INDIAN POINT IMPINGEMENT STUDY REPORT FOR THE PERIOD 1 JANUARY 1974 THROUGH 31 DECEMBER 1974

NOVEMBER 1975

Prepared for

CONSOLIDATED EDISON COMPANY OF NEW YORK, INC.

4 Irving Place
New York, New York 10003

by

TEXAS INSTRUMENTS INCORPORATED
ECOLOGICAL SERVICES

P.O. Box 5621
Dallas, Texas 75222

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FOREWORD

Consolidated Edison has contracted with three major research organizations to conduct studies to assess the ecological impact of entrainment, impingement, and discharges of the Indian Point Nuclear Power Station. The major contractors and their primary study responsibilities are as follows:

- New York University Medical Center Laboratory for Environmental Studies
  - laboratory and field studies on effects of entrainment
- Lawler, Matusky, and Skelly Engineers
  - mathematical prediction of entrainment and impingement effects on the striped bass population
- Texas Instruments Incorporated
  - biological impact of thermal and chemical effluents
  - impingement monitoring and testing
  - ecological significance of impingement and entrainment

This progress report, which has been prepared for Consolidated Edison Company of New York, Inc. (Con Edison), by the Ecological Services branch of Texas Instruments Incorporated (TI), presents analyses and interpretations of impingement monitoring and testing data collected at Indian Point from 1 January through 31 December 1974. This study was required, in part, by the Nuclear Regulatory Commission (NRC) Environmental Technical Specifications of Indian Point Units 1 and 2.

In addition to the specific objectives of the impingement monitoring and testing program, the monitoring of fish impingement at Indian Point provides data for other aspects of the Hudson River ecological study:

- Estimation of the direct impact of impingement

- Collection of impinged fish to supplement samples from other fishing gear used in the study of population dynamics

- Assessment of physical, chemical, temporal, and species variables associated with vulnerability to plant impact

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SUMMARY

This Second Annual Indian Point Impingement Report includes analyses and discussion of data collected during calendar year 1974.

The Hudson River estuary serves as spawning and nursery ground for several resident and anadromous species, the young-of-the-year and yearling of which compose the majority of impingement collections at any time of the year. To quantify the impingement phenomenon at Indian Point, intake screens were washed and fish collections enumerated and identified daily at Units 1, 2, and 3. During the monitoring program from 1 January to 31 December 1974, 924,244 fish were collected. Atlantic tomcod was the most abundant species impinged at Unit 1 (37.4%) and Unit 3 (69.6%); most tomcod were impinged as young-of-the-year during the summer when Unit 3 operation was most consistent. White perch comprised 31.8% and 15.2% of Units 1 and 3 collections. Unit 2 collections were dominated by white perch (42.5%) and tomcod (39.7%). Striped bass comprised a minor segment of impingement collections at Units 1 (0.9%), 2 (0.7%), and 3 (0.57%). The total number and weight of impinged fish collected at Indian Point in 1974 was as follows: Unit 1, 138,976 fish for 901 kg (1982 lb); Unit 2, 750,182 fish for 3792 kg (8342 lb); and Unit 3, 35,086 fish for 177 kg (389 lb).

During 1974, an attempt was made to evaluate the efficiency of the fish collection procedures by artificial impingement of marked fish. These tests assumed that all marked dead test specimens were impinged and that live fish would be affected in the same manner as the dead test fish. These tests resulted in an 8-15% recovery of marked test fish during air-curtain operation and 38-80% without the air curtain. This would seem to indicate that the air curtain decreases efficiency of the collection process. However, when the air

curtain did not operate, other factors became the major variables affecting loss of impinged fish. These factors include large numbers of environmental and operational variables such as flow rate, tide stage, debris load, and duration of impingement. With the existence of these uncontrolled variables and unverified assumptions, the results of these tests are too preliminary to compute impingement estimates.

Fish vulnerability is an important factor in evaluating the causes and impact of impingement. Sonar, gill nets, beach seines, and trawls were used to identify the spatiotemporal distribution of fish in the Indian Point region and near the intake screens. Catches from these four gear were evaluated in terms of short- and long-term vulnerability and impingement prediction. Size selectivity and gear avoidance may have been responsible for species composition and abundance differences determined for these gear and intake screens. Gear selection for different segments of the river population that are impinged negates their value as predictors except for regional and seasonal abundance estimates.

Of the environmental and plant variables examined, only river conductivity and time of day were strongly related to impingement. When the salt front moves through the Indian Point region, the relative magnitude of impingement increases. Tomcod impingement peaks generally precede conductivity peaks, while white perch impingement increases as the salt front retreats downriver from Indian Point. In addition to conductivity-related changes between days, distinct daily impingement peaks occur between 2200 and 0600 hr; diel peaks in impingement may be related to circadian activity patterns or nocturnal vertical or channel/shoal fish movements. No consistent relationship between impingement and temperature, dissolved oxygen, thermal recirculation, head loss, or intake current velocity was found. Water velocity profiles at Unit 2 screens showed increased velocities from bottom to surface, which may explain the depth distribution of impinged fish; at least 70% of impinged fish were collected from the upper half of the fixed screens.

Another factor affecting vulnerability is the physical condition of fish in the Indian Point region. The incidence of pathological deterioration and parasitic infestation indicates that a weaker segment of the river population is being impinged. While the Indian Point generating plants may not increase parasitic infestation and pathological conditions, they do act as selective predators on weaker fish. Some fish collected from the river and from intake screens have demonstrated symptoms of gas bubble disease, a disease caused by the release of supersaturated gases from the blood and gas accumulation in tissues and blood vessels. Supersaturation of dissolved gas has been identified in some water samples collected in the discharges canal as would be anticipated after rapid heating of water. Indian Point and other existing potential sources of gas bubble disease have not been sufficiently sampled to assess the regional extent of gas supersaturation and the significance of Indian Point effluent.

