are generally considered a nuisance species because they may be a serious predator on more valued species and may compete with these species for food.

The ambiguity of the terms "high" and "low" water quality leads to necessary speculation of the role of various species as water quality indicators. Water of low quality is generally considered as warm, turbid, with excessive algal or other plant growth and with depressed dissolved oxygen. Scott and Crossman (1973) was used as a life history source for the species in the matrix. The plasticity of many fish species with regard to all but oppressive water quality makes judgements subjective regarding water quality.

The matrix indicates that the full gamut of possible water quality indicators inhabit the study area.

No threatened or endangered species were caught in the study area. Some species were considered unique from an ichthyological standpoint in that they alone represent a particular family in the waters of the study area. Bowfin is the lone representative of the Amiidae; central mudminnow, Umbridae; burbot, Gadidae; banded killifish, Cyprinodontidae; and trout-perch, Percopsidae.

Occurrence of fishes in the various discharge areas at various times of the year was relatively clear-cut for the summer maximum and winter minimum categories in that the fish was either present or not present during sampling (if no sampling, then occurrence was unknown). Other species may have been present, but because they were not caught their occurrence is designated by an "N". (did not occur). Some species (forage fishes and YOY) were caught in the discharge during entrainment studies. Although they were not taken during regular trap net sampling, they might have remained in the discharge canal and thus were considered as occurring in the immediate discharge area during the winter minimum. The fall and spring transitional periods cover a longer time period so the probability of occurrence (even though not caught) is noted by a "L" (likely to occur). Some species such as the carp, short-head redhorse, silver redhorse, white sucker and smallmouth bass were ubiquitous and most likely would be caught in any area at any time of the year.

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FIGURE 3.4-1

A map of the Monticello ecological study area showing five electrofishing sectors. (From Hopwood 1973, p. C-380)

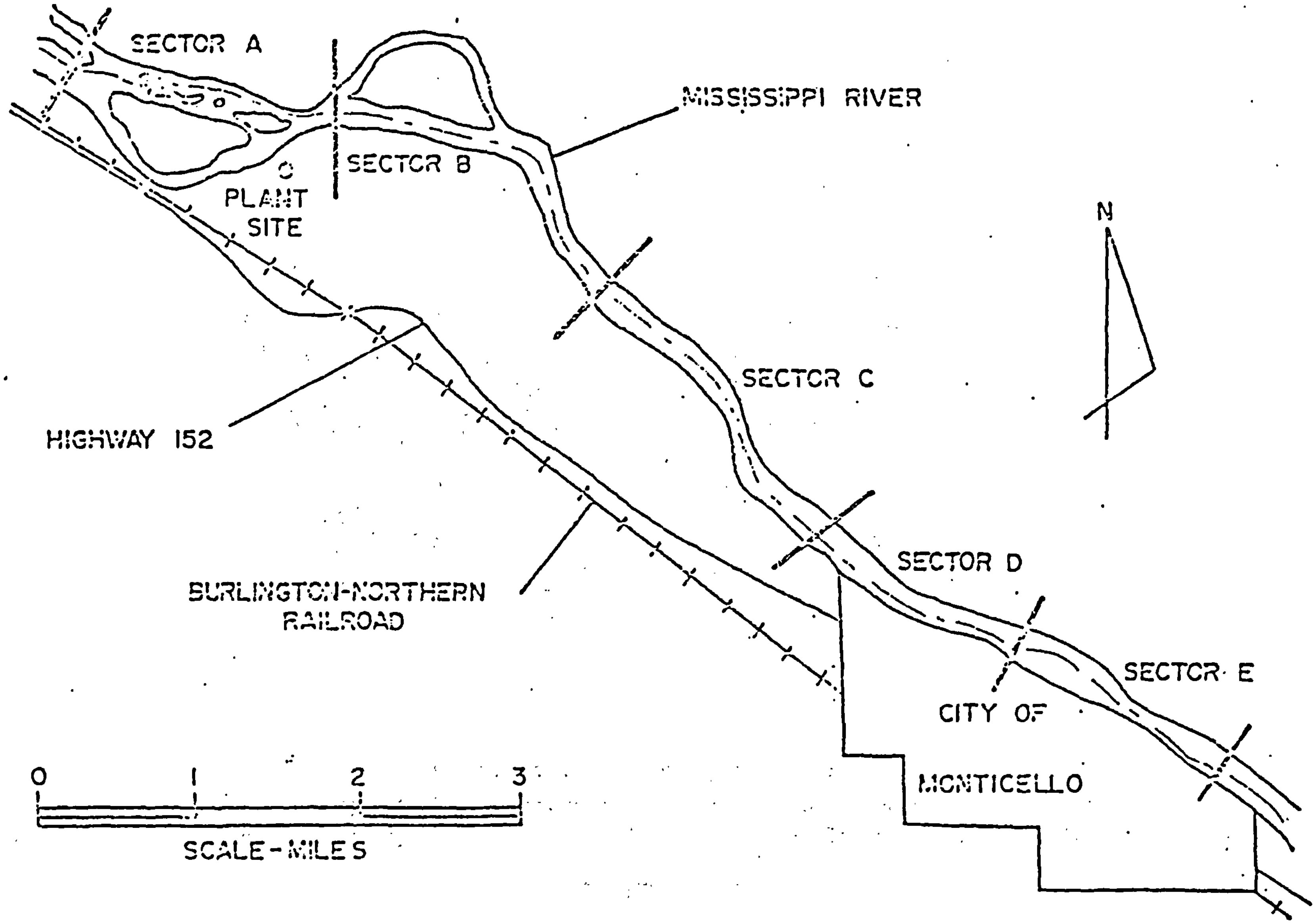

FIGURE 3.4-2

A map of the Mississippi River near Monticello, Minnesota showing the location of sounding ranges

(From Hopwood 1974a, p. 8)

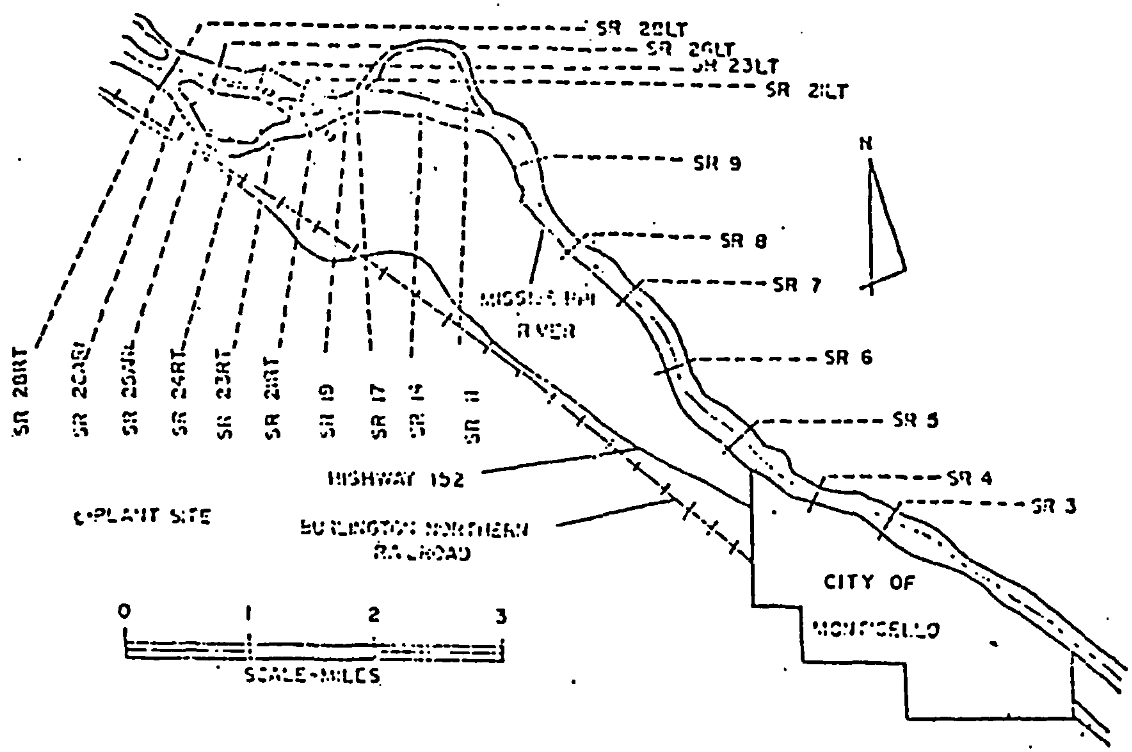

FIGURE 3.4-3

A map showing seining areas used in preoperational studies on fish populations. (From Hopwood 1974b, p. C-258)

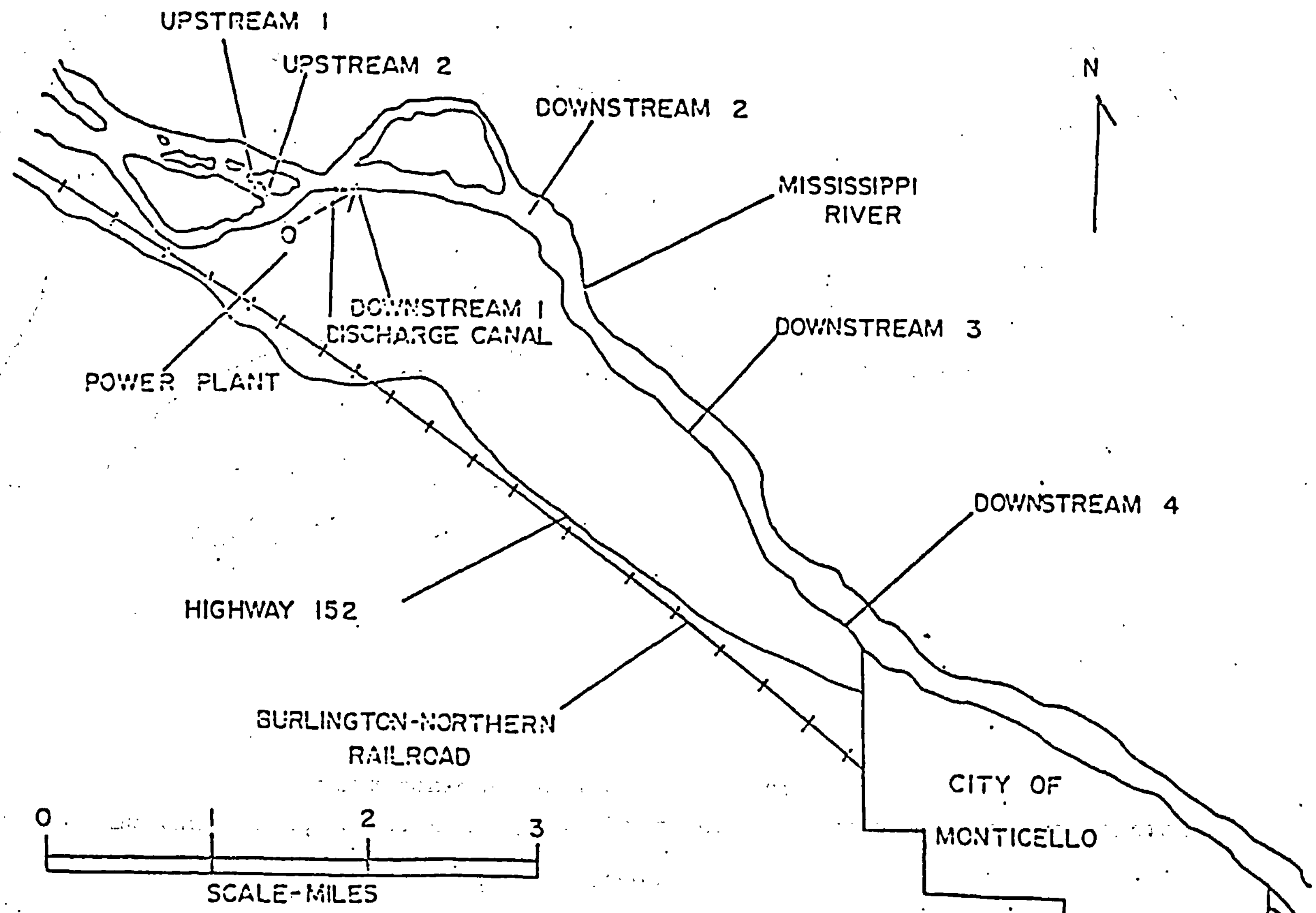

FIGURE 3.4-4

A map showing upstream seining areas used in operational studies on fish populations. (From Hopwood 1974b, p. C-260)

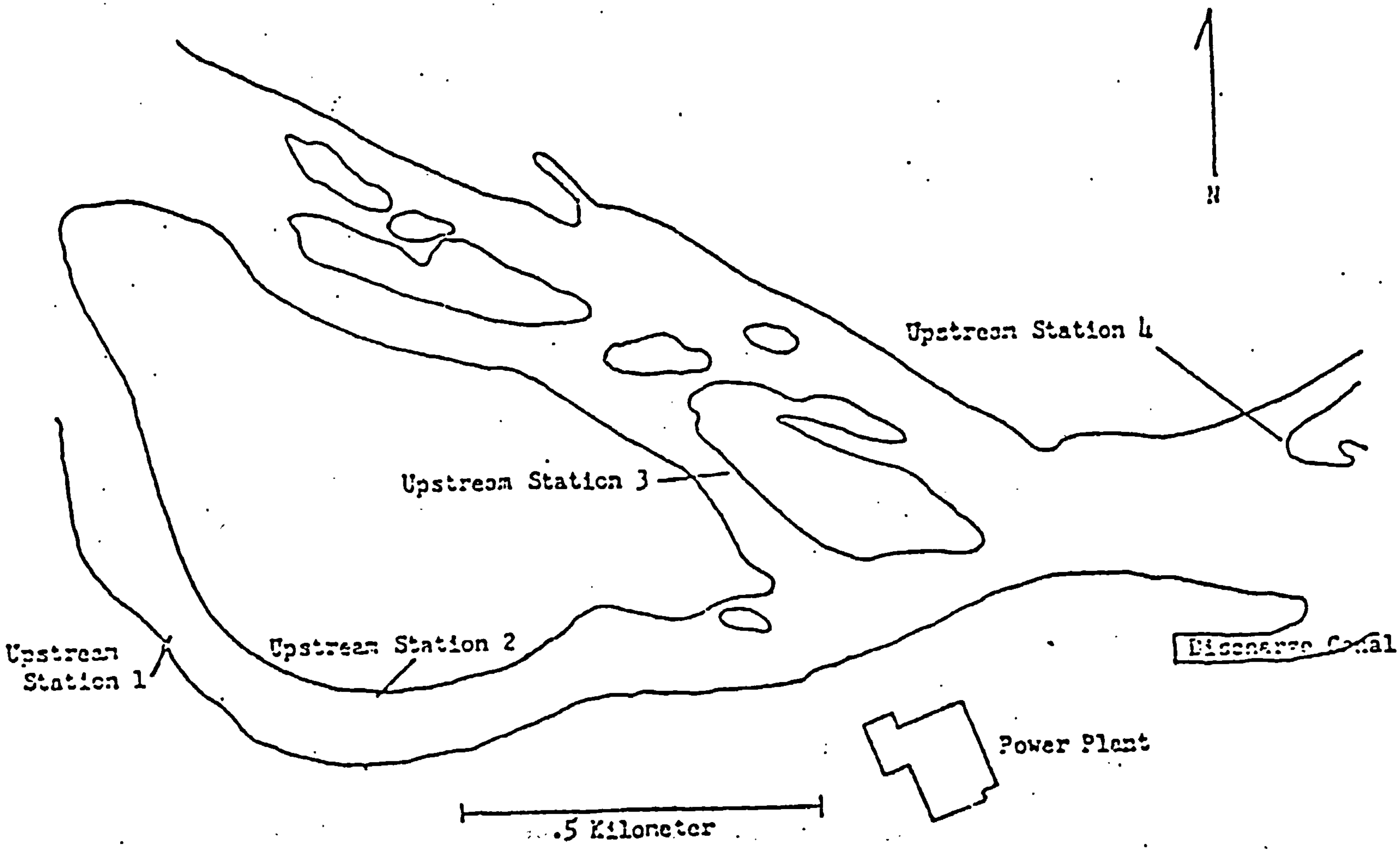

FIGURE 3.4-5

A map showing downstream seining areas used in operational studies on fish populations. (From Hopwood 1974b, p. C-261)

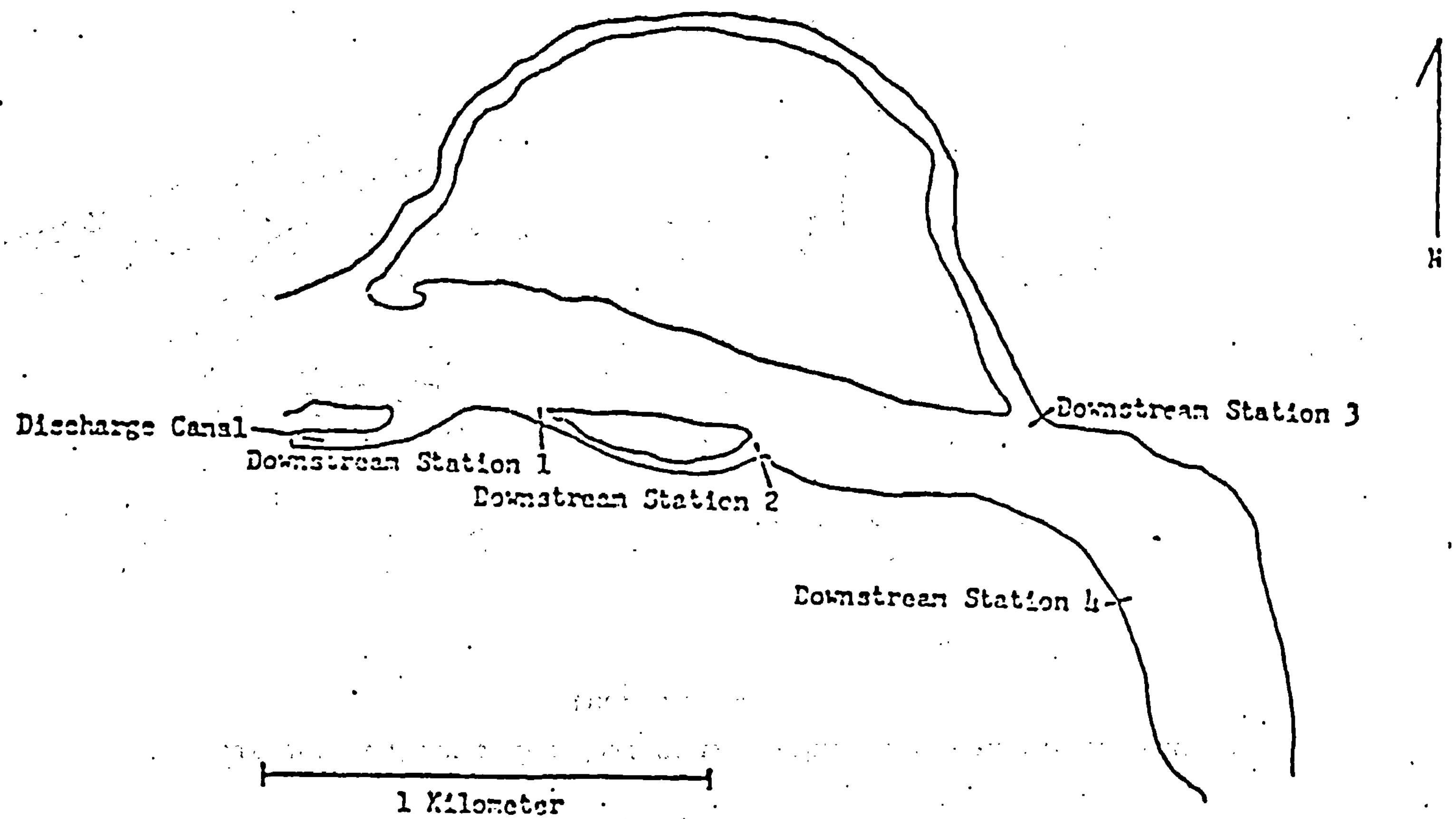

FIGURE 3.4-6

Seining stations for YOY smallmouth bass and white sucker (Heberling

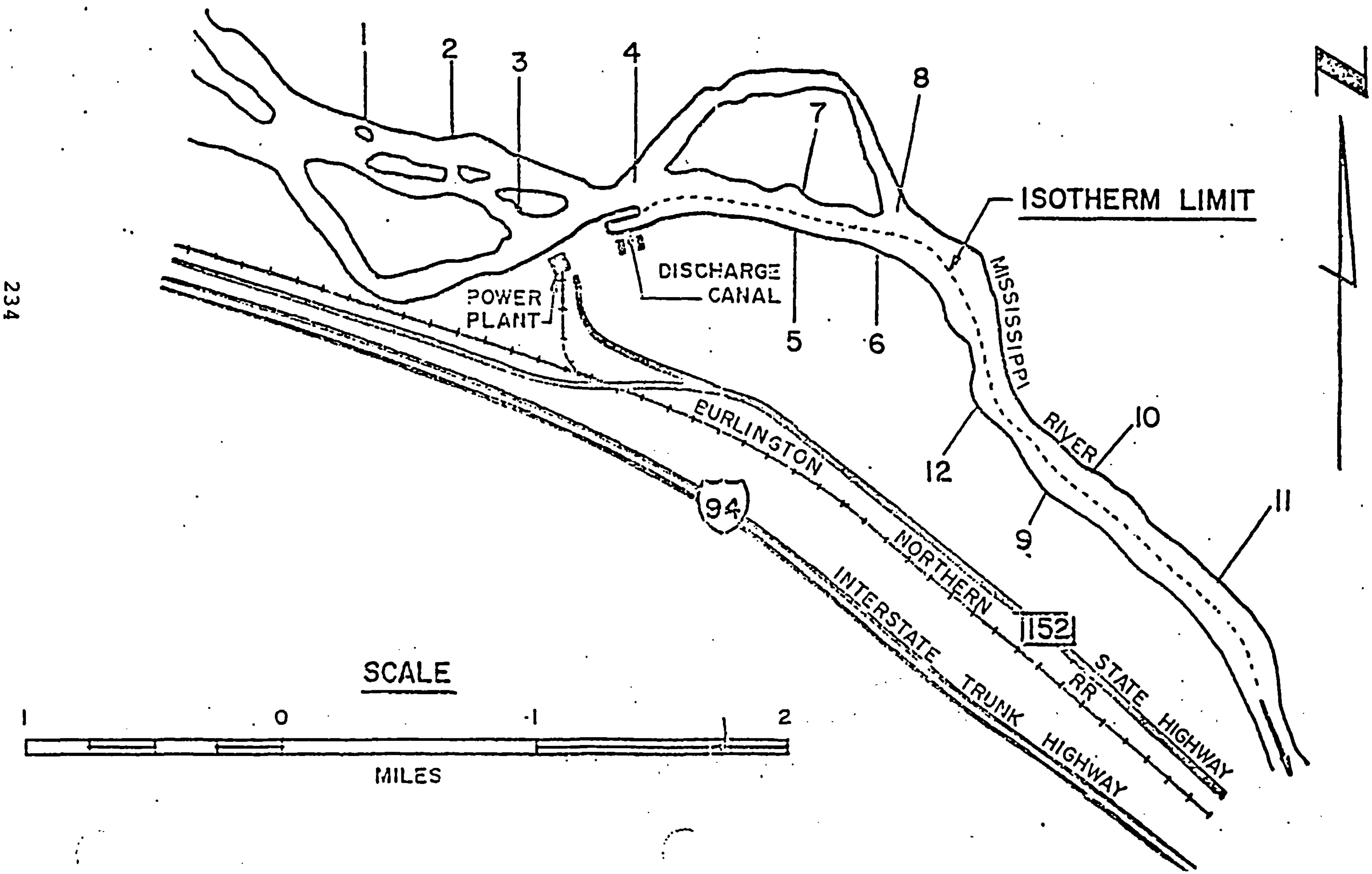

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FIGURE 3.4-7

Locations of sampling sites for the Monticello Creel Survey (1973)
(From NSP 1974b, p. C-274)

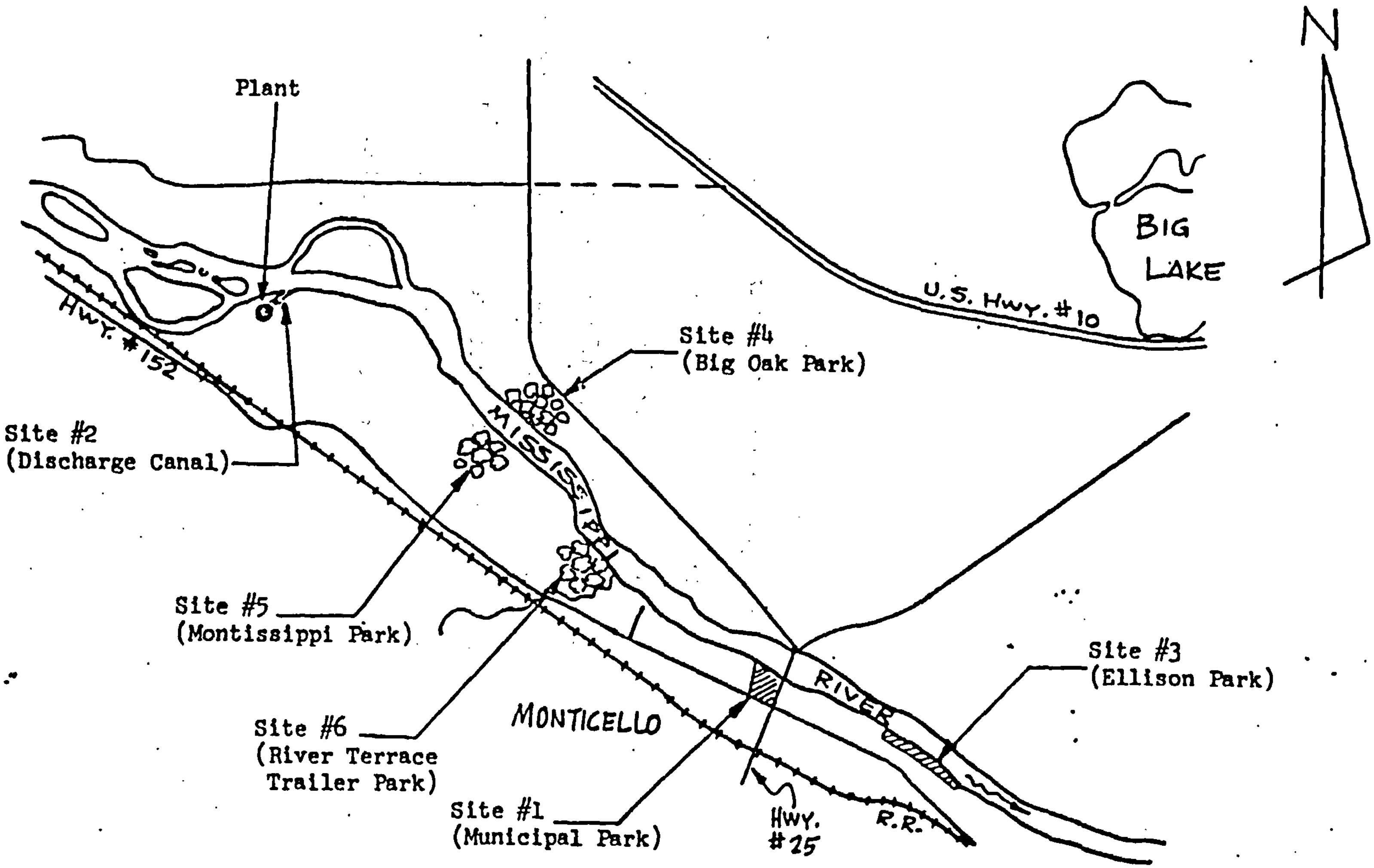


FIGURE 3.4-8

Catch per electrofishing-hours of rough fish in the immediate discharge area in 1973. Rough fish species included: shorthead redhorse, carp, silver redhorse, black bullhead, burbot, brown bullhead and white sucker. Triangles represent the maximum temperature recorded during electrofishing runs. Gaps in temperature data plots indicate water temperature was not taken.

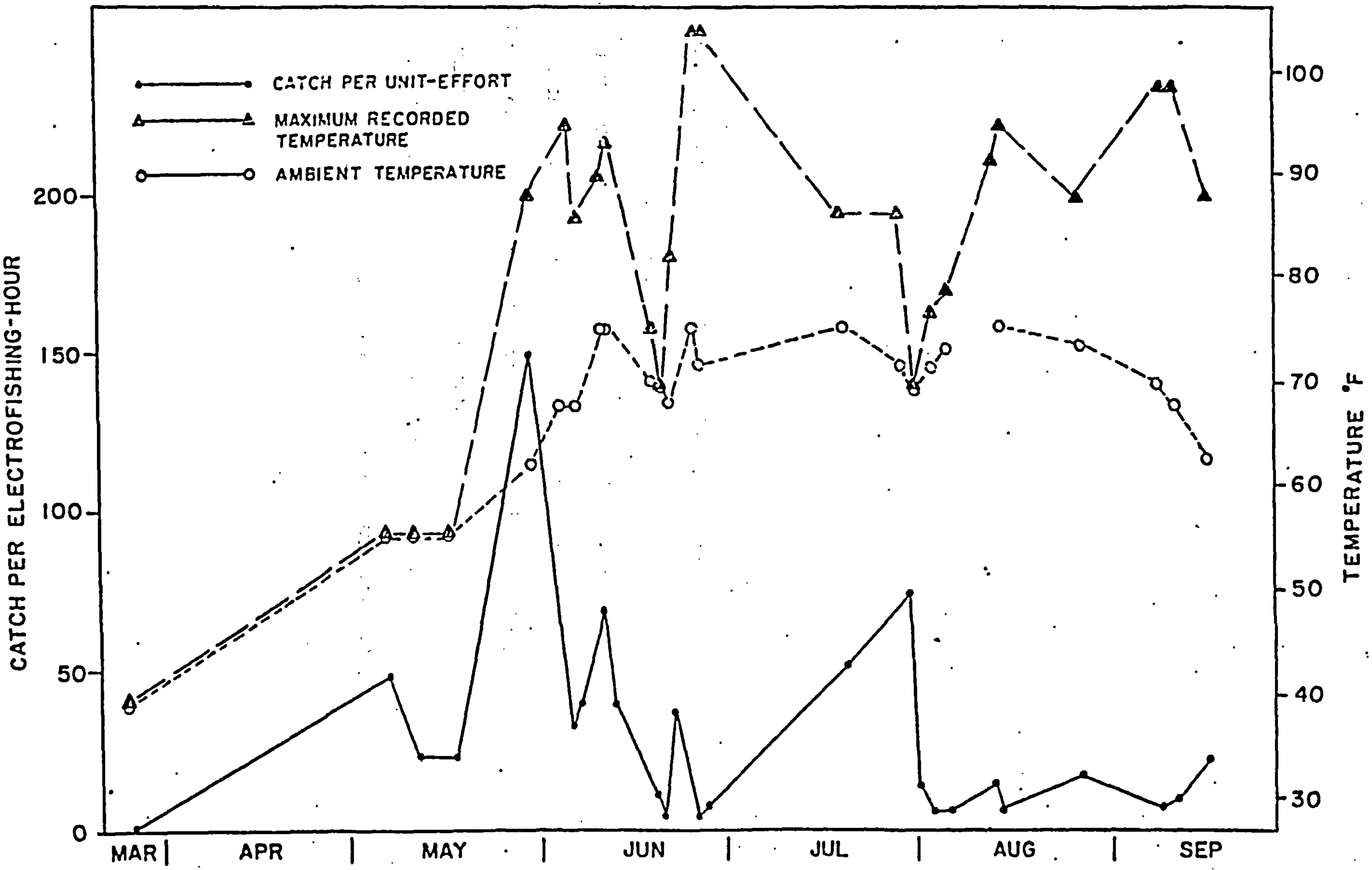

CATCH PER UNIT-EFFORT
MAXIMUM RECORDED TEMPERATURE
AMBIENT TEMPERATURE
CATCH PER ELECTROFISHING-HOUR
TEMPERATURE °F
0
50
100
150
200
30
40
50
60
70
80
90
100
MAR
APR
MAY
JUN
JUL
AUG
SEP

FIGURE 3.4-9

Catch per electrofishing-hour of game fish in the immediate discharge area in 1973. Game fish species included: rock bass, black crappie, walleye, northern pike, pumpkinseed, smallmouth bass and bluegill. Triangles represent the maximum temperature recorded during electrofishing runs. Gaps in temperature data plots indicate water temperature was not taken.

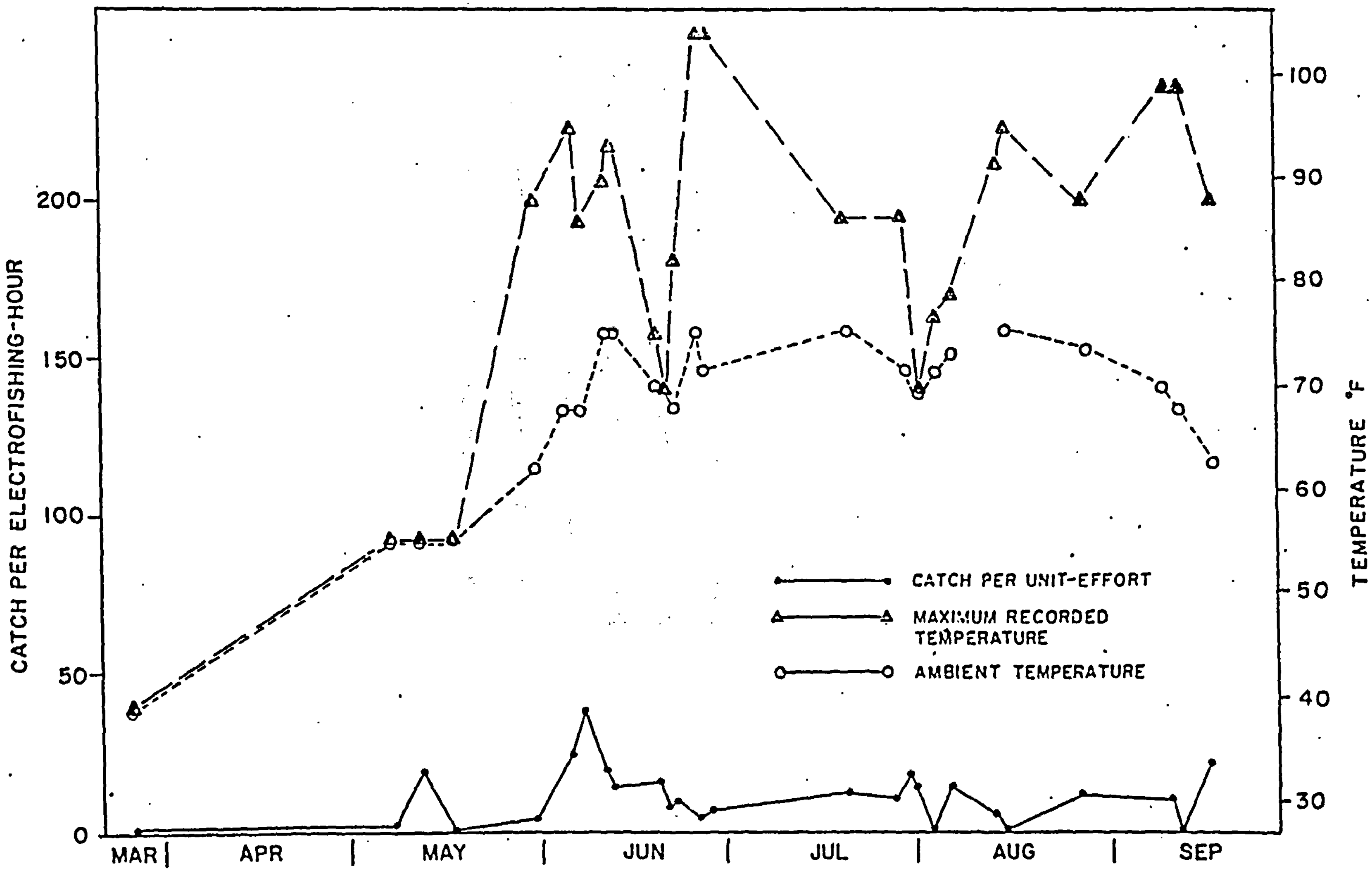

CATCH PER ELECTROFISHING-HOUR
0
50
100
150
200
TEMPERATURE °F
30
40
50
60
70
80
90
100
MAR
APR
MAY
JUN
JUL
AUG
SEP
CATCH PER UNIT-EFFORT
MAXIMUM RECORDED TEMPERATURE
AMBIENT TEMPERATURE

FIGURE 3.4-10

Catch per electrofishing-hour of carp in the immediate discharge zone in 1973. Triangles represent the maximum temperature recorded during electrofishing runs. Gaps in temperature data plots indicate water temperature was not taken.

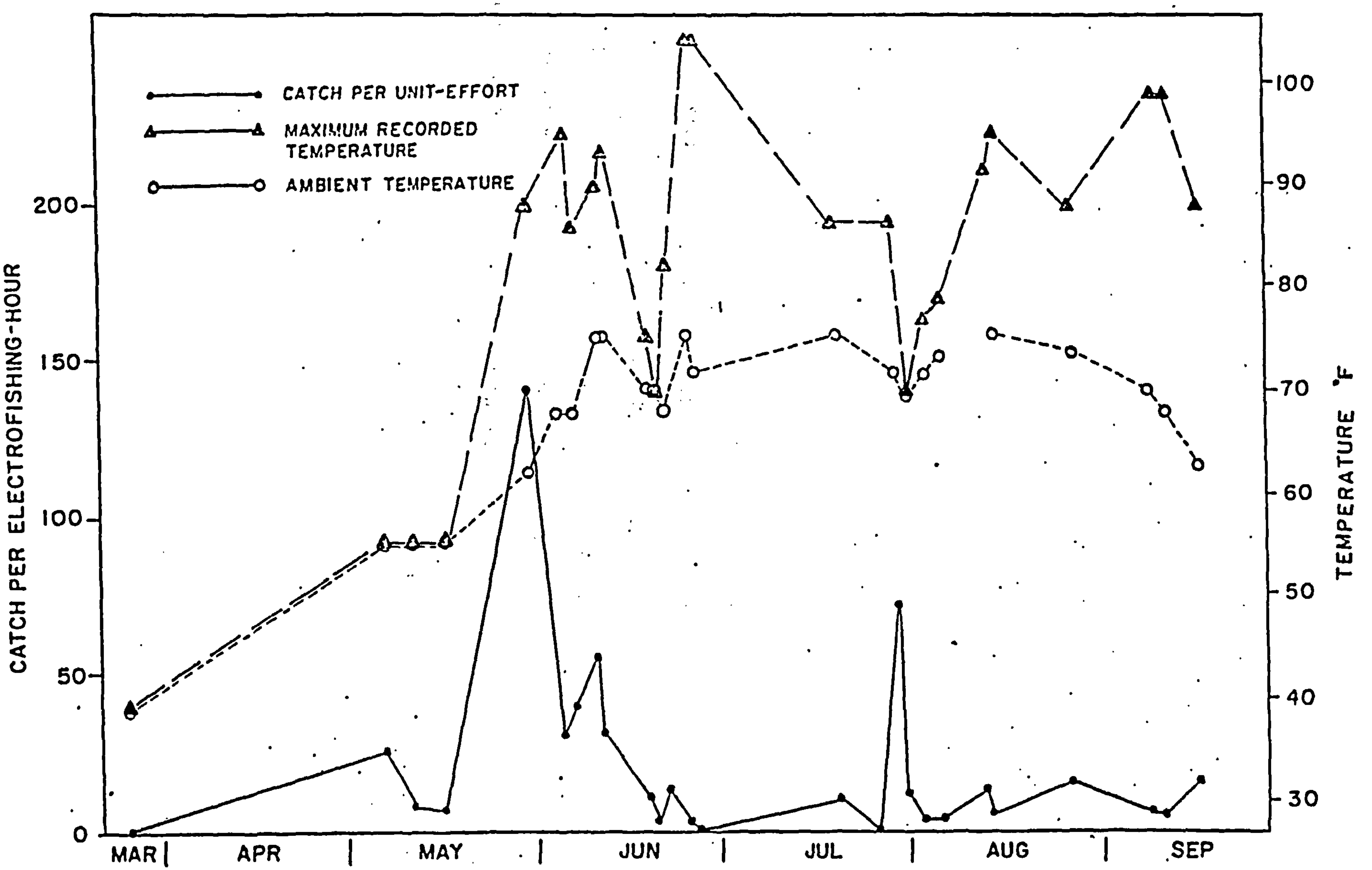

CATCH PER UNIT-EFFORT
MAXIMUM RECORDED TEMPERATURE
AMBIENT TEMPERATURE
CATCH PER ELECTROFISHING-HOUR
TEMPERATURE °F
0
50
100
150
200
30
40
50
60
70
80
90
100
MAR
APR
MAY
JUN
JUL
AUG
SEP

FIGURE 3.4-11

Catch per electrofishing-hour of smallmouth bass in the immediate discharge area in 1973. Triangles represent the maximum temperature recorded during electrofishing runs. Gaps in temperature data plots indicate water temperature was not taken.

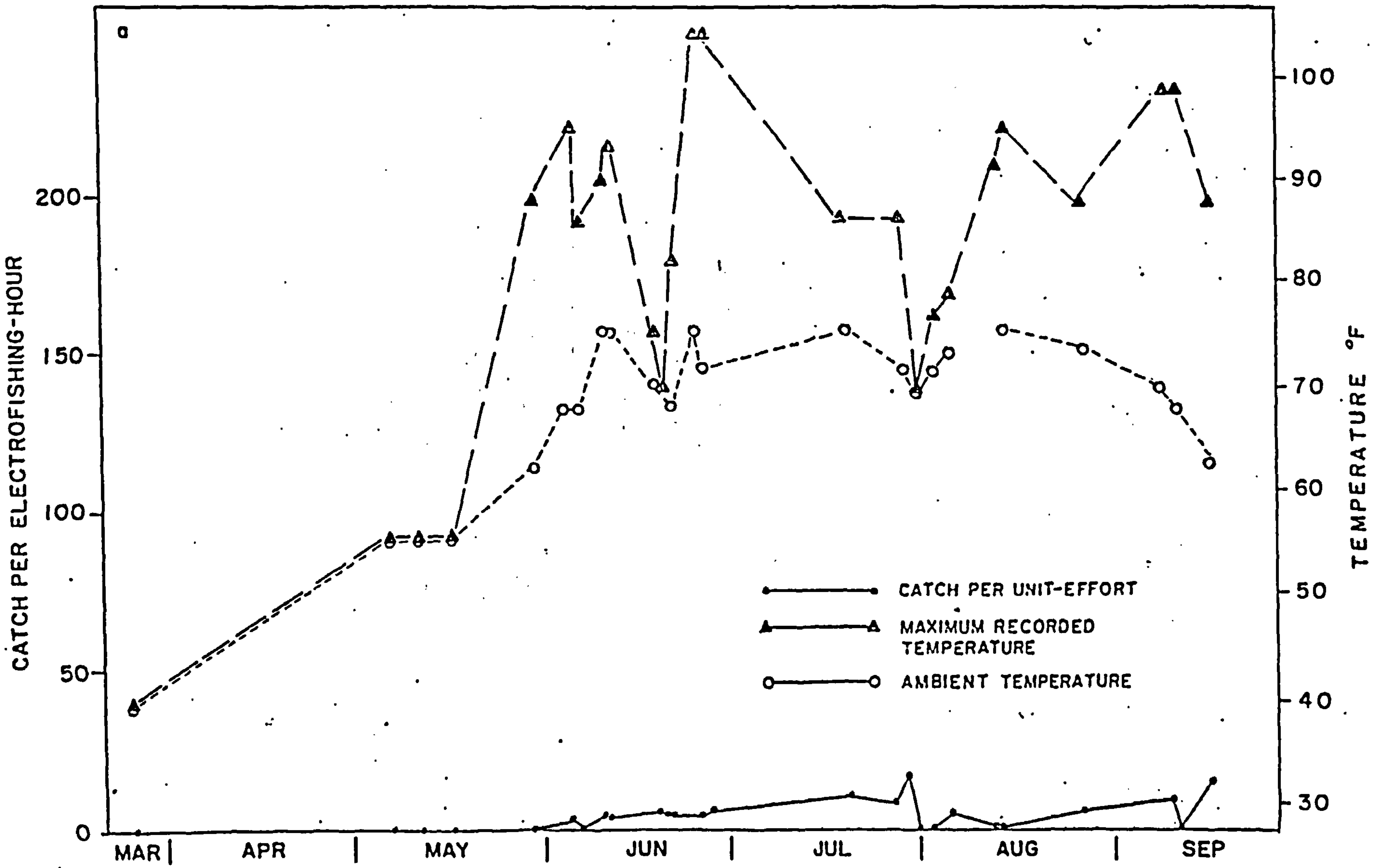
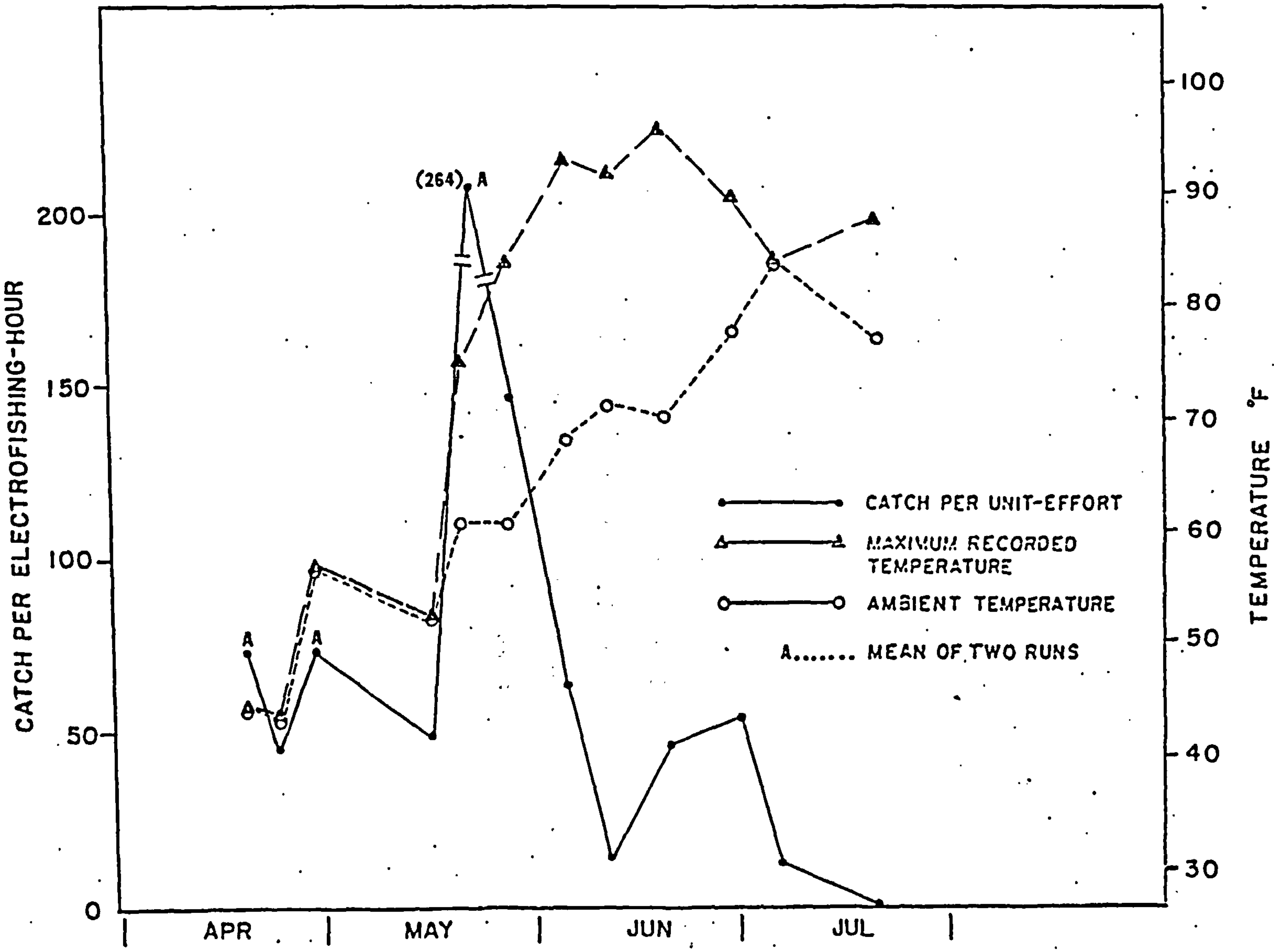

a
CATCH PER ELECTROFISHING-HOUR
TEMPERATURE °F
0
50
100
150
200
30
40
50
60
70
80
90
100
MAR
APR
MAY
JUN
JUL
AUG
SEP
CATCH PER UNIT-EFFORT
MAXIMUM RECORDED TEMPERATURE
AMBIENT TEMPERATURE

FIGURE 3.4-12

Catch per electrofishing-hour of rough fish in the immediate discharge area in 1974. Rough fish species included: white sucker, shorthead redhorse, carp, silver redhorse, bowfin and black bullhead. Triangles represent the maximum temperature recorded during electrofishing runs.



CATCH PER ELECTROFISHING-HOUR
TEMPERATURE °F
0
50
100
150
200
30
40
50
60
70
80
90
100
APR
MAY
JUN
JUL
(264)
A
CATCH PER UNIT-EFFORT
MAXIMUM RECORDED TEMPERATURE
AMBIENT TEMPERATURE
A....... MEAN OF TWO RUNS

FIGURE 3.4-13

Catch per electrofishing-hour of carp in the immediate discharge area in 1974. Triangles represent the maximum temperature recorded during electrofishing runs.

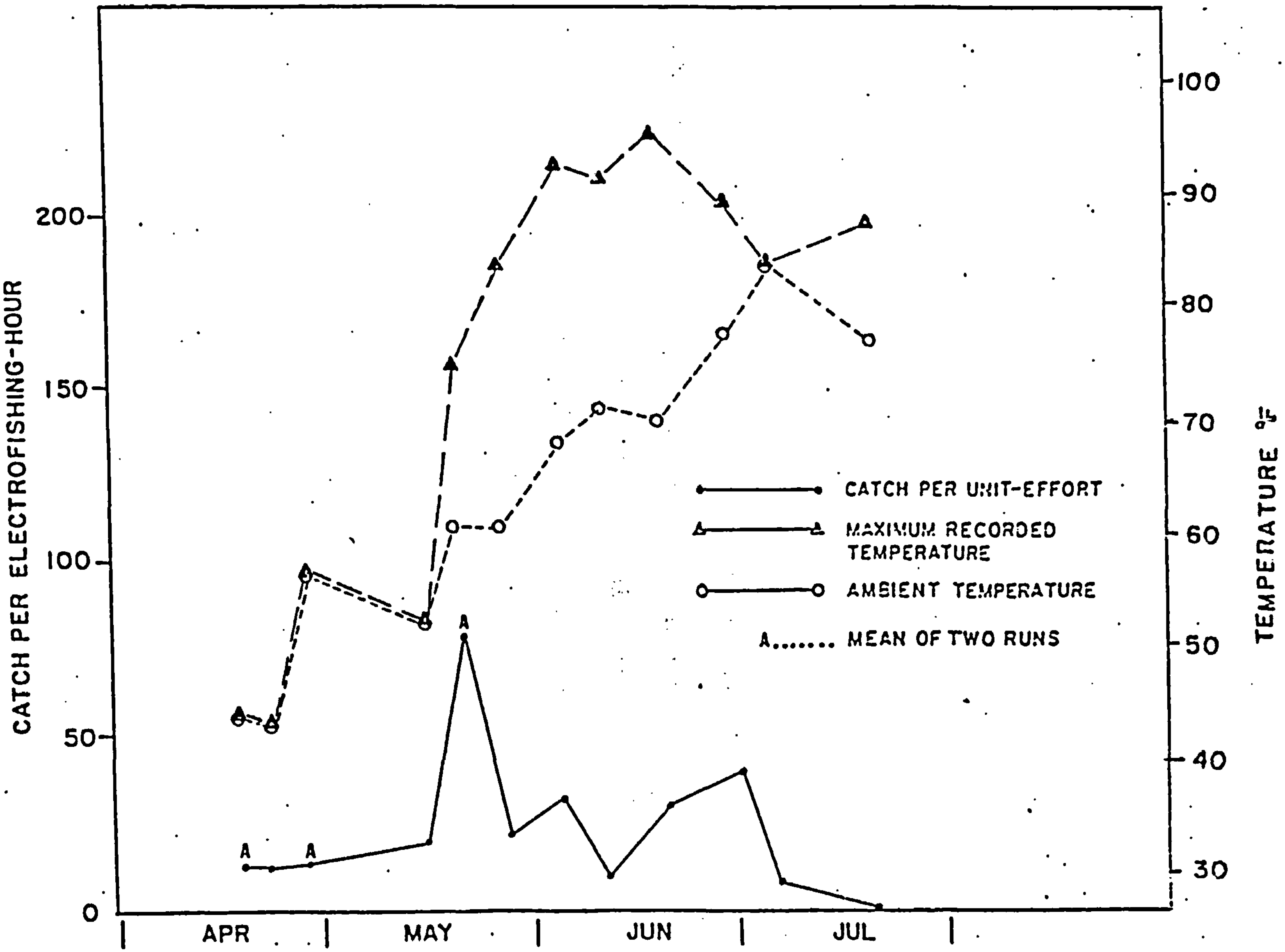
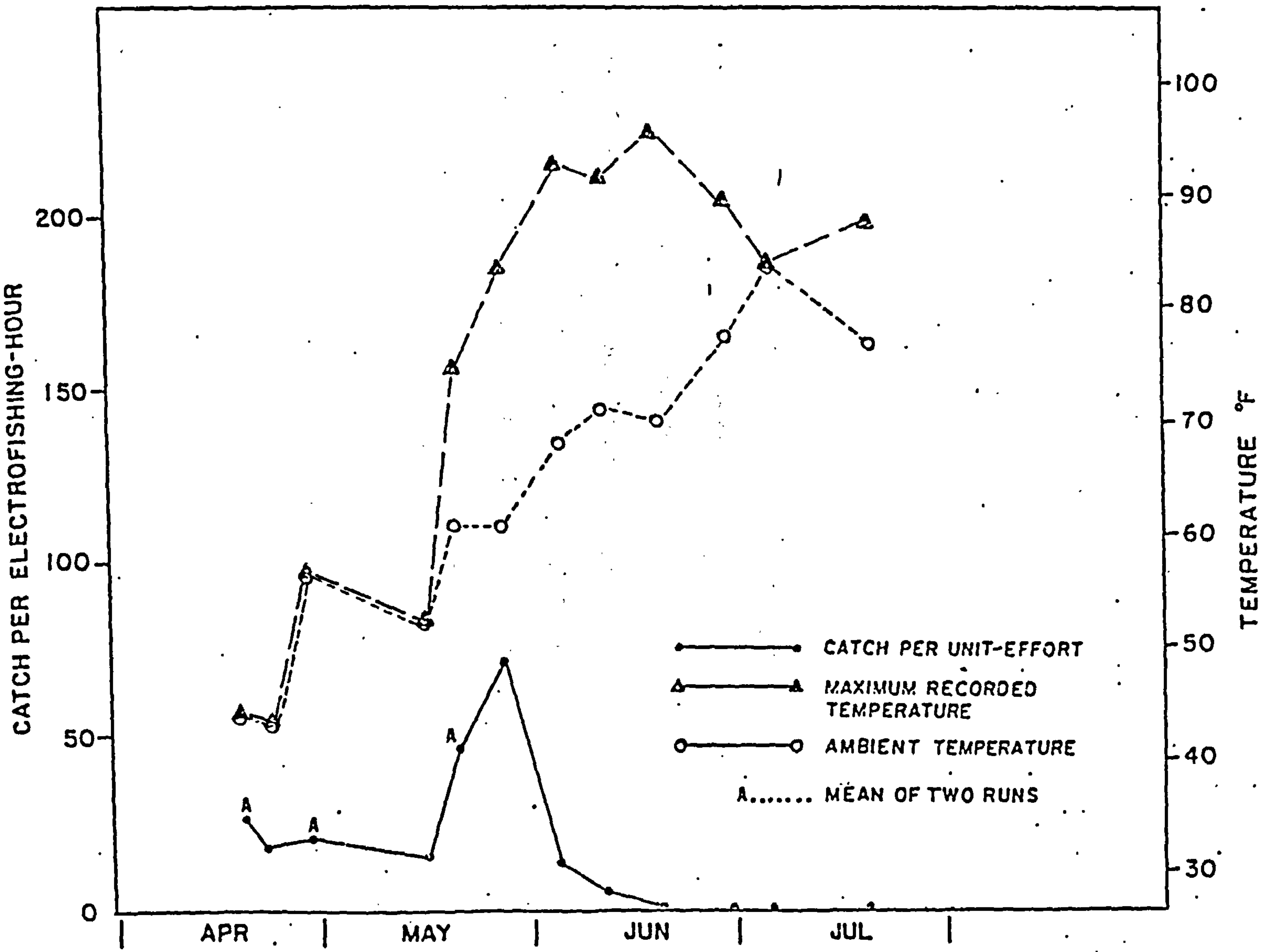

CATCH PER ELECTROFISHING-HOUR
0
50
100
150
200
TEMPERATURE °F
30
40
50
60
70
80
90
100
APR
MAY
JUN
JUL
CATCH PER UNIT-EFFORT
MAXIMUM RECORDED TEMPERATURE
AMBIENT TEMPERATURE
A....... MEAN OF TWO RUNS
A
A
A

FIGURE 3.4-14

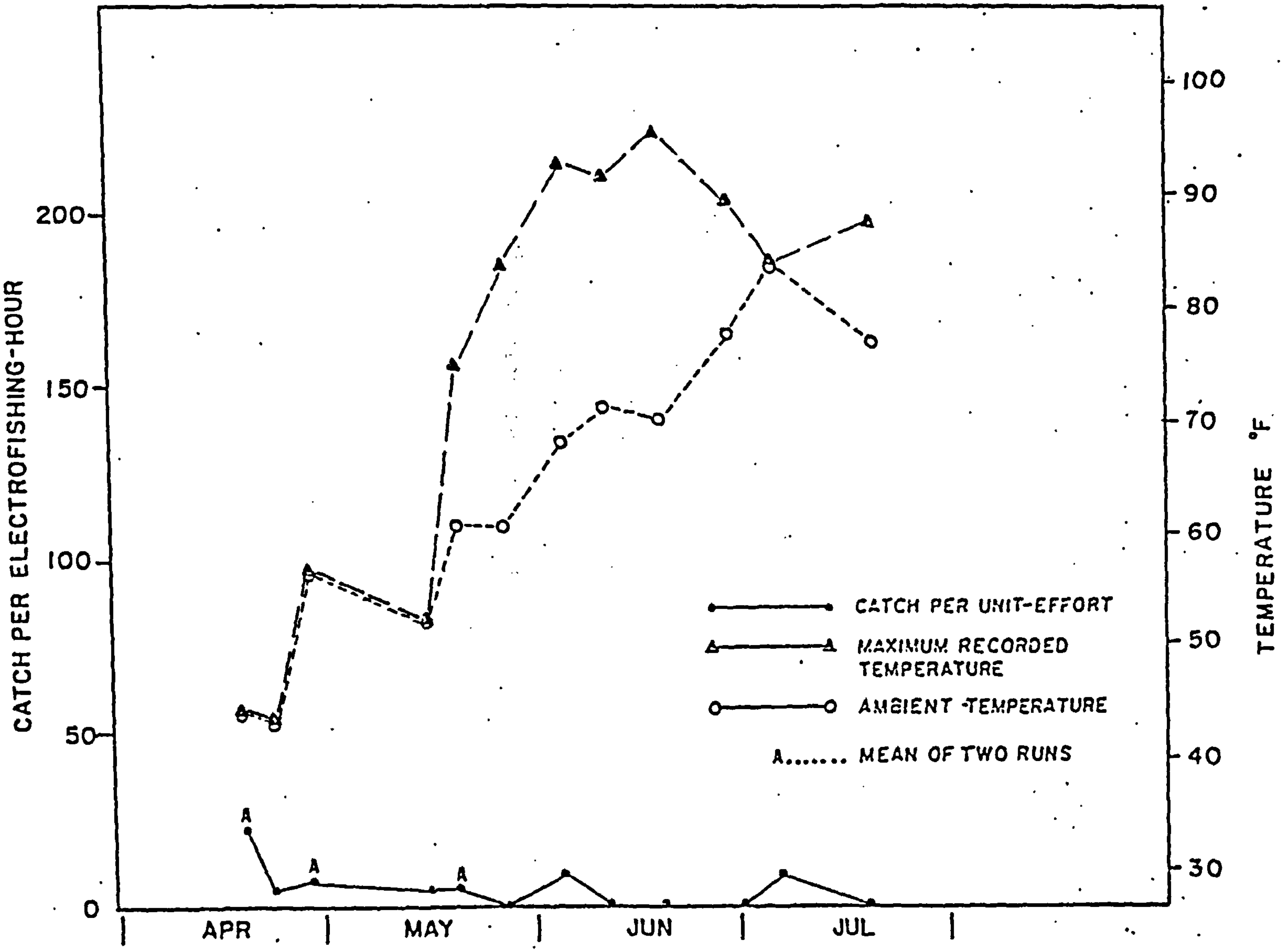
Catch per electrofishing-hour of shorthead redhorse in the immediate discharge area in 1974. Triangles represent the maximum temperature recorded during electrofishing runs.



CATCH PER ELECTROFISHING-HOUR
TEMPERATURE °F
0
50
100
150
200
30
40
50
60
70
80
90
100
APR
MAY
JUN
JUL
A
CATCH PER UNIT-EFFORT
MAXIMUM RECORDED TEMPERATURE
AMBIENT TEMPERATURE
A....... MEAN OF TWO RUNS

FIGURE 3.4-15

Catch per electrofishing-hour of gamefish in the immediate discharge area in 1974. Game fish species included northern pike, black crappie, smallmouth bass and walleye. Triangles represent the maximum temperature recorded during electrofishing runs.



CATCH PER ELECTROFISHING-HOUR
TEMPERATURE °F
0
50
100
150
200
30
40
50
60
70
80
90
100
APR
MAY
JUN
JUL
CATCH PER UNIT-EFFORT
MAXIMUM RECORDED TEMPERATURE
AMBIENT TEMPERATURE
A....... MEAN OF TWO RUNS
A
A
A

FIGURE 3.4-16

Catch per electrofishing-hour of smallmouth bass in the immediate discharge area in 1974. Triangles represent the maximum temperature recorded during electrofishing runs.

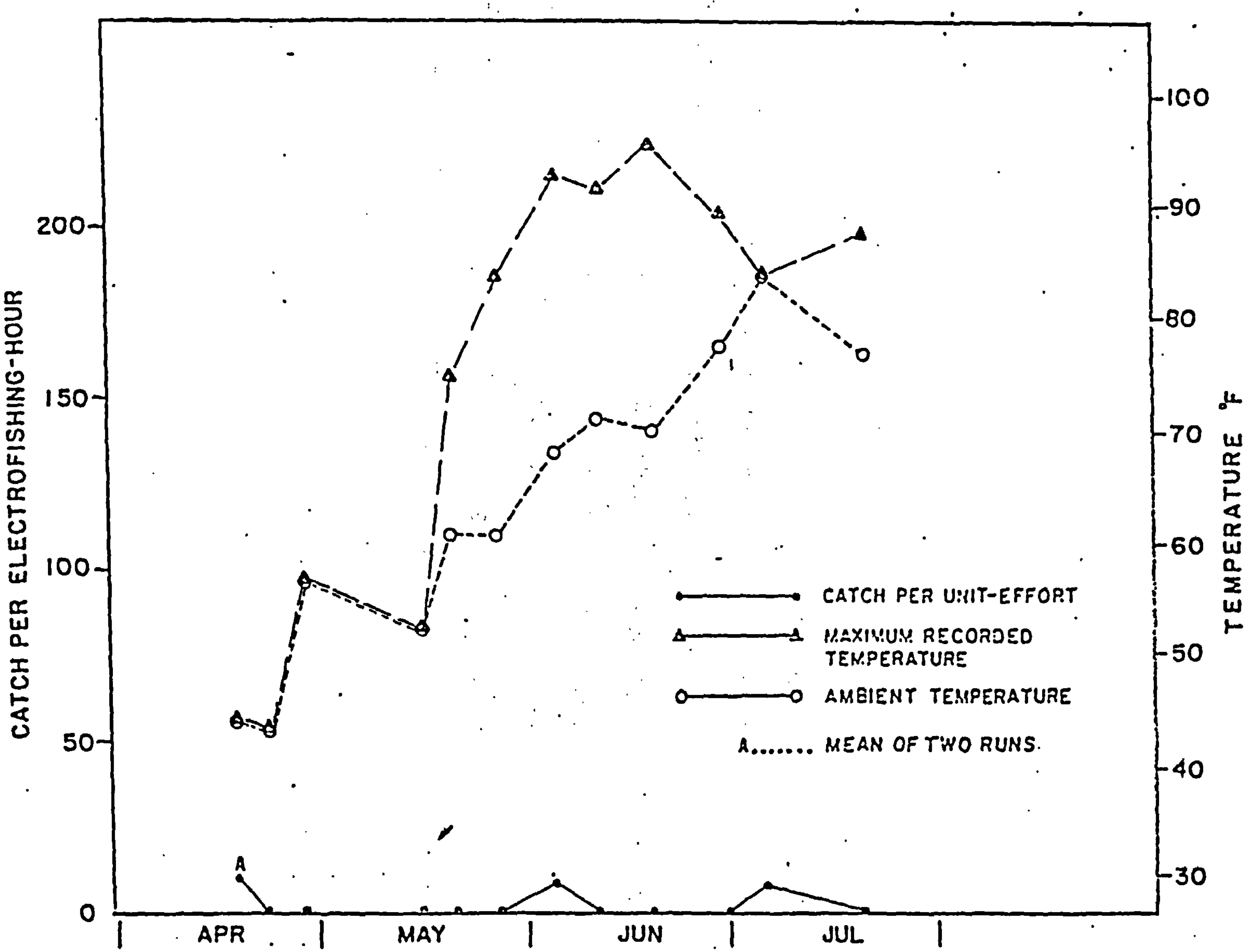

CATCH PER ELECTROFISHING-HOUR
TEMPERATURE °F
200
150
100
50
0
100
90
80
70
60
50
40
30
APR
MAY
JUN
JUL
CATCH PER UNIT-EFFORT
MAXIMUM RECORDED TEMPERATURE
AMBIENT TEMPERATURE
A....... MEAN OF TWO RUNS
A

FIGURE 3.4-17

Catch per electrofishing-hour of rough fish in the intermediate discharge area in 1973. Rough fish species included: shorthead redhorse, silver redhorse, white sucker and carp. Triangles represent the maximum temperature recorded during electrofishing runs. Gaps in temperature data plots indicate water temperature was not taken.

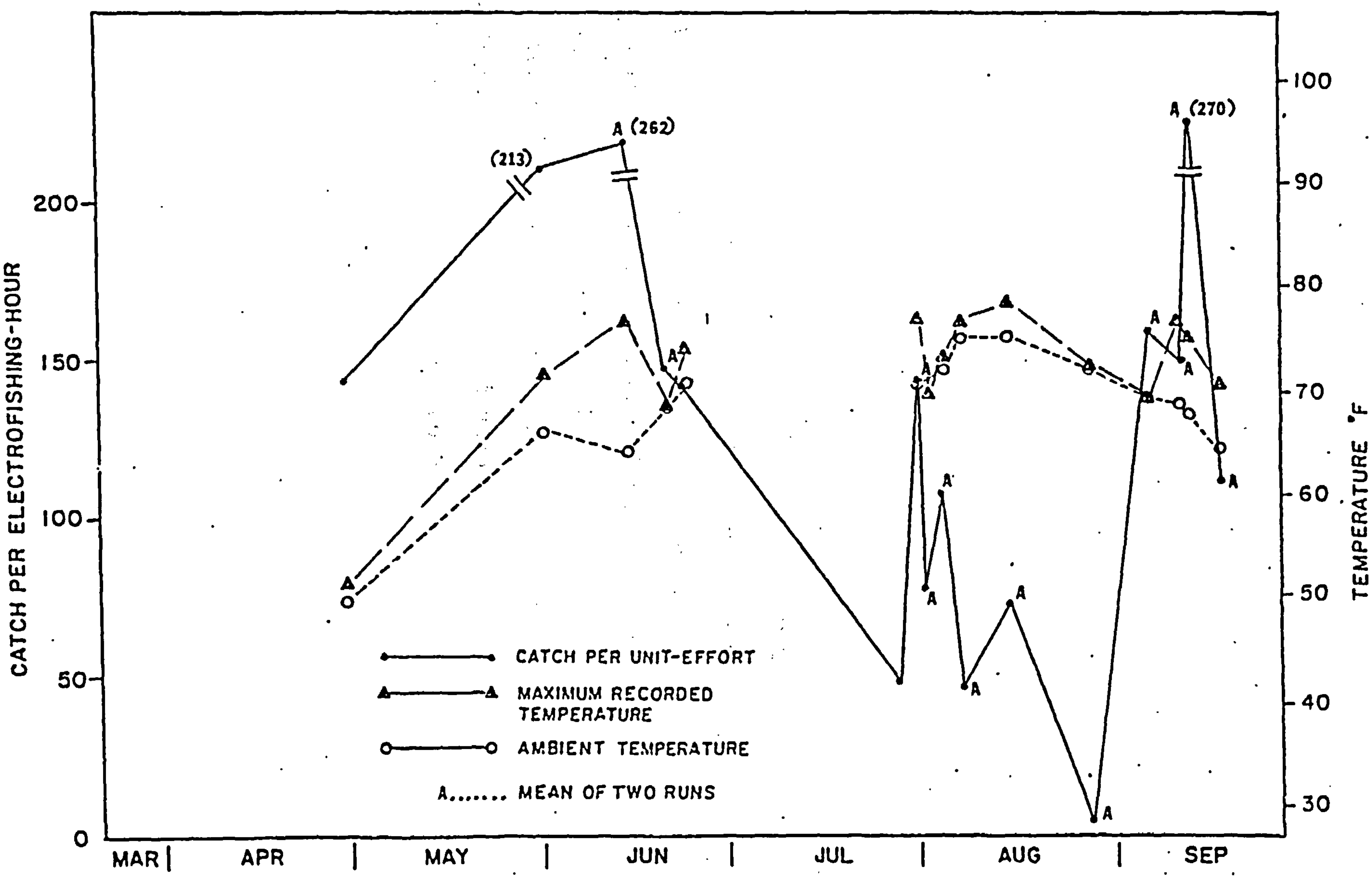
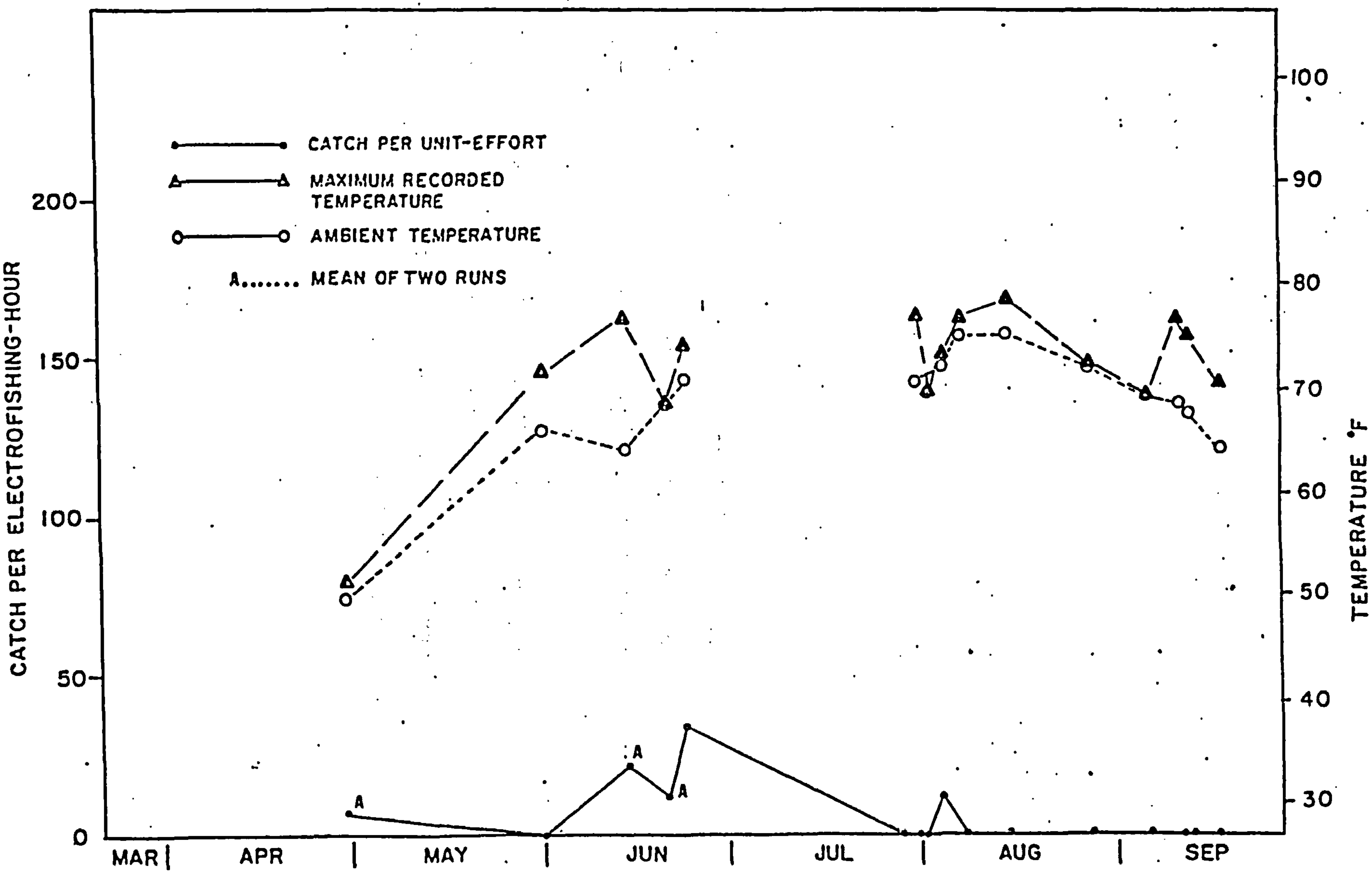

CATCH PER ELECTROFISHING-HOUR
TEMPERATURE °F
0
50
100
150
200
30
40
50
60
70
80
90
100
MAR
APR
MAY
JUN
JUL
AUG
SEP
(213)
A (262)
A (270)
CATCH PER UNIT-EFFORT
MAXIMUM RECORDED TEMPERATURE
AMBIENT TEMPERATURE
A....... MEAN OF TWO RUNS

FIGURE 3.4-18

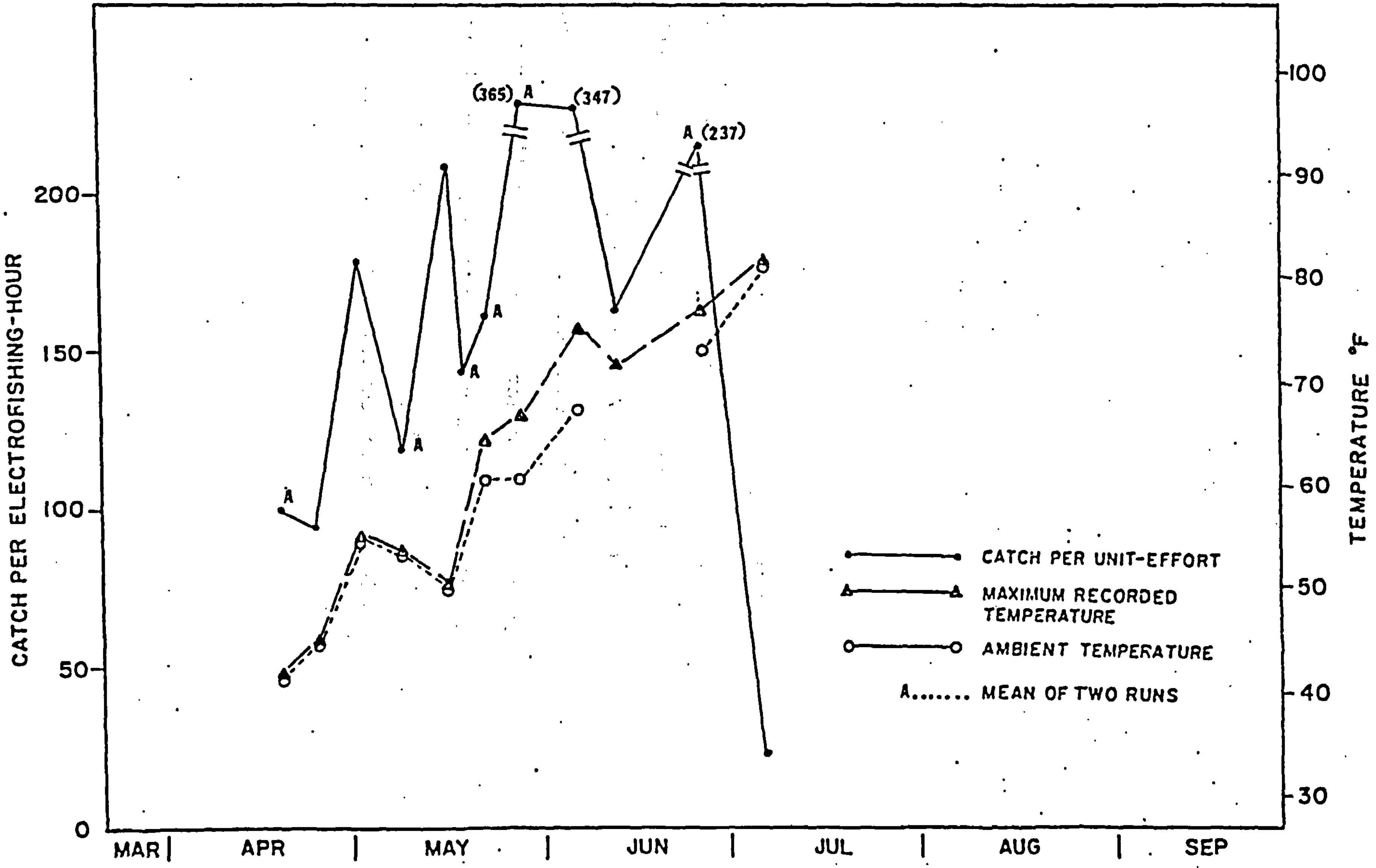
Catch per electrofishing-hour of game fish in the intermediate discharge area in 1973. Game fish species included: northern pike, walleye, black crappie and smallmouth bass. Triangles represent the maximum temperature recorded during electrofishing runs. Gaps in temperature data plots indicate water temperature was not taken.



CATCH PER UNIT-EFFORT
MAXIMUM RECORDED TEMPERATURE
AMBIENT TEMPERATURE
A....... MEAN OF TWO RUNS
CATCH PER ELECTROFISHING-HOUR
TEMPERATURE °F
0
50
100
150
200
30
40
50
60
70
80
90
100
MAR
APR
MAY
JUN
JUL
AUG
SEP
A
A
A

FIGURE 3.4-19

Catch per electrofishing-hour of rough fish in the intermediate discharge zone in 1974. Rough fish species included: shorthead redhorse, silver redhorse, white sucker and carp. Triangles represent the maximum temperature recorded during electrofishing runs. Gaps in temperature data plots indicate water temperature was not taken.



CATCH PER ELECTROFISHING-HOUR
TEMPERATURE °F
0
50
100
150
200
30
40
50
60
70
80
90
100
MAR
APR
MAY
JUN
JUL
AUG
SEP
(365) A
(347)
A (237)
A
CATCH PER UNIT-EFFORT
MAXIMUM RECORDED TEMPERATURE
AMBIENT TEMPERATURE
A....... MEAN OF TWO RUNS

FIGURE 3.4-20

Catch per electrofishing-hour of game fish in the intermediate discharge area in 1974. Game fish species included: northern pike, walleye, smallmouth bass, black crappie and rock bass. Triangles represent the maximum temperature recorded during electrofishing runs. Gaps in temperature data plots indicate water temperature was not taken.

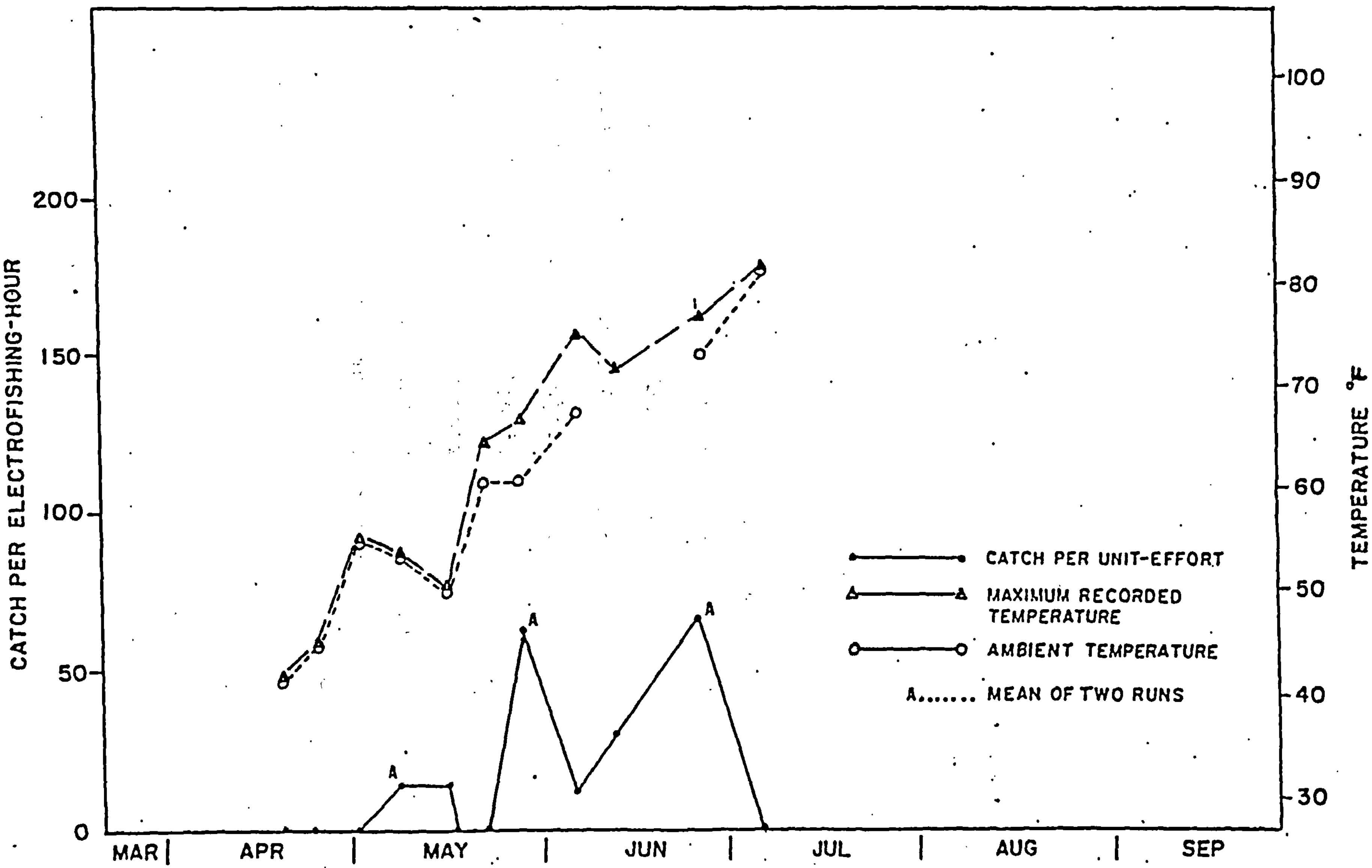

CATCH PER ELECTROFISHING-HOUR
0
50
100
150
200
TEMPERATURE °F
30
40
50
60
70
80
90
100
MAR
APR
MAY
JUN
JUL
AUG
SEP
A
A
A
CATCH PER UNIT-EFFORT
MAXIMUM RECORDED TEMPERATURE
AMBIENT TEMPERATURE
A....... MEAN OF TWO RUNS

FIGURE 3.4-21

Catch per electrofishing-hour of rough fish in the outer discharge area in 1973. Rough fish species included: shorthead redhorse, carp, silver redhorse, white sucker and black bullhead. Triangles represent the maximum temperature recorded during electrofishing runs. Gaps in temperature data plots indicate water temperature was not taken.

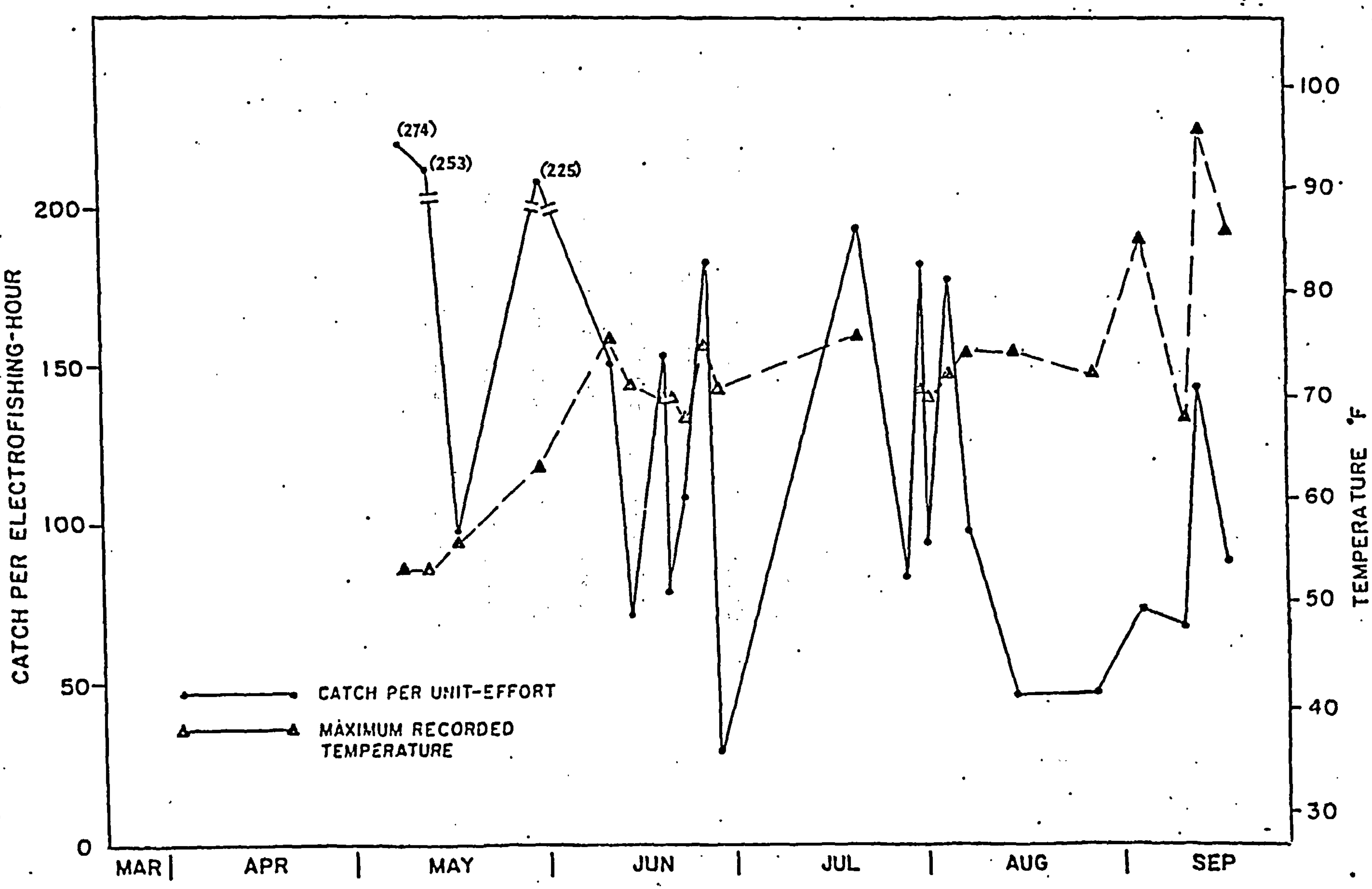

(274)
(253)
(225)
200
150
100
50
0
CATCH PER ELECTROFISHING-HOUR
100
90
80
70
60
50
40
30
TEMPERATURE °F
CATCH PER UNIT-EFFORT
MAXIMUM RECORDED TEMPERATURE
MAR
APR
MAY
JUN
JUL
AUG
SEP

FIGURE 3.4-22

Catch per electrofishing-hour of game fish in the outer discharge area in 1973. Game fish species included: smallmouth bass, black crappie and northern pike. Triangles represent the maximum temperature recorded during electrofishing runs. Gaps in temperature data plots indicate water temperature was not taken.

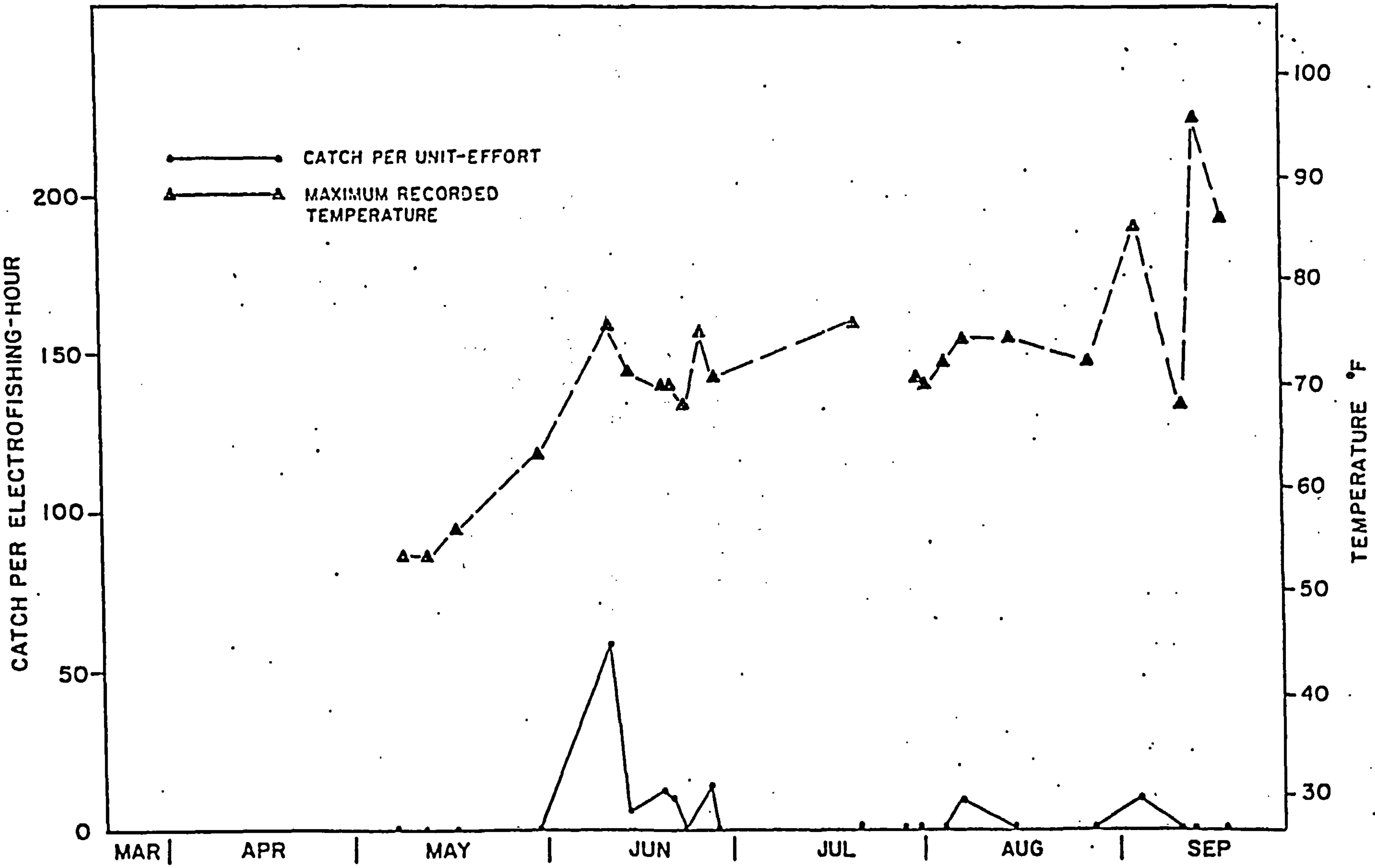
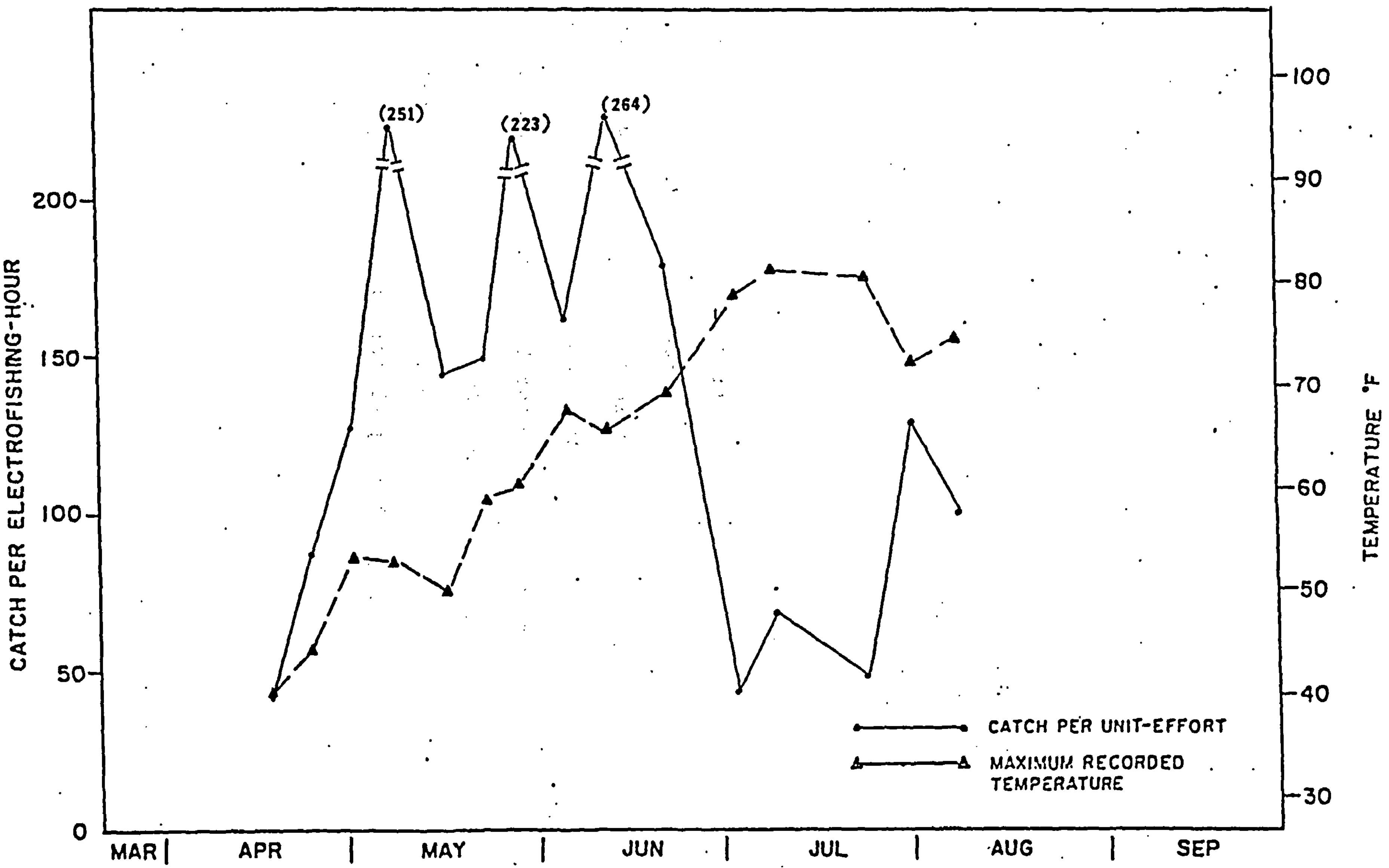

CATCH PER UNIT-EFFORT
MAXIMUM RECORDED TEMPERATURE
CATCH PER ELECTROFISHING-HOUR
TEMPERATURE °F
200
150
100
50
0
100
90
80
70
60
50
40
30
MAR
APR
MAY
JUN
JUL
AUG
SEP

FIGURE 3.4-23

Catch per electrofishing-hour of rough fish in the outer discharge area in 1974. Rough fish species included: silver redhorse, shorthead redhorse, carp and white sucker. Triangles represent the maximum temperature recorded during electrofishing runs.