Various protective devices have been employed at Indian Point to reduce impingement. Air curtains, intake screen design, and fish pumps were evaluated during 1974. Statistical analysis demonstrated that air curtain operation did not significantly reduce the impingement of fish at Unit 2. This conclusion is supported by other studies which have demonstrated the ineffectiveness of air curtains as a visual, behavioral avoidance stimulus in turbid water and darkness. The majority of impingement at Indian Point occurs under both conditions. Statistical comparison of impingement rates on the Unit 3 traveling screens and Unit 2 fixed screens revealed no significant difference between the two screen designs. Although impingement rates were similar, previous studies indicated higher survival of fish collected from traveling screens.

The use of a fish pump to return live impinged fish to the river is a feasible approach to reducing the impact of impingement. Results of tests conducted during 1973 and 1974 indicated that a properly instituted pumping regime could provide approximately 80% survival of pumped fish. Survival could be maximized in such a system if fish remained in water during transport and were returned to an area providing temporary protection from predators while fish become reoriented and resume normal activity.

Results of TI studies since June 1972 suggest that the use of protective devices as behavioral avoidance stimuli will be of limited value. Interspecific and life history variations in behavioral response, habituation, physiological condition, and seasonal changes in species composition would require broad spectrum applicability of a behavioral device; few devices have such application. High turbidity and diel impingement distribution further reduce the value of visual stimulus devices.

SECTION I

INTRODUCTION

A. DESCRIPTION AND LOCATION OF PLANT INTAKES

The Indian Point Nuclear Generating Plant (Figure I-1) is located on the east bank of the Hudson River estuary at river mile (RM) 42.5 (km 68) near Peekskill, New York. The plant (Figure I-2) consists of three nuclear reactors (Units 1, 2, and 3) and associated apparatus for power generation and water circulation. The respective licensed generating capabilities for Units 1 and 2 are 265 Mw (electric) and 873 Mw (electric); the capacity of Unit 3, still under construction, is 1033 Mw (electric). All three units have a combined water pumping capacity of 2,058,000 gallons per minute (gpm) [7700 cubic meters per minute (m^3/min)]. Unit 1 has two 140,000-gpm (530-m^3/min) circulating pumps, each drawing water through two intake bays. Three service pumps with a combined capacity of 19,000 gpm (72 m^3/min) draw water from each circulator forebay. Units 2 and 3 have six 140,000-gpm (530-m^3/min) circulating pumps each, and each draws water through one intake bay. Both Units 2 and 3 have service water pumps with a total unit capacity of 30,000 gpm (114 m^3/min) which draw through separate service water bays located in the middle of each unit intake structure.

Units 1 and 2 have fixed screens at the entrance to the intake bays and vertical traveling screens behind the fixed screens (Figure I-3); Unit 3 has only vertical traveling screens located at the entrance to the intake bays. All screens are 0.375 in. (9.5 mm) square mesh.

B. SYNOPSIS OF IMPINGEMENT PHENOMENA AT INDIAN POINT

Fish are impinged when they are held against the intake screens by the force of water flow or by entanglement in the mesh screen. Impingement can result in death due to shock, exhaustion, or other debilitating factors.