CATCH PER ELECTROFISHING-HOUR
TEMPERATURE °F
0
50
100
150
200
30
40
50
60
70
80
90
100
(251)
(223)
(264)
MAR
APR
MAY
JUN
JUL
AUG
SEP
CATCH PER UNIT-EFFORT
MAXIMUM RECORDED TEMPERATURE

FIGURE 3.4-24

Catch per electrofishing-hour of game fish in the outer discharge area in 1974. Game fish species included: black crappie, walleye, northern pike and smallmouth bass. Triangles represent the maximum temperature recorded during electrofishing runs.
Triangles represent the maximum temperature recorded during electrofishing runs.

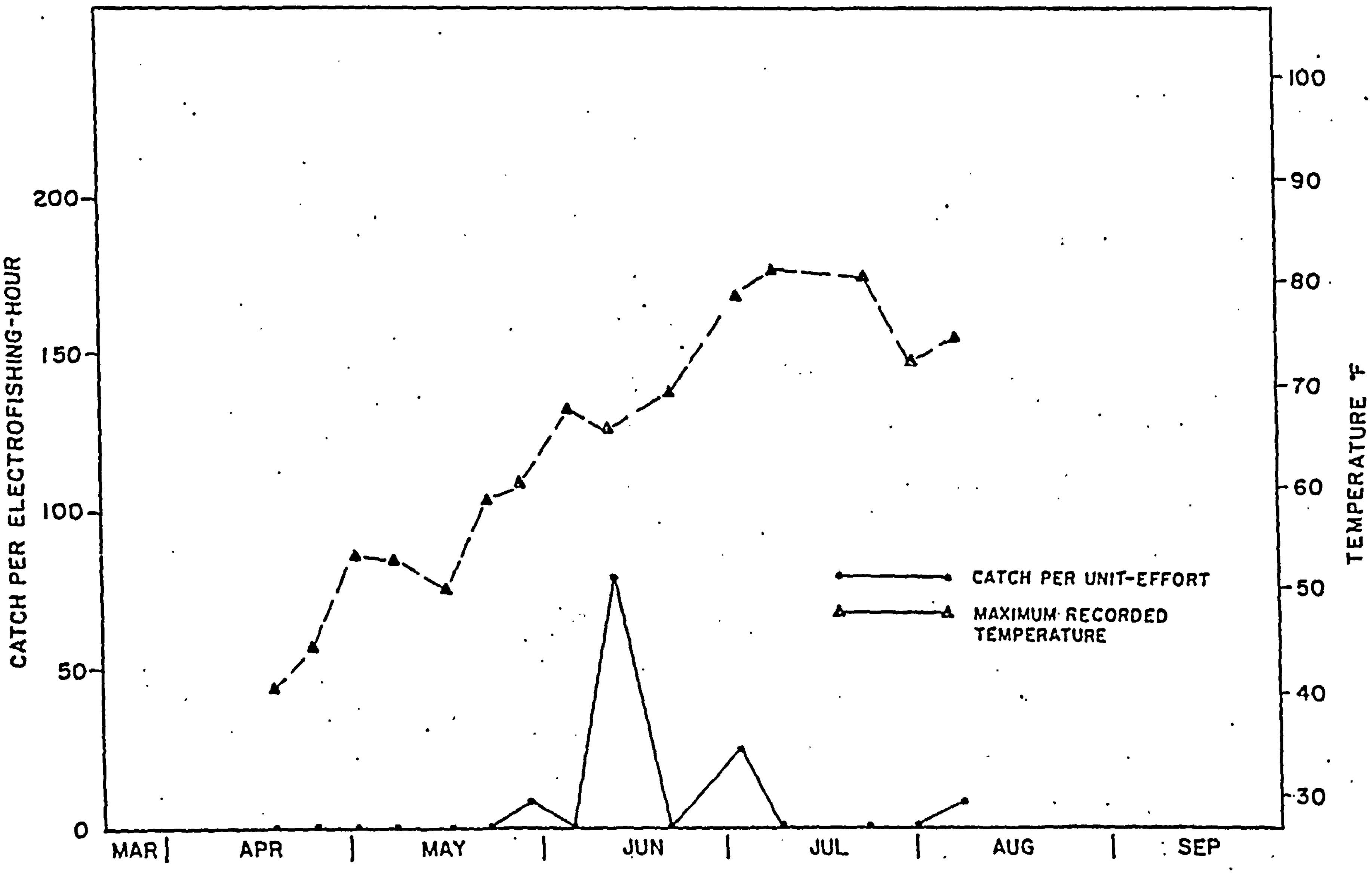

CATCH PER ELECTROFISHING-HOUR
0
50
100
150
200
TEMPERATURE °F
30
40
50
60
70
80
90
100
MAR
APR
MAY
JUN
JUL
AUG
SEP
CATCH PER UNIT-EFFORT
MAXIMUM RECORDED TEMPERATURE

FIGURE 3.4-25

Map showing the location of spawning grounds relative to the Monticello Nuclear Generating Plant.

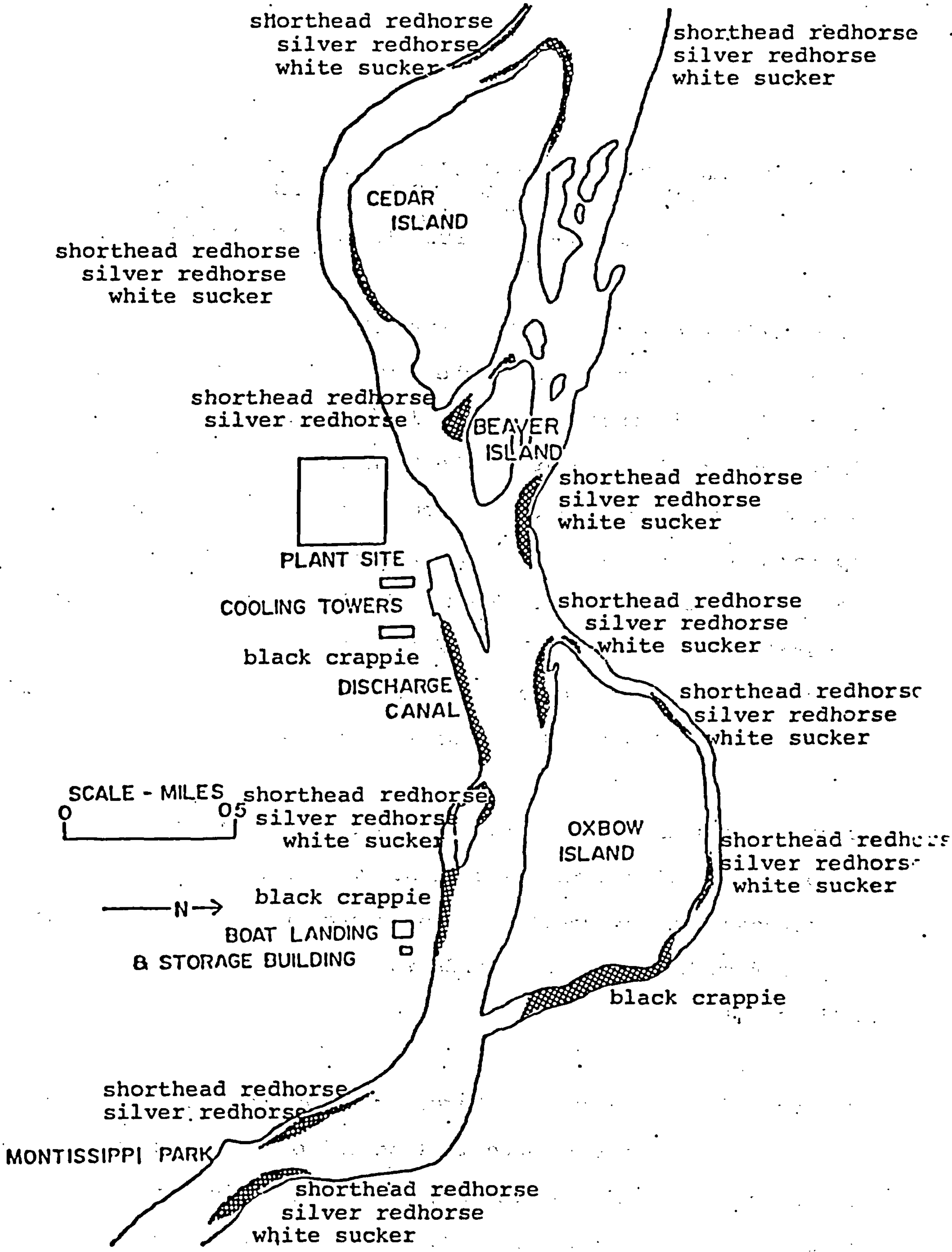

shorthead redhorse
silver redhorse
white sucker
shorthead redhorse
silver redhorse
white sucker
CEDAR ISLAND
shorthead redhorse
silver redhorse
white sucker
shorthead redhorse
silver redhorse
BEAVER ISLAND
shorthead redhorse
silver redhorse
white sucker
PLANT SITE
COOLING TOWERS
shorthead redhorse
silver redhorse
white sucker
black crappie
DISCHARGE CANAL
shorthead redhorse
silver redhorse
white sucker
SCALE - MILES
0
0.5
shorthead redhorse
silver redhorse
white sucker
OXBOW ISLAND
N
black crappie
BOAT LANDING & STORAGE BUILDING
black crappie
shorthead redhorse
silver redhorse
MONTISSIPPI PARK
shorthead redhorse
silver redhorse
white sucker

TABLE 3.4-1

GENERAL PHYSICAL DESCRIPTION OF EACH ELECTROFISHING SECTOR NEAR THE MONTICELLO NUCLEAR GENERATING PLANT (ADAPTED FROM HOPWOOD 1974a, p. 7, 9) SEE FIGURE A-2 FOR LOCATION OF SOUNDING RANGES.

Sector A (Adjacent Water Body Segment)

Extends from one mile above the power plant discharge to sounding range 17, a distance of about 1.1 river miles. This sector includes two flows separated by Cedar Island. On the right side of the island the river flows through two deep pools at approximately SR26R to 23R, and SR22R to SR17, and two rapids at SR27R to 26R and at SR22A-R. The left flow is subdivided by several small islands. Much of this flow is less than three feet deep, however, there are pools at SR25L to 24L in the middle channel and SR21L to 20L in the left channel.

Bottom types in Sector A range from silt and mud in the pools to rubble and boulders in the rapids. The right and left channel substrates consist mostly of stones and gravel. That of the middle flow between the islands is composed of silt, fine sand and gravel.

Sector B (Intermediate Discharge Area, Outer Discharge Area)

Extends from sounding range 17 (the end of the upstream side of the discharge canal) to sounding range 8 (Montissippi Park), 1.5 river miles. Below the confluence of the flows around the islands the river bed broadens (SR17 to SR9). The bottom is fairly uniform, composed mainly of gravel and sand. Some silt deposits occur at the bend area between the rapids at SR9 and the discharge of the left side channel. Large boulders are strewn in the rapids at SR9 where the flow is constricted into a narrow bed. The river then flows through a pool about 200 yards long before broadening into a shallow area of less than three feet deep.

Sector C (Intermediate Discharge Area, Outer Discharge Area) Extends from sounding range 8 to sounding range 5 (discharge of Otter Creek), 1.2 river miles. At SR7 the channel deepens, forming a relatively slow-flowing, lake-like area below SR6. This section contains some fallen trees, stumps and roots suitable for fish cover.

Sector D (Intermediate Discharge Area, Outer Discharge Area) Extends from sounding range 5 to sounding range 3 (State Highway 25 bridge), 0.8 river miles. A rapids about 50 yards above SR5 marks the upstream end of Sector D. This area is very shallow on the left, deep and swift on the right. There are large boulders among the rubble under the swift water near the right bank. The highest flow velocity in the study area was recorded midway between SR5 and SR4 on the right side. Below SR4 the deep flow changes abruptly from right to left.

Sector E (Intermediate Discharge Area, Outer Discharge Area) Extends from sounding range 3 to .25 miles below Ellison Park on the south end of Monticello, one river mile. The river flow under the bridge is swift over a shallow riffle extending over most of the width from the right side. A deeper channel lies between the right bank and the north bridge support. Substrates in this area range from boulders and rubble in the swift areas near the bridge to sand and gravel elsewhere. Silt is restricted to areas between the right bank and the islands on the right side of the river.

Immediate Discharge Area

The portion of the immediate discharge area under investigation was within the confines of the power plant discharge canal. The discharge canal is approximately 1,000 feet long, 100 feet wide and 6 feet deep. Estimated velocities range from 0.5 fps at the point of dishcarge to the river to 1.3 fps at the discharge from the plant to the river. The substrate is sand with some large boulders.

TABLE 3.4-2

GENERAL PHYSICAL DESCRIPTIONS OF SEINING STATIONS IN THE PRE-OPERATIONAL FISHERY STUDY (FROM MORGENWECK, 1971, p. 9-11).

Upstream 1 (Adjacent Water Body Segment)

The station was free of rooted vegetation from 26 May 1970, until 9 June 1970 when some quackgrass and willow began growing from sand and gravel bottom. On 25 June 1970 the original sampling site had dried up and a new one was selected further into the river. An alga, Cladophora sp. became very dense on the river bottom in areas of slow flow and remained as a dense covering until late in October 1970. On 6 July 1970 the sampling station was moved downstream 30 to 40 yards into a backwater. The move was prompted by the dropping water level which had left a deep trough of rapidly flowing water at the previous site. The current velocity in the trough was too great to allow efficient seine operation. No minnows were observed in the trough. Seining continued in the backwater and its outlet until 23 October 1970 when rising water covered the backwater. From 23 October 1970, until operations ended, seining took place at the original site.

TABLE 3.4-2 (Cont'd.)

The current velocity at the first site ranged from 0.3 to 4.0 feet per second (fps) and averaged 1.9 fps. The current velocity at the backwater site ranged from zero to 2.2 fps and averaged 1.1 fps.

The average water depths at the first site ranged from 4.0 to 12.0 inches and averaged 7.6 inches at the first site. The water depth at the backwater ranged from 2.0 to 9.0 inches and averaged 5.1 inches.

Upstream 2 (Adjacent Water Body Segment)
Seining operations began in a backwater on 26 May 1970 and continued there until 13 July 1970 when it dried up. The sampling area was moved to the river's edge at the mouth of the backwater where seining continued until the end of the sampling season.

In the backwater, the bottom materials were composed of organic debris, silt, and sand. At the mouth of the backwater, sand, gravel, and rubble were the bottom materials.

The vegetation consisted of quackgrass, horsetail, curly pondweed, sago pondweed, coontail, and arrowhead. The water depths at the backwater site ranged from 3.0 to 12.0 inches and averaged 7.6 inches. The average water depths at the backwater mouth ranged from 3.5 to 17.0 inches and averaged 6.6 inches.

The current in the backwater ranged from zero to 0.4 fps and averaged 0.1 fps. The current velocity at the backwater mouth ranged from zero to 2.1 fps and averaged 1.3 fps.

Downstream 1 (Immediate Discharge Area)
From the start of seining until 13 July 1970, seining was carried on in the inlet of a backwater. Then the backwater dried up and seining operations were moved to the edge of the river where they continued until the end of the sampling period.

The bottom materials in the backwater were composed of sand and gravel which supported no rooted aquatic vegetation but did support willow. The bottom materials at the river's edge were gravel and rubble which supported one small bed of bigleaf pondweed.

The current velocity in the backwater ranged from zero to 1.7 fps and averaged 1.0 fps. The current velocity at the river's edge ranged from 0.7 to 1.7 fps and averaged 1.0 fps.

The water depth in the backwater ranged from 2.0 to 24.0 inches and averaged 9.9 inches. The water depth at the river's edge ranged from 4.5 to 13.5 inches and averaged 9.1 inches.

Downstream 2 (Outer Discharge Area)
The bottom materials were composed of a small amount of silt, one boulder, and sand. Willow, silver maple, coontail, curly

TABLE 3.4-2 (Cont'd.)

pondweed, bigleaf pondweed, and sedges were the dominant vegetation types. The current velocity ranged from 0.2 to 1.5 fps and averaged 0.5 fps.

The water depths ranged from 5.0 to 18.0 inches and averaged 10.1 inches.

Downstream 3 (Intermediate Discharge Area)
The bottom materials were composed of rubble with some sand and gravel which supported little rooted vegetation early in seining operations. As the water level dropped, sago pondweed, willow, quackgrass, and Cladophora became evident.

The current velocity ranged from 0.7 to 4.3 fps and averaged 2.5 fps.

The water depths ranged from 4.5 to 18.0 inches and averaged 8.9 inches.

Downstream 4 (Intermediate Discharge Area)
The bottom materials consisted of sand and gravel with a small amount of rubble. These materials supported little vegetation except at the downstream edge of the sampling area where extensive beds of bigleaf pondweed were found.

The current velocity ranged from 0.4 to 1.9 fps and averaged 1.1 fps.

The water depths ranged from 4.0 to 19.0 inches and averaged 10.8 inches.

TABLE 3.4-3

GENERAL PHYSICAL DESCRIPTION OF SEINING STATIONS IN THE OPERATIONAL FISHERY STUDY (FROM OTT 1973, p. 7-8)

Upstream Station 1 (Adjacent Water Body Segment)

This was the most upstream station. This station was on the west shore of the main channel, 1.6 km above the discharge near a large sandy outwash in the bank. The bottom was rugged and consisted of rubble, gravel, some sand and a few boulders.

Upstream Station 2 (Adjacent Water Body Segment)

This station was approximately 300 m downstream from Upstream Station 1 on the west shore of Cedar Island (thus it is on the east bank of the main channel) and was about 1.3 km upstream from the discharge. The bottom was almost exclusively gravel and sand.

Upstream Station 3 (Adjacent Water Body Segment)

This was the principal upstream station. It was located in the channel between Cedar and Beaver Islands about 0.7 km above the discharge. The station was relocated to the edge of the gravel bar several times when the water dropped leaving the old location dry. The bottom material was mostly gravel and sand with a little rubble.

TABLE 3.4-3 (Cont'd.)

Upstream Station 4 (Outer Discharge Area)
This station was located across the river and no more than 100 m upstream from the discharge. This station was at the entrace to the large oxbow channel. The bottom was composed of gravel and rubble with a few boulders.

Downstream Station 1 (Immediate Discharge Area)
This station is located about 30 m below the discharge on the west bank of the river and at the entrance to a small oxbow channel that flowed intermittently. This was the principal downstream station. During higher flow, trials were run in the backwater of the oxbow channel and during periods of lower flow the sampling was moved to the edge of the main channel. The bottom in the backwater channel was composed of gravel and sand while the river channel bottom was mainly gravel and rubble with a few boulders.

Downstream Station 2 (Intermediate Discharge Area)
This station was located 350 m below Downstream Station 1 at the outflow of the same small side channel described for Downstream Station 1. The bottom there consisted of sand and silt, although gravel was present in places when the side channel was flowing.

Downstream Station 3 (Outer Discharge Area)
Station located 0.9 km below the discharge on the east shore of the main channel and at the outflow of the large oxbow channel. This station was not subject to the heated water effluent from the power plant. The bottom there was exclusively sand.

TABLE 3.4-3 (Cont'd.)

Downstream Station 4 (Intermediate Discharge Area)

This site was 1.3 km below the discharge on the west shore of the main channel, on the tip of a gravel bar. The bottom consisted of gravel and rubble with a small amount of sand.

TABLE 3.4-4

PHYSICAL CHARACTERISTICS AND CORRESPONDING NOTATION USED TO DETERMINE SEX AND DESCRIBE BREEDING CONDITION OF FISHES COLLECTED FROM THE MONTICELLO AREA OF THE MISSISSIPPI RIVER FROM 6 APRIL TO 14 AUGUST, 1974 (FROM EBERLEY 1975)

Physical Characteristics and Breeding Condition	Notation
Male, determined by the presence of tubercules on anal or caudal fin (redhorse, white sucker), or trace of milt from genital opening (all species)	M
Female, determined by the presence of minute tubercules on anal or caudal fin (redhorse), or trace of eggs from genital opening (all species)	F
Mature; fish liberate milt or eggs with moderate pressure of hand on the abdomen	M+, F+
Ripe; fish liberate milt or eggs spontaneously upon handling	M++, F++
Sex undetermined	–

TABLE 3.4-5

FISHES COLLECTED IN THE UPPER MISSISSIPPI RIVER DRAINAGE ABOVE ST. ANTHONY FALLS

Species	Occurrence						
	1(a)	2(b)	3(c)	4(d)	5(e)	6(f)	7(g)
Lampreys							
American Brook Lamprey	x						
Gars							
Shortnose Gar	x						
Bowfins							
Bowfin	x	x		x		x	
Freshwater Eels							
American Eel	x						
Trouts							
Cisco or Lake Herring	x						
Lake Whitefish	x						
Rainbow Trout	x	*					
Brown Trout	x	*					
Brook Trout	x	*					
Lake Trout	x						
Mudminnows							
Central Mudminnow	x	x				x	
Pikes							
Northern Pike	x	x	x	x		x	
Muskellunge	x	*		x		x	
Minnows and Carps							
Stoneroller	x	x					
Carp	x	x	x	x	x	x	
Brassy Minnow	x	x				x	
Hornyhead Chub	x	x				x	
Golden Shiner	x	x				x	
Pugnose Shiner	x						
Emerald Shiner	x						
River Shiner	x						
Common Shiner	x	x				x	
Bigmouth Shiner	x	x				x	
Blackchin Shiner	x	x					
Blacknose Shiner	x	x					
Spottail Shiner	x	x				x	
Spotfin Shiner	x	x				x	
Sand Shiner	x					x	

TABLE 3.4-5 (Cont'd.)

Species	Occurrence 1[(a)]	2[(b)]	3[(c)]	4[(d)]	5[(e)]	6[(f)]	7[(g)]
Minnows and Carps (continued)							
Mimic Shiner	x	x					
Northern Redbelly Dace	x	x				x	
Finescale Dace	x						
Bluntnose Minnow	x	x				x	
Fathead Minnow	x	x				x	
Blacknose Dace	x	x				x	
Longnose Dace	x	x				x	
Creek Chub	x	x				x	
Pearl Dace	x	x					
Suckers							
White Sucker	x	x	x	x	x	x	
Northern Hog Sucker				x			
Bigmouth Buffalo	x	*	x				
Silver Redhorse	x	x	x	x	x	x	
Golden Redhorse				x			
Shorthead Redhorse	x	x	x	x	x	x	
Freshwater Catfishes							
Black Bullhead	x	x	x			x	
Yellow Bullhead	x	x	x	x			x
Brown Bullhead	x	x				x	
Tadpole Madtom	x	x					
Trout-Perches							
Trout-Perch	x	x				x	
Codfishes							
Burbot	x	*		x		x	
Killifishes							
Banded Killifish							x
Silversides							
Brook Silverside	x	x					
Sticklebacks							
Brook Stickleback	x	x					
Ninespine Stickleback	x						

TABLE 3.4-5 (Cont'd.)

Species	Occurrence						
	1[a]	2[b]	3[c]	4[d]	5[e]	6[f]	7[g]
Sunfishes							
Rockbass	x	x	x	x		x	
Green Sunfish	x	x				x	
Pumpkinseed	x	x	x	x		x	
Bluegill	x	x	x	x		x	
Smallmouth Bass	x	x	x	x	x	x	
Largemouth Bass	x	x				x	
White Crappie						x	
Black Crappie	x	x	x	x		x	
Perches							
Iowa Darter	x	*					
Least Darter	x						
Johnny Darter	x	x				x	
Yellow Perch	x	x		x		x	
Logperch	x	x				x	
Walleye	x	x	x	x	x	x	
Sculpins							
Mottled Sculpin	x						
Slimy Sculpin	x	*					

[a] Eddy et al., 1963. p. 114-115.
[b] Moyle, 1940. p. 59-63.
[c] Anon., 1960. p. 4.
[d] Schneider, 1966, Sectors I-V. p. 9-10.
[e] Schneider, 1966, Section V only. p. 9-10.
[f] Hopwood, 1974b. p. 69-70.
[g] NSP, 1975. Knutson, 1974.

Asterisk (*) indicates a species previously reported or collected from this area, listed by Moyle (1940).

TABLE 3.4-6

SCIENTIFIC AND COMMON NAMES* OF FISHES REPORTED FROM THE UPPER MISSISSIPPI DRAINAGE, ABOVE ST. ANTHONY FALLS

Scientific Name	Common Name
Petromyzontidae	Lampreys
Lampetra lamottei	American Brook Lamprey
Lepisosteidae	Gars
Lepisosteus platostomus	Shortnose Gar
Amiidae	Bowfins
Amia calva	Bowfin
Anguillidae	Freshwater Eels
Anguilla rostrata	American Eel
Salmonidae	Trouts
Coregonus artedii	Cisco or Lake Herring
Coregonus clupeaformis	Lake Whitefish
Salmo gairdneri	Rainbow Trout
Salmo trutta	Brown Trout
Salvelinus fontinalis	Brook Trout
Salvelinus namaycush	Lake Trout
Umbridae	Mudminnows
Umbra limi	Central Mudminnow
Esocidae	Pikes
Esox lucius	Northern Pike
Esox masquinongy	Muskellunge
Cyprinidae	Minnows and Carps
Campostoma anomalum	Stoneroller
Cyprinus carpio	Carp
Hybognathus hankinsoni	Brassy Minnow
Nocomis biguttatus	Hornyhead Chub
Notemigonus crysoleucas	Golden Shiner
Notropis anogenus	Pugnose Shiner
Notropis atherinoides	Emerald Shiner
Notropis blennius	River Shiner
Notropis cornutus	Common Shiner
Notropis dorsalis	Bigmouth Shiner
Notropis heterodon	Blackchin Shiner
Notropis heterolepis	Blacknose Shiner
Notropis hudsonius	Spottail Shiner
Notropis spilopterus	Spotfin Shiner
Notropis stramineus	Sand Shiner
Notropis volucellus	Mimic Shiner
Phoxinus eos	Northern Redbelly Dace

TABLE 3.4-6 (Cont'd.)

Scientific Name	Common Name
Phoxinus neogaeus	Finescale Dace
Pimephales notatus	Bluntnose Minnow
Pimephales promelas	Fathead Minnow
Rhinichthys atratulus	Blacknose Dace
Rhinichthys cataractae	Longnose Dace
Semotilus atromaculatus	Creek Chub
Semotilus margarita	Pearl Dace
Catostomidae	Suckers
Catostomus commersoni	White Sucker
Hypentelium nigricans	Northern Hog Sucker
Ictiobus cyprinellus	Bigmouth Buffalo
Moxostoma anisurus	Silver Redhorse
Moxostoma erythrurum	Golden Redhorse
Moxostoma macrolepidotum	Shorthead Redhorse
Ictaluridae	Freshwater Catfishes
Ictalurus melas	Black Bullhead
Ictalurus natalis	Yellow Bullhead
Ictalurus nebulosus	Brown Bullhead
Noturus gyrinus	Tadpole Madtom
Percopsidae	Trout-Perches
Percopsis omiscomaycus	Trout-Perch
Gadidae	Codfishes
Lota lota	Burbot
Cyprinodontidae	Killifishes
Fundulus diaphanus	Banded Killifish
Atherinidae	Silversides
Labidesthes sicculus	Brook Silverside
Gasterosteidae	Sticklebacks
Culaea inconstans	Brook Stickleback
Pungitius pungitius	Ninespine Stickleback
Centrarchidae	Sunfishes
Ambloplites rupestris	Rock Bass
Lepomis cyanellus	Green Sunfish
Lepomis gibbosus	Pumpkinseed
Lepomis macrochirus	Bluegill
Micropterus dolomieui	Smallmouth Bass
Micropterus salmoides	Largemouth Bass
Pomoxis annularis	White Crappie
Pomoxis nigromaculatus	Black Crappie

TABLE 3.4-6 (Cont'd.)

Scientific Name	Common Name
Percidae	Perches
Etheostoma exile	Iowa Darter
Etheostoma microperca	Least Darter
Etheostoma nigrum	Johnny Darter
Perca flavescens	Yellow Perch
Percina caprodes	Logperch
Stizostedion vitreum	Walleye
Cottidae	Sculpins
Cottus bairdi	Mottled Sculpin
Cottus cognatus	Slimy Sculpin

*American Fisheries Society 1970. Data compiled from Moyle (1940), Anon. (1960), Eddy et al. (1963), Schneider (1966), Hopwood (1974b).

TABLE 3.4-7

INDIGENOUS FISH SPECIES ABOVE ST. ANTHONY FALLS
(854 MILES ABOVE OHIO RIVER)***

Family	Genus	Species
Amiidae	Amia	calva
Salmonidae	Coregonus	clupeaformis*
	Coregonus	artedii*
	Salmo	trutta**
	Salmo	gairdneri**
	Salvelinus	fontinalis*
	Salvelinus	namaycush*
Castostomidae	Ictiobus	cyprinellus
	Moxostoma	anisurum
	Moxostoma	macrolepidotum
	Catostostomus	commersoni
Cyprinidae	Cyprinus	carpio**
	Notemigonus	crysoleucas
	Semotilus	atromaculatus
	Semotilus	margarita
	Phoxinus	eos
	Phoxinus	neogaeus
	Nocomis	biguttatus
	Rhinichthys	atratulus
	Rhinichthys	cataractae
	Notropis	atherinoides
	Notropis	cornutus
	Notropis	heterodon
	Notropis	hudsonius
	Notropis	blennius
	Notropis	dorsalis
	Notropis	spilopterus
	Notropis	stramineus
	Notropis	heterolepis
	Notropis	volucellus
	Notropis	anogenus
	Hybognathus	hankinsoni
	Pimephales	notatus
	Pimephales	promelas
	Campostoma	anomalum
Ictaluridae	Ictalurus	punctatus
	Ictalurus	nebulosus
	Ictalurus	melas
	Ictalurus	natalis
	Noturus	gyrinus

TABLE 3.4-7 (Cont'd.)

Family	Genus	Species
Umbridae	Umbra	limi
Esocidae	Esox Esox	lucius masquinongy
Cyprinodontidae	Fundulus	diaphanus
Gadidae	Lota	lota
Percopsidae	Percopsis	omiscomaycus
Percidae	Stizostedion Perca Percina Estheostoma Estheostoma Estheostoma	vitreum flavescens carprodes nigrum exile microperca
Centrarchidae	Micropterus Micropterus Lepomis Lepomis Lepomis Ambloplites Pomoxis Pomoxis	salmoides dolomieui cyanellus gibbosus macrochirus rupestris nigromaculatus annularis
Antherinidae	Labidesthes	sicculus
Cottidae	Cottus Cottus	cognatus bairdi
Gasterostedidae	Culaea Pungitius	inconstans pungitius

*Transient species - infrequently found in the waterbody segment but may not be indigenous to that area.

**Species may have been introduced to this segment of the Mississippi River or be a transient species.

***Adapted from 1975 MPCA 316 Guidelines, p. 60-61.

TABLE 3.4-8

REPRESENTATIVE IMPORTANT SPECIES
(FROM MPCA, 1975, p. 50-51)

Population or Species Category	Rationale[1]	Thermal Discharge	Evaluation[2]	Intake	Evaluation[2]
Fish					
Ichthyomyzon unicupsis	CI,N	X	adult		
Polyodon spathula	CI,T	X	all		
Acipenser fulvescens	T,CI	X	all	X	all
Aplodinotus grunniens	SC	X	all	X	all
Dorosoma cepedianum	N,F	X	all	X	all
Salmo trutta	SC	X	all	X	all
Salvelinus namaycush	SC	X	all	X	all
Coregonus artedii	SC	X	all	X	all
Coregonus clupeaformis	SC	X	all	X	all

TABLE 3.4-8 (Cont'd.)

Population or Species Category	Rationale[1]	Thermal Discharge	Evaluation[2]	Intake	Evaluation[2]
*Esox lucius	SC	X	all	X	all
Notropis atherinoides	F	X	all	X	all
Notropis rubellus	F	X	all	X	all
Hybopsis storeriana	F	X	all	X	all
*Catostomus commersoni	SC	X	all	X	all
Ictalurus punctatus	SC	S	adult	X	all
Anguilla rostrata	SC,CI	X	adult		
*Perca flavescens	SC, F	X	all	X	all
*Percopsis omiscomaycus	F	X	all	X	all
*Pomoxis nigromaculatus	SC	X	all	X	all
Morone chrysops	SC	X	all	X	all

TABLE 3.4-8 (Cont'd.)

Population or Species Category	Rationale[1]	Thermal Discharge	Evaluation[2]	Intake	Evaluation[2]
**Micropterus salmoides*	SC	X	all	X	all
**Micropterus dolomieui*	SC	X	all	X	all
**Lepomis macrochirus*	SC	X	all	X	all
**Stizostedion vitreum*	SC	X	all	X	all
**Stizostedion canadense*	SC	X	all	X	all

[1] CI, Community Integrity; F, forage; N, nuisance species, population not to be enhanced; PT, pollution tolerant, population not to be enhanced; SC, sport or commercial; T, threatened or endangered species.

[2] Unless otherwise specified, "all" means the applicable descripters of the following: eggs, larvae, fry, yearlings, adults, spawning, feeding, migration, reproduction, growth, metabolism and other activities which are or may be necessary to maintain population integrity.

*Taken in present study.

TABLE 3.4-9

PERCENTAGE DISTRIBUTION OF SPECIES CAPTURED BY ELECTROFISHING DURING 1968 AND 1969.
MISCELLANEOUS GROUP INCLUDES BULLHEADS, ROCK BASS, BURBOT, LOG PERCH, AND BLUEGILLS.
CALCULATED FROM FISH PER ELECTROFISHING HOUR.
(FROM HOPWOOD 1973, p. C-381).

	Shorthead Redhorse	Carp	Silver Redhorse	Black Crappie	White Sucker	Small Mouth Bass	Walleye	Northern Pike	Miscellaneous	Total % of Game Fish	Total % of Rough Fish
Sector A											
1968	34.5	50.7	4.4	0.5	2.7	1.5	4.8	0.5	0.3	7.3	92.3
1969	48.6	29.4	7.4	4.9	4.5	1.8	2.0	0.0	1.0	8.7	89.9
Sector B											
1968	58.9	34.3	2.9	0.0	3.0	0.4	0.03	0.0	0.03	0.4	99.1
1969	65.1	17.3	9.6	0.4	4.8	2.0	1.2	0.0	0.4	3.6	96.8
Sector C											
1968	58.6	21.5	3.6	3.6	1.7	0.03	4.6	0.0	5.4	8.2	85.4
1969	44.3	18.3	5.0	20.8	2.5	5.0	1.2	0.6	1.8	27.6	70.1
Sector D											
1968	56.9	29.2	5.4	0.8	1.5	1.5	3.8	0.0	0.8	6.1	93.0
1969	59.6	25.4	4.3	0.0	5.2	2.6	2.6	0.0	0.0	5.2	94.5
Sector E											
1968	60.7	22.6	2.3	2.0	3.0	4.4	3.5	0.0	1.4	9.9	88.6
1969	48.0	27.5	1.0	12.5	1.0	6.0	2.5	0.0	1.5	21.0	77.5
Total											
1968	53.9	31.7	3.7	1.4	2.4	1.6	3.3	0.1	1.6	6.4	91.7
1969	53.1	23.6	5.5	7.7	3.6	3.5	1.9	0.1	0.9	13.2	85.8

TABLE 3.4-10

RELATIVE ABUNDANCE OF FISH SEINED FROM EACH STATION[1] IN THE PRE-OPERATIONAL STUDY AND THE TOTAL PERCENT REPRESENTED BY EACH SPECIES (IN PARENTHESES) (FROM MORGENWECK, 1971, p. 14-15)

Species	Up-1	Up-2	D-1	D-2	D-3	D-4	Total
Bigmouth shiner	830 (49.4)	297 (27.4)	177 (12.5)	318 (23.0)	121 (11.8)	234 (35.7)	1977 (27.3)
Black bullhead	---	---	---	1 (0.07)	---	1 (0.1)	2 (0.02)
Black crappie	---	---	---	2 (0.1)	---	---	2 (0.02)
Blacknose dace	---	4 (0.4)	11 (0.8)	---	6 (0.6)	9 (1.4)	30 (0.4)
Common shiner	6 (0.4)	7 (0.6)	84 (6.0)	19 (1.4)	29 (2.8)	64 (9.8)	209 (2.9)
Creek chub	---	1 (0.09)	20 (1.4)	---	4 (0.4)	---	25 (0.3)
Golden shiner	---	---	---	---	1 (0.1)	---	1 (0.01)
Hornyhead chub	4 (0.2)	8 (0.7)	57 (4.0)	7 (0.5)	127 (12.4)	25 (3.8)	228 (3.1)
Johnny darter	14 (0.8)	87 (8.0)	90 (6.4)	90 (6.5)	26 (2.5)	56 (8.5)	363 (5.0)
Longnose dace	53 (3.2)	4 (0.4)	14 (1.0)	---	152 (14.8)	1 (0.1)	224 (3.1)
Redhorse sucker	1 (0.06)	---	6 (0.4)	2 (0.14)	10 (1.0)	1 (0.1)	20 (0.3)
Rock bass	---	---	---	1 (0.07)	---	---	1 (0.01)
Sand shiner	614 (36.5)	303 (27.7)	96 (6.8)	253 (18.3)	33 (3.2)	34 (5.2)	1333 (18.4)
Smallmouth Bass	34 (2.0)	32 (2.9)	17 (1.2)	3 (0.2)	4 (0.4)	31 (4.7)	121 (1.7)

TABLE 3.4-10 (Cont'd.)

Species	Up-1	Up-2	D-1	D-2	D-3	D-4	Total
Spotfin shiner	48 (2.9)	231 (21.1)	429 (30.4)	461 (33.3)	264 (25.8)	95 (14.5)	1528 (21.1)
Spottail shiner	4 (0.2)	3 (0.3)	23 (1.6)	3 (0.2)	34 (3.3)	8 (1.2)	75 (1.0)
White sucker	20 (1.2)	27 (2.5)	66 (4.7)	37 (2.7)	14 (1.4)	20 (3.1)	184 (2.5)
Bluntnose minnow	53 (3.2)	89 (8.1)	321 (22.7)	187 (13.5)	199 (19.4)	76 (11.6)	925 (12.7)
TOTAL NUMBER % TOTAL	1681 (23.2)	1093 (15.1)	1411 (19.5)	1384 (19.1)	1024 (14.1)	655 (9.0)	7248

[1]Preoperational stations were in areas later designated as:

Up-1 Adjacent Water Body Segment
Up-2 Adjacent Water Body Segment
D-1 Immediate Discharge Area
D-2 Outer Discharge Area
D-3 Intermediate Discharge Area
D-4 Intermediate Discharge Area

TABLE 3.4-11

TOTAL NUMBER AND PERCENT OF EACH SPECIES SEINED DURING THE OPERATIONAL STUDY[1]
(FROM OTT 1973, P. 14-15)

Species	Up-1	Percent	Up-2	Percent	Up-3	Percent	Up-4	Percent	D-1	Percent	D-2	Percent	D-3	Percent	D-4	Percent	Total	Percen
	Stations																	
Spotfin shiner	42	15.8	106	38.4	193	9.8	129	30.2	830	33.6	168	36.9	271	17.5	47	26.3	1786	23.5
Bigmouth shiner	107	40.1	4	1.4	612	30.9	19	4.5	274	11.0	20	4.4	608	39.3	12	6.7	1656	21.8
Sand shiner	45	16.9	94	34.1	754	38.0	12	2.8	404	16.4	69	15.2	249	16.1	14	7.8	1641	21.6
Bluntnose minnow	21	7.9	31	11.2	117	5.9	73	17.1	506	20.5	137	30.1	320	20.7	24	13.4	1229	16.2
Common shiner	21	7.9	2	0.7	52	2.6	5	1.2	122	4.9	18	4.0	26	1.7	9	5.0	255	3.4
Hornyhead chub	10	3.7	14	5.1	22	1.1	5	1.2	43	1.7	2	0.4	23	1.5	7	3.9	126	1.7
Johnny darter	8	3.0	2	0.7	49	2.5	8	1.9	84	3.4	7	1.6	24	1.6	14	7.8	196	2.6
Fathead minnow	1	0.4	--	--	2	0.1	17	4.0	34	1.4	1	0.2	6	0.4	5	2.8	66	0.9
Spottail shiner	1	0.4	1	0.4	20	1.0	1	0.2	24	1.0	10	2.2	4	0.3	1	0.6	62	0.8
Creek chub	3	1.1	--	--	--	--	--	--	3	0.1	--	--	--	--	--	--	6	0.1
Longnose dace	--	--	--	--	42	2.1	--	--	3	0.1	--	--	--	--	11	6.1	56	0.7
Blacknose dace	1	0.4	--	--	19	1.0	1	0.2	4	0.2	--	--	--	--	--	--	25	0.3
Redhorse sucker spp.	2	0.8	21	7.6	4	0.2	1	0.2	7	0.3	2	0.4	5	0.3	7	3.9	49	0.6
White sucker	--	--	1	0.4	33	1.7	121	28.3	105	4.2	8	1.8	9	0.6	18	10.1	295	3.9
Smallmouth bass	1	0.4	--	--	41	2.1	9	2.1	17	0.7	2	0.4	--	--	9	5.0	79	1.0
Largemouth bass	--	--	--	--	--	--	2	0.5	3	0.1	2	0.4	--	--	--	--	7	0.1
Logperch	2	0.8	--	--	--	--	6	1.4	4	0.2	--	--	--	--	--	--	12	0.2
Troutperch	1	[illegible]	--	--	12	0.6	2	0.5	4	0.2	9	2.0	--	--	--	--	28	0.4
Brassy minnow	--	--	--	--	8	0.4	15	3.5	--	--	--	--	--	--	1	0.6	24	0.3
N.Redbelly dace	--	--	--	--	--	--	1	0.2	--	--	--	--	--	--	--	--	1	nil
Total	266		276		1980		427		2471		455		1545		179		7599	

[1]Operational Stations were in the following areas:

Up-1	Adjacent Water Body Segment	D-1	Immediate Discharge Area
Up-2	Adjacent Water Body Segment	D-2	Intermediate Discharge Area
Up-3	Adjacent Water Body Segment	D-3	Outer Discharge Area
Up-4	Outer Discharge Area	D-4	Intermediate Discharge Area

TABLE 3.4-12

COMPARISON OF SPECIES COMPOSITION, BY PERCENTAGE, OF PRE-OPERATIONAL AND OPERATIONAL FISH POPULATIONS SAMPLED BY SEINING IN THE MISSISSIPPI RIVER (FROM HOPWOOD 1974b, p. C-268).

	Stations					
	Adjacent Water Body Segment		Immediate Discharge Area		Outer Discharge Area	
Species	Pre Up-1	Op Up-1	Pre D-1	Op D-1	Pre D-2	Op D-3
Spotfin shiner	2.9	9.8	30.4	33.6	33.3	17.5
Bigmouth shiner	49.4	30.9	12.5	11.0	23.0	39.3
Sand shiner	36.5	38.0	6.8	16.4	18.3	16.1
Bluntnose minnow	3.2	5.9	22.7	20.5	13.5	20.7
Common shiner	0.4	2.6	6.0	4.9	1.4	1.7
Hornyhead chub	0.2	1.1	4.0	1.7	0.5	1.5
Johnny darter	0.8	2.5	6.4	3.4	6.5	1.6
Spottail shiner	0.2	1.0	1.6	1.0	0.2	0.3
Creek chub	-	-	1.4	0.1	-	-
Longnose dace	3.2	2.1	1.0	0.1	-	-
Blacknose dace	-	1.0	0.8	0.2	-	-
Redhorse sp.	0.06	0.2	0.4	0.3	0.14	0.3
White sucker	1.2	1.7	4.7	4.2	2.7	0.6
Smallmouth bass	2.0	2.1	1.2	0.7	0.2	-

TABLE 3.4-13

RESULTS OF A RANK CORRELATION CALCULATION PERFORMED ON THE ABUNDANCE OF THE VARIOUS SPECIES COLLECTED IN PRE-OPERATIONAL AND OPERATIONAL SEINING OPERATIONS. SPECIES ARE CODED MOST ABUNDANT AS 1 AND LEAST ABUNDANT AS 14. THE FORMULA (FREUND, 1970) USED TO CALCULATE THE CORRELATION IS

$$f' = 1 - 6(d^2)/n(n^2 - 1)$$

WHERE (d) IS THE DIFFERENCE BETWEEN THE RANK OF THE SPECIES AND (n) IS THE NUMBER OF SPECIES BEING COMPARED (FROM HOPWOOD, 1974b, p. C-269).

	Adjacent Water Body Segment				Immediate Discharge Area				Outer Discharge Area			
	Past Rank	Present Rank	d	d^2	Past Rank	Present Rank	d	d^2	Past Rank	Present Rank	d	d^2
Spotfin shiner	5	3	2	4	1	1	0	0	1	3	2	4
Bigmouth shiner	1	2	1	1	3	4	1	1	2	1	1	1
Sand shiner	2	1	1	1	4	3	1	1	3	4	1	1
Bluntnose minnow	3.5	4	0.5	0.25	2	2	0	0	4	2	2	4
Common shiner	9	5	4	16	6	5	1	1	7	5	2	4
Hornyhead chub	10.5	10	0.5	0.25	8	8	0	0	8	7	1	1
Johnny darter	8	6	2	4	5	7	2	4	5	6	1	1
Spottail shiner	10.5	11.5	1	1	9	9	0	0	9.5	9.5	0	0
Creek chub	13.5	14	0.5	0.25	10	13.5	3.5	12.25	13	12.5	0.5	0.25
Longnose dace	3.5	7.5	4	16	12	13.5	1.5	2.25	13	12.5	0.5	0.25
Blacknose dace	13.5	11.5	2	4	13	12	1	1	13	12.5	0.5	0.25
Redhorse sucker	12	13	2	4	14	11	3	9	11	9.5	1.5	2.25
White sucker	7	9	2	4	7	6	1	1	6	8	2	4
Smallmouth bass	6	7.5	1.5	2.25	11	10	1	1	9.5	12.5	3	9
		r' = .873				r' = .926				r' = .930		

TABLE 3.4-14

1973 MEAN MONTHLY ABUNDANCE INDICES (NO. COLLECTED/ha.) OF YOY SMALLMOUTH BASS AND WHITE SUCKER COLLECTED BY SEINING (FROM HEBERLING 1975)

Smallmouth Bass (*Micropterus dolomieui*)

Month	Upstream (Adjacent Water Body Segment)	Downstream Cool (Outer Discharge Area)	Downstream Warm (Intermediate Discharge Area)
June	445	48	109
July	315	164	395
August	190	94	389
September	74	60	127

White Sucker (*Catostomus commersoni*)

Month	Upstream (Adjacent Water Body Segment)	Downstream Cool (Outer Discharge Area)	Downstream Warm (Intermediate Discharge Area)
June	5860	4850	3060
July	1130	434	932
August	487	349	283
September	47	29	36

TABLE 3.4-15

1974 MEAN MONTHLY ABUNDANCE INDICES (NO. COLLECTED/ha.) OF YOY SMALLMOUTH BASS AND WHITE SUCKER COLLECTED BY SEINING (FROM HEBERLING 1975)

Smallmouth Bass (*Micropterus dolomieui*)

Month	Upstream (Adjacent Water Body Segment)	Downstream Cool (Outer Discharge Area)	Downstream Warm Intermediate Discharge Area)
June	0	0	212
July	1135	252	1114
August	342	307	447
September	44	49	72

White Sucker (*Catostomus commersoni*)

Month	Upstream (Adjacent Water Body Segment)	Downstream Cool (Outer Discharge Area)	Downstream Warm (Intermediate Discharge Area)
June	-	-	-
July	974	152	202
August	27	156	11
September	0	4	4

TABLE 3.4-16

SUBSTRATE COMPOSITION OF THE SPAWNING GROUNDS OF THE SHORTHEAD AND SILVER REDHORSE IN THE MONTICELLO AREA OF THE MISSISSIPPI RIVER (FROM EBERLEY 1975, p. 60)

Name of Particle	Particle Size Range (mm)	Mean Percent of Total Weight			
		Site 1	Site 2	Site 3	Site 4
Boulder	≥256	-	-	-	-
Cobble	64-256	10.4	2.4	6.1	15.3
Pebble	32-64	35.8	22.6	27.2	28.1
	16-32	38.9	60.8	26.1	42.8
Gravel	8-16	11.7	13.3	34.7	12.0
	4-8	0.8	0.7	4.0	0.7
	2-4	0.4	0.1	0.2	0.1
Very Coarse Sand	1-2	0.5	0.1	0.3	0.3
Coarse Sand	0.5-1	0.7	*	0.4	0.3
Medium Sand	0.25-0.5	0.3	*	0.7	0.3
Fine Sand	0.125-0.25	0.2	*	0.2	0.1
Very Fine Sand	0.0625-0.125	0.1	*	0.1	*
Silt	≤0.0625	0.1	*	0.1	0.1

*Less than 0.1% by weight.

TABLE 3.4-17

SUBSTRATE COMPOSITION OF THE SPAWNING GROUNDS OF THE WHITE SUCKER IN THE MONTICELLO AREA OF THE MISSISSIPPI RIVER (FROM EBERLEY 1975, p. 62)

Name of Particle	Particle Size Range (mm)	Mean Percent of Total Weight: Site 1	Site 2	Site 3	Site 4
Boulder	≥256	-	-	-	-
Cobble	64-256	1.1	-	3.8	7.7
Pebble	32-64	3.6	5.2	8.5	29.8
	16-32	40.4	41.3	28.7	41.0
Gravel	8-16	46.4	47.1	45.8	18.0
	4-8	7.2	4.7	10.6	2.5
	2-4	0.4	0.5	0.3	0.2
Very Coarse Sand	1-2	0.2	0.5	0.3	0.3
Coarse Sand	0.5-1	0.4	0.3	0.5	0.2
Medium Sand	0.25-0.5	0.4	0.3	1.2	0.2
Fine Sand	0.125-0.25	*	0.1	0.3	0.1
Very Fine Sand	0.0625-0.125	*	*	*	*
Silt	≥0.0625	0.1	0.1	0.1	0.1

*Less than 0.1% by weight.

TABLE 3.4-18

NOTES ON SPAWNING AND REPRODUCTION OF 26 SPECIES TAKEN DURING THE MONTICELLO ECOLOGICAL STUDY

Species	*Amia calva* (Bowfin)
Maturation by Year - Class or Length (mm total length)	Male: III-V[6], 457; 380[5]; Female: 610[6].
Fecundity	23,600-64,000[5]
Spawning Season	Mid-May through June, possibly as early as late April (Canada)[6]; late March through May[5].
Temperature (°C)	16-19[5]
Area	Shallow vegetated waters in lakes and rivers[1]; shallow, sluggish, stagnant water up to 122cm or deeper[5].
Egg Deposition	38-76 cm diameter nets among thick vegetation hollowed out circular or elliptical depression with bottom of fibrous roots, water-soaked leaves or gravel, also under stumps, logs, and bushes. 2,000-5,000 eggs per nest; eggs attach to decaying vegetation and reeds by thread-like extensions of egg surface[5].
Type	Adhesive, darker from original creamy yellow[6]; attachment structure[5].
Water-hardened Size (mm)	2.2-3.0, capsule progressively distends to twice original size[5].
Incubation Period (days)	8-10[6]; 4-14[5].
Larvae	
Hatching Size (mm total length)	8[6]; 3-7[5]
Habits, Behavior Survival	Larvae attach to vegetation with adhesive on the tip of the snout for 7-9 days by which time thev are 10-13 mm total length, young guarded by male parent for several weeks until young are about

TABLE 3.4-18 (Continued)

Amia calva (cont'd.)

102 mm total length[6] ; larvae also attach to roots and lie on bottom of nest, then form tight guarded swarms, larvae 9-13 mm at yolk absorbtion, young among weeks in shallows[5].

TABLE 3.4-18 (Continued)

Species	*Esox lucius* (Northern pike)
Maturation by Year - Class or Length (mm total length)	Male: I-II, 305[2]; II-III[6]; Female: II-IV, 325[2]
Fecundity	595,000,32,000[6]; 2,000-545,000[2]; 32,000[1].
Spawning Season	March through May (Canada)[6]; March to May (Michigan)[1]; February to mid-June[2].
Temperature (°C)	4.4-11.1[6]; 5-14[2].
Area	Heavily vegetated flood plains of rivers, marshes, and bays; larger lakes, often in water no deeper than 18cm[6]; shallow areas with vegetation[2]; swamps, ponds, and lakes[1]; grassy or rush beds[4].
Egg Deposition	Eggs scattered at random and attach to vegetation[6]; no nest[2]; no parental care[4]; eggs clear and amber[6].
Type	Demersal, adhesive[6]
Water-hardened Size (mm)	2.5-3.0[6]; 2.2-3.4[1].
Incubation Period (days)	12-14, 4.5 @17.8-20°C[6]
Survival	Fertility rate over 50%[6], 52-99% fertile, 64-90% egg hatch[2].
Larvae	
Hatching Size	6-7[6]; 6.5-8 with average of 7[2]; 9-10[4].
Habits, Behavior, Survival	99.8% mortality prior to young leaving spawning grounds; young attach to vegetation with adhesive glands on head for 6-10 days while consuming yolk; young grow rapidly, 43 mm by first

TABLE 3.4-18 (Continued)

Esox lucius (cont'd.)

month and 152 mm by the end of first summer, young after yolk absorption feed on larger zooplankton and immature insects for 7-10 days then begin consuming small fish; by 50 mm, fish are a predominant food[6]; begin feeding at 13.3-15.1 mm, 99.6-99.9% mortality from egg to fingerling[2].

TABLE 3.4-18 (Continued)

Species	*Cyprinus carpio* (Carp)
Spawning Season	Late April to mid-August (Great Lakes)[6]; mid-May through August (Wisconsin)[2]; May through mid-August (Pennsylvania)[7]; mid-May to early July (Maryland)[5]; March through August (U.S.)[5]. Late March through mid-June (Okla.)[8].
Temperature (°C)	17-28[6]; 14.5-23.4 but mostly at 18.5-20[2 & 5], 10-30 but optimal at 22[5].
Area	Weedy or grassy shallows of lakes, ponds, tributaries, swamps, flood plains, and marshes; 8-180 cm in depth[1, 2, 4, 5, 6, 8, 9].
Egg Deposition	Broadcast randomly, eggs attach frequently in clusters to weeds, grasses or roots[1, 2, 4, 5, 6, 8, 9].
Type	Adhesive[1, 2, 5, 6]
Water-hardened Size (mm)	1[6], 1.0-2.0[5].
Incubation Period (days)	3-6[6]; 3-16, 3-5 @ 20°C, 4-8 @ 17.6-18.4°C, 12-16[1]; 2-3 at 22°C[5].
Survival	High mortality[8]
Larvae	
Hatching Size (mm total length)	3-6.4[5]
Habits, Behavior, Survival	Larvae attach to or lie among vegetation after hatching[5]; most larvae remain in shallow water, few are found in deeper open water[8]; after 12 mm, total length, young appear to move from near-shore surface water to deeper water[7].

TABLE 3.4-18 (Continued)

Species	*Notropis hudsonius* (Spottail shiner)
Spawning Season	May through July (Lake Erie)[4,6]; June to early July (Lake Erie)[2].
Temperature (°C)	20.0[2]
Area	Over sandy shoals in water 90-150 cm deep[6].
Egg Deposition	Found in algae masses along Lake Erie shore.
Fecundity (mm Total Length)	100-2600[2].

TABLE 3.4-18 (Continued)

Species	*Notropis spilopterus* (Spotfin shiner)
Maturation by Year - Class or Length (mm total length)	I, 47 mm (minimum)[2]
Fecundity	225-1,580[6]
Spawning Season	Mid-May through August (New York)[6]; late May to early September (New York)[2]; late May through June (Maryland)[2]; early May to mid-September (Pennsylvania)[7].
Egg Deposition	Underside of logs and roots[6]; underside of submerged objects[9]; attached to branches and logs in clusters[2].
Type	Adhesive[6]
Larvae Habits, Behavior Survival	Larvae appear to prefer the shallow shoreline to the more open waters[7].

TABLE 3.4-18 (Continued)

Species	Notropis dorsalis (Bigmouth shiner)
Spawning Season	Late May to early September[2]; late June to late August (Colorado)[1].
Area	Probably spawns in mid-stream[2].
Egg Deposition	Eggs probably carried by current[2].
Type	Pelagic[2]

TABLE 3.4-18 (Continued)

Species	*Pimephales notatus* (Bluntnose minnow)
Maturation by Year - Class or Length (mm total length)	Male: II[6]; III[2]; Female: I[6]; I-II[2]
Fecundity	1,743-2,223 averaging 2,005[2].
Spawning Season	May to mid-August (Canada)[6]; May through August (Michigan)[2]; mid-April through August (Illinois, Pennsylvania)[2, 7]; late May to early August (Wisconsin)[1].
Temperature (°C)	21-26[2]; 27.8[4]
Area	Shallow water up to 62 cm deep, sand and gravel bottom shoals[1].
Egg Deposition	Male hollows out nest beneath stone or other object upon which the eggs are laid on the underside[6]; intermittent spawners, 200-500 eggs per spawning[2]; several broods per nest[1].
Type	Adhesive[6]
Water-hardened Size (mm)	1-1.5[6]
Incubation Period (days)	7-14[6]; 8-9 @ 21-24°C[1].
Larvae	
Hatching Size (mm total length)	5[6]
Habits, Behavior, Survival	Larvae are 12 mm 2 weeks after hatching[6].

TABLE 3.4-18 (Continued)

Species	*Rhinichthys cataractae* (Longnose dace)
Fecundity	200-1,200[6]; 160-680[2].
Spawning Season	Late April through July (Canada)[6]; late April to mid-June (Maryland)[2]; late May to early September (Minnesota)[2].
Temperature (^{o}C)	11.7 minimum[6]
Area	In riffles[6]
Egg Deposition	Over gravelly bottom, in or near *Nocomis micropogon* nests, one parent believed to guard area though no nest is built[6].
Type	Adhesive[6]
Incubation Period (days)	7-10 @ 15.6°C
Larvae Habits, Behavior, Survival	Yolk absorbed 7 days after hatching, young are pelagic and remain so for about 4 months[6].

TABLE 3.4-18 (Continued)

Species	*Semotilus atromaculatus* (Creek chub)
Maturation by Year - Class or Length (mm total length)	Male: III[6]; IV[2]; Female: II[6]; III[2]
Fecundity	2,820-4,671; 4,250 average for 76-703 mm total length[1].
Spawning Season	Late April to mid-July (Canada)[6]; April to mid-May (Illinois)[2]; early March to mid-June (Iowa)[2]; mid-April to July (Michigan)[2].
Temperature (°C)	12.8 minimum[6]; 12.8-26.7[1]
Area	Small, gravelly streams in smooth water just above or below a riffle[6]; in quiet riffles or gravel bar in a lake[1].
Egg Deposition	Male creates a nest or depression (trench); eggs deposited in pit, then covered with stones and gravel, male guards nest[6]; conspicuous nests with large stone ridge and oval pit[1].
Type	Demersal[6]

TABLE 3.4-18 (Continued)

Species	Catostomus commersoni (White sucker)
Maturation by Year - Class or Length (mm total length)	III-VIII[6]; 76 mm minimum; Male: IV-VII[2]; Female: III-IX[2]
Fecundity	20,000-139,000[6]; 775-139,000 for fish 120-510 mm total length[2]; average of 20,000-50,000 for fish 410-540 total length[1].
Spawning Season	April through mid-June (Canada)[6]; late March to mid-May (Wisconsin)[1]; early May to early July (Wisconsin)[2]; late March to mid-June (Lake Erie)[1]; April-May (Michigan)[2]; mid-March through early April (Illinois)[2]; early May through early June (New York)[1]; early March through July (U.S.)[5, 8]
Temperature (°C)	6-23[5]; usually 10-20[8].
Area	Gravelly stream, lake margins or quiet areas in blocked streams, usually shallow with gravel, sometimes in rapids[6]; in riffles over gravel[2]; shallow swift water over gravel, may spawn in lakes but not typical[1].
Egg Deposition	Eggs scattered; adhere to gravel or drift downstream[6].
Type	Pelagic, adhesive[4]; slightly adhesive until water-hardened; demersal[5].
Incubation Period (days)	8-11 @ 10-15°C; 5 @ 18°C; 7 @ 15.5-16.1°C, 11 @ 13.6°C[2]; 4 @ 21.1°C, 7 @ 15.6°C, 17-21 @ average of 10.3°C[5].
Larvae Habits, Behavior Survival	Larvae remain in gravel 1-2 weeks then migrate to lake or

TABLE 3.4-18 (Continued)

Catostomus commersoni (cont'd.)

river at which time they are 12-17 mm, may be as little as 3% survival from egg to migrant larvae[6]; prolarvae lie on bottom, larvae in schools in quiet shallows[5]; 12-14 mm at first downstream movement[2]; occasionally pelagic[7].

TABLE 3.4-18 (Continued)

Species	*Moxostoma anisurum* (Silver redhorse)
Maturation by Year - Class or Length (mm total length)	V[2]
Fecundity	14,190-36,340[6]
Spawning Season	April and May[2]; late May through mid-June, possibly as early as late March (Chippewa River, Canada)[6].
Temperature (°C)	13.5[2]; 13.3[6].
Egg Deposition	Swiftly flowing streams, main channel of turbid rivers in 30-91 cm of water, do not ascend tributary streams[6]; spawn upstream[4].
Type	On gravel to rubble bottoms[6].
Larvae Habits, Behavior, Survival	Young inhabit slow-moving waters over hard or soft bottoms with overhanging banks[6].

TABLE 3.4-18 (Continued)

Species	*Moxostoma macrolepidotum* (Shorthead redhorse)
Maturation by Year - Class or Length (mm total length)	II-III[2]
Fecundity	13,580-29,732[6]; 13,500-27,150[5]
Spawning Season	Early April to early May (Iowa)[2]; late May through July (Canada)[6]; early April through May[2]; mid-March through June (Maryland)[5].
Temperature (°C)	11.1[6]
Area	Small rivers or streams gravelly riffles[6]; quieter upper parts of streams at least 10 m wide, also over sand bottoms[5].
Egg Deposition	Eggs scattered[6]; scattered in small lots, buried in bottom[5].

TABLE 3.4-18 (Continued)

Species	Ictalurus melas (Black bullhead)
Maturation by Year - Class or Length (mm total length)	III, 254[2].
Fecundity	3000-6800[6]; 3000-4000[1]; 1638-6200[2].
Spawning Season	Late April through June, possibly through August[6]; June through July (Wisconsin)[1]; late May to July (Ohio)[1]; early May to July (Illinois)[1].
Temperature (°C)	21[6]; begins @ 21-25.
Area	Shallow water among moderate to heavy vegetation[6].
Egg Deposition	Female excavates nest; intermitent spawning, both parents guard and care for eggs, about 200 eggs per brood[6].
Type	Somewhat adhesive; gelatinous coat; pale cream color[6].
Water-hardened Size (mm)	3 [6]
Incubation Period (Days)	5 @ high temperature.
Larvae Habits, Behavior, Survival	Newly hatched young school in loose sphere about parent until 25 mm in length[6]; young school by day[2].

TABLE 3.4-18 (Continued)

Species	*Ictalurus nebulosus* (Brown bullhead)
Maturation by Year - Class or Length (mm total length)	III; 203-330[6].
Fecundity	2000-13000[6].
Spawning Season	Late April to July, possibly through September (Canada)[6]; May to July (Illinois)[1]; May to mid-August (Pennsylvania)[7]; May through June (Maryland)[5].
Temperature (°C)	21.1[6]; 21-25[5].
Area	Among roots of aquatic vegetation, usually near stump, rock, and trees, near shore[6]; sluggish weedy, muddy streams and lakes shallow to a several meters.
Egg Deposition	Shallow nest in bottom of mud; at times in burrows[6]; nests in open excavations in sand, gravel, or rarely mud, and often in shelter logs, rocks or vegetation, in burrows up to one meter long under roots of plants, in cavities of various objects, deposited in clusters[5].
Type	Adhesive; gelatinous, mucous coat pale cream color[6].
Water-hardened Size (mm)	3[6]
Incubation Period (Days)	6-9 @ 20.6-23.3°C[6]; 5 @ 25°C; 2 @ 20-21°C[5]; 5-14[7]; 7[1].
Larvae Hatching Size (mm total length)	6[6]
Habits, Behavior, Survival	Begin swimming and active feeding by 7th day after hatching, school in loose spear with parents until 51 mm total length[6]; larvae in tight mass on bottom for 6-16 days, then herded by parents for a few weeks, sometimes in schools throughout first summer among vegetation or near cover over muddy bottoms[5].

TABLE 3.4-18 (Continued)

Species	*Percopis omiscomaycus* (Trout-perch)
Maturation by Year - Class or Length (mm total length)	I[6]; male 1[2]; female I-II[2].
Fecundity	240-728; averaging 349[6].
Spawning Season	Late April to June[6]; late April through May, possibly to September (Lake Erie)[6]; Lake May through August (Minnesota)[6]; late April through June[2]; late May to mid-June (Lake Erie)[2].
Temperature (°C)	16-20[2]; 19-21.4[1].
Area	Shallow rocky streams, also sand and gravel bottom in 0-1.3 m shoreline water of lakes[6]; shallow swift water over rocky or gravel bottom[1].
Type	Single 0.7 mm diameter, oil globule in fertalized egg[6]; adhesive demersal[2].
Water-hardened Size (mm)	1.36-1.85; 1.25-1.45[6].
Incubation Period (Days)	8 days at 20°C; 250 degree-days above 0°C[2].
Hatching Size (mm)	6.0[4]
Larvae Habits, Behavior, Survival	Young feed mainly on ostracods, *Gammarus*, *Leptodora*, chironomids, or zooplankton[2].

TABLE 3.4-18 (Continued)

Species	*Lota lota* (Burbot)
Maturation by Year - Class or Length (mm total length)	III-IV, 280-480[6]; III, 343-419[2].
Fecundity	45,600-1362007[6]; 68498-1153144[2]; 160,000-670000[1].
Spawning Season	Late December through March (Canada)[6]; mid-January to March[2]; late September through March, possibly through April[1,4].
Temperature (°C)	0.6-1.7[6].
Area	30-120 cm of water over sand or gravel in shallow bays or gravel shoals 1.5-3 m deep, usually in lakes but has been known to move into rivers[6]; deep holes in streams or "Bear" deep water[1].
Egg Deposition	Spawn as a writing ball, 61 cm in diameter of 10-12 interwined and constantly moving individuals; no nest or parental care[6]; eggs scattered loose on bottom[1]; 250 eggs at a time[2].
Type	Semi-pelagic[6]; non-adhesive[1].
Water-hardened Size (mm)	1.25-1.77[6]; 1.7[1].
Incubation Period (Days)	30 @ 6.1°C; 3-4 weeks[1].

TABLE 3.4-18 (Continued)

Species	*Ambloplites rupestris* (Rock bass)
Maturation by Year - Class or Length (mm total length)	II-V but typically II-III[3]; 109-267[6].
Fecundity	3,000-11,000[6]; averaging over 5,000[3].
Spawning Season	Late March through July[3]; late April to July (Lake Erie)[4]; late March to July (New York)[1]; May-June (Indiana)[1]; May to August (Pennsylvania)[7].
Temperature (°C)	15.6-21.1[6]; 20.5-26[3].
Area	Swamps to gravel shoals, very diverse[6]; near vegetation in shallow water up to 62 cm deep[1].
Egg Deposition	Male digs shallow nest up to 61 cm diameter; female spawns intermittently: male guards eggs; nest produces average of 800 larvae[6]; nests on gravel, soil, marl, in swampy places, near rocks, sticks, etc.[1]
Type	Adhesive[6].
Incubation Period (Days)	3-4 @ 20.5-21.0°C.
Larvae Habits, Behavior, Survival	Male broods young for short time; young usually inhabit protected areas only[1].

TABLE 3.4-18 (Continued)

Species	*Micropterus salmoides* (Largemouth bass)
Maturation by Year - Class or Length (mm total length)	II-V, occasionally less than I[3]; male: IV-V[6]; female: III-IV[6].
Fecundity	2,000-109,314, average 7,000-94,157[3].
Spawning Season	Late March to August (Lake Erie)[4]; late March to July (New York)[1]; mid-April to July (Illinois, Missouri, New Hampshire)[3]; May (New York, Indiana)[1,3]; mid-April to early July (Wisconsin, Pennsylvania)[1,3,7]. Early April through mid-August (Okla.)[8].
Temperature (°C)	11.5-29, 14.4-23.9[3]; 17.8[1]; 16.7-18.3[6].
Area	In quiet bays among emergent vegetation, gravelly sand, marl, or solt mud in reeds, bullrushes or water lilies[6]; in shallow water, usually less than 61 cm deep, over clean sand, gravel, roots or aquatic vegetation, sometimes on fallen leaves[1,3]; usually near boulders, pilings or under sandstone ledges[3].
Egg Deposition	Nest 61-92 cm diameter; 2-20 cm deep, and 9 m apart; eggs laid over whole bottom of nest, nest guarded by male, nests produced 751-11,457 (averaging 5000-7000) larvae[6]; will not nest on silt bottoms[3]; eggs attach to stones[4]; eggs attach to roots and other objects in nests[1].
Type	Adhesive[4]; demersal, amber to pale yellow[6].
Water-hardened Size (mm)	1.5-1.7
Incubation Period (Days)	3-5[6]; 1.5-13.2, 1.5 @ 30°C, 2.9 @ 20-22.5°C; 4-43 @ 17.5%, 6.8 @ 15°C; 13.2 @ 10°C[3].
Survival	0-94%, averaging 80%, usually 92-100%[3].

TABLE 3.4-18 (Continued)

	Micropterus salmoides (cont'd.)
Larvae	
Hatching Size (mm total length)	3[6]
Habits, Behavior, Survival	Young remain on bottom of nest for 6-7 days and rise and begin to feed at 5.9-6.3 mm total length; brood may remain together for 31 days and 15 guarded by male all or part of the time[6]; free-swimming at 6.2 mm total length; remain in nest two weeks then leave as a compact school[1,4]; survival from 90 days to fall is 58-91% from 47 days to fall is 19-100%[3].

TABLE 3.4-18 (Continued)

Species	*Micropterus dolomieui* (Smallmouth bass)
Maturation by Year - Class or Length (mm total length)	II-IV but usually III-IV[3]; male II-IV[6]; female IV-VI.
Fecundity	5,000-14,000[6]; 2,000-20,825, averaging 5,040-13,863[3].
Spawning Season	Early May through July[6]; mid-April to early June (Ohio, Missouri)[3]; May to early July (Maryland, New York, Michigan)[3]; late May through July (Cayuga Lake)[3]; late April through July (Pennslyvania, Lake Erie)[4,7].
Temperature (°C)	16.1-18.3[6]; 15.5-17.8; 11.7-21, usually 15-21[3].
Area	Lakes and rivers; sandy, gravely or rocky bottom usually near rocks, logs, or more rarely dense vegetation[6]; usually in shallow water near overhead cover, stumps, stones, steep banks or at edges of pools, in tributatries[1,3,4,8]; along lake shores[1].
Egg Deposition	Nests, depressions, formed in clean gravel or sand with bedrock, wood debris, or clam shells on bottom[1,3,4,8]; nest circular, 30-120 cm in diameter eggs usually attach to stones at center of nest; nest guarded by male[6].
Type	Demersal, adhesive, light amber to pale yellow[6].
Water-hardened Size (mm)	1.2-2.5[6].
Incubation Period (Days)	2.2-16[1,3,4]; 2.2 @ 75°C, 9.8 @ 12.8°C, 7 @ 15°C 3.2 @ 21.1°C[3]; 4-10[6].
Survival	55.2 - 100%,average 94.1%[3].
Larvae Hatching Size	5.6-5.9[6].

TABLE 3.4-18 (Continued)

	Micropterus dolomieui (cont'd.)
Habits, Behavior, Survival	Young guarded for 2-10 days or up to 28 days after leaving nests[3]; yolk absorbed 12 days after hatching at which time they are 8.7-9.9 mm total length and leave the nest, still guarded[6].

TABLE 3.4-18 (Continued)

Species	*Lepomis macrochirus* (Bluegill)
Maturation by Year - Class or Length (mm total length)	I-II, rarely 0[3]; I[1]; female III-IV[6]; male II-III[6].
Fecundity	7,208-38,184, 4,670-224,900[6]; 2,360-81,104, means of 3,820-58,000 for fish 122-151 mm total length[3].
Spawning Season	Late April to mid-September (Wisconsin)[3]; June to mid-October (Michigan)[3]; June to July (Indiana)[1]; mid-May through August (Pennsylvania)[7]; late April through September (Illinois)[3]. Early May through late September (Okla.)[8]
Temperature (°C)	24.5[6]; 22-26, 17-32[3].
Area	Water less than 120 cm deep over variety of substrates but fine gravel or clean sand preferred, area usually exposed to sun[3].
Egg Deposition	Nests in colonies over hard bottom of sand or mud with little vegetation[1]; nest is a shallow depression 45-60 cm in diameter; guarded by male[6].
Type	Adhesive, demersal, amber[6]; very heavy[1].
Incubation Period (Days)	3.5[6]; 13.3, 3 @ 22.6°C; 1.4 @ 26.9°C; 1.3 @ 22.3°C; 2.1 @ 24°C; 1.7 @ 23.5°C in light but 1.8 in dark[3].
Survival	56% @ 22.6°C; 83% @ 26.9°C; 90% @ 27.3°C[3]; survival higher where dense vegetation is present[3].
Larvae Hatching Size (mm total length)	2-3[6].

TABLE 3.4-18 (Continued)

	Lepomis macrochirus
Habits, Behavior, Survival	Mortality rate of larvae is very high[6]; young free-swimming four days after hatching leave nests and remain in littoral zone until 10-12 mm when they move to limetic zone; when 21-25 mm they return to littoral zone[3]; larvae found in both limetic and littoral zones[7].

TABLE 3.4-18 (Continued)

Species	*Poxomis annularis* (White crappie)
Maturation by Year - Class or Length (mm total length)	II-III[1]; II-IV; 152-203[6].
Spawning Season	Late April to mid-July (Ohio)[1]; mid-May through July (Pennsylvania)[7]. mid-March to mid-June (Okla.)[8]
Temperature (°C)	14-23, mostly 16-20[6].
Area	Shallow water up to 1.7 meters deep[8]; near or under overhanging ledges[1].
Egg Deposition	Eggs adhere to plants and rootlets[1,8]; clean ill-defined nests, 300 mm diameter with no depression over a variety of bottoms, nests isolated or in colonies of 35-50, 61-122 cm apart, eggs adhere to substate, especially algae and each other[6].
Type	Adhesive; demersal, colorless[6].
Water-hardened Size (mm)	0.89[6]
Incubation Period (Days)	2-2.2 @ 21.1-23.3°C[3]; 2-4.5, 4 @ 14.4°C[6].
Larvae Habits, Behavior, Survival	Larvae present in limnetic and near shore waters of Conewingo Reservoir, PA (Darrel E. Snyder); tiny young remain in nest for a very short time, sometimes only four days[6].

TABLE 3.4-18 (Continued)

Species	*Pomoxis nigromaculatus* (Black crappie)
Maturation by Year - Class or Length (mm total length)	II-IV[6]
Fecundity	20,000-140,000[1]; 26,700-65,570, averaging 37,796[6]/
Spawning Season	Late April to early August (Indiana, South Dakota)[1]; late April through June[6].
Temperature (°C)	17.8[1]; 19-20[6].
Area	Shallow water, usually with bottom of fine sand or gravel[6].
Egg Deposition	Male clears shallow depression or just section of bottom of sand, gravel, or mud where there is some vegetation; nests, 20-40 cm diameter, colonial, 1.6-1.9 m apart, male guards nest[6].
Type	Adhesive, demersal, whitish, transparent[6].
Water-hardened Size (mm)	1[6]
Incubation Period (Days)	3-5[6]
Larvae Habits, Behavior, Survival	Male guards young in nest until a few days after hatching[6].

TABLE 3.4-18 (Continued)

Species	<u>Etheostoma</u> <u>nigrum</u> (Johnny darter)
Spawning Season	May to early July[6].
Area	Shallow water, usually small streams[1].
Egg Deposition	Eggs deposited one by one on underside of rocks, 30-200 eggs at each of 5 or 6 spawning sessions, male guards territory including nest and eggs (even if eggs or rock with eggs are removed)[6]; eggs laid on under surface of submerged objects in single layer[1].
Type	Adhesive[6]; spherical[1].
Incubation Period (Days)	5-8 @ 22-24°C[6].

TABLE 3.4-18 (Continued)

Species	Perca flavescens (Yellow perch)
Maturation by Year - Class or Length (mm total length)	Male: III[6]; Female: IV[6].
Fecundity	3,035-109,000[6].
Spawning Season	Mid-March to July (Lake Erie)[4]; mid-April through May, possibly through July;[6] mid-April through May (Lake Erie).[11]
Temperature (°C)	6.7-12.2[1]; 8.9-12.2[6]; 6.6-12.6[11]
Area	Usually over or near aquatic vegetation or brush[1]; shallows of lakes, tributary streams, sometimes over gravel or sand[6].
Egg Deposition	Eggs extruded in unique transparent, gelatinous, accordian-folded strands as long as 2.1 m and as wide as 51 to 102 mm weighing as much as a kilogram and containing 2,000 to 90,000 eggs (average: 23,000); strands undulate by water movement and adhere to bottom or submerged vegetation, eggs are easily cast ashore and lost, no parental care[6].
Type	Adhesive in gelatinous, porous strands; transparent, semi-buoyant[1].
Water-hardened Size (mm)	3.5[6]
Incubation Period (Days)	27 @ 8.3°C[1]; 8-10[6].
Larvae	
Hatching Size (mm total length)	5[6]
Habits, Behavior, Survival	Larvae limnetic, late May to early June (D.E. Snyder personal observations based on Conowingo Reservoir collections 1966-1971). In Oneida Lake, N.Y., larvae pelagic soon after hatching to 25.4 mm (May and June) and usually occupy upper 6 m of water column.[12]

TABLE 3.4-18 (Continued)

Species	*Percina caprodes* (Logperch)
Spawning Season	Mid-March through May (Oklahoma)[8]
Area	Probably a short distance from creek mouth[4]; sandy inshore shallows[6].
Egg Deposition	Female joined by male on bottom substrate to spawn their vibration tends to bury the eggs; 10-20 eggs released with each spawning session; act repeated with other males[6].
Water-hardened Size (mm)	1.3[6]
Survival	Embryos survive 22 days @ 26°C[6].
Larvae Habits, Behavior, Survival	Larvae limnetic (D. E. Snyder)

TABLE 3.4-18 (Continued)

Species	*Stizostedion vitreum* (Walleye)
Maturation by Year - Class or Length (mm total larvae)	Female: III-VI, 356,432; Male: II-IV, > 279[6]; Male: II Female: III[13]
Fecundity	50,000-3,000,000[1]; 612,000 for an 801 mm specimen[6]; 72,000-110,000 per 3,178-3,405 g female[13].
Spawning Season	Mid-March to early July[1]; mid-March through April (Lake Erie)[4]; mid-April to early July[6]; April and May[11 and 13]; April (Lake Erie)[14]
Temperature (°C)	4.4-10[1]; 5.6-11.1[6]; 3.9-10.0[11].
Area	Upstream spawning runs soon after ice breaks, prefers sandy bars in shallow water spawns in water 1-3 m deep, usually on gravel or sand with good water flow[1]; rocky areas in white water below impassible falls and dams in rivers, or boulder to coarse gravel shoals of lakes.[6]
Egg Deposition	Eggs spread over bottom[1]; eggs released in shallow water[6]. Broadcast and fall into crevices in substrate.[14,17]
Type	Adhesive[1,6]; non-adhesive after water hardening[6].
Water-hardened Size (mm)	1.5-2[6]
Incubation Period (Days)	12-18[6] (at temperatures prevalent on spawning grounds)
Larvae	
Hatching Size (mm total length)	6-8.6 mm total length[6].
Habits, Behavior, Survival	Larvae begin feeding before yolk is completely absorbed; yolk absorbed rapidly; larvae disperse to upper levels of open water 10-15 days after hatching[6]. Pelagic but become demersal near end of summer.[6]

TABLE 3.4-18 (Continued)

1. Breder and Rosen. 1966.
2. Carlander. 1969.
3. Carlander. Undated.
4. Fish. 1932.
5. Mansueti and Hardy. 1967.
6. Scott and Crossman. 1973.
7. Snyder. 1971.
8. Taber. 1969.
9. Trautman. 1957.
10. Snyder. 1975. Personal communication.
11. Ohio Department of Natural Resources. Undated.
12. Noble. 1968.
13. Parsons. 1972.
14. Ohio Department of Natural Resources. 1971.

TABLE 3.4-19

SPECIES COMPOSITION OF FISHES FROM THE MONTICELLO DISCHARGE CANAL (IMMEDIATE DISCHARGE AREA) DURING PERIODS OF "COLD SHOCK" SUSCEPTIBILITY (NOV. 1972-MAR. 1975) (NSP, 1975)

	11/1/74	11/4/74	12/4/74	12/6/74	12/27/74	12/31/74	1/7/75	1/8/75	1/25/74 S.C.U.B.A.	2/19/73 Electro-fishing	1/29/73 Electro-fishing	1/18/74 S.C.U.B.A.	12/5/72 Trapnet	Total Number	% Composition
Northern pike	-	-	2	1	-	3		-	-	-	1	-	2	9	1.5
Carp	1	-	-	-	-	-		-	5	2	1	12	5	26	4.3
Shorthead redhorse	-	2	-	-	-	-		-	-	-	1	-	1	4	0.7
Silver redhorse	-	-	-	-	-	-	-	-	-	1	-	-	-	1	0.2
White sucker	-	-	1	1	-	1		-	-	-	-	-	2	5	0.8
Black bullhead	11	24	5	2	-	2	22	2	-	-	-	-	1	69	11.3
Yellow bullhead	1	9	-	-	-	2	4	1	-	-	-	-	3	20	3.3
Burbot	-	-	-	-	-	-	1	-	-	-	-	-	-	1	0.2
Smallmouth bass	-	-	-	-	-	-	1	1	8	-	-	9	-	19	3.1
Rockbass	124	61	47	9	18	26	33	13	-	-	-	-	8	339	55.8
Black crappie	-	4	11	2	-	3	1	4	-	-	-	-	2	27	4.4
Bluegill sunfish	24	18	2	-	1	-	2	1	-	-	-	-	-	48	7.9
Walleye	1	4	9	-	-	3		2	12	-	-	6	3	40	6.6

TABLE 3.4-20

POPULATION AND STANDING CROP ESTIMATES FOR SELECTED SPECIES OF FISH FROM THE MONTICELLO DISCHARGE CANAL (IMMEDIATE DISCHARGE AREA) DURING FALL AND WINTER OF 1974-1975 (NSP 1975)

Species	Canal Population Estimate	Canal No./ha.	Canal Kg./ha.	Canal lbs./a.
Black bullhead	147 ± 136	256 ± 237	29.7	26.5
Rockbass	354 ± 129	617 ± 225	77.0	68.8
Black crappie	22 ± 15	38 ± 26	3.3	2.9
Bluegill sunfish	216 ± 138	377 ± 241	21.7	19.4

TABLE 3.4-21

CALCULATED CONDITION FACTORS K(TL) FOR FISH FROM THE MONTICELLO DISCHARGE CANAL (IMMEDIATE DISCHARGE AREA) IN RELATION TO REPORTED K(TL) VALUES FROM OTHER WATERBODIES (NSP 1975)

Species	Canal $\bar{x}$-K(TL)	$\bar{x}$-K(TL)	
Northern Pike	0.65	0.61[1]	0.60[3]
Carp	1.22	1.37[1]	1.05-1.69[2]
Black bullhead	1.08	-	-
Yellow bullhead	1.65	1.21[1]	-
Rockbass	2.41	2.40[4]	1.80[5]
Bluegill sunfish	2.42	2.46[3]	-
Black crappie	1.61	1.76[3]	-
Smallmouth bass	1.44	1.40[3]	-
Walleye	0.77	0.88[3]	-

(1) Carlander. 1969.

(2) Andersen. 1972.

(3) Krosch. 1971. K(TL) derived from use of K = 0.277C.

(4) Minnesota Department of Natural Resources. 1973.

(5) Hile. 1941.

TABLE 3.4-22

MATRIX OF FISH DATA FOR NSP MONTICELLO PLANT

	Historical Significance	Energy Transfer	Nuisance Potential	Indicative of Water and Environmental Quality: Low	Indicative of Water and Environmental Quality: High	Threatened, Endangered or Unique	Adjacent Water Body Segment: Spring Transitional	Adjacent Water Body Segment: Winter Minimum	Adjacent Water Body Segment: Fall Transitional	Adjacent Water Body Segment: Summer Maximum	Outer Discharge Area: Spring Transitional	Outer Discharge Area: Winter Minimum	Outer Discharge Area: Fall Transitional	Outer Discharge Area: Summer Maximum	Intermediate Discharge Area: Spring Transitional	Intermediate Discharge Area: Winter Minimum	Intermediate Discharge Area: Fall Transitional	Intermediate Discharge Area: Summer Maximum	Immediate Discharge Area: Spring Transitional	Immediate Discharge Area: Winter Minimum[a]	Immediate Discharge Area: Fall Transitional	Immediate Discharge Area: Summer Maximum
Bowfin	Y	P	Y	Y	U	Y	L	U	L	N	L	U	L	N	U	U	U	N	U	U	U	N
Central Mudminnow	N	F	N	Y	U	Y	L	U	L	N	L	U	L	N	U	U	U	N	U	N	U	N
Northern Pike	N	P	N	Y	Y	N	L	U	L	Y	L	U	L	N	L	U	L	N	L	Y	L	N
Muskellunge	N	P	N	Y	Y	N	L	U	L	N	L	U	L	N	U	U	U	N	U	N	U	N
Carp	N	P	Y	Y	N	Y	L	U	L	Y	Y	U	Y	Y	Y	U	Y	Y	L	Y	Y	Y
Brassy Minnow	N	F	N	Y	U	N	L	U	L	N	L	U	L	N	U	U	U	N	U	N	U	N
Hornyhead Chub	N	F	N	N	Y	N	L	U	L	N	L	U	L	N	U	U	U	N	U	N	U	N
Golden Shiner	N	F	N	N	Y	N	L	U	L	N	L	U	L	N	U	U	U	N	U	N	U	N
Common Shiner	N	F	N	U	Y	N	L	U	L	N	L	U	L	N	U	U	U	N	U	Y	U	N
Bigmouth Shiner	N	F	N	U	U	N	L	U	L	N	L	U	L	N	U	U	U	N	U	Y	U	N
Spottail Shiner	N	F	N	U	U	N	L	U	L	N	L	U	L	N	U	U	U	N	U	Y	U	N
Spotfin Shiner	N	F	N	Y	Y	N	L	U	L	N	L	U	L	N	U	U	U	N	U	Y	U	N
Sand Shiner	N	F	N	N	Y	N	L	U	L	N	L	U	L	N	U	U	U	N	U	Y	U	N
Northern Redbelly Dace	N	F	N	Y	U	N	L	U	L	N	L	U	L	N	U	U	U	N	U	N	U	N
Fathead Minnow	N	F	N	Y	U	N	L	U	L	N	L	U	L	N	U	U	U	N	U	Y	U	N
Bluntnose Minnow	N	F	N	N	Y	N	L	U	L	N	L	U	L	N	U	U	U	N	U	N	U	N

TABLE 3.4-22 (Cont'd.)

	Historical Significance	Energy Transfer	Nuisance Potential	Indicative of Water and Environmental Quality: Low	Indicative of Water and Environmental Quality: High	Threatened, Endangered or Unique	Adjacent Water Body Segment: Spring Transitional	Adjacent Water Body Segment: Winter Minimum	Adjacent Water Body Segment: Fall Transitional	Adjacent Water Body Segment: Summer Maximum	Outer Discharge Area: Spring Transitional	Outer Discharge Area: Winter Minimum	Outer Discharge Area: Fall Transitional	Outer Discharge Area: Summer Maximum	Intermediate Discharge Area: Spring Transitional	Intermediate Discharge Area: Winter Minimum	Intermediate Discharge Area: Fall Transitional	Intermediate Discharge Area: Summer Maximum	Immediate Discharge Area: Spring Transitional	Immediate Discharge Area: Winter Minimuma	Immediate Discharge Area: Fall Transitional	Immediate Discharge Area: Summer Maximum
Blacknose Dace	N	F	N	N	Y	N	L	U	L	N	L	U	L	N	U	U	U	N	U	Y	U	N
Longnose Dace	N	F	N	N	Y	N	L	U	L	N	L	U	L	N	U	U	U	N	U	N	U	N
Creek Chub	N	F	N	N	Y	N	L	U	L	N	L	U	L	N	U	U	U	N	U	N	U	N
White Sucker	N	P	Y	U	U	N	L	U	L	N	Y	U	L	N	L	U	L	N	L	Y	L	N
Silver Redhorse	N	P	Y	N	Y	N	L	U	L	Y	Y	U	Y	Y	Y	U	L	Y	L	Y	Y	Y
Shorthead Redhorse	N	P	Y	U	U	N	U	L	U	Y	Y	U	Y	Y	Y	U	Y	Y	L	Y	L	N
Black Bullhead	N	P	Y	Y	N	N	L	U	L	N	L	U	L	N	L	U	L	N	L	Y	L	N
Yellow Bullhead	N	P	Y	U	U	N	L	U	L	N	L	U	L	N	U	U	U	N	U	Y	L	N
Brown Bullhead	N	P	Y	Y	N	N	L	U	L	N	L	U	L	N	L	U	L	N	L	N	L	N
Trout-Perch	N	F	N	U	U	Y	L	U	L	N	L	U	L	N	U	U	U	N	U	N	U	N
Burbot	N	P	Y	U	U	Y	L	U	L	N	L	U	L	N	U	U	U	N	U	Y	L	N
Banded Killifish	N	F	N	U	U	Y	L	U	L	N	L	U	L	N	U	U	U	N	U	Y	U	U
Rock Bass	N	P	N	U	U	N	L	U	L	N	L	U	L	N	L	U	L	Y	L	Y	L	N
Green Sunfish	N	P	N	Y	U	N	L	U	L	N	L	U	L	N	U	U	U	N	U	N	U	N
Pumpkinseed	N	P	N	N	Y	N	L	U	L	N	L	U	L	N	U	U	L	N	L	N	L	N
Bluegill	N	P	N	Y	Y	N	L	U	L	N	L	U	L	N	U	U	L	N	L	Y	L	N
Smallmouth Bass	N	P	N	U	Y	N	L	U	L	Y	Y	U	L	Y	L	U	L	N	L	Y	Y	Y

TABLE 3.4-22 (Cont'd.)