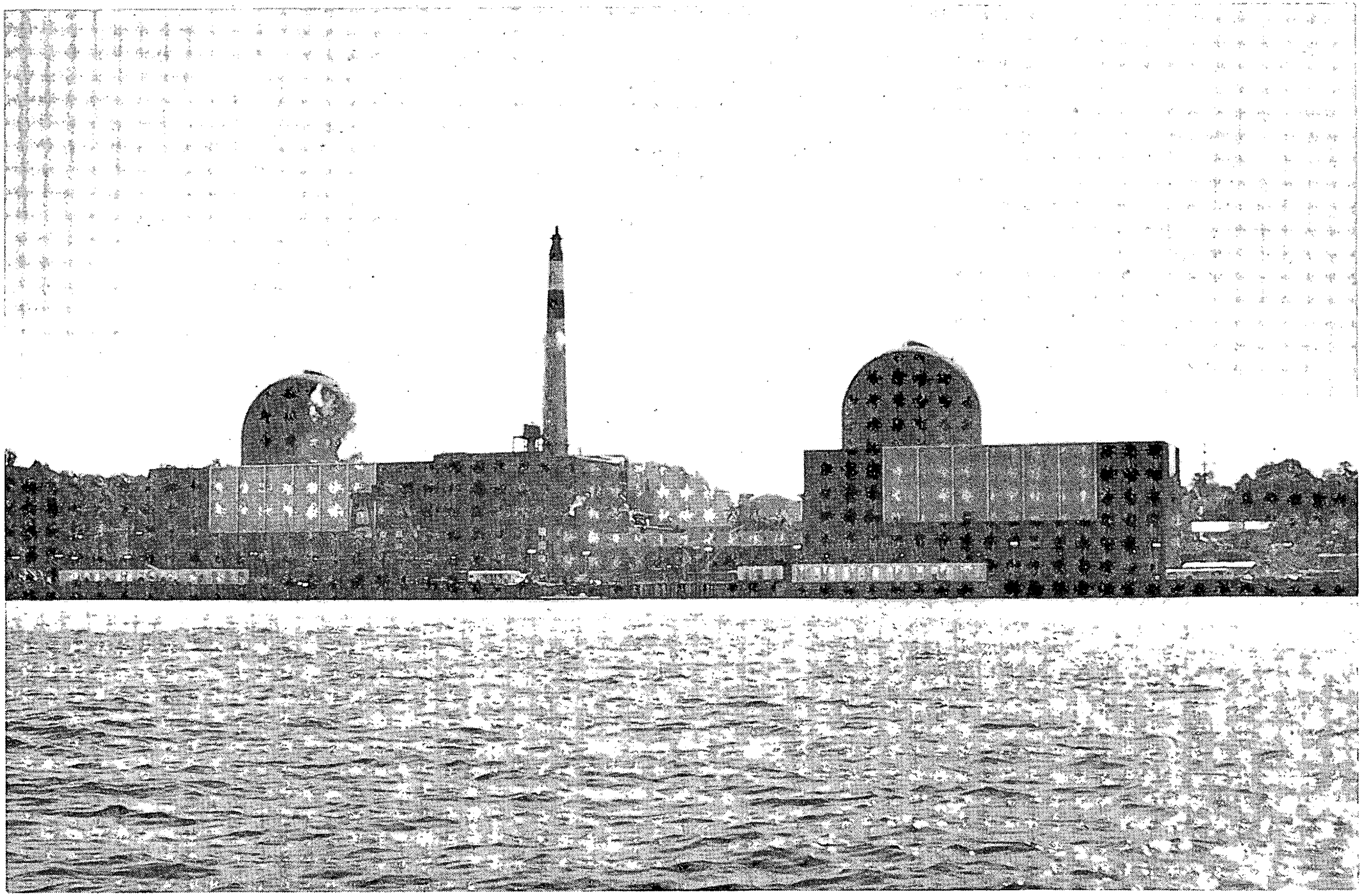

Figure I-1. Indian Point Nuclear Power Generating Plants, Units 2, 1, and 3 (left to right) at River Mile 42 on Hudson River

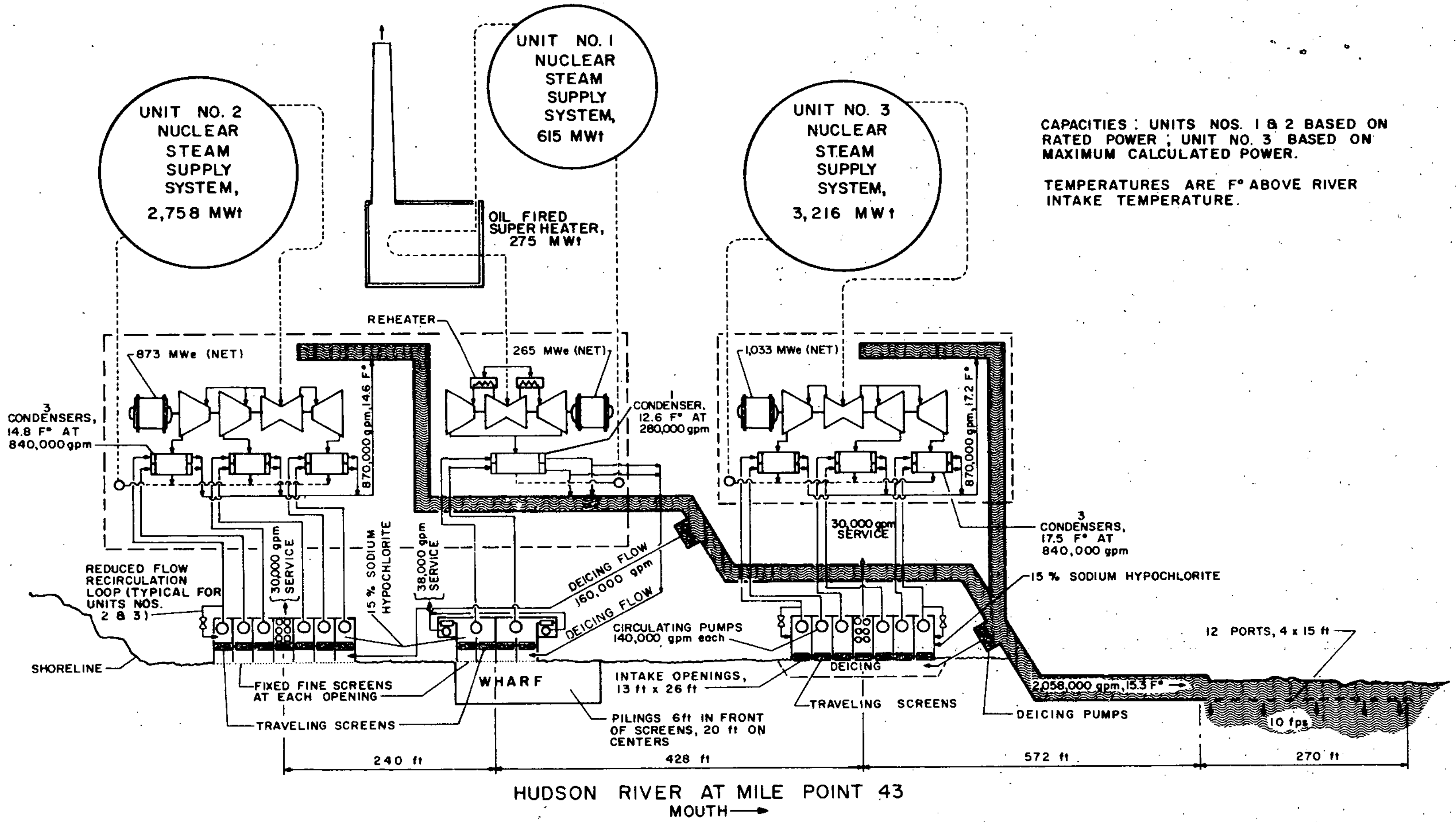

Figure I-2. Indian Point Plant Layout. (Courtesty of Consolidated Edison Company of New York)

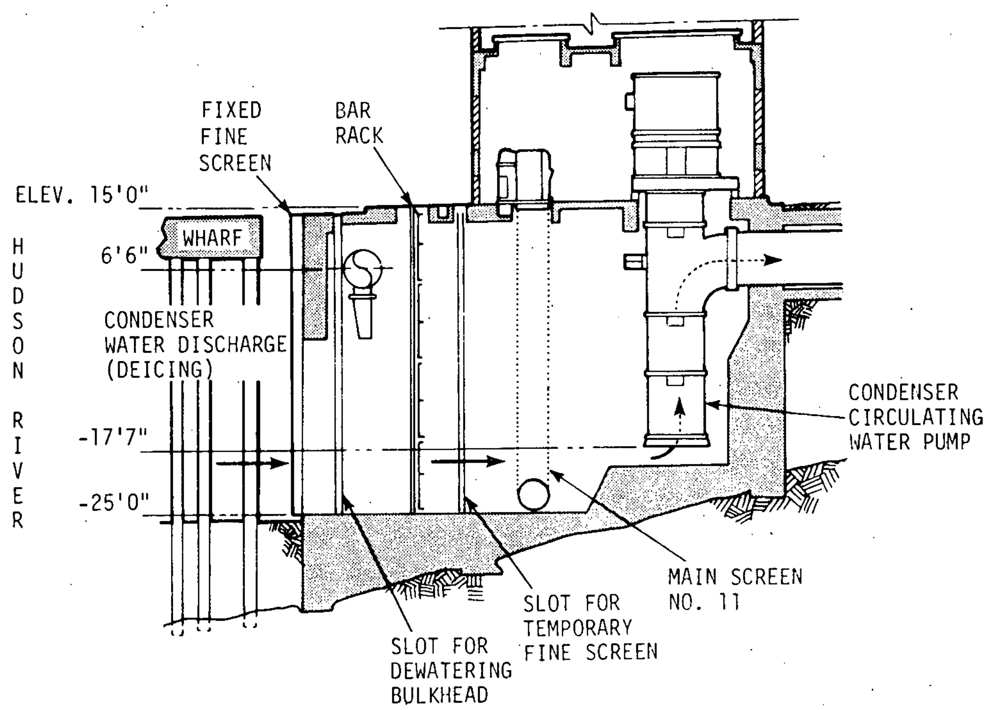

Figure I-3. Cross Section of Unit 1 Intake

Since Indian Point Unit 1 began operation in 1962, fish impingement has received attention from Con Edison, regulatory agencies and members of the public. A complete history of fish impingement at Indian Point can be found in Appendix BB of the Applicant's Environmental Report for Unit 3.

During February 1972, two Unit 2 circulators were operated for 1 day and one circulator for 4 days; an estimated 175,000 fish were impinged during the test period. After hearings, Con Edison agreed to a consent order issued by the New York State Department of Environmental Conservation (DEC) with the following conditions:

(1) Reduce circulator pump flows to 60% capacity when Hudson River temperatures are below 40°F (4.4°C)

(2) Install double air curtains in front of each unit

(3) Develop plans (i.e., feasibility study) for a screened lagoon

(4) Construct a screened lagoon dependent on air curtain efficiency and lagoon feasibility study results

Since 15 June 1972, Texas Instruments Incorporated (TI), under contract with Consolidated Edison Company of New York, Inc. (Con Edison), has been conducting impingement studies at Indian Point. The general objectives are to:

(1) Monitor and record impinged fish collections, river physical/chemical variables in the plant vicinity, and selected plant operational variables

(2) Determine factors influencing impingement

(3) Provide information needed to evaluate what biological impact Indian Point impingement has on fish populations of the Hudson River

(4) Evaluate methods for reducing impingement

TI pursued these objectives in fulfillment of the 1974 scope of work (Appendix A) in three phases: monitoring (quantification), evaluation of causes, and solutions.

C. PROGRAM TASKS

1. Impingement Monitoring and Quantification

Before impingement causes and impact could be evaluated, it was necessary to use some method of quantifying the magnitude of impingement. The magnitude of impingement is influenced by fluctuations in the volume of water drawn through intake screens, which is a function of circulator flow rates and duration of circulator operation. Therefore, empirical fish counts were converted to rates (i.e., catch per volume of water pumped); since this accounted for variations in sampling volume, impingement rates could be analyzed to identify sources of variation in impingement.

As suggested previously, impingement collections may not indicate the actual numbers of fish impinged, since some fish impinged on the outer screens may not be collected. Several factors including air curtain operation, circulator flow rate, and tide stage may effect the loss of impinged fish. Impinged fish can be washed into the river, caught on the support framework of the screen, or held up by floating debris in front of the intake openings. Some of the lost fish may be reimpinged and collected on adjacent traveling screens during the same or later wash periods. During 1974, experiments were conducted to assess collection efficiency and the potential impact of fish loss on calculated impingement rates.

Several means of monitoring local and regional fish abundance were examined to determine their sensitivity and selectivity as indicators of impingement magnitude. Catch per unit effort (CPUE) data calculated from standard river stations were used to indicate the relative abundance of fish populations in the Hudson River near the Indian Point generating plants. Gill net, stationary sonar, and screen basket CPUE data were used to identify fluctuations of impingement due to changes in relative abundance.

2. Study of Factors Affecting Impingement

a. Environmental Variables

Studies conducted in 1972 and 1973 suggested that fish vulnerability to impingement was affected by fluctuations in conductivity, water temperature, and dissolved oxygen (Texas Instruments, 1974b) which influence their distribution and general physiological condition. Diel movement and activity rhythms of fish related to photoperiod and tidal stage may play an important role in daily impingement patterns. Therefore, during 1974, impingement rates were studied in relation to variations in conductivity, temperature, dissolved oxygen, time of day, and tide stage.

b. Plant Operation Variables

Under certain conditions of season and thermal history of fishes, recirculation of the thermal plume may attract, repel, or stress fish. Approach velocity and head differential at the screens can affect the ability of fish to avoid intake screens. Since these functions of plant operation may influence fish distribution and vulnerability, tests to evaluate impingement rates in terms of these operational variables were performed during 1974.

c. Fish Condition

Relative impingement rates of healthy fish and fish with parasitic infestation, pathological deterioration of selected organs, or physiological stress may differ. The general conditions of impinged fish and fish taken in field sampling were compared to determine whether potentially weaker fish were selectively impinged at Indian Point.