	Historical Significance	Energy Transfer	Nuisance Potential	Indicative of Water and Environmental Quality: Low	Indicative of Water and Environmental Quality: High	Threatened, Endangered or Unique	Adjacent Water Body Segment: Spring Transitional	Adjacent Water Body Segment: Winter Minimum	Adjacent Water Body Segment: Fall Transitional	Adjacent Water Body Segment: Summer Maximum	Outer Discharge Area: Spring Transitional	Outer Discharge Area: Winter Minimum	Outer Discharge Area: Fall Transitional	Outer Discharge Area: Summer Maximum	Intermediate Discharge Area: Spring Transitional	Intermediate Discharge Area: Winter Minimal	Intermediate Discharge Area: Fall Transitional	Intermediate Discharge Area: Summer Maximum	Immediate Discharge Area: Spring Transitional	Immediate Discharge Area: Winter Minimum[a]	Immediate Discharge Area: Fall Transitional	Immediate Discharge Area: Summer Maximum
Largemouth Bass	N	P	N	Y	U	N	L	U	L	N	L	U	L	N	U	U	U	N	U	N	U	N
White Crappie	N	P	N	Y	Y	N	L	U	L	N	L	U	L	N	U	U	U	N	U	N	U	N
Black Crappie	N	P	N	N	Y	N	L	U	L	N	L	U	L	N	L	U	L	Y	L	Y	Y	N
Johnny Darter	N	F	N	U	U	N	L	U	L	N	L	U	L	N	U	U	U	N	U	Y	U	N
Yellow Perch	N	P	N	U	Y	N	L	U	L	N	L	U	L	N	U	U	U	N	U	N	U	N
Log Perch	N	F	N	U	Y	N	L	U	L	N	L	U	L	N	U	U	U	N	U	N	U	N
Walleye	N	P	N	Y	Y	N	L	U	L	N	L	U	L	N	L	U	L	Y	L	Y	Y	N

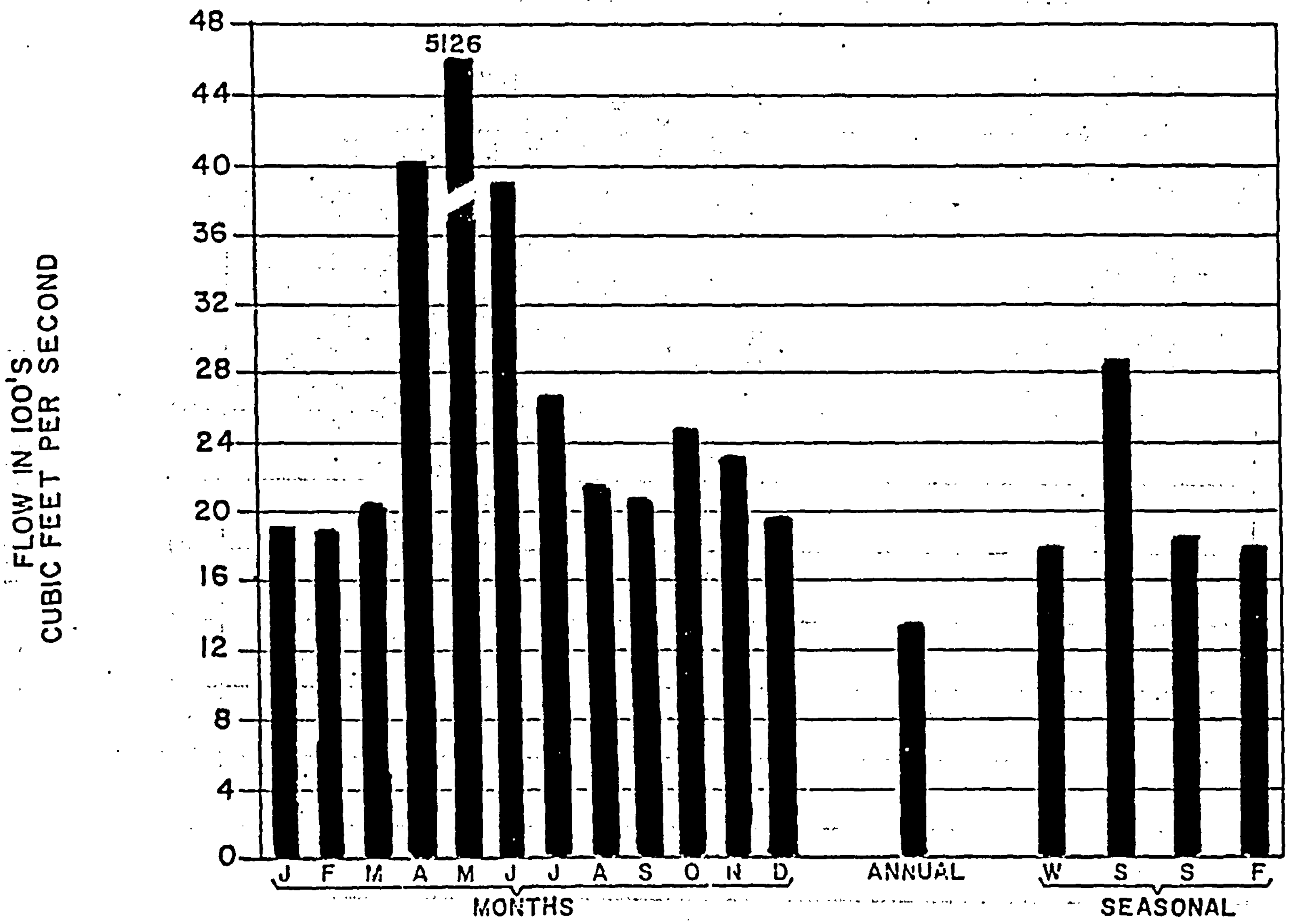
Y - Yes
N - No
L - Likely to occur
U - Unknown
F - Forage
P - Predator or herbivore

[a]Includes forage fish and YOY collected during entrainment study of Knutson (1974)

APPENDIX A

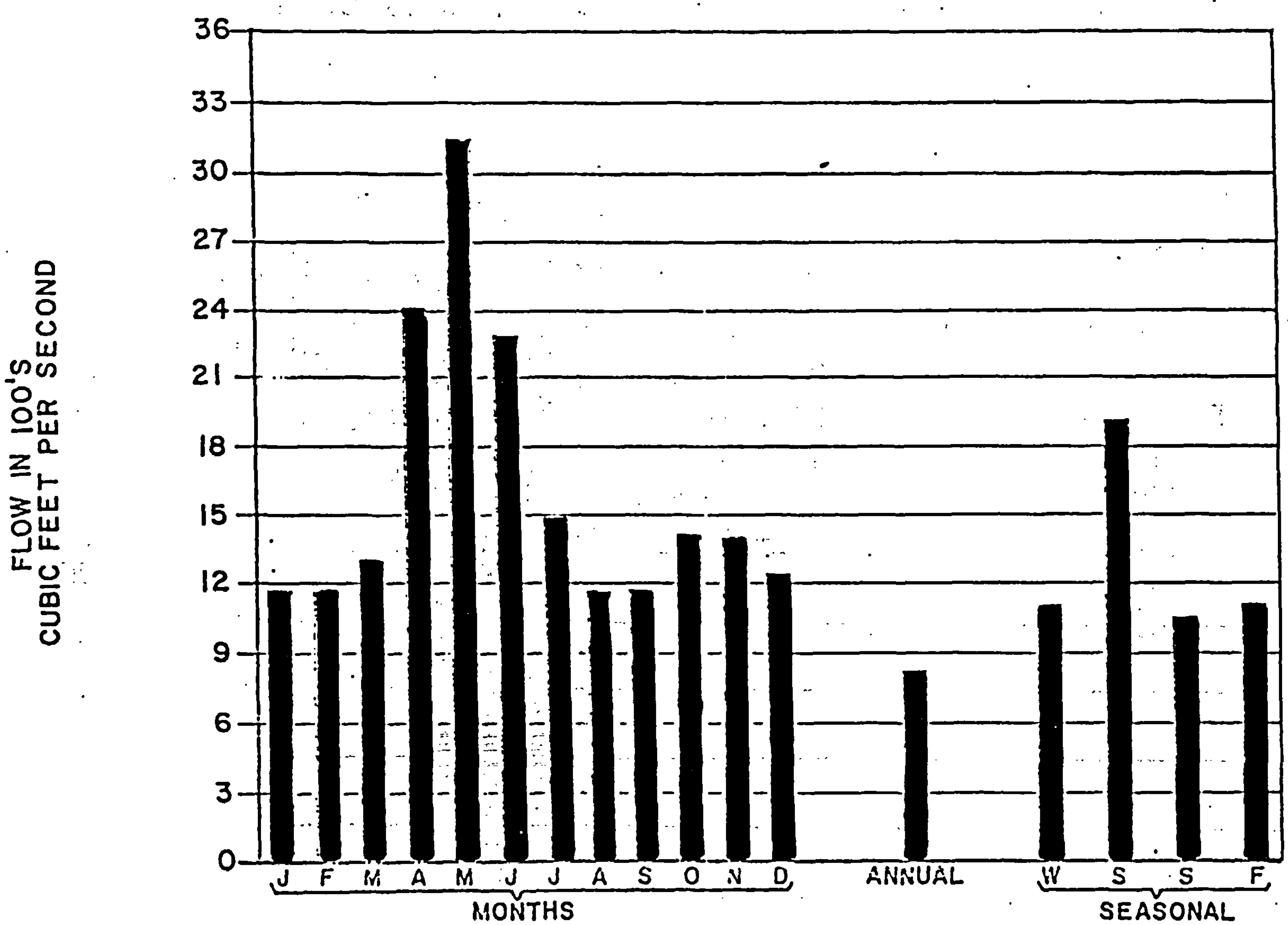
SEVEN-DAY LOW FLOW SUMMARIES FOR MISSISSIPPI RIVER AT ST. CLOUD, MINNESOTA 1926-1970

FIGURE A-1



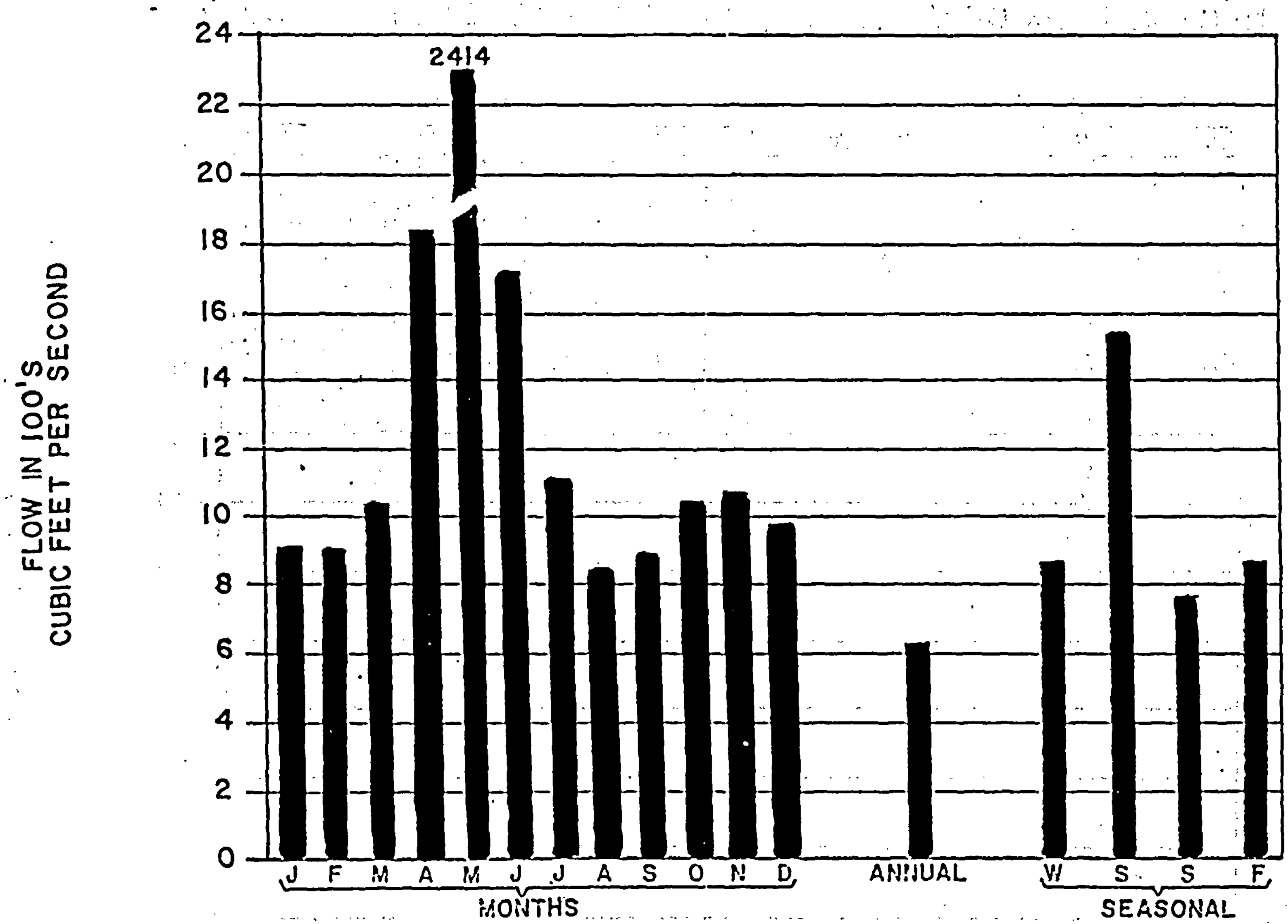
7 CONSECUTIVE DAY AVERAGE LOW FLOW-2 YEAR RETURN
MISSISSIPPI RIVER NEAR ST. CLOUD, MINNESOTA (1926-1970)

FIGURE A-2



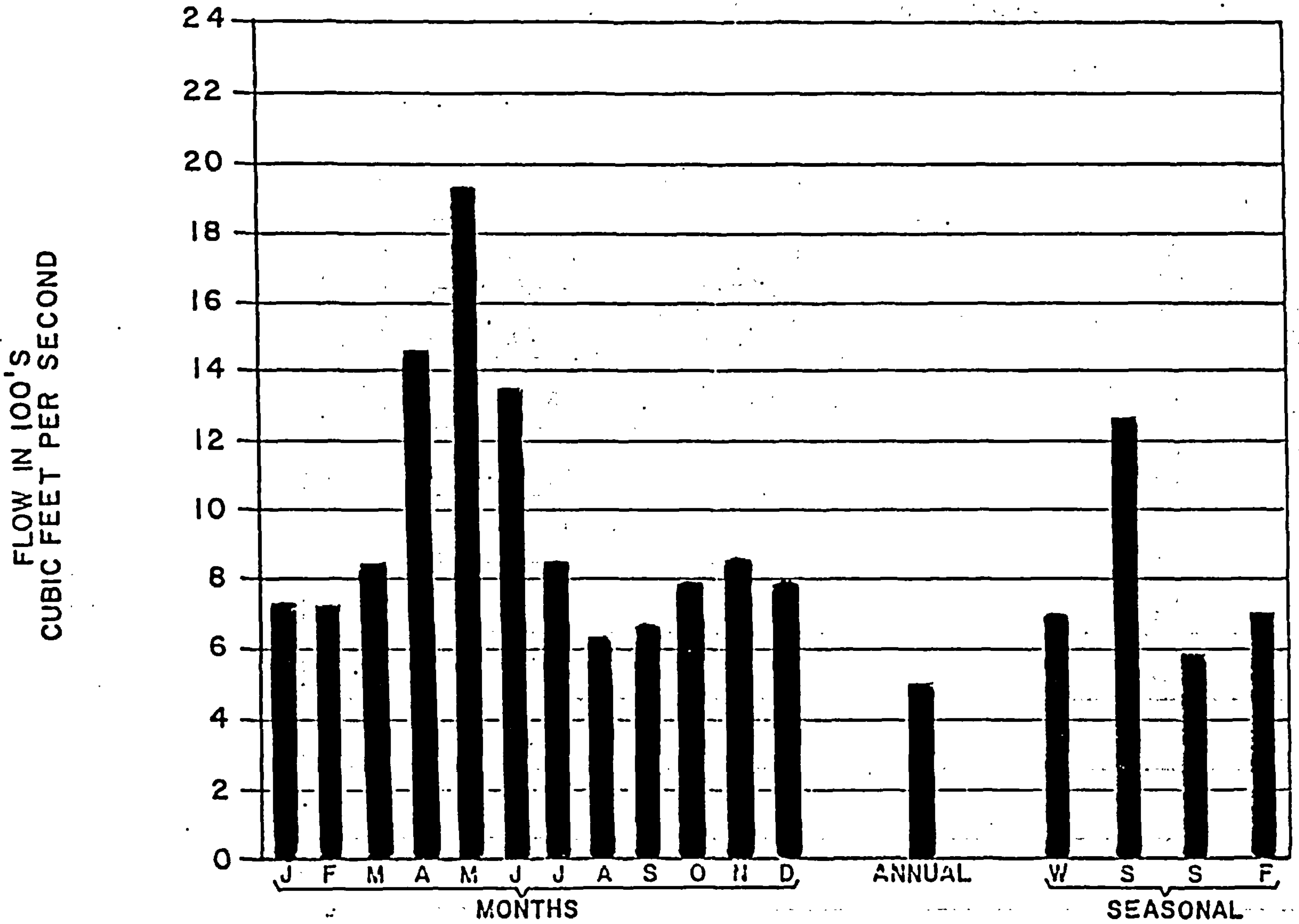
7 CONSECUTIVE DAY AVERAGE LOW FLOW-5 YEAR RETURN
MISSISSIPPI RIVER NEAR ST. CLOUD, MINNESOTA (1926-1970)

FIGURE A-3



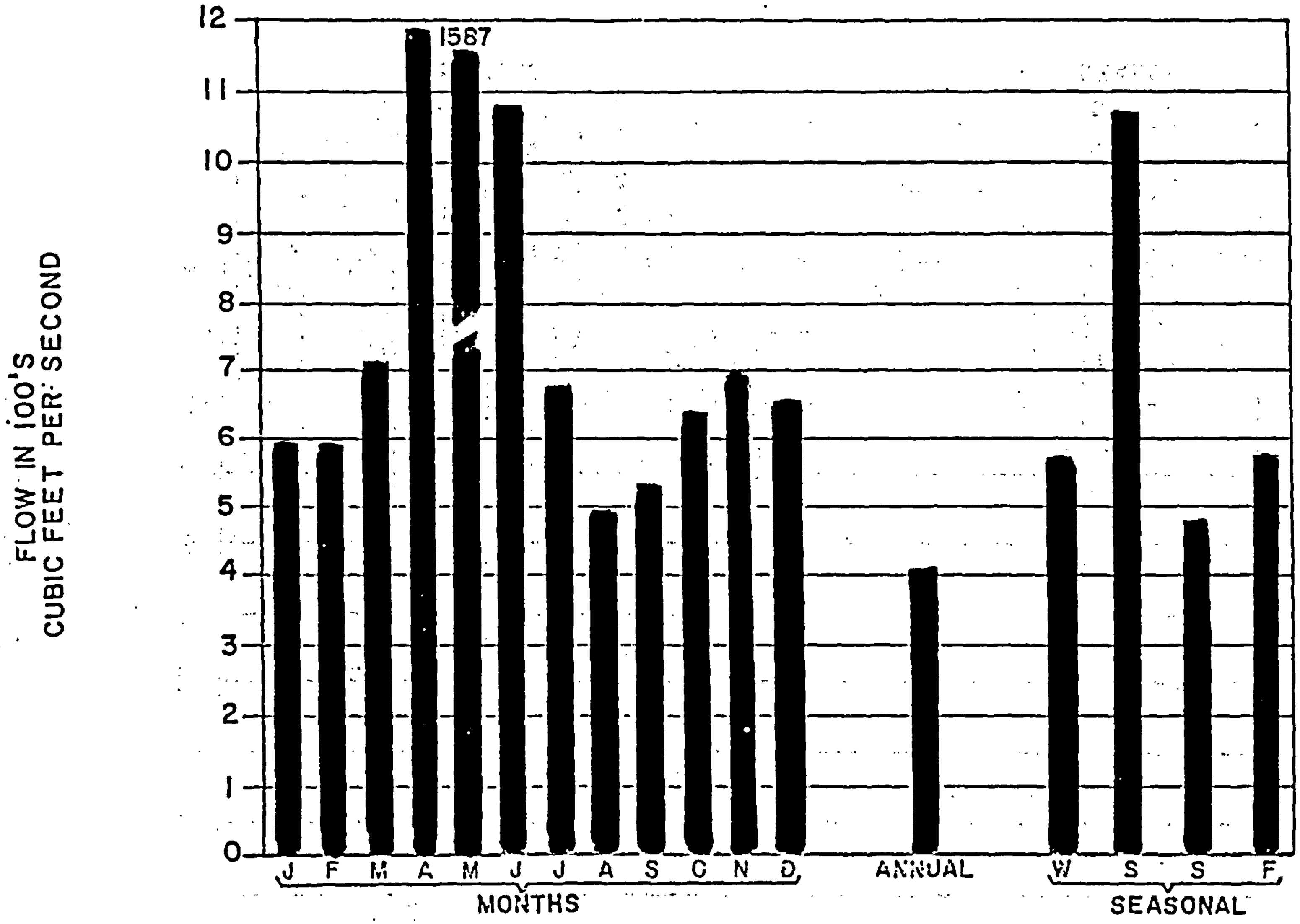
7 CONSECUTIVE DAY AVERAGE LOW FLOW-10 YEAR RETURN
MISSISSIPPI RIVER NEAR ST. CLOUD, MINNESOTA (1926-1970)

FIGURE A-4



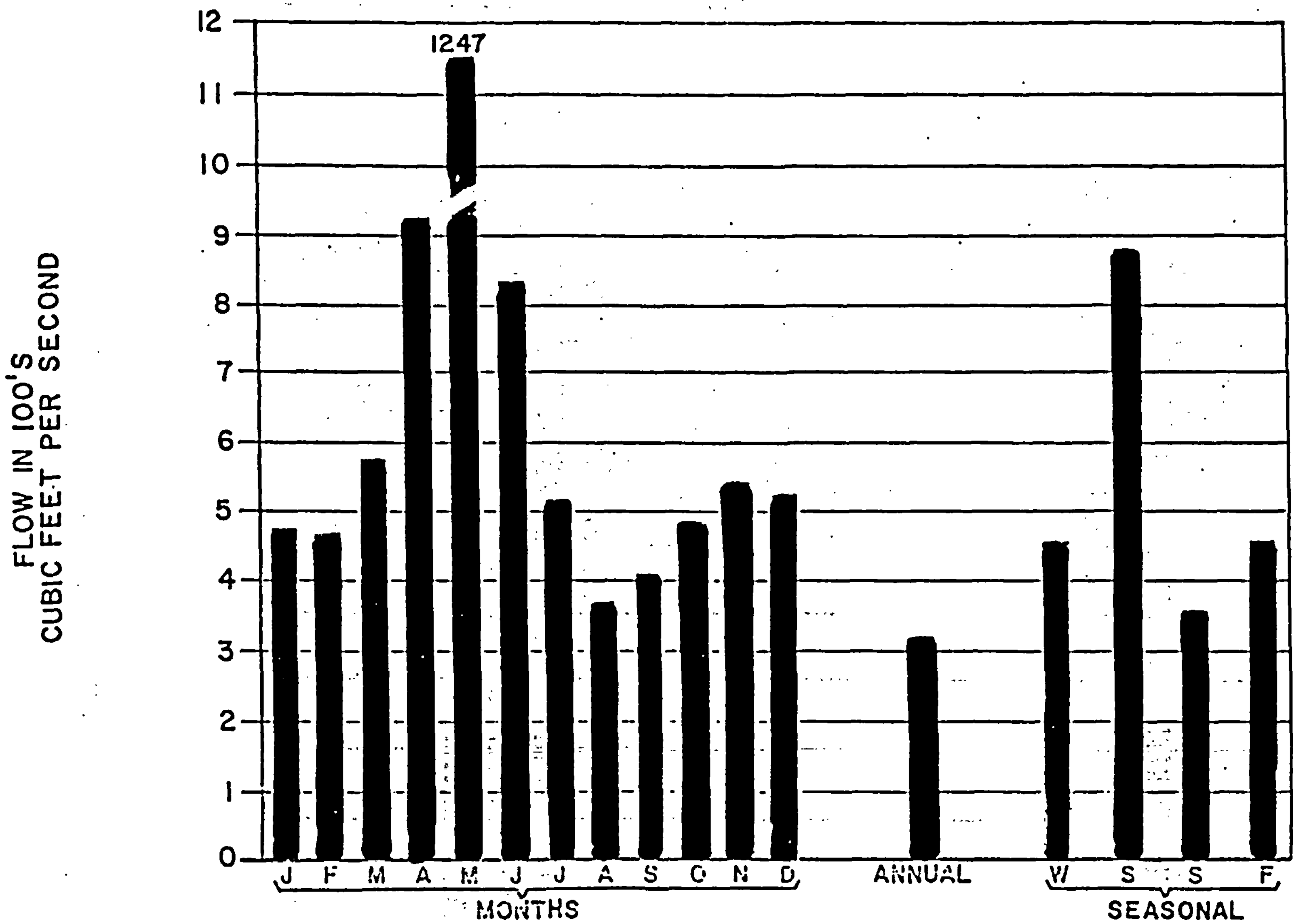
7 CONSECUTIVE DAY AVERAGE LOW FLOW-20 YEAR RETURN
MISSISSIPPI RIVER NEAR ST. CLOUD, MINNESOTA (1926-1970)

FIGURE A-5



7 CONSECUTIVE DAY AVERAGE LOW FLOW-40 YEAR RETURN
MISSISSIPPI RIVER NEAR ST. CLOUD, MINNESOTA (1926-1970)

FIGURE A-6

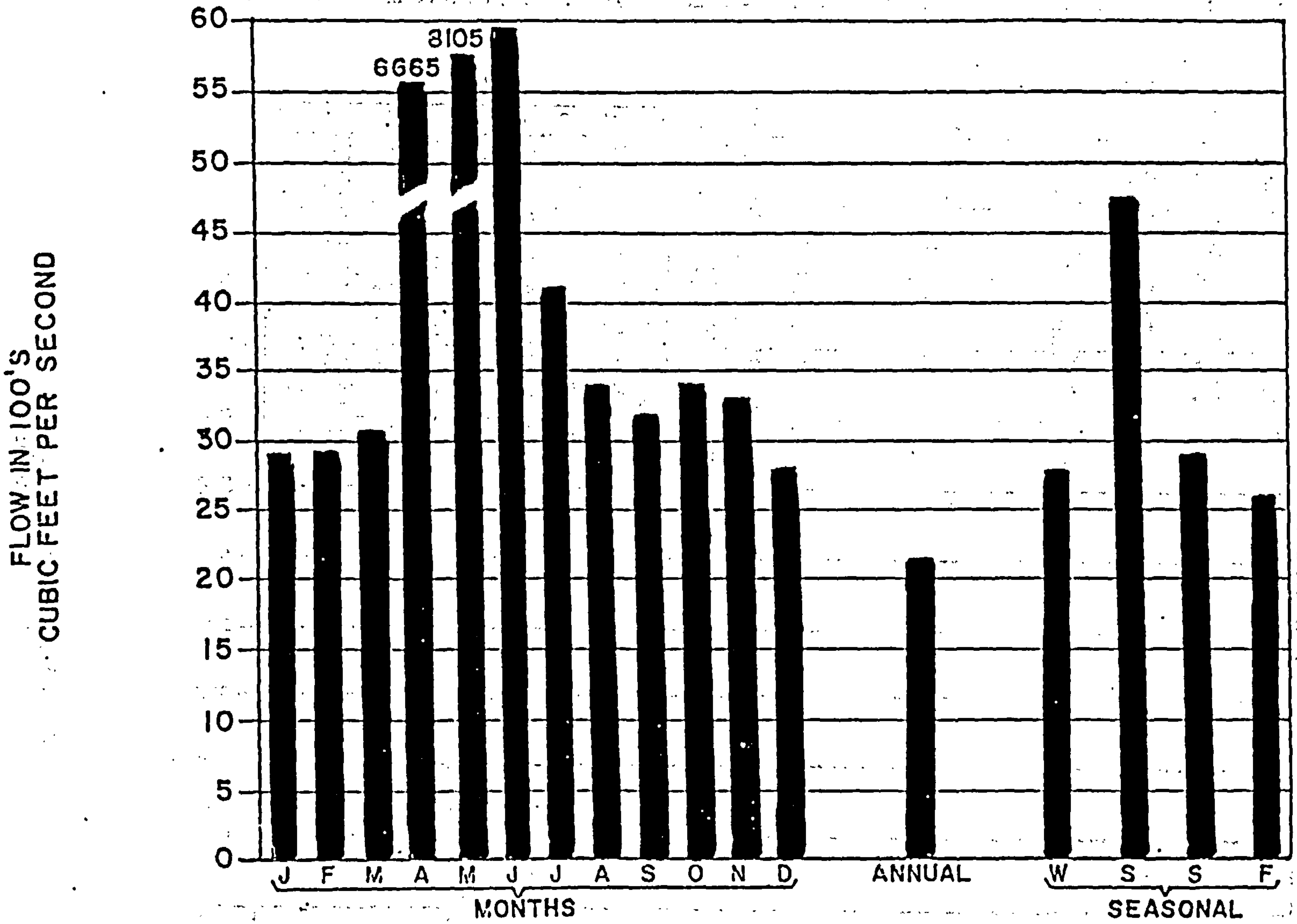


7 CONSECUTIVE DAY AVERAGE LOW FLOW-100 YEAR RETURN
MISSISSIPPI RIVER NEAR ST. CLOUD, MINNESOTA (1926-1970)

APPENDIX B

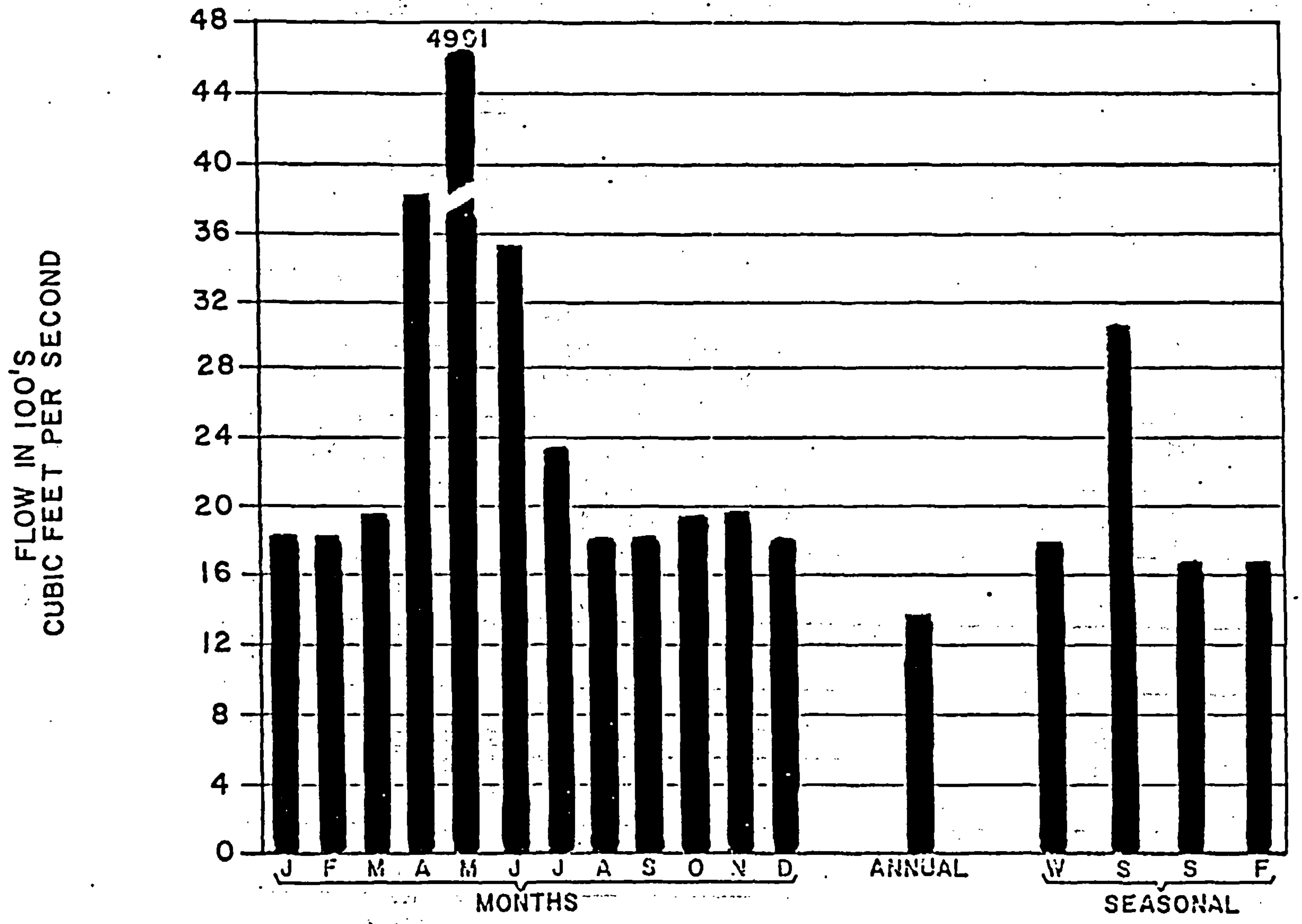
SEVEN-DAY LOW FLOW SUMMARIES FOR MISSISSIPPI RIVER AT ANOKA, MINNESOTA, 1931-1973

FIGURE B-1



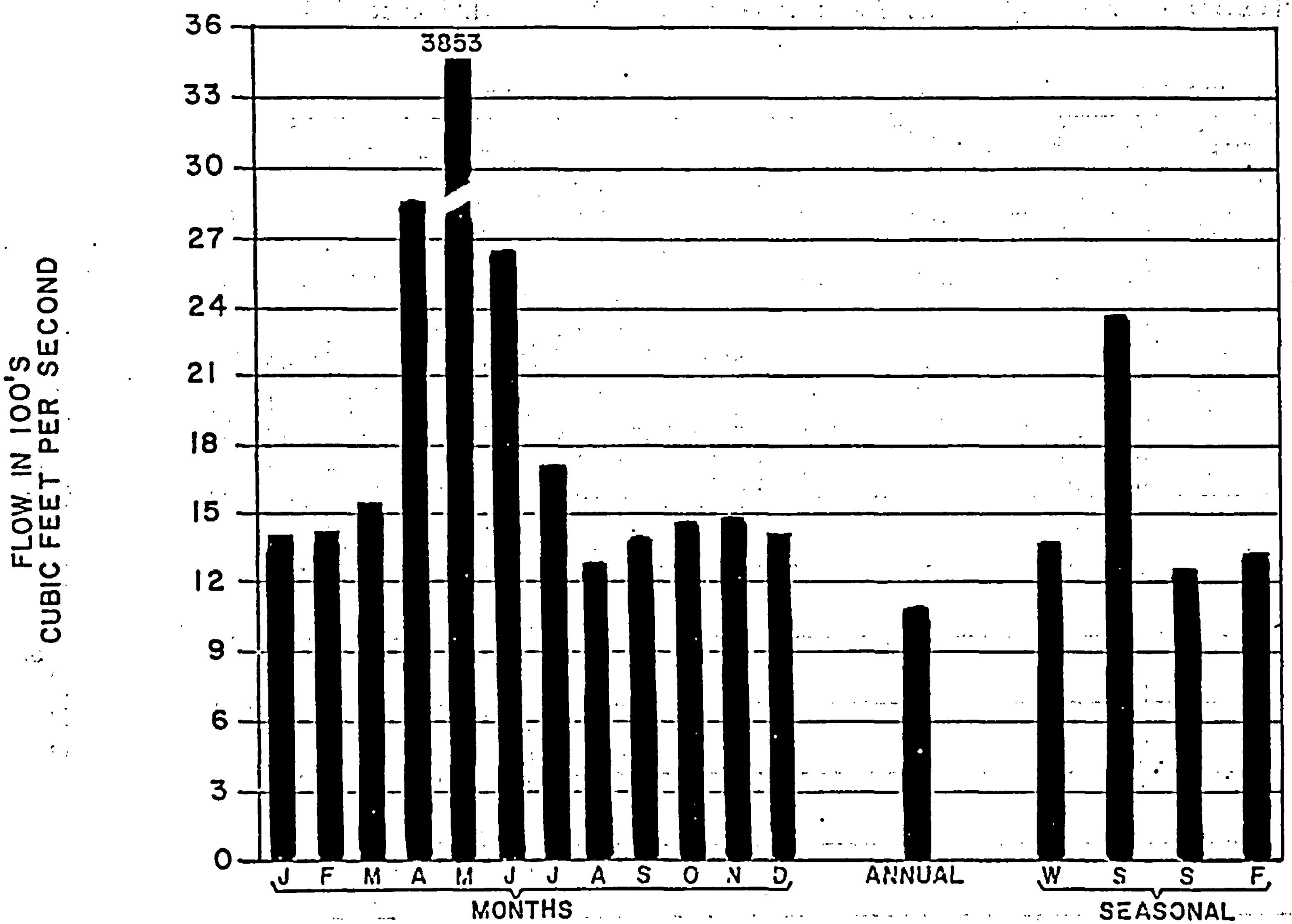
7 CONSECUTIVE DAY AVERAGE LOW FLOW-2 YEAR RETURN
MISSISSIPPI RIVER NEAR ANOKA, MINNESOTA (1931-1973)

FIGURE B-2



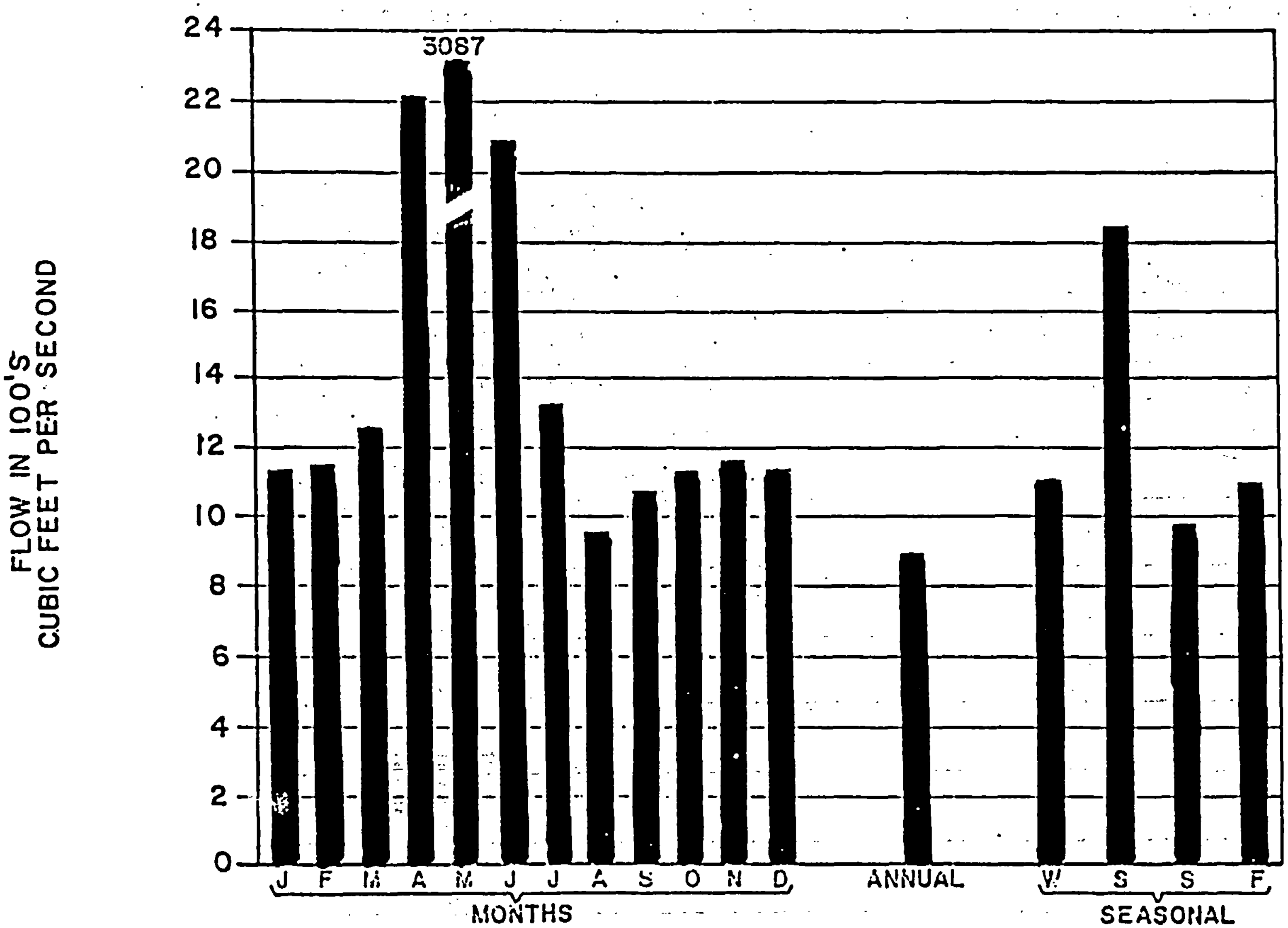
7 CONSECUTIVE DAY AVERAGE LOW FLOW-5 YEAR RETURN
MISSISSIPPI RIVER NEAR ANOKA, MINNESOTA (1931-1973)

FIGURE B-3



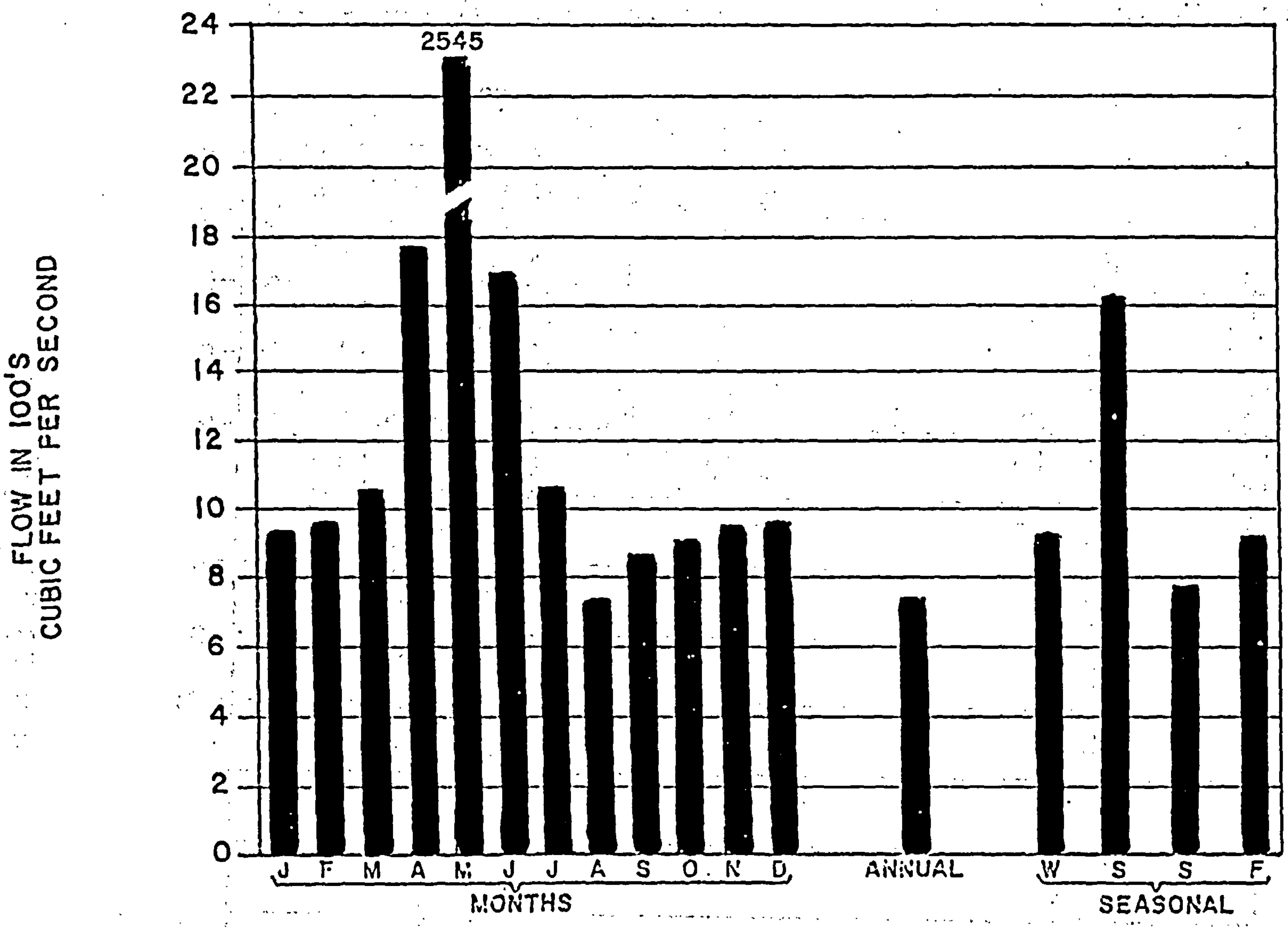
7 CONSECUTIVE DAY AVERAGE LOW FLOW-10 YEAR RETURN
MISSISSIPPI RIVER NEAR ANOKA, MINNESOTA (1931-1973)

FIGURE B-4



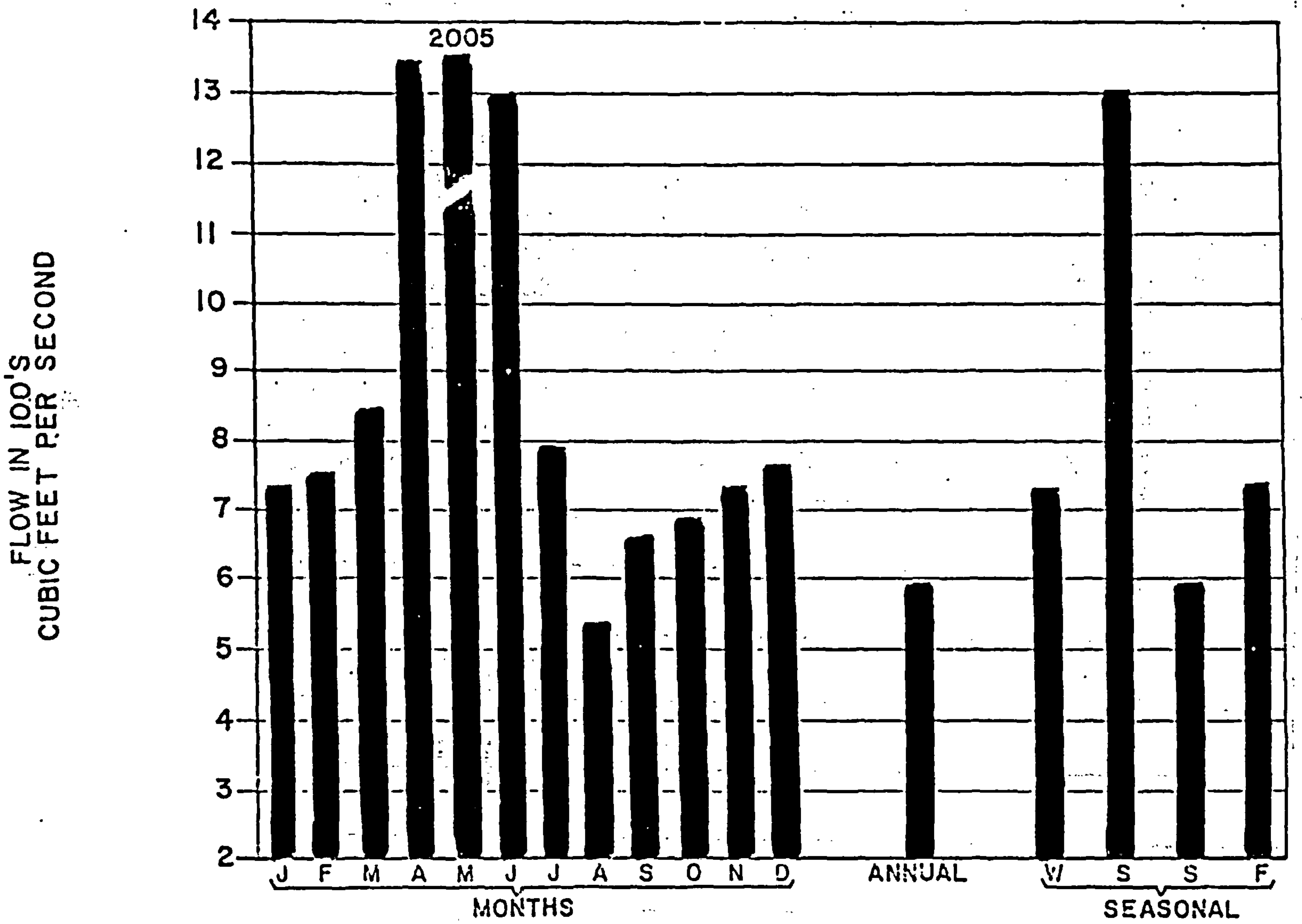
7 CONSECUTIVE DAY AVERAGE LOW FLOW-20 YEAR RETURN
MISSISSIPPI RIVER NEAR ANOKA, MINNESOTA (1931-1973)

FIGURE B-5



7 CONSECUTIVE DAY AVERAGE LOW FLOW-40 YEAR RETURN
MISSISSIPPI RIVER NEAR ANOKA, MINNESOTA (1931-1973)

FIGURE B-6



7 CONSECUTIVE DAY AVERAGE LOW FLOW-100 YEAR RETURN
MISSISSIPPI RIVER NEAR ANOKA, MINNESOTA (1931-1973)

APPENDIX C

ANNUAL AND MONTHLY FLOW DURATION CURVES FOR MISSISSIPPI RIVER AT ST. CLOUD, MINNESOTA, 1926-1970

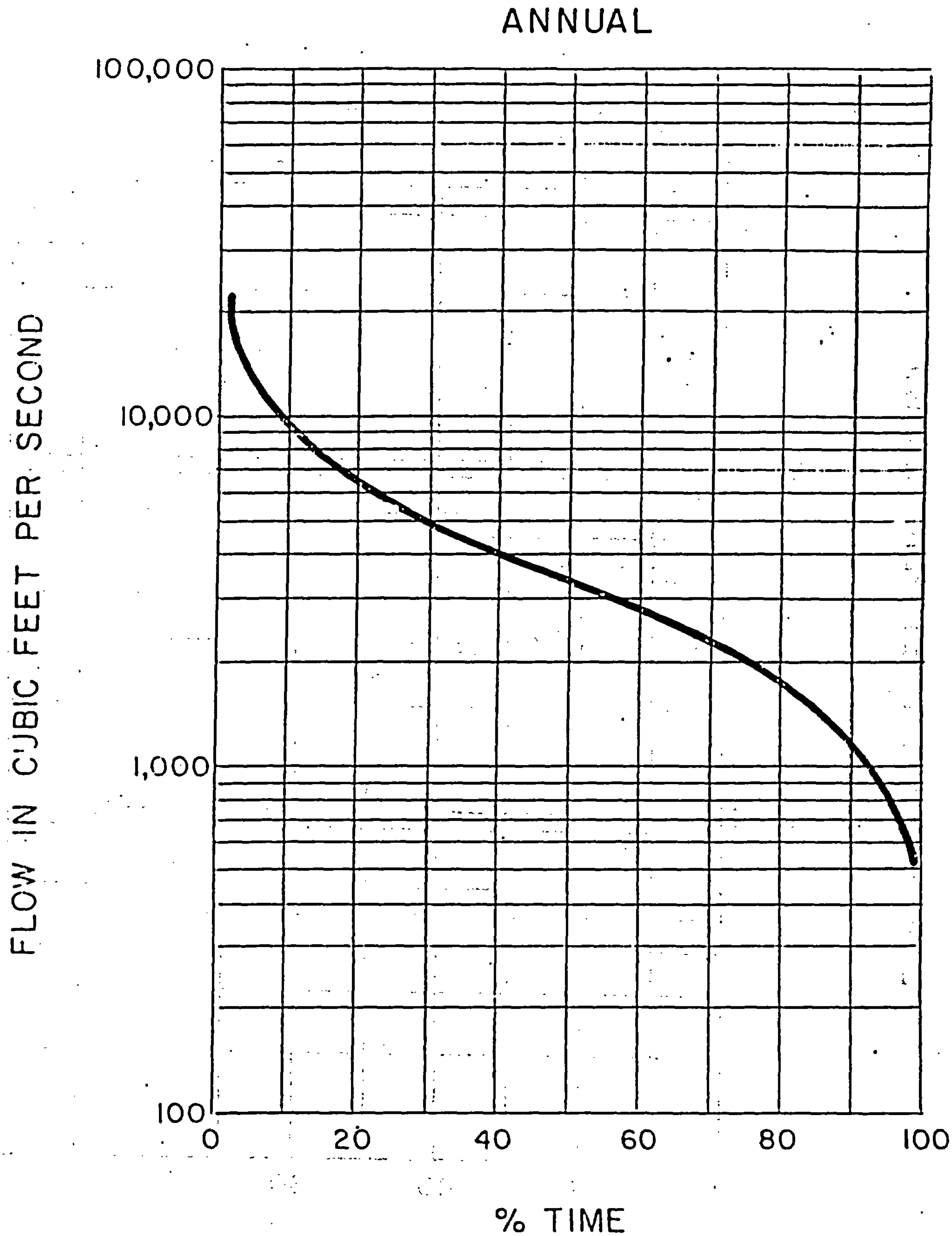


FIGURE C-1

Annual Flow Duration Curve for Mississippi River at St. Cloud, Minnesota. 1926-1970.