3. Protective Devices

Various mechanical or behavioral devices may be employed in an attempt to prevent or reduce impingement. An alternate approach is to accept impingement as an inevitable fact and maximize survival of impinged fish for subsequent return to the water source. The 1974 studies evaluated air curtains, various intake screen combinations (fixed vs traveling, intermittent vs continuous traveling), and a fish pump as means of reducing impingement or the impact of impingement.

SECTION II

IMPINGEMENT MONITORING AND QUANTIFICATION

A. INTRODUCTION

The 1974 Indian Point monitoring program was designed to collect data with which to analyze seasonal occurrence, numbers, species, and size composition of fish collected at Units 1, 2, and 3. To support this objective, total numbers of fish collected per species were obtained and impingement rates calculated. The efficiency of the fish collection process was also determined. The influence of relative fish abundance and distribution in the Indian Point region on Indian Point impingement was evaluated using stationary sonar, gill nets, and standard station beach seine and trawl samples. The power plant as a gear type in the fisheries mark/recapture program provided fish for use in population estimates and direct impact assessment.

B. METHODS

1. Fish Collection

The fixed screens at Indian Point Units 1 and 2 were washed daily between 0800 and 1200 by high-pressure water jets. Circulator flow drew a portion of the fish and debris from the screens into the forebay where they were impinged on traveling screens, each of which was washed individually, with the wash water being drained through a sluice containing a 0.375-in. square mesh collection screen. Approximately 20 min was allowed for the wash in order to assure completion of a full circuit of the screen. Fish and debris were removed from the collection screen by hand or scap net. It was sometimes necessary to stop the washing process and drain the sluice several times when debris load was heavy so the collecting screen could be cleaned without losing fish. Unscheduled screen washings performed to alleviate head loss due to high debris loading or impingement were recorded in the data base whenever possible.

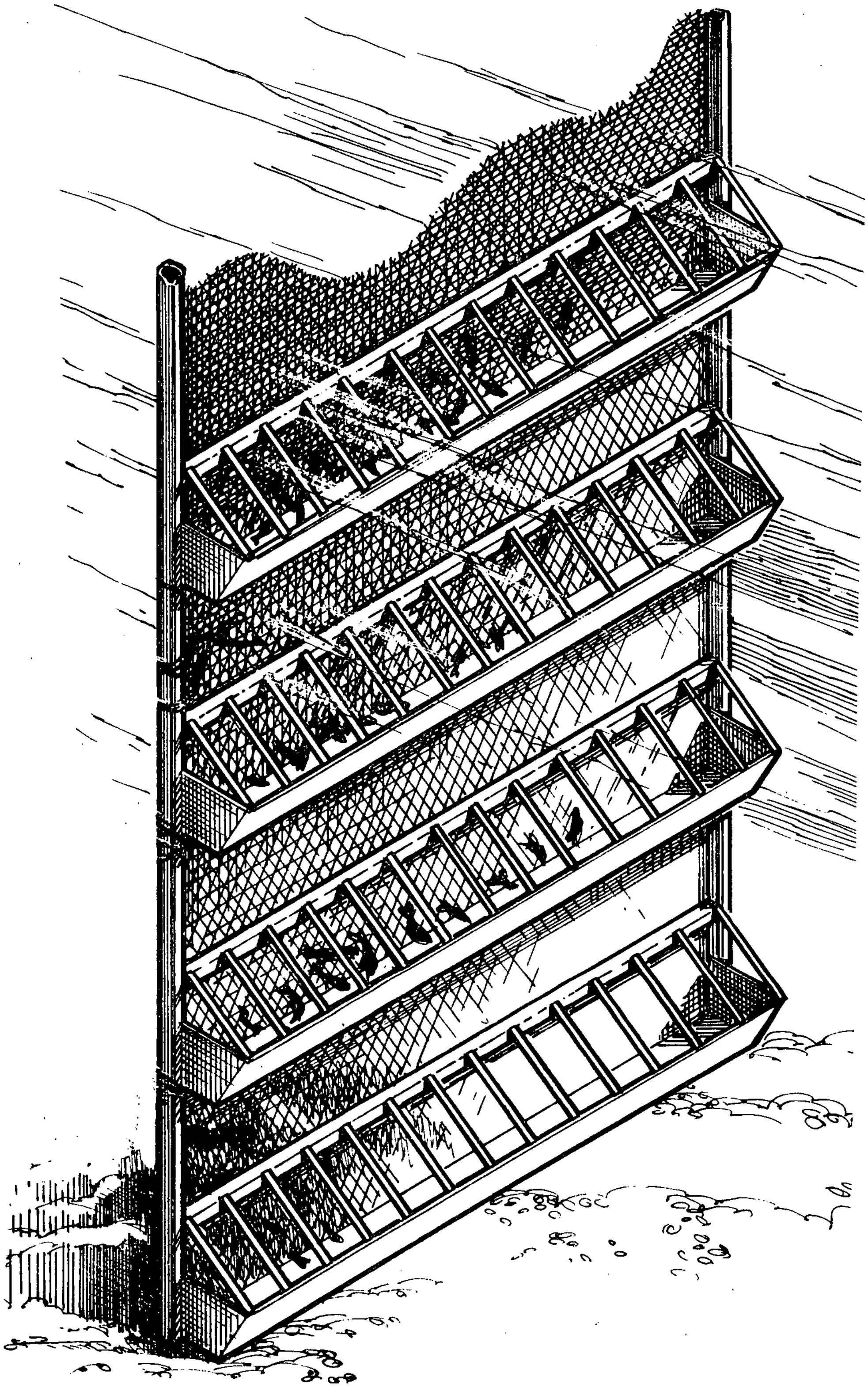

Figure II-1. Artist's Concept (Not Drawn to Scale) of Baskets Located at 6-f t (1.8-m) Depth Intervals on Fixed Screens 23 and 26

In March 1974, horizontal baskets were attached to Unit 2 fixed screens 23 and 26 at depths of 0, 6, 12, and 18 ft (0, 1.8, 3.7, and 5.5 m) above the river bottom to study vertical distribution of impinged fish (Figure II-1). Fish were removed from the baskets and screens by hand. Unit 3 forebays are equipped with traveling screens at the river edge but have no fixed screens. Two modes of screen washing were employed: screens were rotated and washed continuously or once every 4 hr, with the screens completing one circuit every 10 min. During both modes, fish accumulated in a screen box in the wash water sluice and were collected by hand or net at 4-hr intervals.

2. Fish Collection Processing

After total weights and numbers were recorded by species except for striped bass, white perch, and Atlantic tomcod, individual lengths and weights were recorded for a random sample of 25% of the first 100 or less fish plus 1% of the fish in excess of 100 for each species. For the other three species, a stratified sampling scheme was initiated which consisted of sorting each species into four length classes (strata):

1 = 0 mm - x

2 = x + 1 mm - 150 mm

3 = 151 mm - 250 mm

4 = ≥ 251 mm

where x is a variable length used to separate age class 0 from age class I. Sampling then proceeded by randomly choosing from each stratum for each species 25% of the first 100 or less fish plus 1% of the fish exceeding 100. Individual lengths and weights of all specimens in the subsamples were recorded for use in a comparative study of the length/weight relationship of river and impinged fish.

From January to October 1974, scale samples were obtained from the first striped bass and white perch collected in each length division from each screen wash; during November, five individuals per division and species were sampled for scales; in December, 15 individuals per division and species were collected. Scale sample abundance changes were initiated in November and December to make the impingement sample size comparable to river samples with which they were statistically compared in an examination of condition factors.

All striped bass, white perch, and adult Atlantic tomcod from each washing were individually examined for the presence of tags or fin clips. These data supported the mark/recapture, population estimation, direct impact assessment, and hatchery striped bass survival studies.

3. Impingement Rate Determination

Performance engineers at Indian Point provided TI with circulator flow rates and operating duration data (i.e., the time between consecutive washings at a specific screen), and these data were used to calculate the total volume of water circulated during a sampling period for each circulator. Numbers of fish collected during a screen washing were divided by millions of cubic meters of water circulated during the sampling period to produce an average impingement rate [numbers of fish per million cubic meters (10^6 m^3)], which has been used as catch per unit effort (CPUE). Division of the sum of daily impingement numbers by the sum of daily flow volumes for a specific period results in weekly, monthly, seasonal, and annual average rates for each unit. Weekly rates are reported for consecutive 7-day intervals beginning on 1 January (Table B-1, Appendix B); calendar months are used for monthly rates. Water temperature, Figure II-2, was used to determine seasonal delineations as follows:

Winter	Jan 1 - Mar 19	Low and relatively constant
Spring	Mar 20 - Jun 17	Rising
Summer	Jun 19 - Sep 17	High and relatively constant
Fall	Sep 18 - Dec 31	Falling