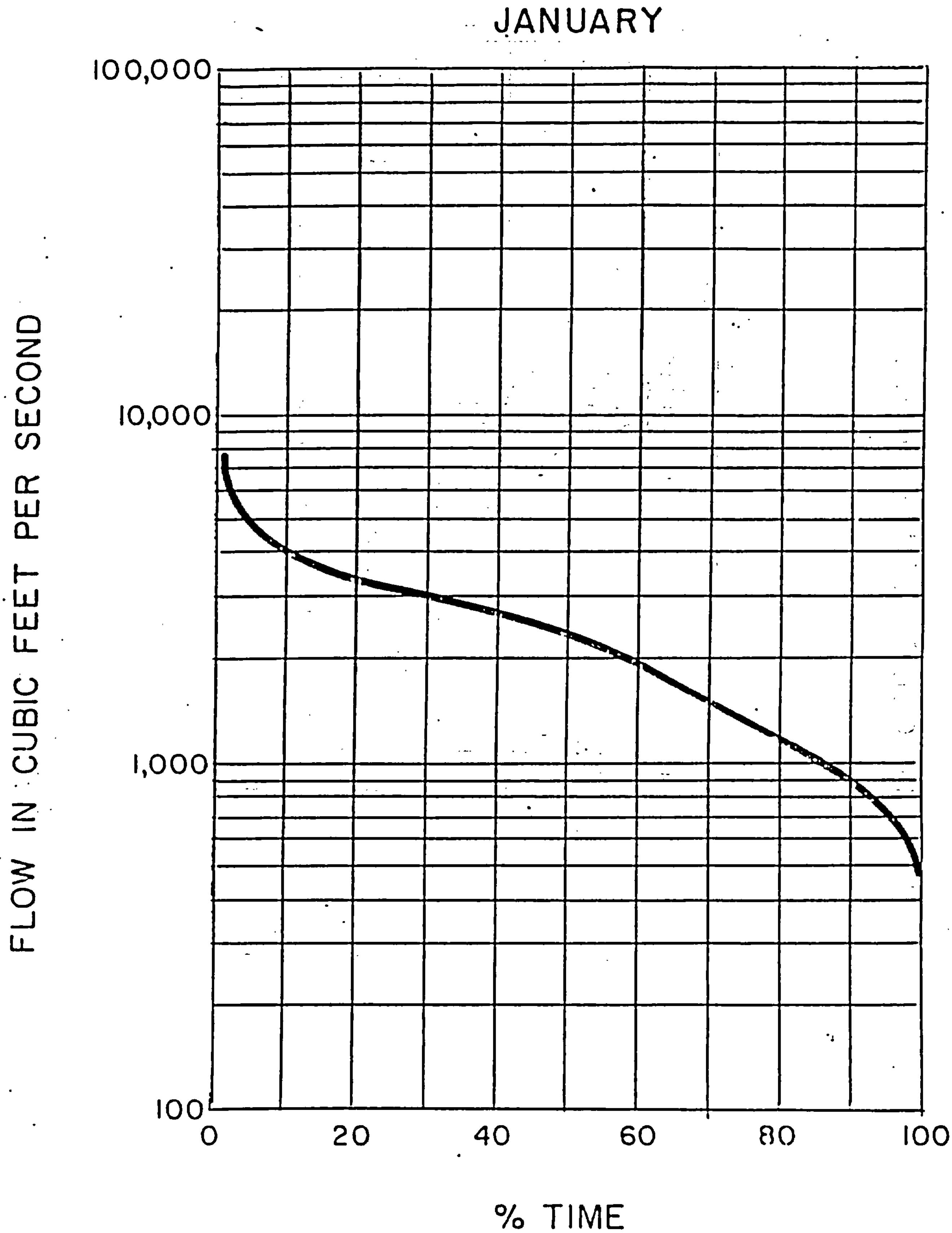


FIGURE C-2

January Flow Duration Curve for Mississippi River at St. Cloud, Minnesota. 1926-1970.

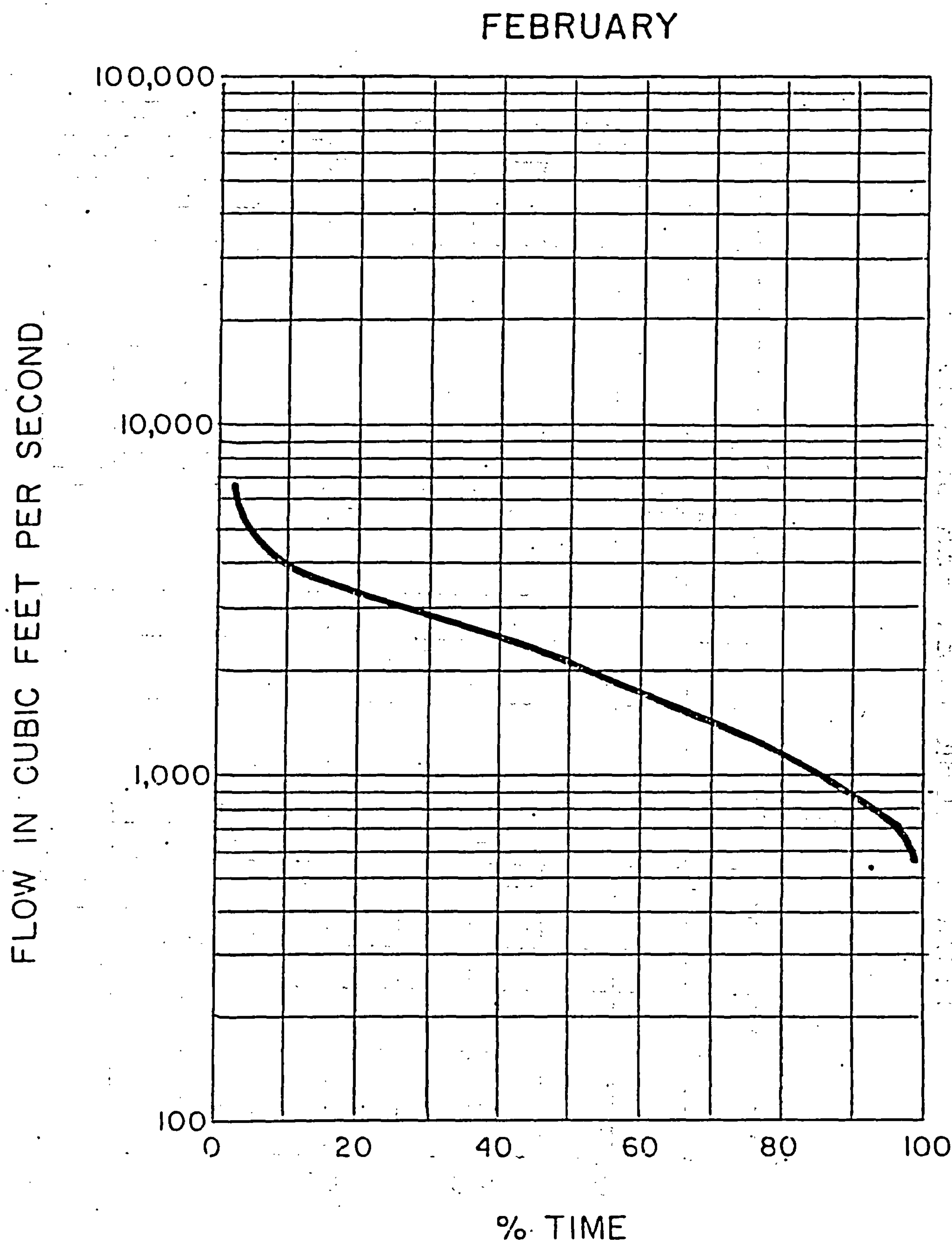


FIGURE C-3

February Flow Duration Curve for Mississippi River at St. Cloud, Minnesota. 1926-1970.

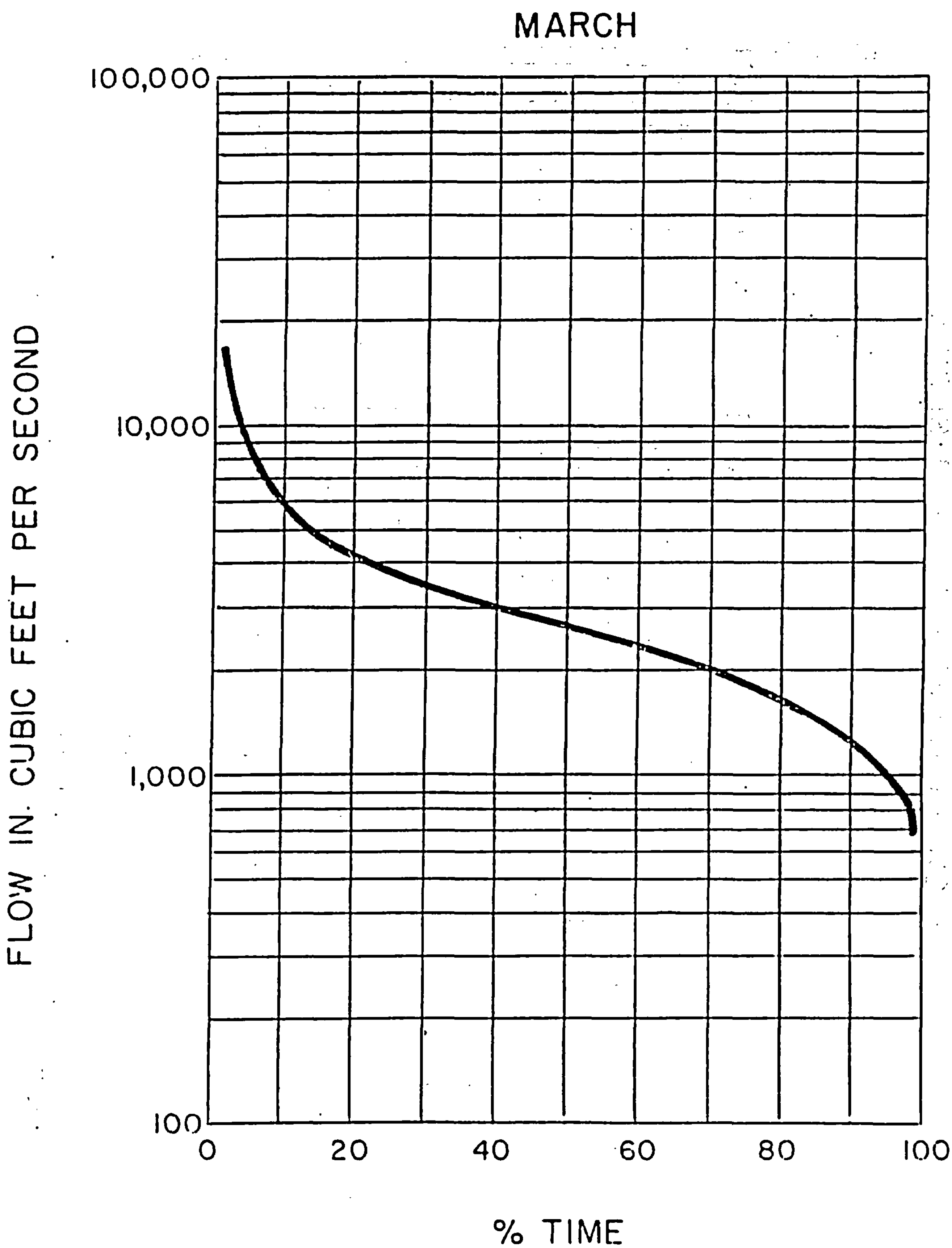


FIGURE C-4

March Flow Duration Curve for Mississippi River at St. Cloud, Minnesota. 1926-1970.

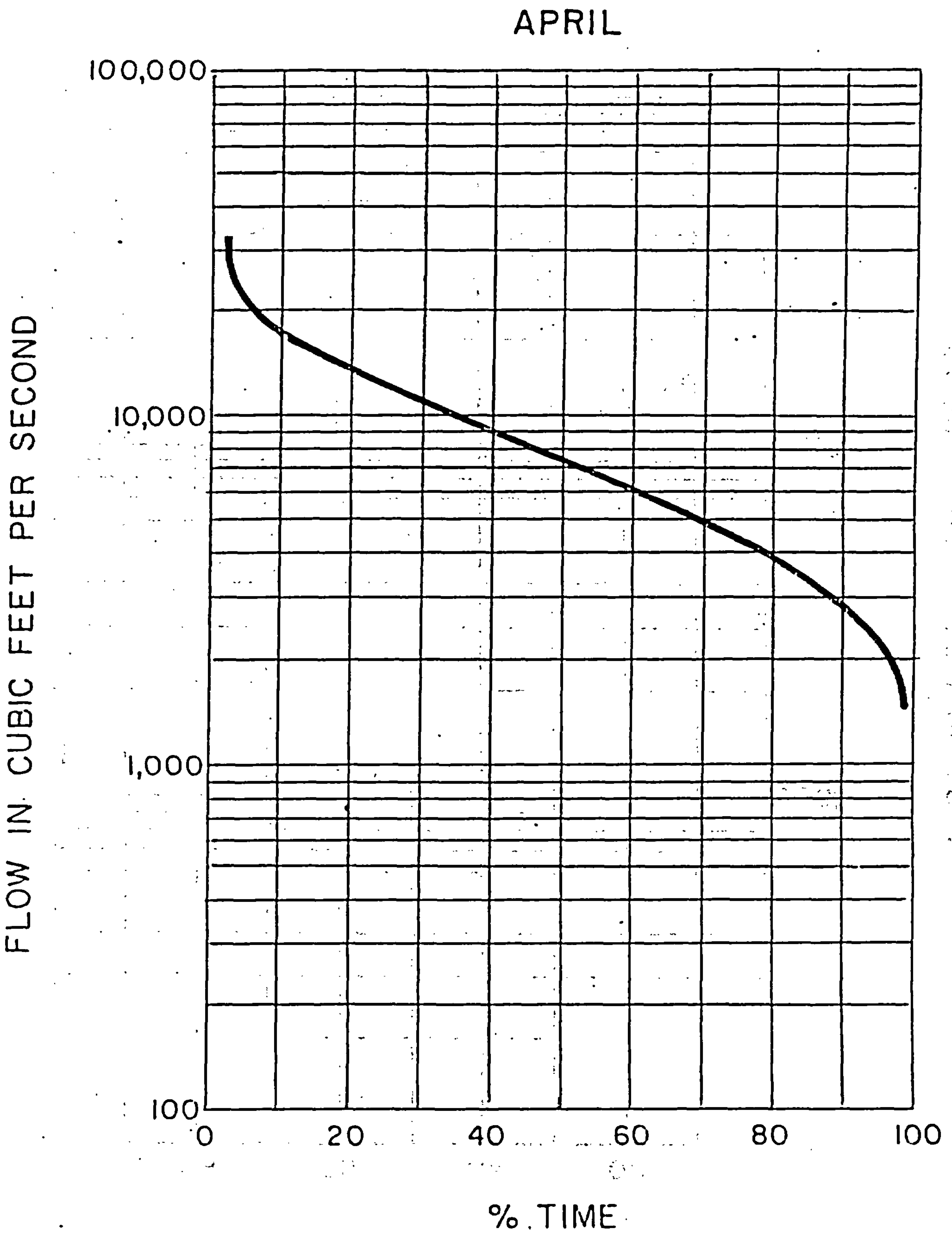


FIGURE C-5

April Flow Duration Curve for Mississippi River at St. Cloud, Minnesota. 1926-1970.

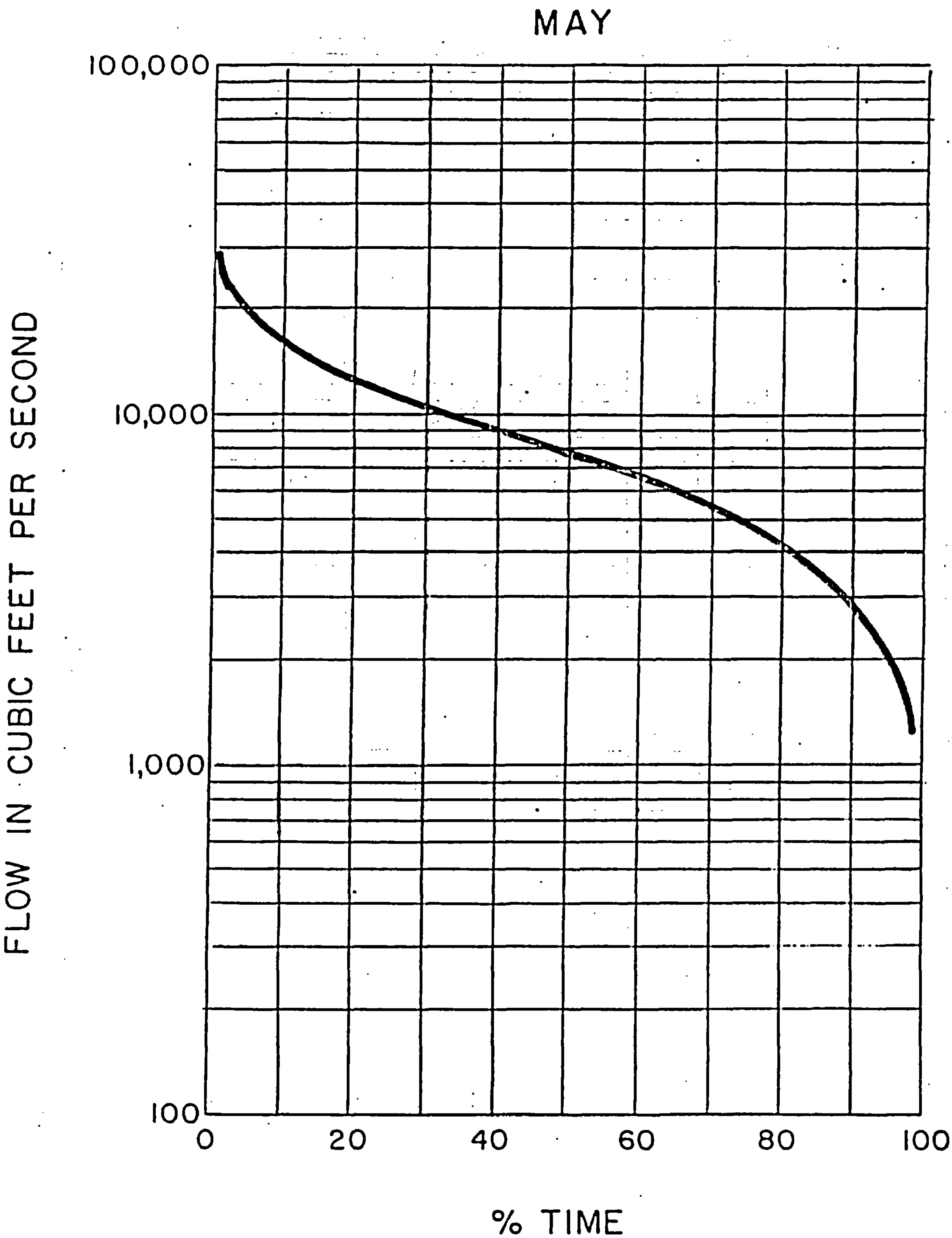


FIGURE C-6

May Flow Duration Curve for Mississippi River at St. Cloud, Minnesota. 1926-1970.

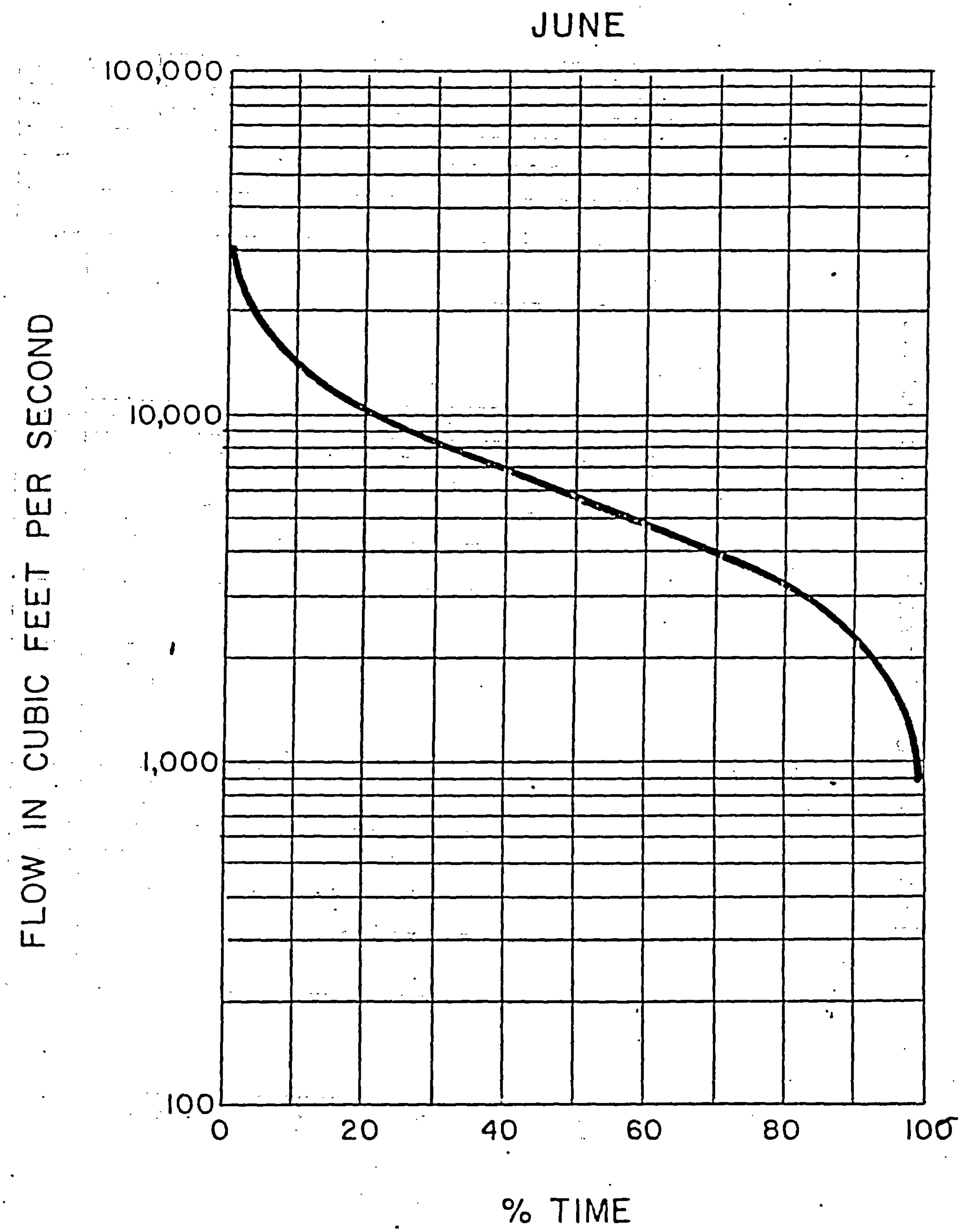


FIGURE C-7

June Flow Duration Curve for Mississippi River at St. Cloud, Minnesota. 1926-1970.

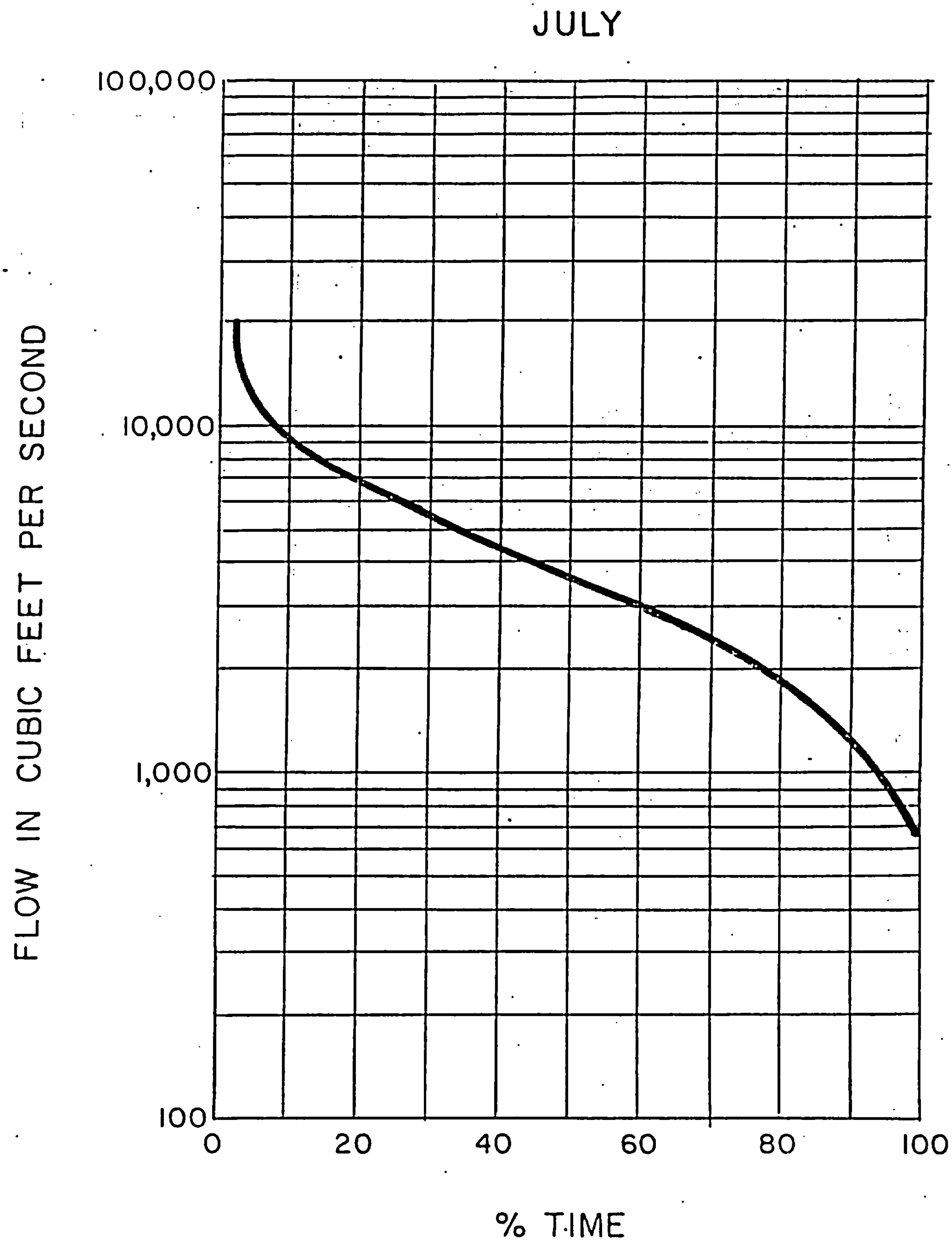


FIGURE C-8

July Flow Duration Curve for Mississippi River at St. Cloud, Minnesota. 1926-1970.

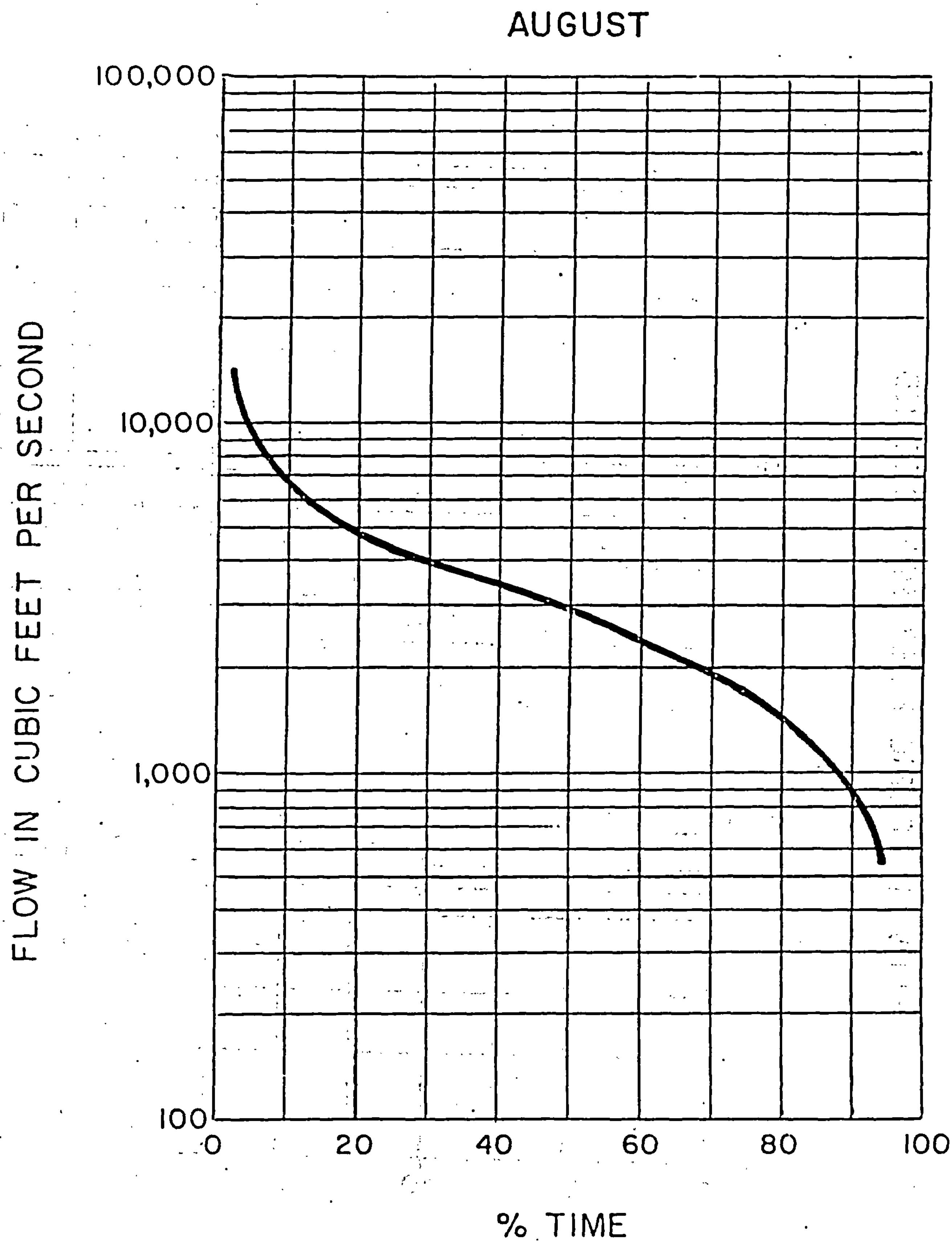


FIGURE C-9

August Flow Duration Curve for Mississippi River at St. Cloud, Minnesota. 1926-1970.

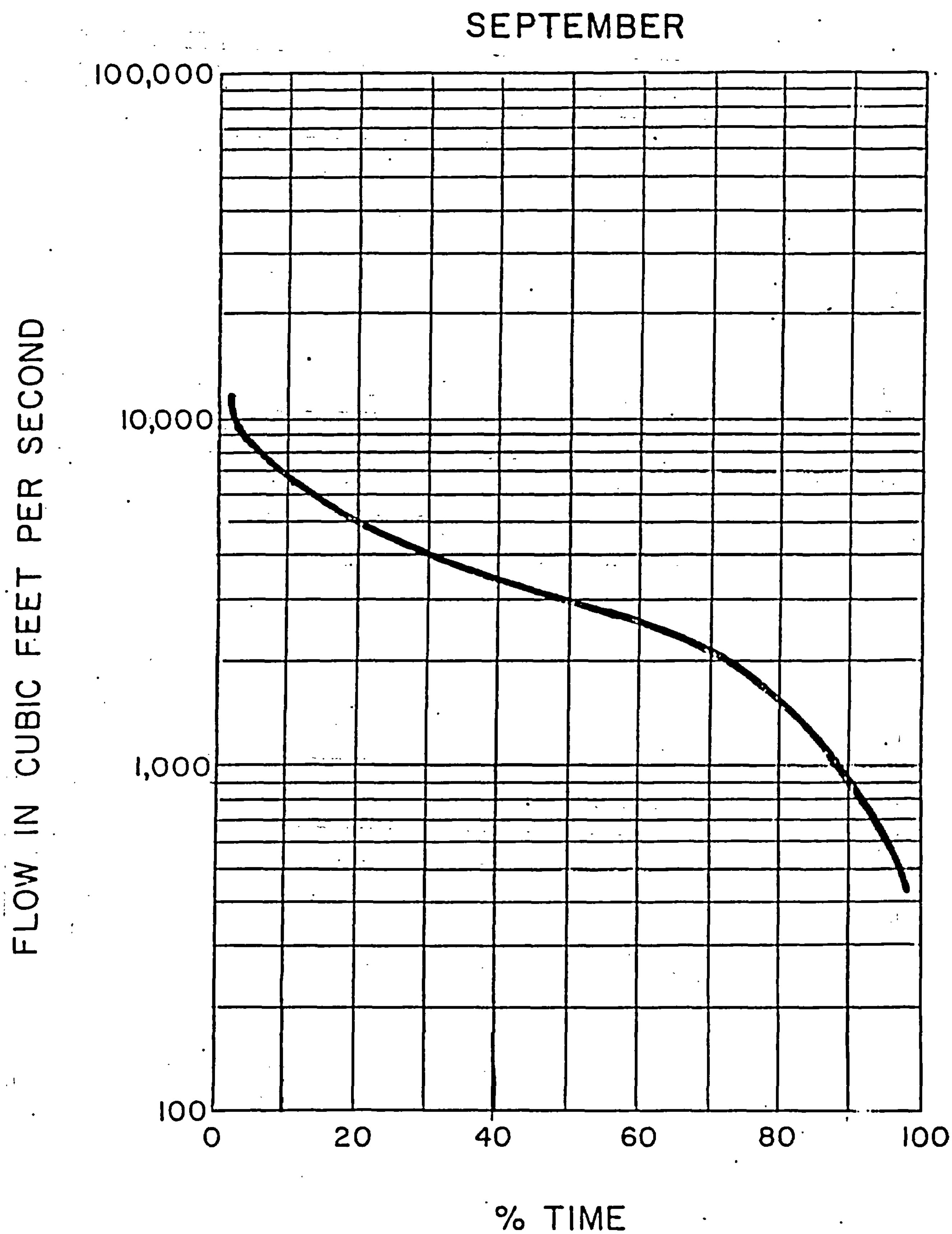


FIGURE C-10

September Flow Duration Curve for Mississippi River at St. Cloud, Minnesota. 1926-1970.

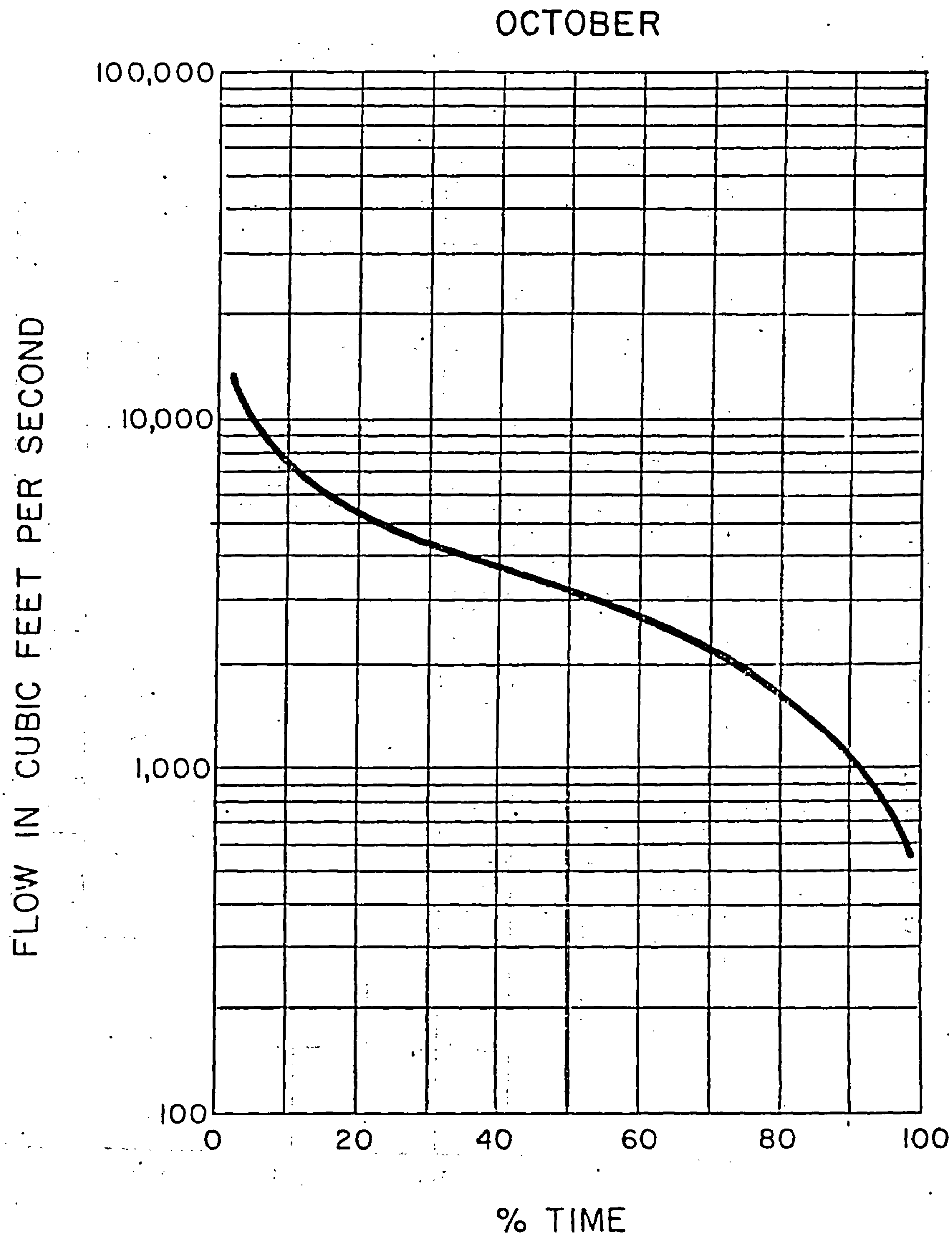


FIGURE C-11

October Flow Duration Curve for Mississippi River at St. Cloud, Minnesota. 1926-1970.

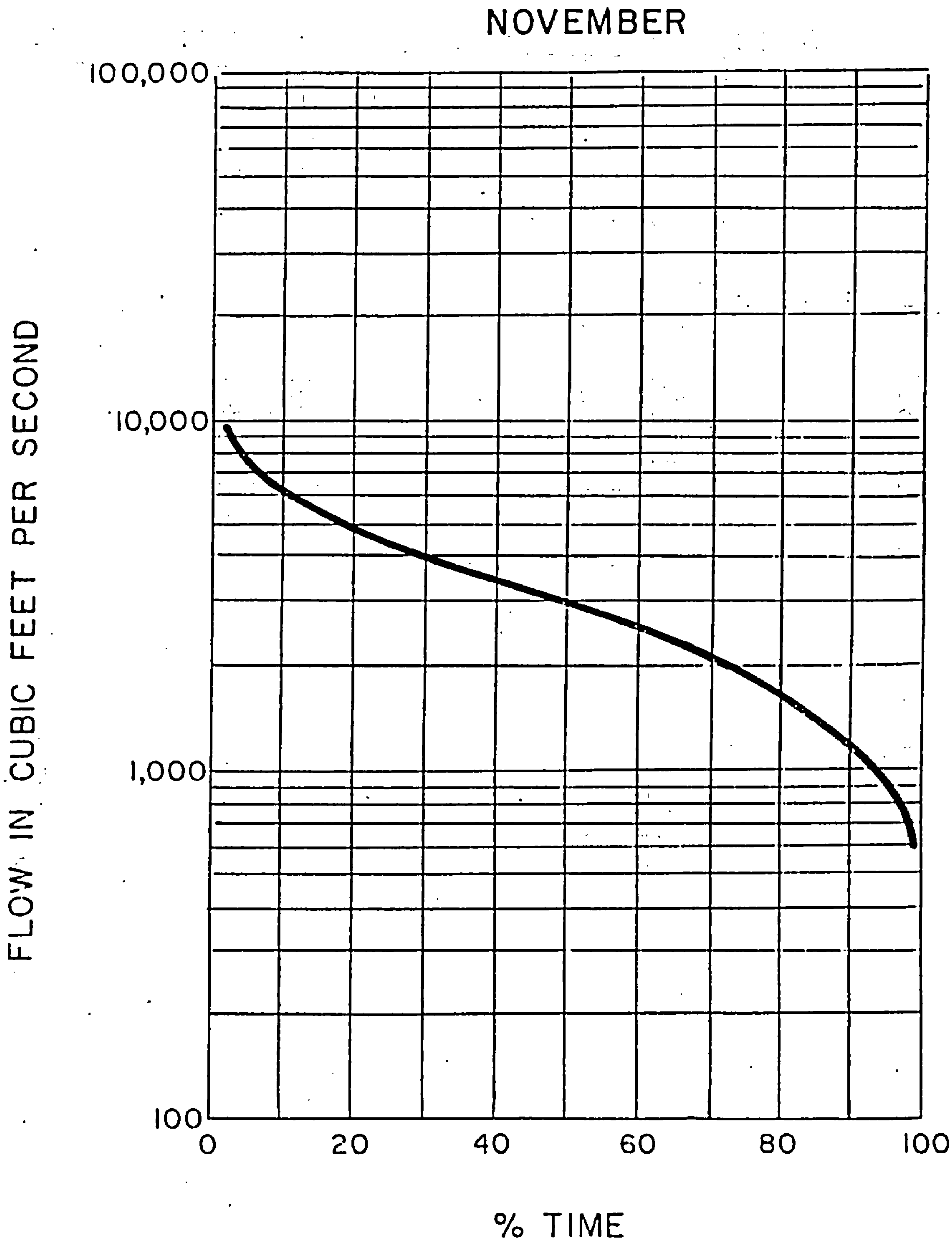


FIGURE C-12

November Flow Duration Curve for Mississippi River at St. Cloud, Minnesota. 1926-1970.

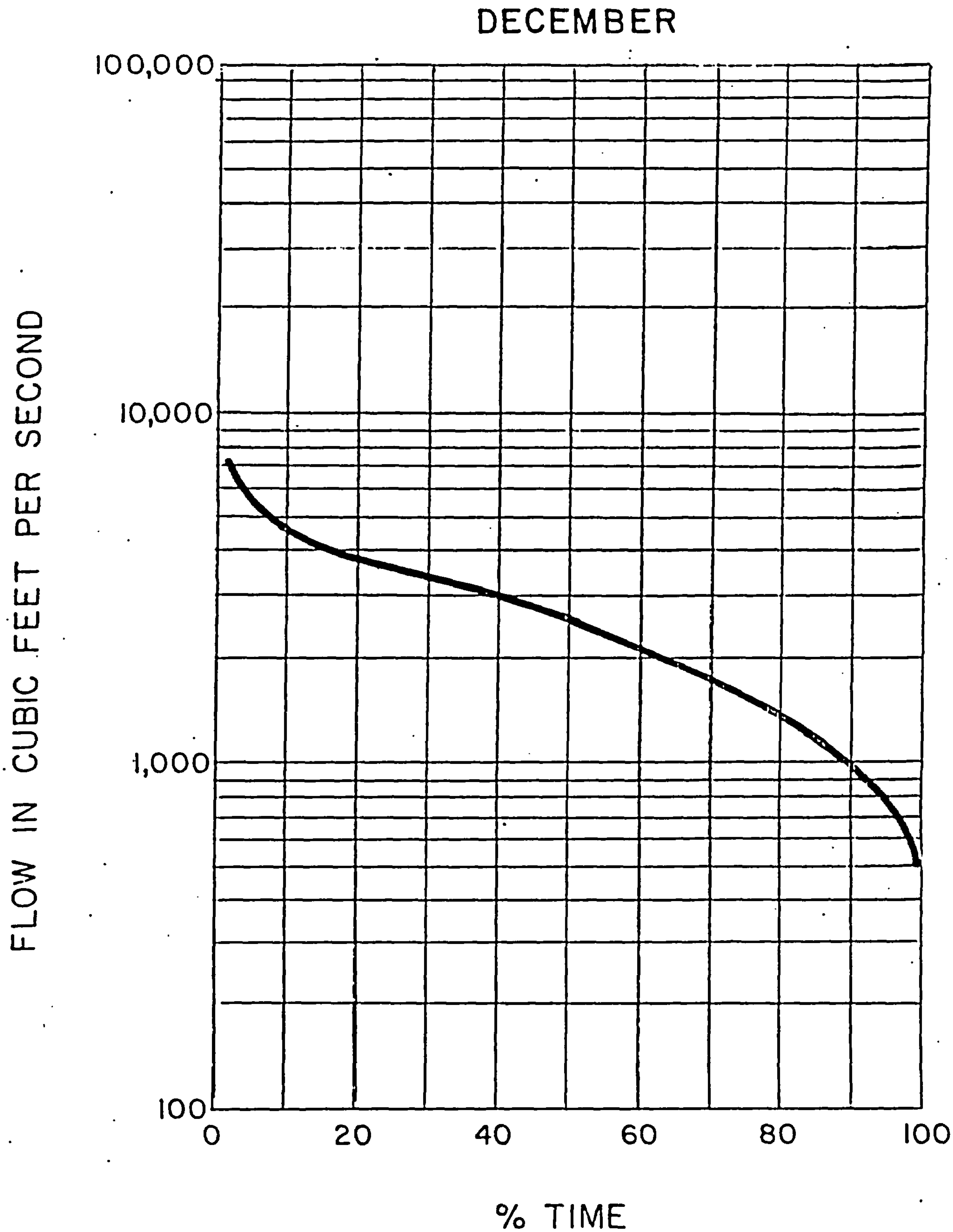


FIGURE C-13

December Flow Duration Curve for Mississippi River at St. Cloud, Minnesota. 1926-1970.

APPENDIX D

ANNUAL AND MONTHLY FLOW DURATION CURVES
FOR MISSISSIPPI RIVER AT ANOKA, MINNESOTA,
1931-1973

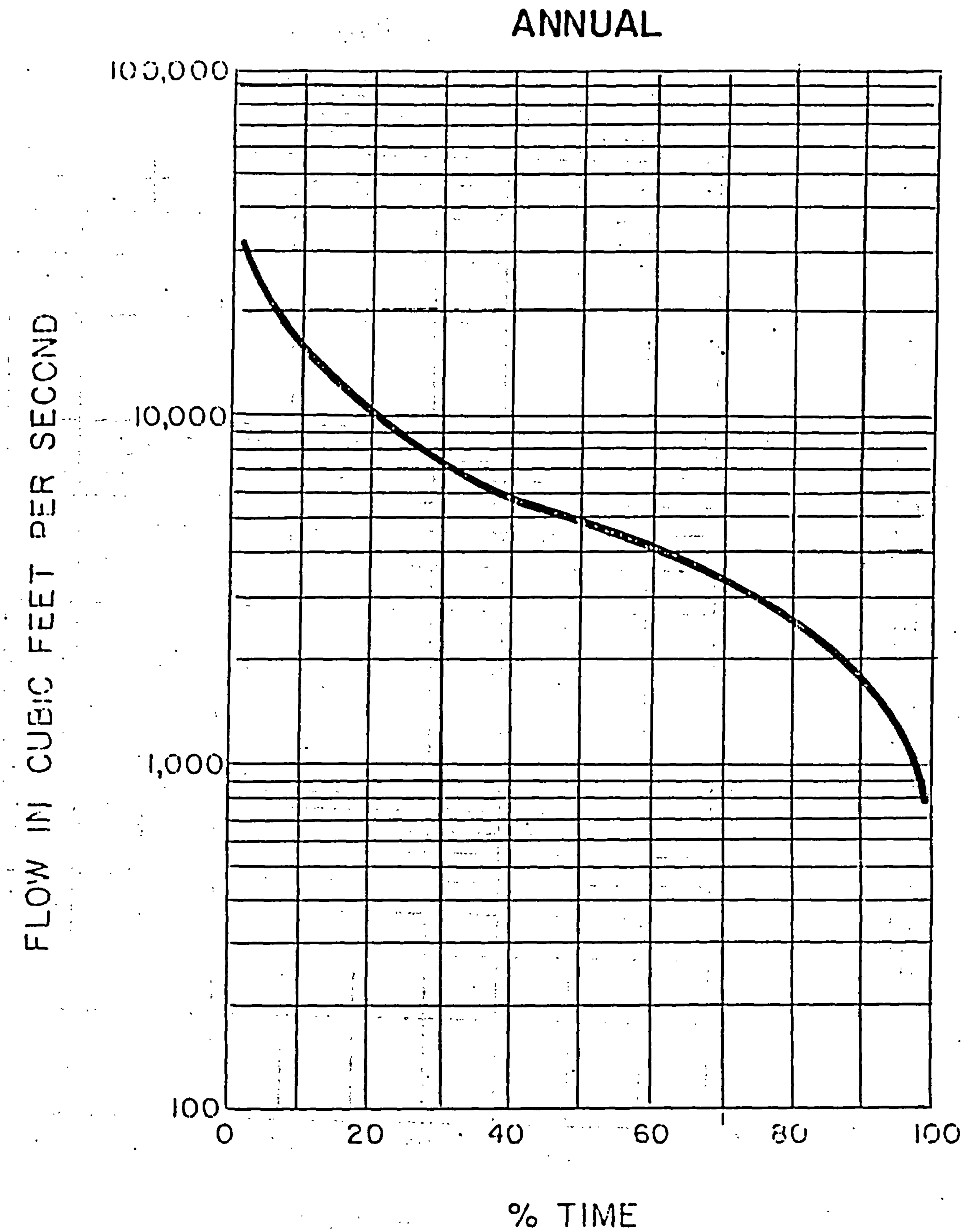


FIGURE D-1

Annual Flow Duration Curve for Mississippi River at Anoka, Minnesota. 1931-1973.

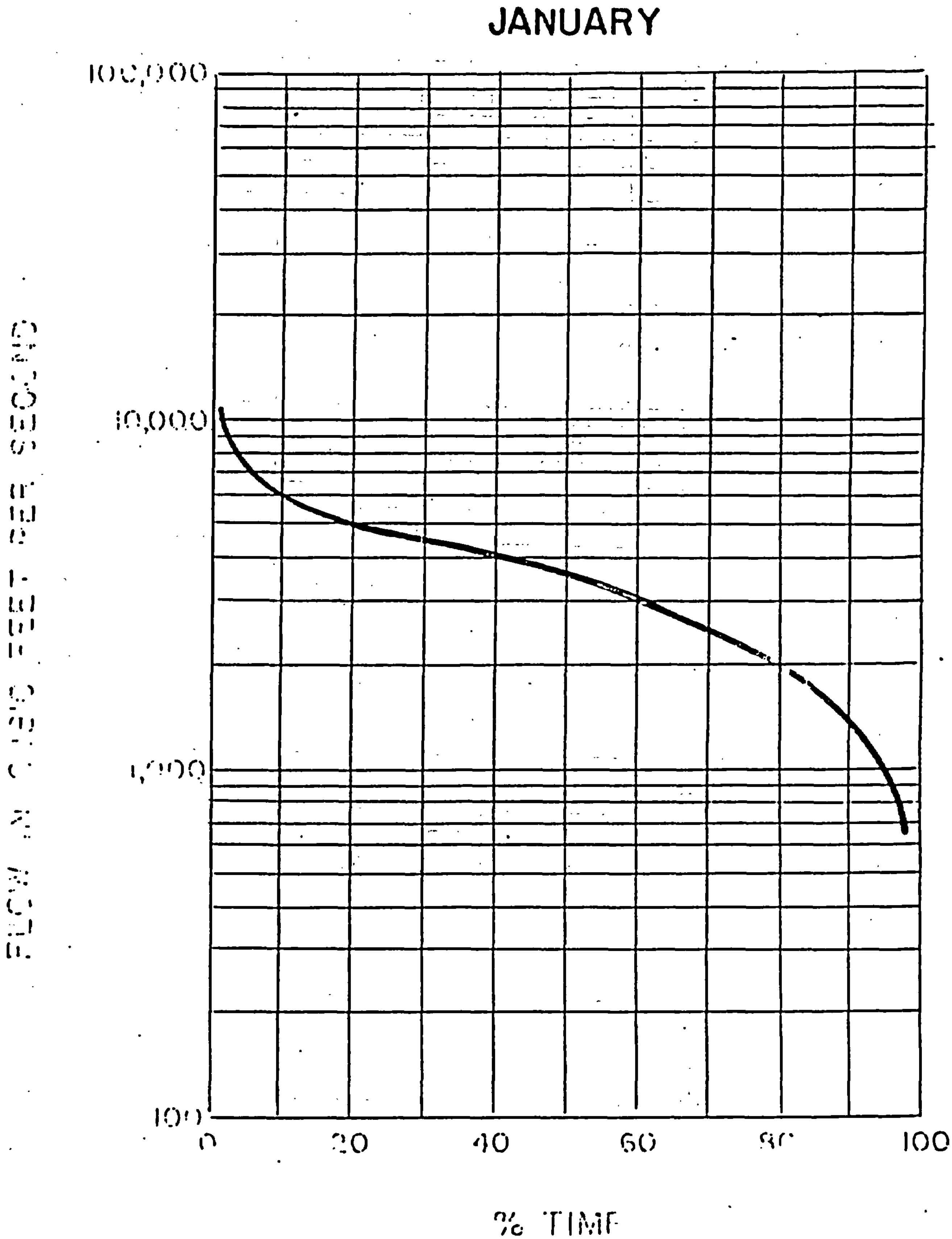


FIGURE D-2

January Flow Duration Curve for Mississippi River at Anoka, Minnesota. 1931-1973.

FEBRUARY

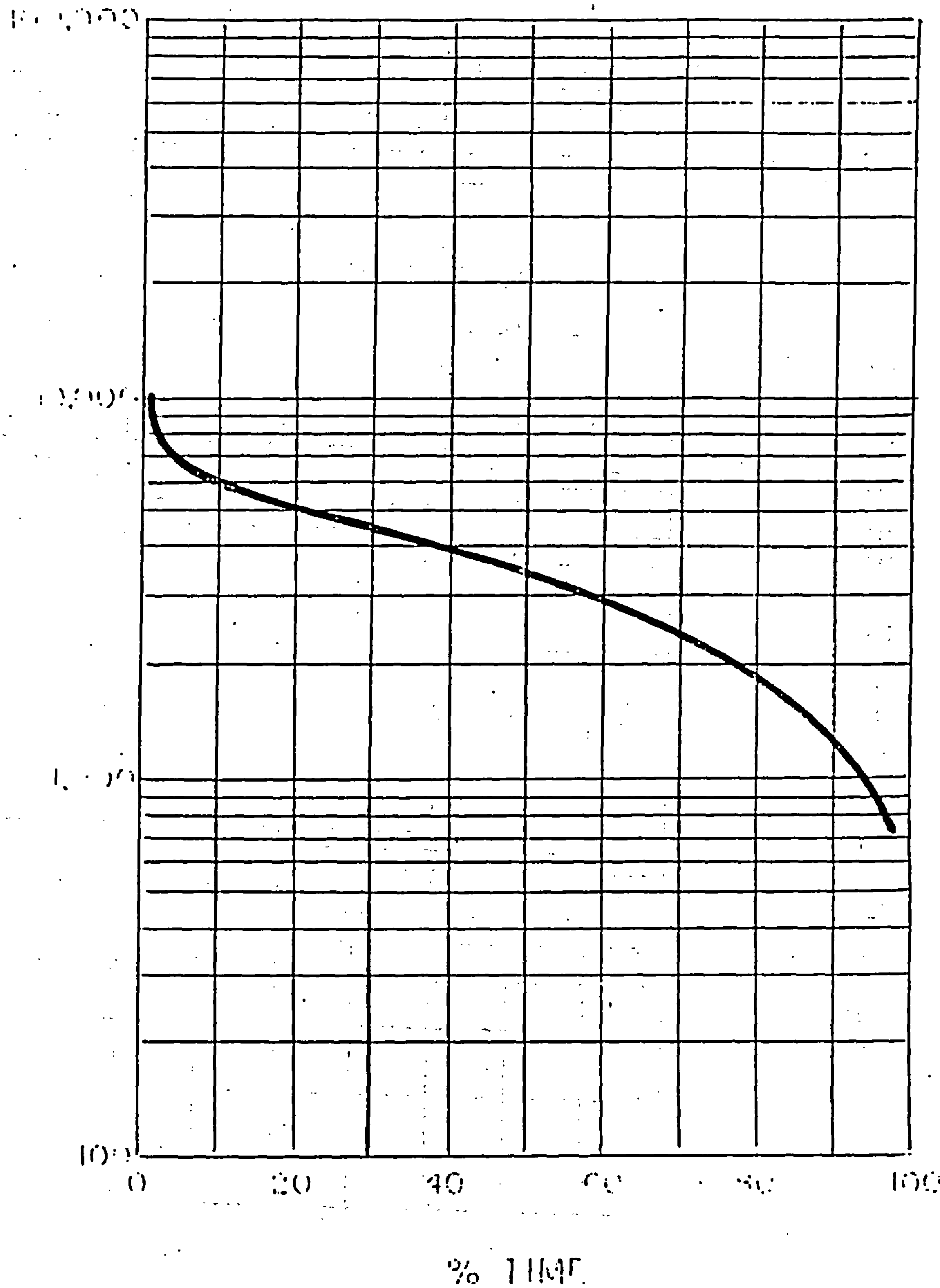


FIGURE D-3

February Flow Duration Curve for Mississippi River at Anoka, Minnesota. 1931-1973.

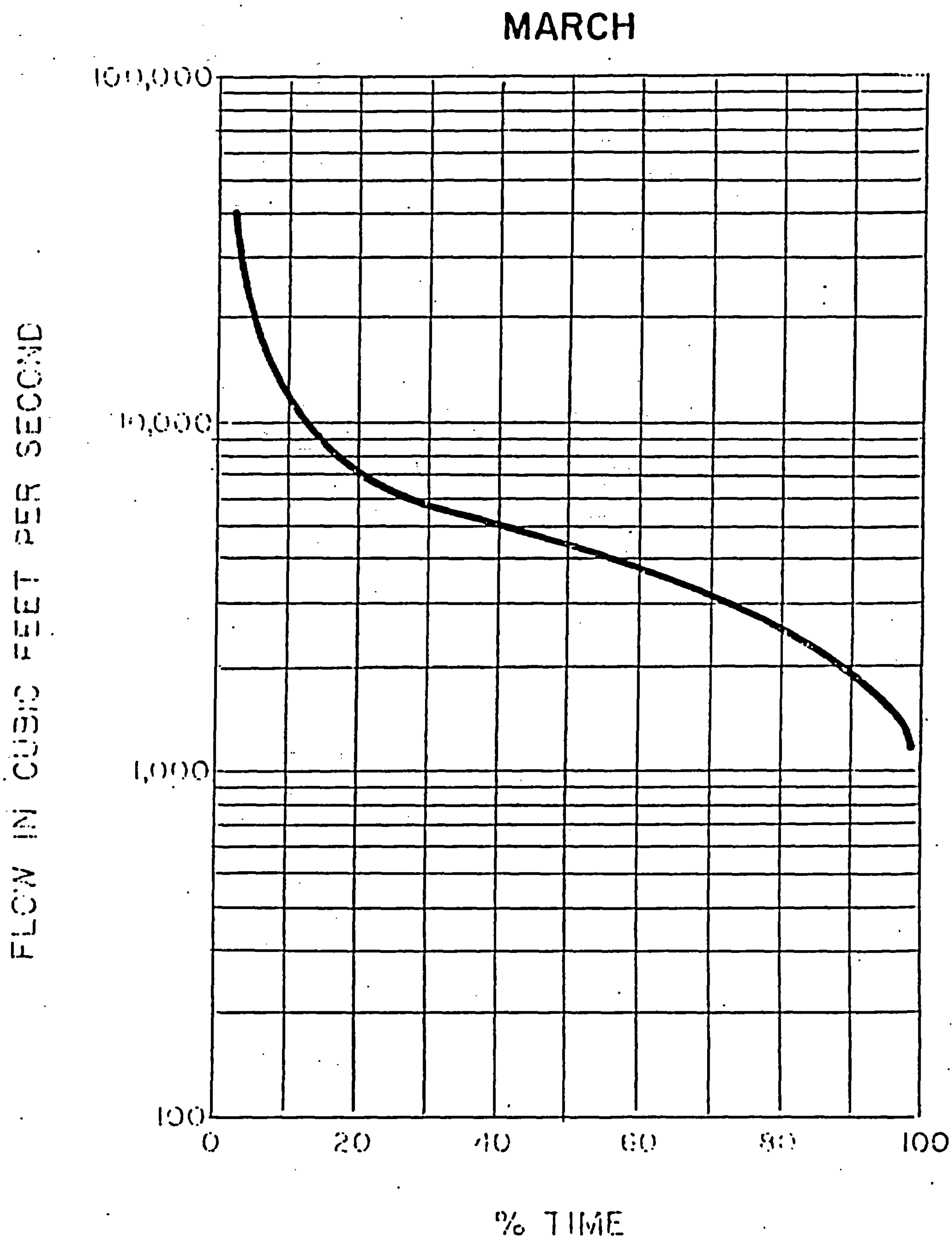


FIGURE D-4

March Flow Duration Curve for Mississippi River at Anoka, Minnesota. 1931-1973.

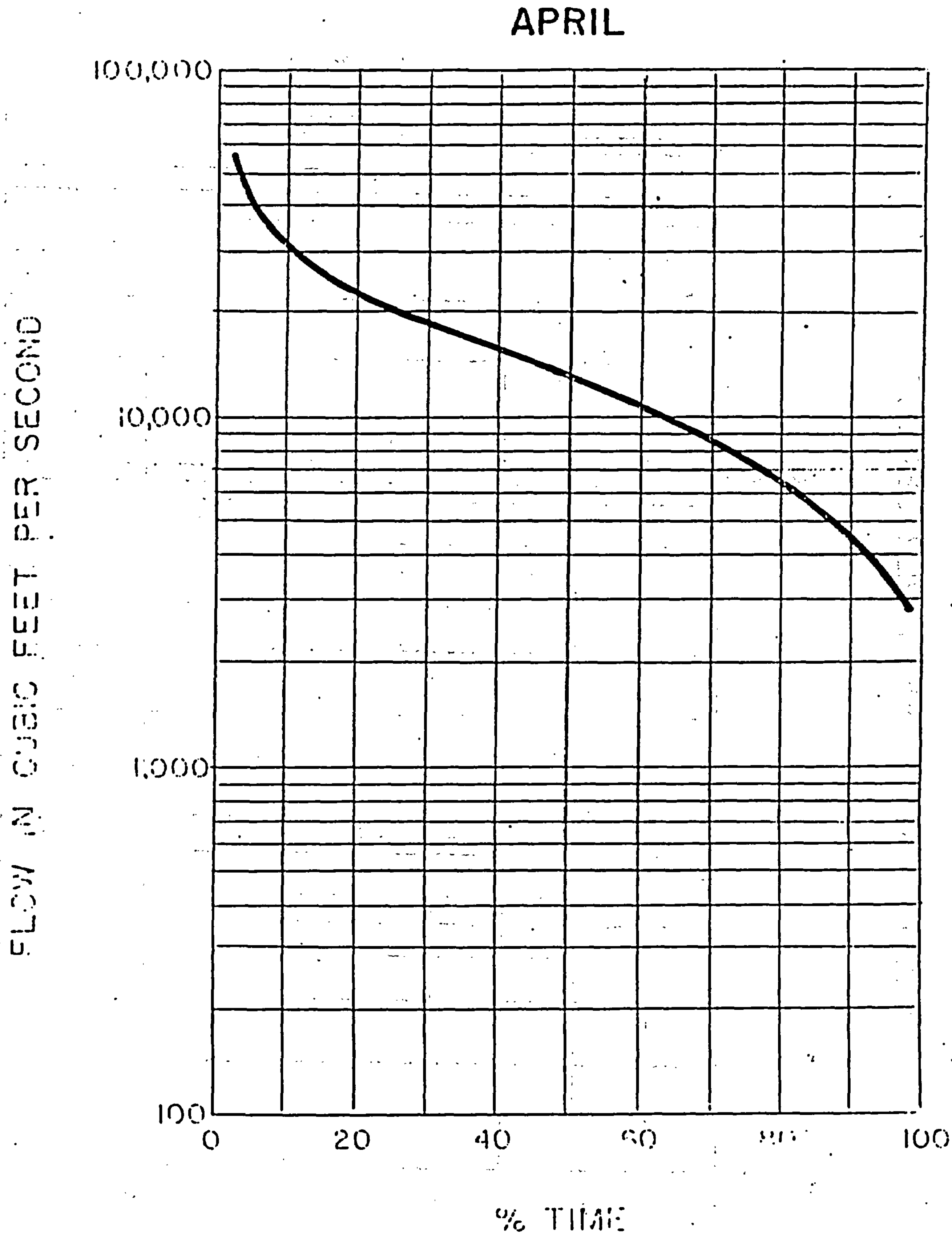


FIGURE D-5

April Flow Duration Curve for Mississippi River
at Anoka, Minnesota. 1931-1973.

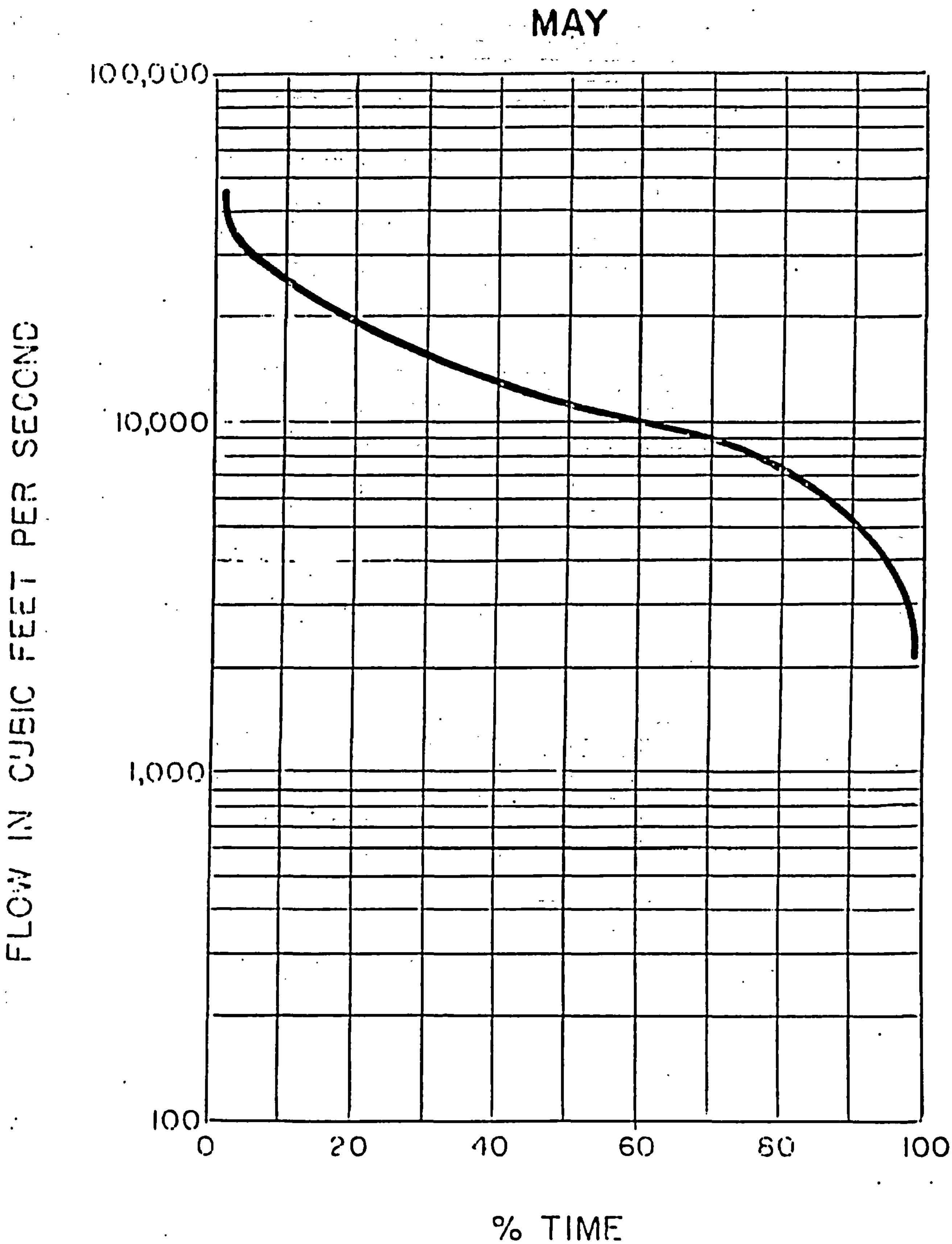


FIGURE D-6

May Flow Duration Curve for Mississippi River at Anoka, Minnesota. 1931-1973.

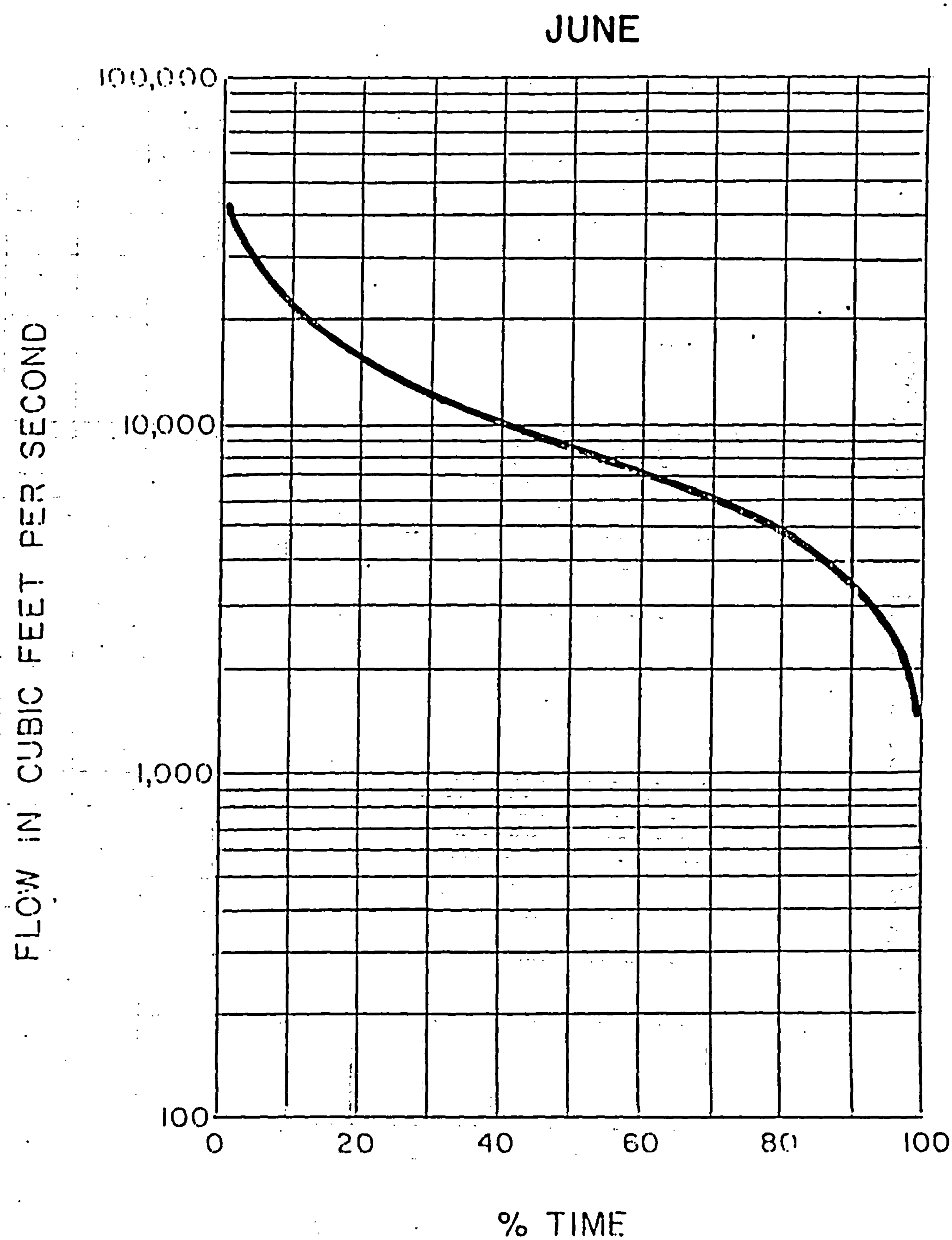


FIGURE D-7

June Flow Duration Curve for Mississippi River at Anoka, Minnesota. 1931-1973.

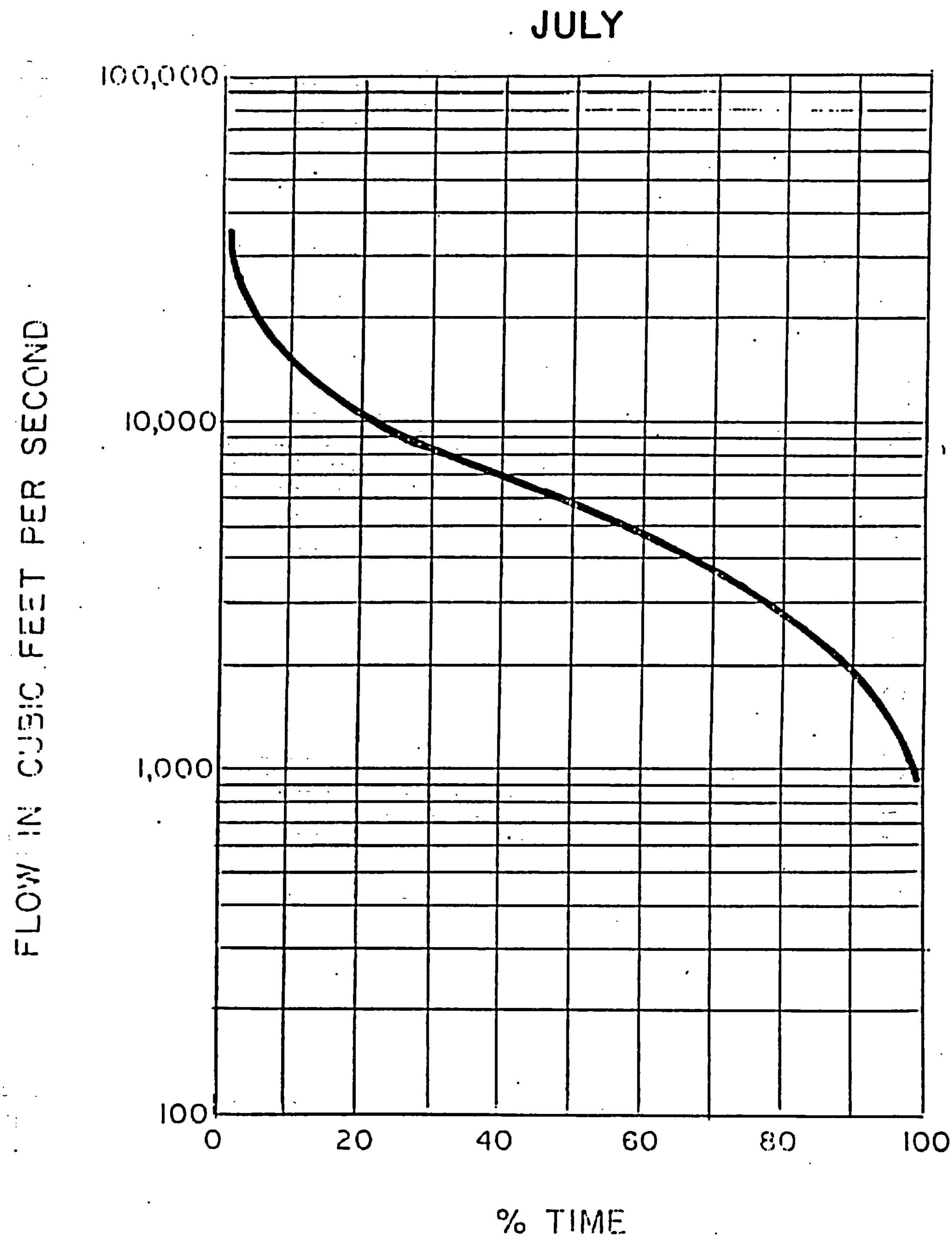


FIGURE D-8

July Flow Duration Curve for Mississippi River
at Anoka, Minnesota. 1931-1973.

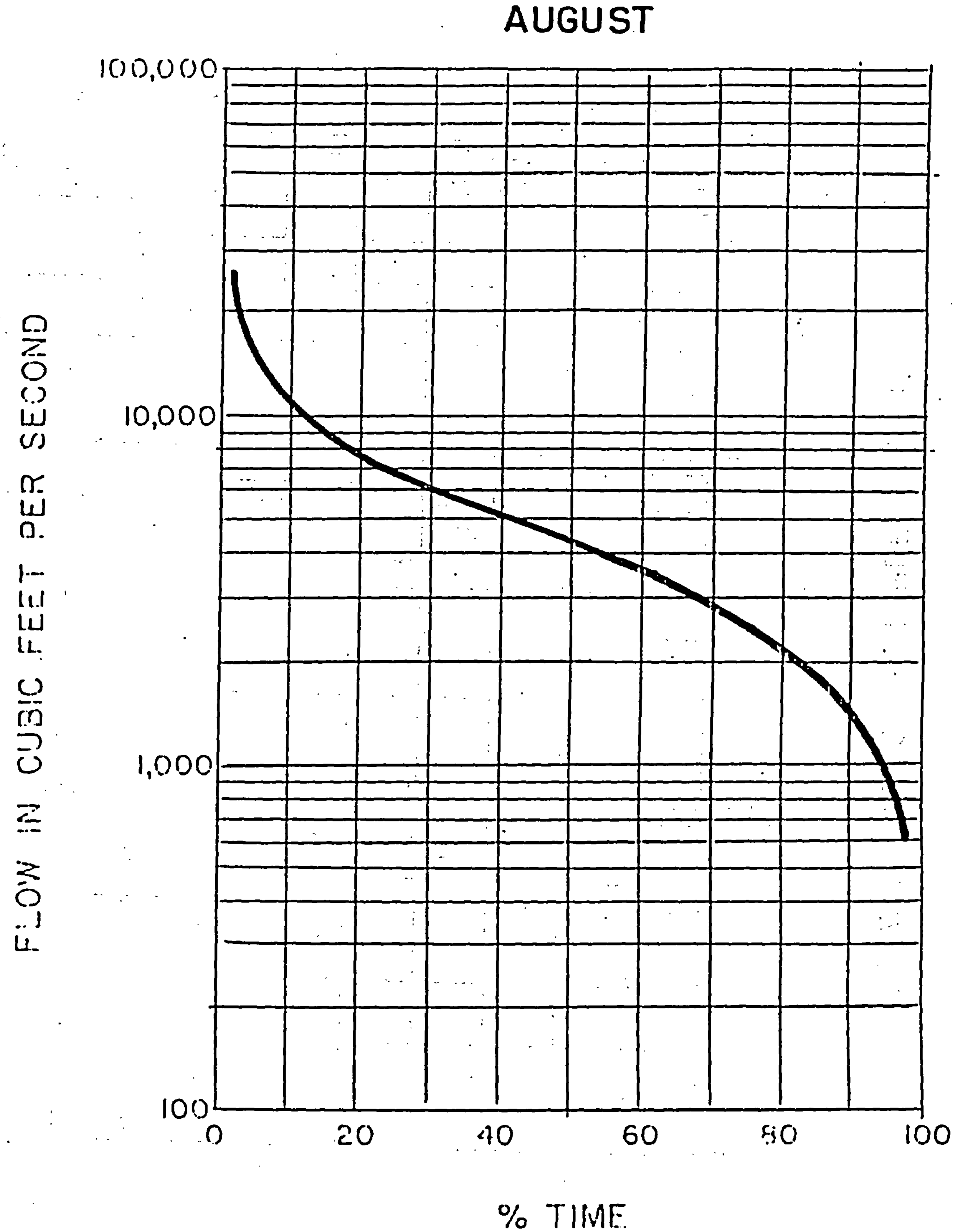


FIGURE D-9

August Flow Duration Curve for Mississippi River at Anoka, Minnesota. 1931-1973.

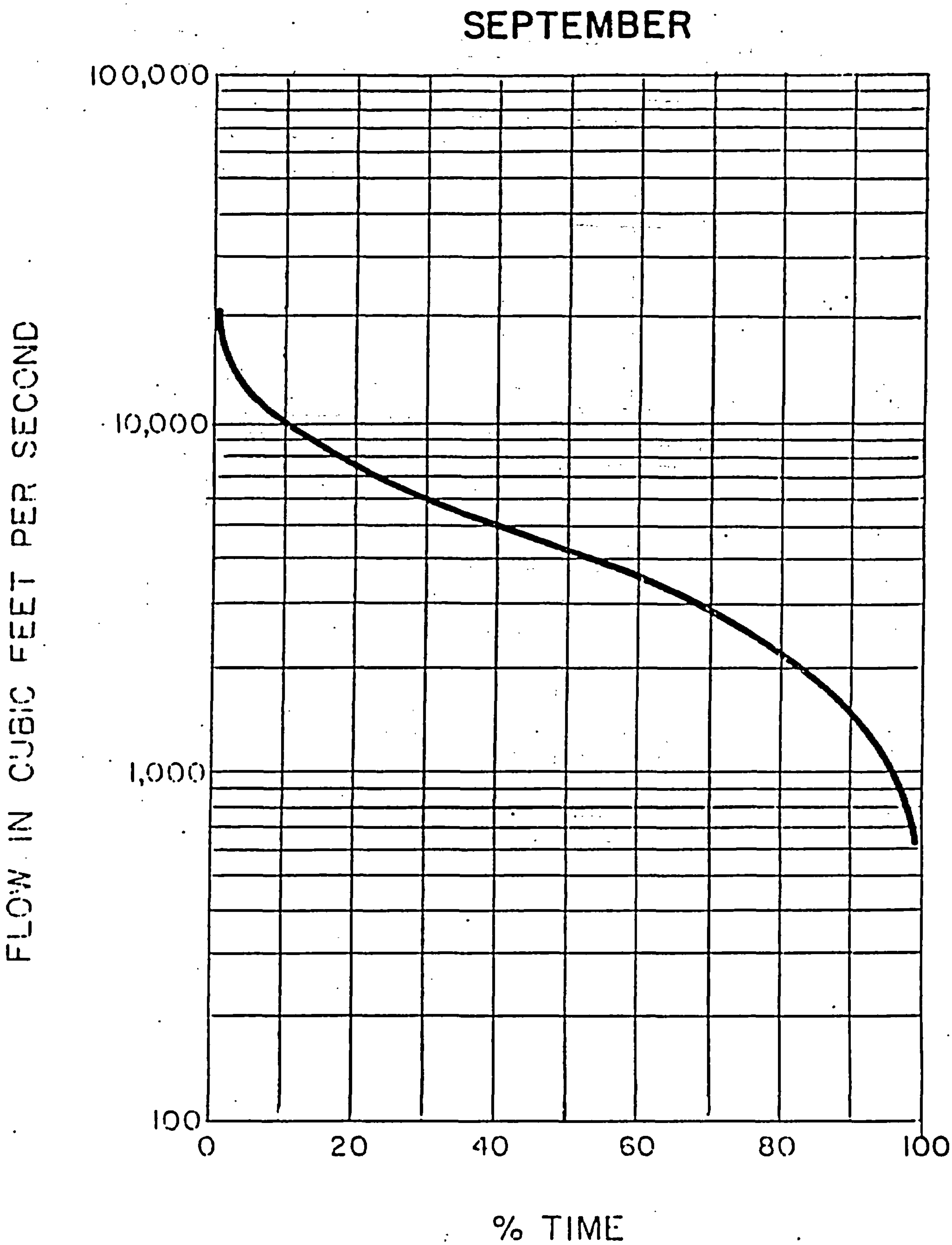


FIGURE D-10

September Flow Duration Curve for Mississippi River at Anoka, Minnesota. 1931-1973.

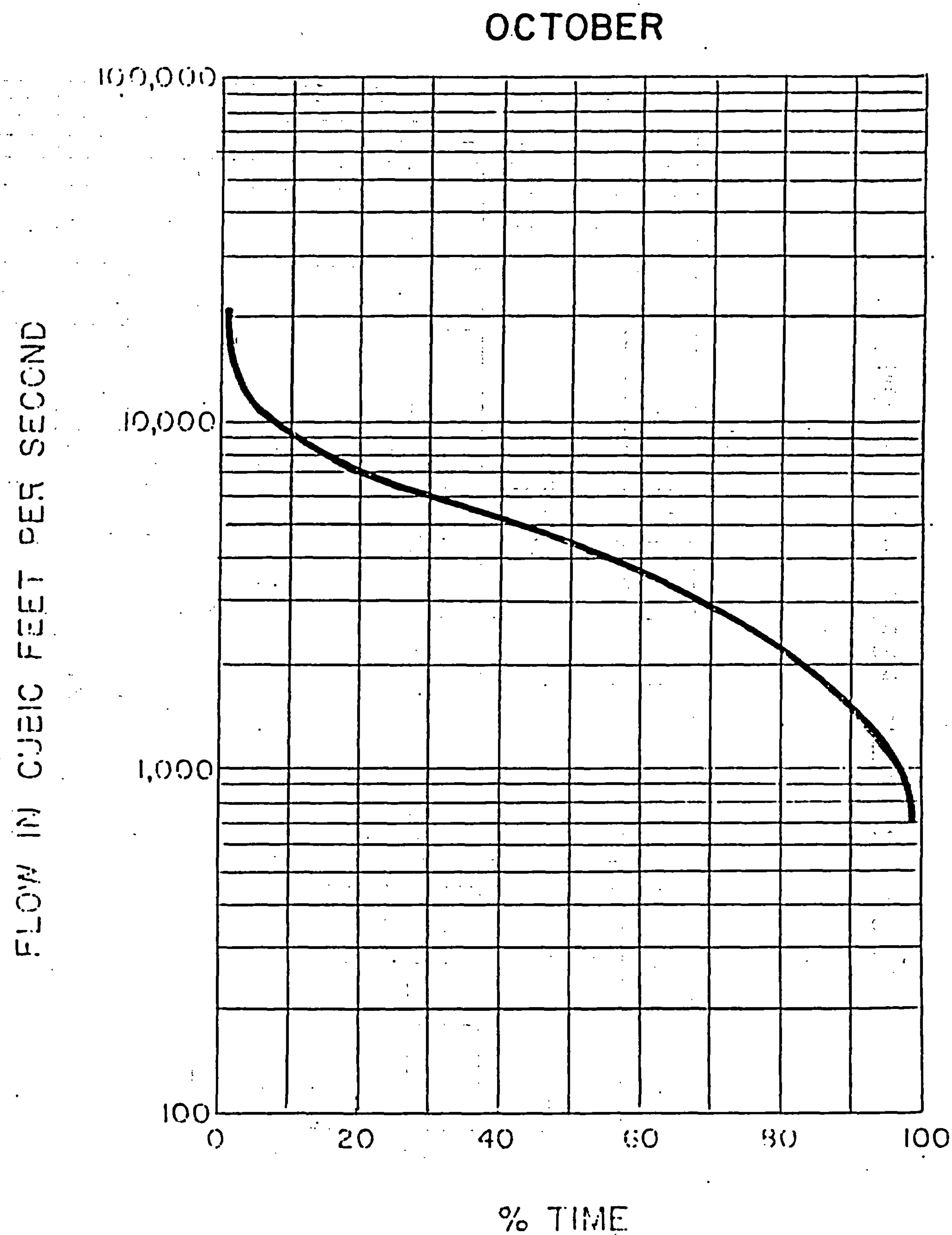


FIGURE D-11

October Flow Duration Curve for Mississippi River at Anoka, Minnesota. 1931-1973.

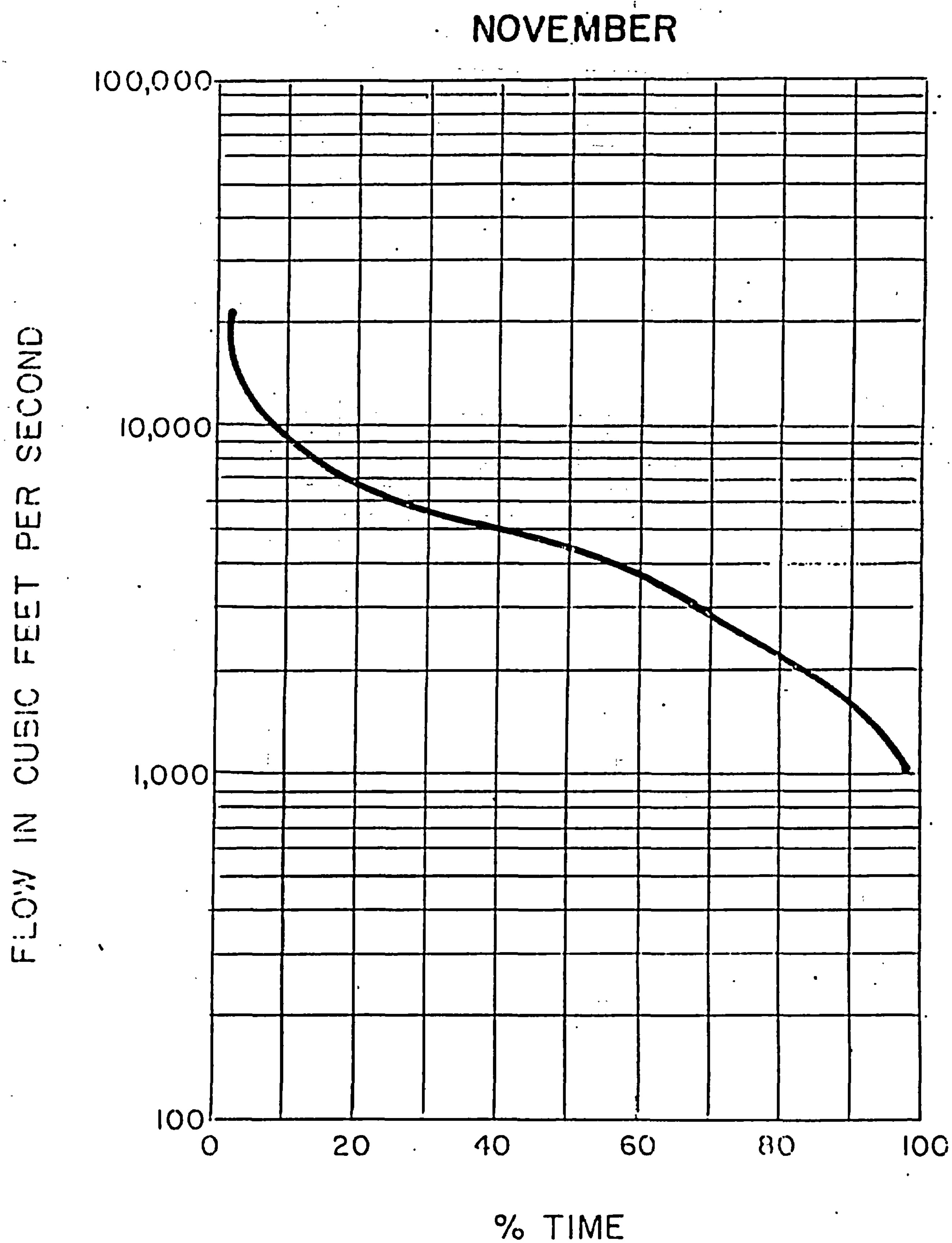


FIGURE D-12

November Flow Duration Curve for Mississippi River at Anoka, Minnesota. 1931-1973.

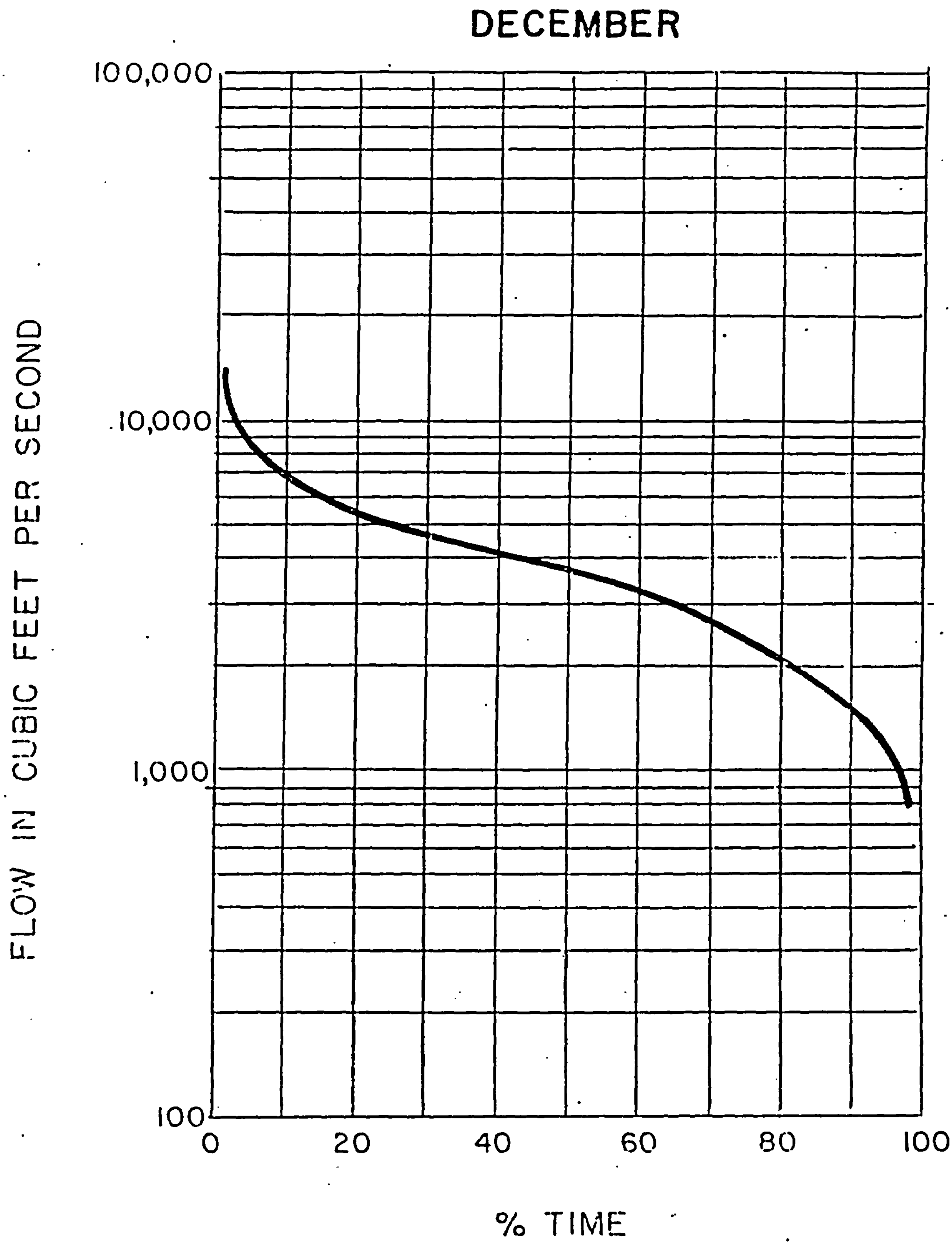


FIGURE D-13

December Flow Duration Curve for Mississippi River at Anoka, Minnesota. 1931-1973.

APPENDIX E

SUMMARIES OF TEMPERATURE DATA COLLECTED AT STATIONS 1 AND 2 ABOVE MONTICELLO PLANT INTAKE

Table E-1	Monthly Average Maximum and Minimum Temperatures 1969-1972.
Table E-2	Weekly Average Maximum and Minimum and Absolute Maximum and Minimum Temperatures, Station 1, January 1973-March 1975.
Table E-3	Weekly Average Maximum and Minimum and Absolute Maximum and Minimum Temperatures, Station 2, January 1973-March 1975.