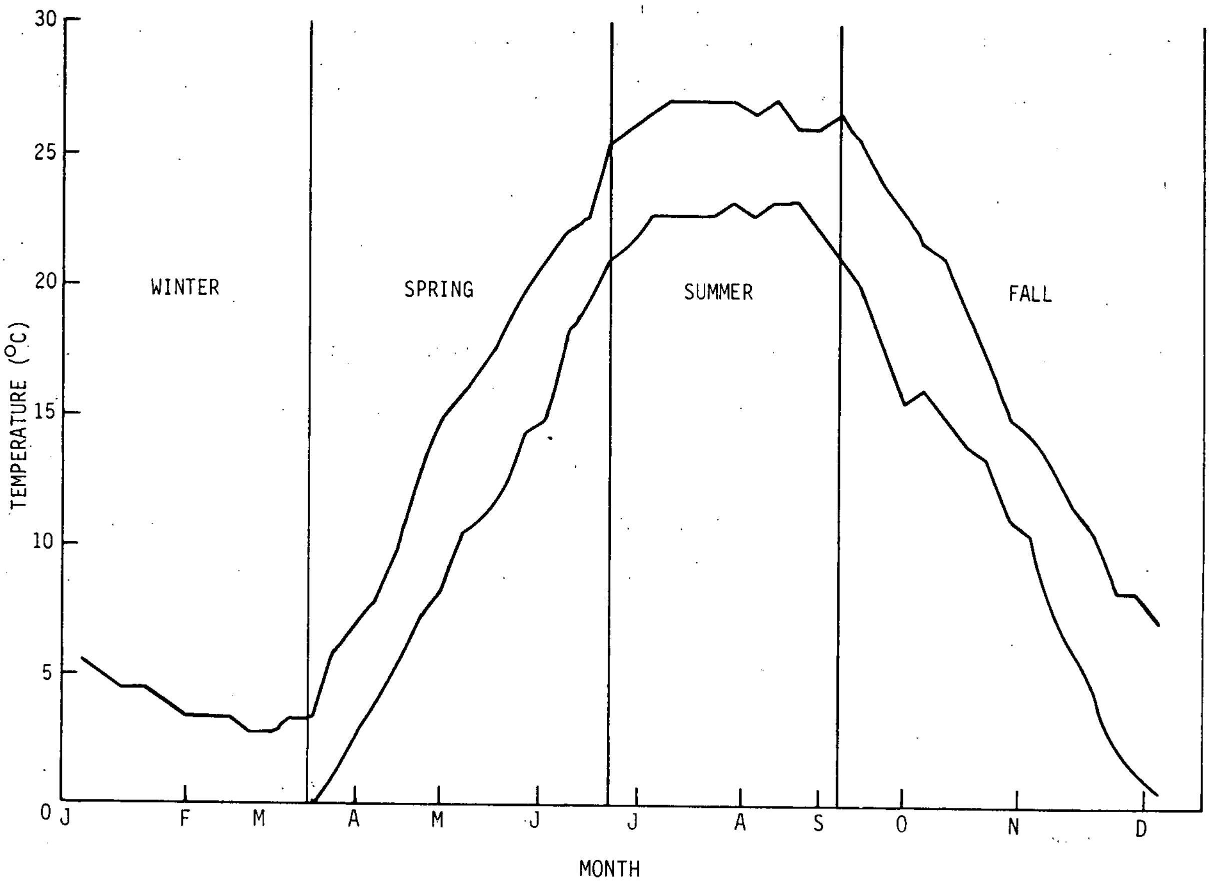

Figure II-2. Annual Water Temperature Graph for Determining Seasons. (Curves show maximum and minimum temperature range)

4. Impingement Collection Efficiency Test

To estimate the number of fish impinged on the fixed screens not recovered from the traveling screens by the collection process, fish marked with water-fast dyes were released at the Unit 2 fixed screens and recovery percentages calculated; all tests were performed when the unit was at 60% flow. The majority of the artificially impinged fish were young-of-the-year white perch, but older white perch and striped bass were also used in numbers roughly proportional to their frequency in past collections. Test specimens were released in front of screens 21 and 25 because recovery rates might have been affected by the reimpingement of lost fish on adjacent screens.

Screen 21 at the southern end of the Unit 2 intake structure is bounded on only one side by another intake (22), while intake 25 is bounded on both sides by other intakes (24 and 26).

Since recovery may depend on impingement duration and exposure to loss factors such as trophic scavenging and scrubbing by air curtain flows, dead fish were distributed 3, 9, 15, and 21 hr before collection. In two tests, live fish were released 9 hr before collection in order to identify differences between live and dead fish in the test design. The point on the screen where fish are impinged may also influence the potential for recovery; therefore, fish were released at five screen sites per time period (Figure II-3). The test design is summarized in Table II-1.

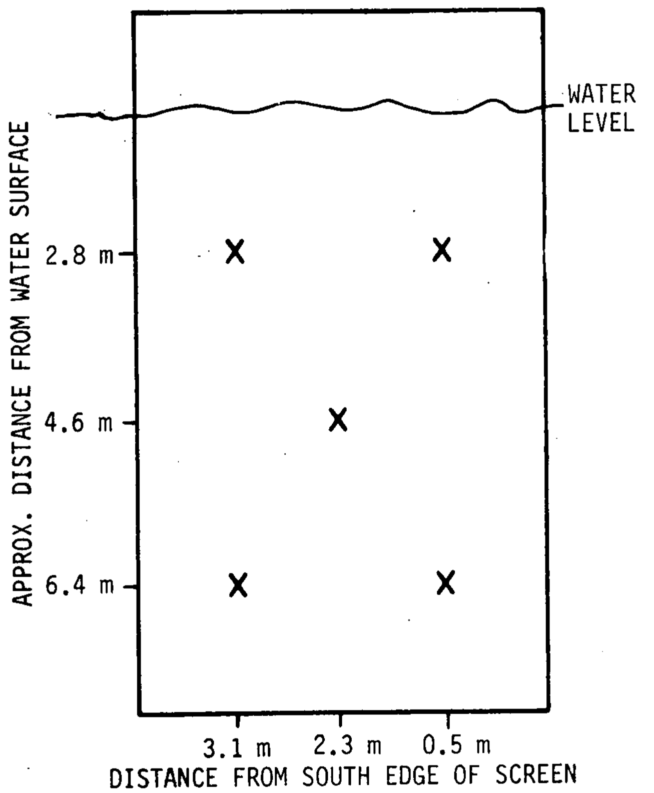

Figure II-3

Distribution of Fish Releases at Unit 2 Fixed Intake Screens 21 and 25 for Impingement Collection Efficiency Tests

Marked fish were placed in a release mechanism consisting of a 0.25-ft x 1.0-ft (7.5-cm x 30.5-cm) tube with stoppered ends (Figure II-4), and the mechanism was positioned between the air bubbler structure and the fixed screen less than 0.5 m from the screen (Figure II-3). Ten fish were released at each of the five screen locations. While impingement could not be directly observed, impingement of dead fish was assumed to be occurring.

Table II-1

Summary of Test Design for Release of Marked Fish Used to Estimate Efficiency of Impingement Collection Process*

Date (1974)	Fish Released, Each Location on Screens	No. of Locations Each Screen	No. of Screens	No. of Releases during 24-Hr Tests	Air Curtain Operation during Test	Total No. of Fish Released per Test	Test Fish Condition
Nov 13	10	5	2	4	On	400	Dead
18	10	5	2	4	Off	400	Dead
Dec 4	10	5	2	4	On	400	Dead
4	10	5	2	1	On	100	Live
9	10	5	2	4	Off	400	Dead
9	10	5	2	1	Off	100	Live

*Unit 2 was 60% flow throughout all four tests.