TABLE E-1

MONTHLY AVERAGE MAXIMUM AND MINIMUM TEMPERATURES (°F)
TAKEN AT STATIONS 1 AND 2 DURING 1969, 1970, 1971, and 1972.
(WAPORA 1975)

	1969		1970		1971		1972	
	Max	Min	Max	Min	Max	Min	Max	Min
Station #1								
January	---		---		34.9	34.7	34.3	33.6
February	---		---		32.9	32.8	34.3	33.4
March	---		---		32.8	32.6	33.7	32.8
April	---		---		---		40.4	38.9
May	---		57.3	54.8	---		60.3	58.3
June	---		69.8	67.4	75.6	72.6	69.5	66.3
July	75.9	72.8	77.9	74.2	73.1	69.9	72.0	69.1
August	77.1	74.2	76.6	72.1	71.6	67.2	69.5	67.1
September	67.1	64.4	65.2	61.9	63.7	60.1	62.2	60.3
October	51.6	50.0	50.9	48.5	52.1	50.1	46.8	45.1
November	40.5	39.5	40.1	39.2	35.5	34.7	36.1	35.5
December	35.7	35.5	34.9	34.6	33.8	33.2	---	
Station #2								
January	---		---		34.2	34.1	33.9	33.8
February	---		---		33.0	33.0	33.8	33.7
March	---		34.0	34.0	32.9	32.6	33.3	33.2
April	---		41.5	38.5	41.6	39.8	39.3	37.6
May	---		57.6	54.6	56.3	53.1	59.8	56.8
June	---		72.3	69.2	72.5	68.9	68.4	64.7
July	76.1	71.5	78.9	73.2	74.9	70.9	71.1	67.5
August	77.1	72.3	76.3	70.6	72.2	69.2	68.7	65.7
September	66.8	62.3	64.5	59.4	65.0	60.3	61.6	58.9
October	50.3	47.5	52.9	48.9	55.1	52.4	45.7	43.7
November	37.2	36.1	38.5	37.4	36.0	35.2	34.6	33.9
December	34.3	34.1	34.2	34.0	33.7	33.5	---	

TABLE E-2

WEEKLY AVERAGE MINIMUM AND MAXIMUM AND
ABSOLUTE MINIMUM AND MAXIMUM WATER TEMPERATURES (°F)
MEASURED AT STATION 1,
JANUARY 1973 - MARCH 1975

Time Period	Average[1] Max	Average[1] Min	Absolute[2] Max	Absolute[2] Min
1973				
January 1-7	---	---	---	---
January 8-14	---	---	---	---
January 15-21	31.9	31.5	32.0	31.3
January 22-28	32.0	31.5	32.9	31.2
Jan. 29-Feb. 4	32.5	32.0	33.0	32.0
February 5-11	32.9	32.4	33.4	32.0
February 12-18	32.9	32.3	33.0	32.0
February 19-25	---	---	---	---
Feb. 26-March 4	---	---	---	---
March 5-11	---	---	---	---
March 12-18	32.8	32.3	33.5	32.0
March 19-25	34.8	34.0	36.4	33.0
Mar. 26-April 1	38.3	36.3	38.6	35.4
April 2-8	41.2	39.6	41.3	38.7
April 9-15	40.7	38.1	44.3	36.5
April 16-22	48.3	45.3	51.3	39.9
April 23-29	49.0	47.1	49.6	46.8
April 30-May 6	47.1	44.8	49.8	43.2
May 7-13	52.4	49.8	53.6	47.7
May 14-20	54.2	51.3	58.0	48.2
May 21-27	56.9	55.0	59.4	52.5
May 28-June 3	60.4	58.0	63.8	52.1
June 4-10	67.3	63.2	74.1	61.9
June 11-17	75.5	71.9	78.7	66.0
June 18-24	73.0	69.5	75.9	66.1
June 25-July 1	73.9	69.8	76.3	67.8
July 2-8	78.9	74.7	81.3	73.6
July 9-15	78.5	75.6	81.2	72.3
July 16-22	77.5	74.1	79.8	72.0
July 23-29	74.8	71.6	79.7	67.8
July 30-Aug. 5	74.9	71.5	77.8	69.7
August 6-12	78.3	75.1	81.0	73.7
August 13-19	77.3	74.6	79.0	73.6
August 20-26	72.8	71.2	76.7	69.0
Aug. 27-Sept. 2	75.9	73.3	77.0	71.0
September 3-9	71.8	70.1	76.3	66.9
September 10-16	67.2	64.7	70.9	60.4
September 17-23	60.1	57.7	64.2	54.3
September 24-30	60.1	59.6	63.0	55.3

[1]Averages of daily minimum and daily maximum water temperatures for the period indicated.

[2]Absolute maximum and minimum water temperatures observed during the the period indicated.

TABLE E-2 (Continued)

Time Period	Average		Absolute	
	Max	Min	Max	Min
1973 (Continued)				
October 1-7	59.1	57.6	60.7	56.6
October 8-14	59.8	58.1	62.9	55.2
October 15-21	52.4	51.7	55.3	49.9
October 22-28	52.1	51.1	53.3	49.3
Oct. 29-Nov. 4	47.1	46.2	48.9	43.1
November 5-11	39.5	38.1	43.1	35.9
November 12-18	38.9	38.2	39.3	37.0
November 19-25	38.7	38.0	39.9	37.7
Nov. 26-Dec. 2	36.8	36.1	37.8	35.3
December 3-9	33.5	32.7	35.9	32.4
December 10-16	33.1	32.7	32.7	32.4
December 17-23	32.6	32.1	32.9	31.8
December 24-31	32.4	32.1	33.3	31.6
1974				
January 1-5	---	---	---	---
January 6-12	33.7	33.0	33.8	32.9
January 13-19	32.6	31.9	33.2	31.7
January 20-26	32.1	31.8	32.5	31.6
Jan. 27-Feb. 2	32.6	32.1	33.0	31.7
February 3-9	32.8	32.2	33.1	31.7
February 10-16	32.4	31.8	32.6	31.5
February 17-23	32.3	31.7	32.7	31.4
Feb. 24-March 2	32.4	31.6	32.7	31.3
March 3-9	32.7	32.1	33.8	31.3
March 10-16	33.8	33.1	34.3	32.9
March 17-23	34.6	33.7	35.0	33.3
March 24-30	34.7	33.5	35.8	33.2
Mar.31-Apr. 6	35.1	33.2	36.7	33.0
April 7-13	36.4	34.7	37.0	33.5
April 14-20	40.0	38.1	44.6	35.2
April 21-27	46.4	44.8	50.6	43.5
April 28-May 4	52.6	51.7	53.4	50.6
May 5-11	50.8	49.2	52.6	47.8
May 12-18	48.7	47.4	50.7	46.4
May 19-25	56.7	54.7	59.1	50.0
May 26-June 1	62.0	59.4	63.3	57.0
June 2-8	67.5	64.2	69.2	60.0
June 9-15	66.9	64.8	68.8	63.6
June 16-23	67.6	64.5	69.8	62.6
June 22-29	72.4	69.1	73.8	67.1
June 30-July 6	76.2	73.5	78.2	71.7

TABLE E-2 (Continued)

Time Period	Average Max	Average Min	Absolute Max	Absolute Min
1974 (Continued)				
July 7-13	79.8	76.2	81.8	74.7
July 14-20	80.5	76.6	82.2	74.8
July 21-27	79.1	73.6	81.2	73.2
July 28-Aug. 3	74.3	70.7	77.6	67.4
August 4-10	72.1	69.4	73.3	65.2
August 11-17	72.8	69.8	74.3	68.2
August 18-24	74.5	71.0	76.2	68.7
August 25-31	69.6	66.4	74.5	61.7
September 1-7	63.8	60.4	64.9	58.8
September 8-14	62.2	56.4	66.3	55.3
September 15-21	62.9	60.0	64.6	57.7
September 22-28	59.6	56.1	62.0	54.0
Sept. 29-Oct. 5	52.7	49.6	56.7	48.0
October 6-12	52.2	49.5	55.2	46.6
October 13-19	49.9	48.3	51.6	47.2
October 20-26	49.1	47.1	50.1	45.0
Oct. 27-Nov. 2	51.7	50.5	52.4	48.2
November 3-9	46.0	44.9	48.9	43.5
November 10-16	41.9	40.7	45.5	37.5
November 17-23	37.8	36.9	39.0	35.1
November 24-30	35.1	34.3	37.7	32.8
December 1-7	33.3	32.9	33.3	32.9
December 8-14	32.9	32.8	32.9	32.8
December 15-21	33.1	32.9	33.3	32.7
December 22-28	33.0	32.5	33.3	32.3
Dec. 29-Jan. 4, 1975	33.0	32.5	33.1	32.4
1975				
January 5-11	---	---	---	---
January 12-18	32.8	32.5	33.0	32.2
January 19-25	32.9	32.3	33.3	32.1
Jan. 26-Feb. 1	32.8	32.3	32.8	32.3
February 2-8	32.8	32.4	33.3	32.0
February 9-15	33.1	32.7	33.4	32.3
February 16-22	32.5	32.0	32.7	31.7
Feb. 23-March 1	32.4	32.0	32.8	31.8
March 2-8	32.6	32.0	33.0	31.8
March 9-15	32.7	31.9	32.9	31.8
March 16-22	32.0	31.5	32.6	31.3

TABLE E-3

WEEKLY AVERAGE MINIMUM AND MAXIMUM AND
ABSOLUTE MINIMUM AND MAXIMUM WATER TEMPERATURES (°F)
MEASURED AT STATION 2,
JANUARY 1973 - MARCH 1975

Time Period	Average[1] Max	Average[1] Min	Absolute[2] Max	Absolute[2] Min
1973				
January 1-7	---	---	---	---
January 8-14	---	---	---	---
January 15-21	---	---	---	---
January 22-28	---	---	---	---
Jan. 29-Feb. 4	---	---	---	---
February 5-11	---	---	---	---
February 12-18	---	---	---	---
February 19-25	---	---	---	---
Feb. 26-March 4	---	---	---	---
March 5-11	---	---	---	---
March 12-18	32.2	31.4	32.5	31.1
March 19-25	33.9	32.4	32.8	31.8
Mar. 26-Apr. 1	---	---	---	---
April 2-8	---	---	---	---
April 9-15	---	---	---	---
April 16-22	---	---	---	---
April 23-29	---	---	---	---
April 30-May 6	---	---	---	---
May 7-13	---	---	---	---
May 14-20	---	---	---	---
May 21-27	---	---	---	---
May 28-June 3	---	---	---	---
June 4-10	---	---	---	---
June 11-17	---	---	---	---
June 18-24	72.9	69.1	76.2	65.7
June 25-July 1	74.4	71.2	77.0	67.8
July 2-8	79.5	74.8	81.9	73.1
July 9-15	78.7	75.3	81.3	71.7
July 16-22	78.4	73.6	79.8	71.7
July 23-29	72.6	71.3	79.7	67.4
July 30-Aug. 5	75.0	71.1	77.7	67.2
Aug. 6-12	77.7	75.4	81.3	73.2
Aug. 13-19	77.7	74.1	79.3	73.1
Aug. 20-26	72.7	71.0	76.1	68.7
Aug. 27-Sept. 2	76.5	73.2	77.8	71.2
September 3-9	71.9	69.7	76.7	66.5
September 10-16	67.3	64.2	71.0	59.9
September 17-23	60.4	57.5	64.3	54.1
September 24-30	61.0	57.8	63.8	55.3

[1]Averages of daily minimum and daily maximum water temperatures for the period indicated.

[2]Absolute maximum and minimum water temperatures observed during the the period indicated.

TABLE E-3 (Continued)

Time Period	Average Max	Average Min	Absolute Max	Absolute Min
1973 (Continued)				
October 1-7	60.2	57.8	61.9	56.7
October 8-14	60.1	58.3	63.7	54.9
October 15-21	52.8	51.7	55.6	50.0
October 22-28	52.7	51.3	54.9	48.9
Oct. 29-Nov. 4	47.3	46.0	49.2	42.6
November 5-11	39.1	37.7	42.6	35.3
November 12-18	39.2	38.2	39.8	37.0
November 19-25	39.0	38.0	40.3	37.4
Nov. 26-Dec. 2	36.8	36.1	38.7	35.3
December 3-9	33.1	32.4	36.3	32.3
December 10-16	32.7	32.6	32.8	32.3
December 17-23	32.6	32.2	32.9	31.8
December 24-31	32.6	32.6	32.8	32.5
1974				
January 1-5	---	---	---	---
January 6-12	33.0	32.9	33.1	32.9
January 13-19	32.7	32.5	32.9	32.4
January 20-26	32.6	32.4	32.7	32.3
Jan. 27-Feb. 2	32.7	32.6	32.8	32.3
February 3-9	32.8	32.6	32.9	32.6
February 10-16	32.7	32.5	32.7	32.3
February 17-23	32.6	32.4	32.8	32.3
Feb. 24-March 2	32.7	32.4	32.7	32.3
March 3-9	33.3	32.6	34.2	32.2
March 10-16	34.2	33.2	34.5	33.1
March 17-23	34.6	33.2	34.8	33.0
March 24-30	34.9	33.3	36.1	33.1
Mar. 31-Apr. 6	35.4	33.2	37.1	33.0
April 7-13	37.0	35.0	37.8	33.2
April 14-20	40.9	38.5	45.5	35.5
April 21-27	47.2	45.1	51.9	43.3
April 28-May 4	53.4	51.9	54.1	50.7
Mar 5-11	51.5	49.4	53.4	48.4
May 12-18	49.7	47.7	51.8	46.5
May 19-25	57.6	55.0	59.3	50.5
May 26-June 1	62.9	58.5	64.3	56.9
June 2-8	68.8	64.5	70.8	60.1
June 9-15	67.6	64.7	69.7	63.7
June 16-22	68.6	64.7	71.1	62.8
June 23-29	73.4	69.4	75.6	67.1
June 30-July 6	77.3	73.9	79.5	71.8

TABLE E-3 (Continued)

Time Period	Average Max	Average Min	Absolute Max	Absolute Min
1974 (Continued)				
July 7-13	80.7	76.8	82.2	75.0
July 14-20	81.4	77.0	83.8	75.1
July 21-27	80.0	76.1	82.5	73.8
July 28-Aug. 3	75.1	71.2	78.5	66.4
August 4-10	73.3	69.5	74.2	65.7
August 11-17	73.9	70.5	75.7	68.3
August 18-24	75.6	71.9	77.9	69.3
August 25-31	70.6	67.2	75.5	62.4
September 1-8	64.8	62.5	66.1	60.9
September 8-14	63.3	59.3	67.2	55.2
September 15-21	---	---	---	---
September 22-28	61.2	57.3	62.7	55.3
Sept. 29-Oct. 5	52.4	49.2	57.0	46.7
October 6-12	54.7	52.6	54.7	52.6
October 13-19	50.7	48.7	52.1	47.6
October 20-26	49.4	47.4	50.3	45.6
Oct. 27-Nov. 2	51.8	50.4	52.7	48.1
November 3-9	45.5	44.1	48.5	42.9
November 10-16	41.4	39.9	45.5	36.0
November 17-23	37.8	36.7	38.9	36.2
November 23-30	34.7	34.1	37.1	33.1
December 1-7	33.2	33.1	33.3	33.1
December 8-14	33.2	33.1	33.4	33.1
December 15-21	33.1	33.1	33.2	33.0
December 22-28	32.9	32.8	33.2	32.7
Dec. 29-Jan. 4, 1975	32.9	32.8	33.0	32.7
1975				
January 5-11	---	---	---	---
January 12-18	---	---	---	---
January 19-25	33.0	32.9	33.1	32.8
Jan. 26-Feb. 1	32.9	32.8	33.0	32.8
February 2-8	32.9	32.8	33.2	32.8
February 9-15	33.0	32.8	33.2	32.8
February 16-22	32.4	32.3	32.8	32.0
Feb. 23-March 1	32.4	32.2	32.5	32.1
March 2-8	32.5	32.3	32.6	32.1
March 9-15	32.5	32.2	32.6	32.1
March 16-22	32.2	32.1	32.5	32.0

APPENDIX G

MINNESOTA WATER QUALITY STANDARDS

MINNESOTA CRITERIA FOR INTERSTATE WATERS

(WPC 15, Criteria for the Classification of the Interstate Waters of the State and the Establishment of Standards of Quality and Purity; Adopted June 30, 1969, June 14, 1967; Amended July 1, 1969, October 13, 1971, and October 4, 1973) current 9/5/75

(a) Introduction.

(1) Scope. The following classifications, criteria and standards of water and effluent quality and purity as hereby adopted and established shall apply to all interstate waters of the state, notwithstanding any other interstate water quality or effluent regulations of general or specific application, except that any more stringent water quality or effluent standards or prohibitions in the other applicable regulations are preserved.

(2) Severability. All provisions of this regulation shall be severable and the inability of any lettered paragraph or any subparagraph or subdivision thereof shall not void any other lettered paragraph or subparagraph, subdivision or any part thereof.

(3) Definitions. The terms "waters of the state" for the purposes of this regulation shall be construed to mean interstate waters as herein below defined, and the terms "sewage," "industrial wastes," and "other wastes," as well as any other terms for which definitions are given in the Water Pollution Control Statutes, as used herein have the meanings ascribed to them in Minnesota Statutes, Sections 115.01 and 115.41, with the exception that disposal systems or treatment works operated under permit of the Agency shall not be construed to be "waters of the state" as the term is used herein. Interstate waters are defined as all rivers, lakes, and other waters that flow across or form a part of state boundaries. Other terms and abbreviations used herein which are not specifically defined in the law shall be construed in conformance with the context, and in relation to the applicable section of the statutes pertaining to the matter at hand, and current professional usage.

(4) Uses of the Interstate Waters. The classifications are listed separately in accordance with the need for interstate water quality protection, considerations of best use in the interest of the public and other considerations, as indicated in Minnesota Statutes, Section 115.44. The classifications should not be construed to be an order of priority, nor considered to be exclusive or prohibitory of other beneficial uses.

(5) Determination of Compliance. In making tests or analyses of the interstate waters of the state, sewage, industrial wastes or other wastes to determine compliance with the standards, samples shall be collected in such manner and place, and of such type, number and frequency as may be considered necessary by the Agency from the viewpoint of adequately reflecting the condition of the interstate waters, the composition of the effluents, and the effects of the pollutants upon the specified uses. Reasonable allowance will be made for dilution of the effluents which are in compliance with Section (c)(6), following discharge into waters of the State. The Agency by allowing dilution may consider the effect on all uses of the interstate waters into which the effluents are discharged. The extent of dilution allowed regarding any specific discharge shall not violate the applicable water quality standards. The samples shall be preserved and analyzed in accordance with procedures given in the 1971 edition of Standard Methods for the Examination of Water and Waste-Water, by the American Public Health Association, American Water Works Association, and the Water Pollution Control Federation, and any revisions or amendments thereto. The Agency may accept or may develop other methods, procedures, guidelines or criteria for measuring, analyzing and collecting samples.

(6) Natural Interstate Water Quality. The interstate waters may, in a state of nature, have some characteristics or properties approaching or exceeding the limits specified in the standards. The standards shall be construed as limiting the addition of pollutants of human origin to those of natural origin, where such be present, so that in total the specified limiting concentrations will not be exceeded in the interstate waters by reason of such controllable additions. Where the background level of the natural origin is reasonably definable and normally is higher than the specified standard the natural level may be used as the standard for controlling the addition of pollutants of human origin which are comparable in nature and significance with those of natural origin. The natural background level may be used instead of the specified water quality standard as a maximum limit of the addition of pollutants, in those instances where the natural level is lower than the specified standard and reasonable justification exists for preserving the quality to that found in a state of nature.

In the adoption of standards for individual interstate waters, the Agency will be guided by the standards set forth herein but may make reasonable modifications of the same on the basis of evidence brought forth at a public hearing if it is shown to be desirable and in the public interest to do so in order to encourage the best use of the interstate waters or the lands bordering such interstate waters.

(7) Non-Degradation. Waters which are of quality better than the established standards shall be maintained at high quality unless a determination is made by the Agency that a change is justifiable as a result of necessary economic or social development and will not preclude

appropriate beneficial present and future uses of the waters. Any project or development which would constitute a source of pollution to waters of the state shall be required to provide the best practicable control technology currently available not later than July 1, 1977 and the best available technology economically achievable not later than July 1, 1983 and any other applicable treatment standards as defined by and in accordance with the requirements of the Federal Water Pollution Control Act, 33 U.S.C. 1251 et seq., as amended, in order to maintain high water quality and keep water pollution at a minimum. In implementing this policy the Administrator of the U. S. Environmental Protection Agency will be provided with such information as he requires to discharge his responsibilities under the Federal Water Pollution Control Act as amended.

(8) Variance from Standards. In any case where, upon application of the responsible person or persons, the Agency finds that by reason of exceptional circumstances the strict enforcement of any provision of these standards would cause undue hardship; that disposal of the sewage, industrial waste or other waste is necessary for the public health, safety or welfare; and that strict conformity with the standards would be unreasonable, impractical or not feasible under the circumstances; the Agency in its discretion may permit a variance therefrom upon such conditions as it may prescribe for prevention, control or abatement of pollution in harmony with the general purposes of these classifications and standards and the intent of the applicable state and national laws. The Environmental Protection Agency will be advised of any permits which may be issued under this clause together with information as to the need therefor.

(b) Water Use Classifications — All Interstate Waters of the State.

Based on considerations of best usage in the interest of the public and in conformance with the requirements of the applicable statutes, the interstate waters of the state shall be grouped into one or more of the following classes:

(1) Domestic Consumption. (To include all interstate waters which are or may be used as a source of supply for drinking, culinary or food processing use or other domestic purposes, and for which quality control is or may be necessary to protect the public health, safety or welfare.)

(2) Fisheries and Recreation. (To include all interstate waters which are or may be used for fishing, fish culture, bathing or any other recreational purposes, and for which quality control is or may be necessary to protect aquatic or terrestrial life, or the public health, safety or welfare.)

(3) Industrial Consumption. (To include all interstate waters which are or may be used as a source of supply for industrial process or cooling water, or any other industrial or commercial purposes, and for which quality control is or may be necessary to protect the public health, safety or welfare.)

(4) Agriculture and Wildlife. (To include all interstate waters which are or may be used for any agriculture purposes, including stock watering and irrigation, or by waterfowl or other wildlife, and for which quality control is or may be necessary to protect terrestrial life or the public health, safety or welfare.)

(5) Navigation and Waste Disposal. (To include all interstate waters which are or may be used for any form of water transportation or navigation, disposal of sewage, industrial waste or other waste effluents, or fire prevention, and for which quality control is or may be necessary to protect the public health, safety or welfare.)

(6) Other Uses. (To include interstate waters which are or may serve the above listed uses or any other beneficial uses not listed herein, including without limitation any such uses in this or any other state, province, or nation of any interstate waters flowing through or originating in this state, and for which quality control is or may be necessary for the above declared purposes, or to conform with the requirements of the legally constituted state or national agencies having jurisdiction over such interstate waters, or any other considerations the Agency may deem proper.)

(c) General Standards Applicable to All Interstate Waters of the State.

(1) No untreated sewage shall be discharged into any interstate waters of the state. No treated sewage, or industrial waste or other wastes containing viable pathogenic organisms, shall be discharged into interstate waters of the state without effective disinfection. Effective disinfection of any discharges, including combined flows of sewage and storm water, will be required where necessary to protect the specified uses of the interstate waters.

(2) No raw or treated sewage, industrial waste or other wastes shall be discharged into any interstate waters of the state so as to cause any nuisance conditions, such as the presence of significant amounts of floating solids, scum, oil slicks, excessive suspended solids, material discoloration, obnoxious odors, gas ebullition, deleterious sludge deposits, undesirable slimes or fungus growths, or other offensive or harmful effects.

(3) Existing discharges of inadequately treated sewage, industrial waste or other wastes shall be abated, treated or controlled so as to comply with the applicable standards. Separation of sanitary sewage from natural run-off may be required where necessary to ensure continuous effective treatment of sewage.

(4) The highest possible levels of water quality, including dissolved oxygen, which are attainable in the interstate waters by continuous operation at their maximum capability of all units of treatment works discharging effluents into the interstate waters shall be maintained in the interstate waters in order to enhance conditions for the specified uses.

(5) Means for expediting mixing and dispersion of sewage, industrial waste, or other waste effluents in the receiving interstate waters are to be provided so far as practicable when deemed necessary by the Agency to maintain the quality of the receiving interstate waters in accordance with applicable standards. Mixing zones be established by the Agency on an individual basis, with primary consideration being given to the following guidelines: (a) mixing zones in rivers shall permit an acceptable passageway for the movement of fish; (b) the total mixing zone or zones at any transect of the stream should

contain no more than 25% of the cross sectional area and/or volume of flow of the stream, and should not extend over more than 50% of the width; (c) mixing zone characteristics shall not be lethal to aquatic organisms; (d) for contaminants other than heat, the 96 hour median tolerance limit for indigenous fish and fish food organisms should not be exceeded at any point in the mixing zone; (e) mixing zones should be as small as possible, and not intersect spawning or nursery areas, migratory routes, water intakes, nor mouths of rivers; and (f) overlapping of mixing zones should be minimized and measures taken to prevent adverse synergistic effects.

(6) It is herein established that the Agency shall require secondary treatment as a minimum for all municipal sewage and biodegradable, industrial or other wastes to meet the adopted water quality standards. A comparable high degree of treatment or its equivalent also be required of all non-biodegradable industrial or other other wastes unless the discharger can demonstrate to the Agency that a lesser degree of treatment or control will provide for water quality enhancement commensurate with present and proposed future water uses and a variance is granted under the provisions of the variance clause. Secondary treatment facilities are defined as works which will provide effective sedimentation, biochemical oxidation, and disinfection, or the equivalent, including effluents conforming to the following:

Substance or Characteristic	Limiting Concentration or Range*
5-Day Biochemical Oxygen demand	25 milligrams per liter
Fecal coliform group organisms	200 most probable number per 100 milliliters
Total suspended solids	30 milligrams per liter
Pathogenic organisms	None
Oil	Essentially free of visible oil
Phosphorus**	1 milligram per liter
Turbidity	25
pH range	6.5-8.5
Unspecified toxic or corrosive substances	None at levels acutely toxic to humans or other animals or plant life, or directly damaging to real property.

In addition to providing secondary treatment as defined above, all dischargers of sewage, industrial wastes or other wastes also shall provide the best practicable control technology not later than July 1, 1977, and best available technology economically achievable by July 1, 1983, and any other applicable treatment standards as defined by and in accordance with the requirements and schedules of the Federal Water Pollution Control Act, 33 U.S.C. 1251 et seq., as amended, and applicable regulations or rules promulgated pursuant thereto by the Administrator of the U.S. Environmental Protection Agency.

(7) Discharges of sewage, industrial waste or other waste effluents shall be controlled so that the water quality standards will be maintained at all stream flows which are equal to or exceeded by 90 percent of the seven consecutive daily average flows of record (the lowest weekly flow with a once in ten year recurrence interval) for the critical month(s). The period of record for determining the specific flow for the stated recurrence interval, where records are available, shall include at least the most recent ten years of record, including flow records obtained after establishment of flow regulation devices, if any. Such calculations shall not be applied to lakes and their embayments which have no comparable flow recurrence interval. Where stream flow records are not available, the flow may be estimated on the basis of available information on the watershed characteristics, precipitation, run-off and other relevant data.

Allowance shall not be made in the design of treatment works for low stream flow augmentation unless such flow augmentation of minimum flow is dependable under applicable laws or regulations.

(8) In any instance where it is evident that the minimal treatment specified in Section (c) (6) and dispersion are not effective in preventing pollution, or if at the applicable flows it is evident that the specified stream flow is inadequate to protect the specified water quality standards, the specific standards may be interpreted as effluent standards for control purposes. In addition, the following effluent standards may be applied without any allowance for dilution where stream flow or other factors are such as to prevent adequate dilution, or where it is otherwise necessary to protect the interstate waters for the stated use:

Item*	Limits
5 day biochemical oxygen demand	5 milligrams per liter
Total suspended solids	5 milligrams per liter

(9) In any case where, after a public hearing, the Agency finds it necessary for conformance with Federal requirements, or conservation of the interstate waters of the state, or protection of the public health, or in furtherance of the development of the economic welfare of the state, it may prohibit or further limit the discharge to any designated interstate waters of any sewage, industrial waste, or other waste effluents, or any component thereof, whether such effluents are treated or untreated,

* The arithmetic mean for concentrations of 5-day biochemical oxygen demand and total suspended solids shall not exceed the stated values in a period of 30 consecutive days and 45 milligrams per liter in a period of 7 consecutive days. Disinfection of wastewater effluents to reduce the coliform organisms levels is required year around. The geometric mean for the fecal coliform organisms shall not exceed the stated value in a period of 30 consecutive days and 400 most probable number per 100 milliliters in a period of 7 consecutive days. The application of the coliform and pathogenic organism standards ordinarily shall be limited to sewage or other effluents containing admixtures of sewage and shall not apply to industrial wastes except where the presence of sewage, fecal coliform organisms or viable pathogenic organisms in such wastes is known or reasonably certain.

** Where the discharge of effluent is directly to or affects a lake or reservoir. Removal of nutrients from all wastes shall be provided to the fullest practicable extent wherever sources of nutrients are considered to be actually or potentially detrimental to preservation or enhancement of the designated water uses.

†The concentrations specified in section (c) (6) of this regulation may be used in lieu thereof if the discharge of effluent is restricted to the spring flush or other high runoff periods when the stream flow rate above the discharge point is sufficiently greater than the effluent flow rate to insure that the applicable water quality standards are met during such discharge period. If treatment works are designed and constructed to meet the specified limits given above for a continuous discharge, at the discretion of the Agency the operation of such works may allow for the effluent quality to vary between the limits specified above and in section (c) (6), provided the water quality standards and all other requirements of the Agency and the U.S. Environmental Protection Agency are being met. Such variability of operation must be based on adequate monitoring of the treatment works and the effluent and receiving waters as specified by the Agency.

or existing or new, notwithstanding any other provisions of classifications or specific standards stated herein which may be applicable to such designated interstate waters.

(10) It shall be incumbent upon all persons responsible for existing or new sources of sewage, industrial wastes or other wastes which are or will be discharged to interstate waters, to treat or control their wastes so as to produce effluents having a common level or concentration of pollutants of comparable nature or effect as may be necessary to meet the specified standards or better, but this shall not be interpreted to prohibit the Agency after providing an opportunity for public hearing from accepting effective loss prevention and/or water conservation measures or process changes or other waste control measures or arrangements as being equivalent to the waste treatment measures required for compliance with applicable effluent and/or water quality standards or load allocations.

(11) All sources of sewage, industrial waste, or other waste which do not at present have a valid operation and discharge permit, or an application for the same pending before the Agency, shall apply for the same within 30 days of the adoption of this regulation, or the Agency may abate the source forthwith. The provisions of section (c) (6) relating to effluent quality standards, and the other provisions of this regulation, are applicable to existing sewage, industrial waste or other waste disposal facilities and the effluent discharged therefrom. Nothing herein shall be construed to prevent the Agency subsequently from modifying any existing permits so as to conform with federal requirements and the requirements of this regulation.

(12) Liquid substances which are not commonly considered to be sewage or industrial wastes but which could constitute a pollution hazard shall be stored in accordance with Regulation WPC 4, and any revisions or amendments thereto. Other wastes as defined by law or other substances which could constitute a pollution hazard shall not be deposited in any manner such that the same may be likely to gain entry into any interstate waters of the state in excess of or contrary to any of the standards herein adopted, or cause pollution as defined by law.

(13) No sewage, industrial waste or other wastes shall be discharged into the interstate waters of the state in such quantity or in such manner alone or in combination with other substances as to cause pollution thereof as defined by law. In any case where the interstate waters of the state into which sewage, industrial wastes or other waste effluents discharged are assigned different standards than the interstate waters into which such receiving interstate waters flow, the standards applicable to the interstate waters into which such sewage, industrial waste or other wastes discharged shall be supplemented by the following:

The quality of any waters of the state receiving sewage, industrial waste or other waste effluents shall be such that no violation of the standards of any interstate waters of the state in any other class shall occur by reason of the discharge of such sewage, industrial waste or other waste effluents.

(14) Questions concerning the permissible levels, or changes in the same, of a substance, or combination of substances, of undefined toxicity to fish or other biota shall be resolved in accordance with the latest methods recommended by the U.S. Environmental Protection Agency. The recommendations of the National Technical Advisory Committee appointed by the U.S. Environmental Protection Agency shall be used as official guidelines in all aspects where the recommendations may be applicable. Toxic substances shall not exceed 1/10 of the 96 hour median tolerance limit (TLM) as a water quality standard except that other more stringent application factors shall be used when justified on the basis of available evidence.

(15) All persons operating or responsible for sewage, industrial waste or other waste disposal systems which are adjacent to or which discharge effluents to these waters or to tributaries which affect the same, shall submit regularly every month a report to the Agency on the operation of the disposal system, the effluent flow, and the characteristics of the effluent and receiving waters. Sufficient data on measurements, observations, sampling and analyses, and other pertinent information shall be furnished as may be required by the Agency to adequately evaluate the condition of the disposal system, the effluent, and the waters receiving or affected by the effluent.

(d) Specific Standards of Quality and Purity for Designated Classes of Interstate Waters of the State. The following standards shall prescribe the qualities or properties of the interstate waters of the state which are necessary for the designated public use or benefit and which, if the limiting conditions given are exceeded, shall be considered indicative of a polluted condition which is actually or potentially deleterious, harmful, detrimental or injurious with respect to such designated uses or established classes of the interstate waters:

(1) Domestic Consumption.

Class A. The quality of this class of the interstate waters of the state shall be such that without treatment of any kind the raw waters will meet in all respects both the mandatory and recommended requirements of the Public Health Service Drinking Water Standards — 1962 for drinking water as specified in Publication No. 956 published by the Public Health Service of the U.S. Department of Health, Education and Welfare, and any revisions, amendments or supplements thereto. This standard will ordinarily be restricted to underground waters with a high degree of natural protection. The basic requirements are given below:

Substance or Characteristic	Limit or Range
Total coliform organisms	1 most probable number per 100 milliliters
Turbidity value	5
Color value	15
Threshold odor number	3
Methylene blue active substance (MBAS)	0.5 milligram per liter
Arsenic (As)	0.01 milligrams per liter
Chlorides (Cl)	250 milligrams per liter
Copper (Cu)	1 milligram per liter
Carbon Chloroform extract	0.2 milligram per liter
Cyanides (CN)	0.01 milligram per liter
Fluorides (F)	1.5 milligrams per liter
Iron (Fe)	0.3 milligram per liter
Manganese (Mn)	0.05 milligram per liter
Nitrates (NO_3)	45 milligrams per liter
Phenol	0.001 milligram per liter

Substance or Characteristic	Limit or Range
Sulfates (SO_4)	250 milligrams per liter
Total dissolved solids	500 milligrams per liter
Zinc (Zn)	5 milligrams per liter
Barium (Ba)	1 milligram per liter
Cadmium (Cd)	0.01 milligram per liter
Chromium (Hexavalent, Cr)	0.05 milligram per liter
Lead (Pb)	0.05 milligram per liter
Selenium (Se)	0.01 milligram per liter
Silver (Ag)	0.05 milligram per liter
Radioactive material	Not to exceed the lowest concentrations permitted to be discharged to an uncontrolled environment as prescribed by the appropriate authority having control over their use.

Class B. The quality of this class of the interstate waters of the state shall be such that with approved disinfection, such as simple chlorination or its equivalent, the treated water will meet in all respects both the mandatory and recommended requirements of the Public Health Service Drinking Water Standards — 1962 for drinking water as specified in Publication No. 956 published by the Public Health Service of the U.S. Department of Health, Education and Welfare, and any revisions, amendments or supplements thereto. This standard will ordinarily be restricted to surface and underground waters with a moderately high degree of natural protection. The physical and chemical standards quoted above for Class A interstate waters shall also apply to these interstate waters in the untreated state, except as listed below:

Class C. The quality of this class of the interstate waters of the state shall be such that with treatment consisting of coagulation, sedimentation, filtration, storage and chlorination, or other equivalent treatment processes, the treated water will meet in all respects both the mandatory and recommended requirements of the Public Health Service Drinking Water Standard — 1962 for drinking water as specified in Publication No. 956 published by the Public Health Service of the U.S. Department of Health, Education and Welfare, and any revisions, amendments or supplements thereto. This standard will ordinarily be restricted to surface waters, and ground waters in aquifers not considered to afford adequate protection against contamination from surface or other sources of pollution. Such aquifers normally would include fractured and channeled limestone, unprotected impervious hard rock where interstate water is obtained from mechanical fractures, joints, etc., with surface connections and coarse gravels subjected to surface water infiltration. The physical and chemical standards quoted above for Class A interstate waters shall also apply to these interstate waters in the untreated state, except as listed below:

Substance or Characteristic	Limit or Range
Fecal coliform organisms	200 most probable number per 100 milliliters
Turbidity value	25

Class D. The quality of this class of the interstate waters of the state shall be such that after treatment consisting of coagulation, sedimentation, filtration, storage and chlorination, plus additional pre, post, or intermediate stages of treatment, or other equivalent treatment processes, the treated water will meet in all respects the recommended requirements of the Public Health Service Drinking Water Standards — 1962 for drinking water as specified in Publication No. 956 published by the Public Health Service of the U.S. Department of Health, Education and Welfare, and any revisions, amendments or supplements thereto. This standard will ordinarily be restricted to surface waters, and ground waters in aquifers not considered to afford adequate protection against contamination from surface or other sources of pollution. Such aquifers normally would include fractured and channeled limestone, unprotected impervious hard rock where water is obtained from mechanical fractures, joints, etc., with surface connections, and coarse gravels subjected to surface water infiltration. The concentrations or ranges given below shall not be exceeded in the raw waters before treatment:

Substance or Characteristic	Limit or Range
Fecal coliform organisms	200 most probable number per 100 milliliters
Arsenic (As)	0.05 milligram per liter
Barium (Ba)	1 milligram per liter
Cadmium (Cd)	0.01 milligram per liter
Chromium (Cr + 6)	0.05 milligram per liter
Cyanide (CN)	0.2 milligram per liter
Fluoride (F)	1.5 milligrams per liter
Lead (Pb)	0.05 milligram per liter
Selenium (Se)	0.01 milligram per liter
Silver (Ag)	0.05 milligram per liter
Radioactive material	Not to exceed the lowest concentrations permitted to be discharged to an uncontrolled environment as prescribed by the appropriate authority having control over their use.

In addition to the above listed standards, no sewage, industrial waste or other wastes, treated or untreated, shall be discharged into or permitted by any person to gain access to any interstate waters classified for domestic consumption so as to cause any material undesirable increase in the taste, hardness, temperature, toxicity, corrosiveness or nutrient content, or in any other manner to impair the natural quality or value of the interstate waters for use as a source of drinking water.

(2) Fisheries and Recreation.

Class A. The quality of this class of interstate waters of the state shall be such as to permit the propagation and maintenance of warm or cold water sport or commercial fishes and be suitable for aquatic recreation of all kinds, including bathing, for which the waters may be usable. Limiting concentrations or ranges of substances or characteristics which should not be exceeded in the interstate waters are given below:

Substance or Characteristic	Limit or Range
Dissolved oxygen	Not less than 7 milligrams per liter from October 1st and continuing through May 31st, and Not less than 6 milligrams per liter at other times.
Temperature	No material increase
Ammonia (N)	0.2 milligram per liter
Chlorides (Cl)	50 milligrams per liter
Chromium (Cr)	0.02 milligram per liter
Copper (Cu)	0.01 milligram per liter or not greater than 1/10 the 96 hour TLM value.
Cyanides (CN)	0.2 milligram per liter.
Oil	0.5 milligram per liter
pH value	6.5 - 8.5
Phenols	0.01 milligram per liter and none that could impart odor or taste to fish flesh or other fresh-water edible products such as crayfish, clams,

Substance or Characteristic	Limit or Range
	prawns and like creatures. Where it seems probable that a discharge may result in tainting of edible aquatic products, bio-assays and taste panels will be required to determine whether tainting is likely or present.
rbidity value	10
lor value	30
al coliform organisms	200 most probable number per 100 milliliters as a monthly geometric mean based on not less than 5 samples per month, nor exceed 400 most probable number per 100 milliliters in more than 10% of all samples during any month.
lioactive materials	Not to exceed the lowest concentrations permitted to be discharged to an uncontrolled environment as prescribed by the appropriate authority having control over their use.

Class B. The quality of this class of the interstate .ters of the state shall be such as to permit the ›pagation and maintenance of sport or commercial ıes and be suitable for aquatic recreation of all kinds, .luding bathing, for which the waters may be usable. niting concentrations or ranges of substances or char- eristics which should not be exceeded in the interstate ters are given below:

Substance or Characteristic	Limit or Range
olved oxygen	Not less than 6 milligrams per liter from April 1 through May 31, and Not less than 5 milligrams per liter at other times.
nperature*	5°F above natural in streams and 3°F above natural in lakes, based on monthly average of the maximum daily temperature, except in no case shall it exceed the daily average temperature of 86°F.
monia (N)	1 milligram per liter
omium (Cr)	0.05 milligram per liter
per (Cu)	0.01 milligram per liter or not greater than 1/10 the 96 hour TLM value.
nides (CN)	0.02 milligram per liter
	0.5 milligram per liter
value	6.5 - 9.0
nols	0.01 milligram per liter and none that could impart odor or taste to fish flesh or other fresh-water edible products such as crayfish, clams, prawns and like creatures. Where it seems probable that a discharge may result in tainting of edible aquatic products, bioassays and taste panels will be required to determine whether tainting is likely or present.
bidity value	25
al coliform organisms	200 most probable number per 100 milliliters as a monthly geometric mean based on not less than 5 samples per month, nor equal or exceed 2000 most probable number per 100 milliliters in more than 10% of all samples during any month.
ioactive materials	Not to exceed the lowest concentration permitted to be discharged to an uncontrolled environment as prescribed by the appropriate authority having control over their use.

following temperature criteria will be applicable for the Mississippi : from Lake Itasca to the outlet of the Metro Wastewater Treatment ks in St. Paul in addition to or superseding the above. The weekly age temperature shall not exceed the following temperatures during pecified months:

January	40°F	July	83°F
February	40°F	August	83°F
March	48°F	September	78°F
April	60°F	October	68°F
May	72°F	November	50°F
June	78°F	December	40°F

For the Mississippi River from Lock and Dam No. 2 at Hastings to the Iowa Border, the weekly average temperature shall not exceed the following temperatures during the specified months:

January	40°F	July	84°F
February	40°F	August	84°F
March	54°F	September	82°F
April	65°F	October	73°F
May	75°F	November	58°F
June	84°F	December	43°F

Class C. The quality of this class of the interstate waters of the state shall be such as to permit the propagation and maintenance of fish of species, commonly inhabiting waters of the vicinity under natural conditions, and be suitable for boating and other forms of aquatic recreation not involving prolonged intimate contact with the water for which the interstate waters may be usable. Limiting concentrations or ranges of substances or characteristics which should not be exceeded in the interstate waters are given below:

Substance or Characteristic	Limit or Range
Dissolved oxygen	Not less than 5 milligrams per liter from April 1 through November 30, and not less than 4 milligrams per liter at other times.
Temperature*	5°F above natural in streams and 3°F above natural in lakes, based on monthly average of the maximum daily temperature except in no case shall it exceed the daily average temperature of 90°F.
Ammonia (N)	1.5 milligrams per liter
Chromium (Cr)	0.05 milligram per liter
Copper (Cu)	0.01 milligram per liter or not greater than 1/10 the 96 hour TLM value.
Cyanides (CN)	0.02 milligram per liter
Oil	10 milligrams per liter, and none in such quantities as to (1) produce a visible color film on the surface, (2) impart an oil odor to water or an oil taste to fish and edible invertebrates, (3) coat the banks and bottom of the watercourse or taint any of the associated biota, or (4) become effective toxicants according to the criteria recommended.
pH value	6.5 - 9.0
Phenols	0.1 milligram per liter and none that could impart odor or taste to fish flesh or other fresh-water edible products such as crayfish, clams, prawns and like creatures. Where it seems probable that a discharge may result in tainting of edible aquatic products, bioassays and taste panels will be required to determine whether tainting is likely or present.
Turbidity value	25
Fecal coliform organisms	200 most probable number per 100 milliliters as a geometric mean nor equal or exceed 2000 most probable number per 100 milliliters in more than 10% of the samples.
Radioactive materials	Not to exceed the lowest concentrations permitted to be discharged to an uncontrolled environment as prescribed by the appropriate authority having control over their use.

*The following temperature criteria will be applicable for the Mississippi River from the outlet of the Metro Wastewater Treatment Works in St. Paul to Lock and Dam No. 2 at Hastings in addition to or superseding the above. The weekly average temperature shall not exceed the following temperatures during the specified months.

January	40°F	July	83°F
February	40°F	August	83°F
March	48°F	September	78°F
April	60°F	October	68°F
May	72°F	November	50°F
June	78°F	December	40°F

For all classes of fisheries and recreation waters, the aquatic habitat, which includes the interstate waters and stream bed, shall not be degraded in any material manner, there shall be no material increase in undesirable slime growths or aquatic plants, including algae, nor shall there be any significant increase in harmful pesticide or other residues in the waters, sediments and aquatic flora and fauna; the normal fishery and lower aquatic biota upon which it is dependent and the use thereof shall not be seriously impaired or endangered, the species composition shall not be altered materially, and the propagation or migration of the fish and other biota normally present shall not be prevented or hindered by the discharge of any sewage, industrial waste or other waste effluents to the interstate waters.

No sewage, industrial waste or other wastes shall be discharged into any of the interstate waters of this category so as to cause any material change in any other substances or characteristics which may impair the quality of the interstate waters or the aquatic biota of any of the above listed classes or in any manner render them unsuitable or objectionable for fishing, fish culture or recreational uses. Additional selective limits or changes in the discharge bases may be imposed on the basis of local needs.

(3) Industrial Consumption.

Class A. The quality of this class of the interstate waters of the state shall be such as to permit their use without chemical treatment, except softening for ground water, for most industrial purposes, except food processing and related uses, for which a high quality of water is required. The quality shall be generally comparable to Class B waters for domestic consumption, except for the following:

Substance or Characteristic	Limit or Range
Chlorides (Cl)	50 milligrams per liter
Hardness	50 milligrams per liter
pH value	6.5 - 8.5
Fecal coliform organisms	200 most probable number per 100 milliliters

Class B. The quality of this class of the interstate waters of the state shall be such as to permit their use for general industrial purposes, except food processing, with only a moderate degree of treatment. The quality shall be generally comparable to Class D interstate waters used for domestic consumption, except for the following:

Substance or Characteristic	Limit or Range
Chlorides (Cl)	100 milligrams per liter
Hardness	250 milligrams per liter
pH value	6.0 - 9.0
Fecal coliform organisms	200 most probable number per 100 milliliters

Class C. The quality of this class of the interstate waters of the state shall be such as to permit their use for industrial cooling and materials transport without a high degree of treatment being necessary to avoid severe fouling, corrosion, scaling, or other unsatisfactory conditions. The following shall not be exceeded in the interstate waters:

Substance or Characteristic	Limit or Range
Chlorides (Cl)	250 milligrams per liter
Hardness	500 milligrams per liter
pH value	6.0 - 9.0
Fecal coliform organisms	200 most probable number per milliliters

Additional selective limits may be imposed for any specific interstate waters as needed.

In addition to the above listed standards, no sewage, industrial waste or other wastes, treated or untreated, shall be discharged into or permitted by any person to gain access to any interstate waters classified for industrial purposes so as to cause any material impairment of their use as a source of industrial water supply.

(4) Agriculture and Wildlife.

Class A. The quality of this class of the interstate waters of the state shall be such as to permit their use for irrigation without significant damage or adverse effects upon any crops or vegetation usually grown in the area, including truck garden crops. The following concentrations or limits shall be used as a guide in determining the suitability of the waters for such use, together with the recommendations contained in Handbook 60 published by the Salinity Laboratory of the U.S. Department of Agriculture, and any revisions, amendments or supplements thereto:

Substance or Characteristic	Limit or Range
Bicarbonates (HCO_3)	5 milliequivalents per liter
Boron (B)	0.5 milligram per liter
pH value	6.0 - 8.5
Specific conductance	1,000 micromhos per centimeter
Total dissolved salts	700 milligrams per liter
Sodium (Na)	60% of total cations as milliequivalents per liter
Fecal coliform organisms	200 most probable number per 100 milliliters
Sulfates (SO_4)	10 milligrams per liter, applicable to water used for production of wild rice during periods when the rice may be susceptible to damage by high sulfate levels.
Radioactive materials	Not to exceed the lowest concentrations permitted to be discharged to an uncontrolled environment as prescribed by the appropriate authority having control over their use.

Class B. The quality of this class of the interstate waters of the state shall be such as to permit their use by livestock and wildlife without inhibition or injurious effects. The limits or concentrations of substances or characteristics given below shall not be exceeded in the interstate waters:

Substance or Characteristic	Limit or Range
pH value	6.0 - 9.0
Total salinity	1,000 milligrams per liter
Fecal coliform organisms	200 most probable number per 100 milliliters
Radioactive materials	Not to exceed the lowest concentrations permitted to be discharged to an uncontrolled environment as prescribed by the appropriate authority having control over their use.
Unspecified toxic substances	None at levels harmful either directly or indirectly.

Additional selective limits may be imposed for any specific interstate waters as needed.

(5) Navigation and Waste Disposal. The quality of this class of the interstate waters of the state shall be such as to be suitable for esthetic enjoyment or scenery and to avoid any interference with navigation or damaging effects on property. The following limits or concentrations shall not be exceeded in the interstate waters:

Substance or Characteristic	Limit or Range
Fecal coliform organisms	200 most probable number per 100 milliliters
pH value	6.0 - 9.0
Hydrogen sulfide	0.02 milligrams per liter

Additional selective limits may be imposed for any specific interstate waters as needed.

(6) Other Uses. The uses to be protected in this class may be under other jurisdictions and in other areas to which the interstate waters of the state are tributary, and may include any or all of the uses listed in the foregoing categories, plus any other possible beneficial uses. The Agency therefore reserves the right to impose any standards necessary for the protection of this class, consistent with legal limitations.