Fish were collected during standard daily monitoring procedures. The screen at which each fish was released, the screen from which each fish was collected, the date and time of collection, and air curtain operations throughout the duration of the test period were recorded. Marked fish were not included in daily fish collections records. Differences between collection efficiency of screens 21 and 25 with and without operations of the Unit 2 air curtain were evaluated with chi-square tests for differences in probabilities (Conover, 1971).

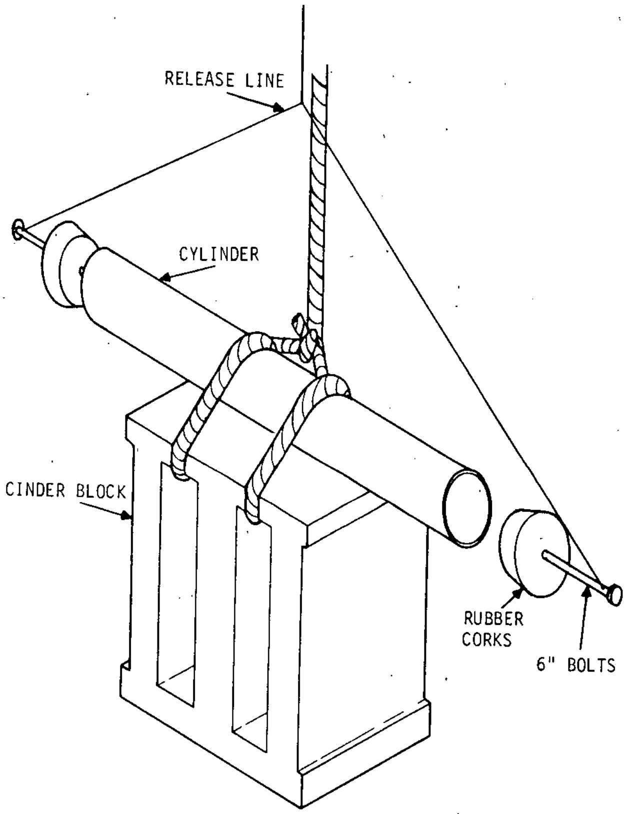

Figure II-4

Release Mechanism for Artificial Impingement of Fish

5. Vertical Distribution of Impinged Fish

Vertical distribution of impinged fish at Unit 2 was evaluated using fixed screen baskets (location and collection procedures described in subsection B.2.). Total numbers of all species combined impinged by week were determined for each basket on screens 23 and 26. Percents of total species catch per basket were calculated instead of rates because data on volume flow per depth interval were not available. Weekly percentages were displayed in a bar diagram. Seasonal mean percents by depth were calculated for two conditions of air curtain operation: on all day or off all day.

6. Relative Abundance Monitoring

a. Standard Station CPUE

Standard station CPUE data (Texas Instruments, 1975) for trawl stations 3 and 4 and beach seine stations 9 and 10, because of their proximity to Indian Point (Figure II-5), were used to analyze relative abundance of the river populations with respect to impingement rates. Standard station collections were made weekly and compared to weekly impingement rates from Indian Point Unit 2 as described in subsection B. 3.

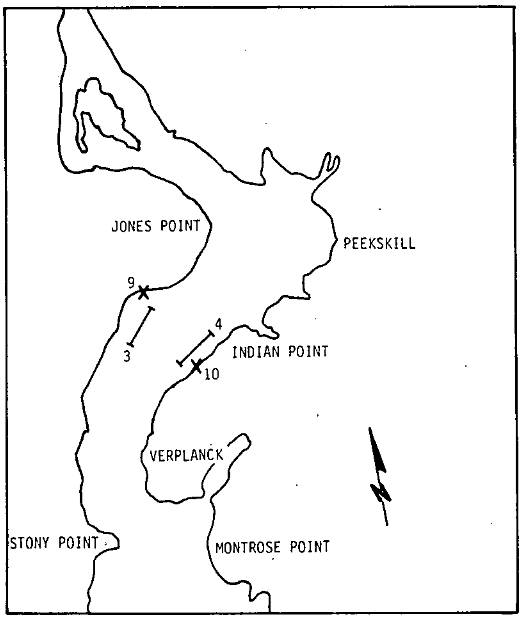

Figure II-5

Locations of Standard Stations 3, 4, (Trawl) 9, and 10 (Beach Seine) Used for Relative Abundance Comparisons with Unit 2 Impingement Rates

To distinguish between river communities in open water and shoals, mean weekly beach seine and trawl data were analyzed separately. Unit 2 impingement rates and standard station weekly and monthly averages were plotted to demonstrate short-term temporal correlations or seasonal trends.

g. Gill Nets

Vertical fish distribution and density in front of Unit 2 were assessed using two parallel 30-ft x 6-ft (9.1-m x 1.8-m) gill nets; the 0.375-in. (9.5-mm) and 0.75-in. (19-mm) bar mesh monofilament nets were joined lengthwise and marked off at 6 ft (9.1-m) intervals parallelling basket intervals on screens 23 and 26. The nets were suspended lengthwise from an anchored floating dock centered approximately 25 ft (7.6 m) from and perpendicular to the Unit 2 intakes (Figure II-6). Fish were removed from gill nets daily and total numbers per species recorded by depth interval. Catch per unit effort (CPUE) was calculated as number of fish collected per hour that the nets were in the water (Appendix H). When gill nets were fished for periods greater than 30 hr, the data were deleted from analysis for consistency with impingement duration. Impingement rates for use in analyses were calculated as described previously (subsection B.3).

Weekly and monthly gill net mean CPUE were graphed with impingement rates to analyze trends in total catch. To evaluate catch composition for evidence of gear selectivity, striped bass, white perch, and Atlantic tomcod percent total catch per effort was graphed by week for gill net and Unit 2.

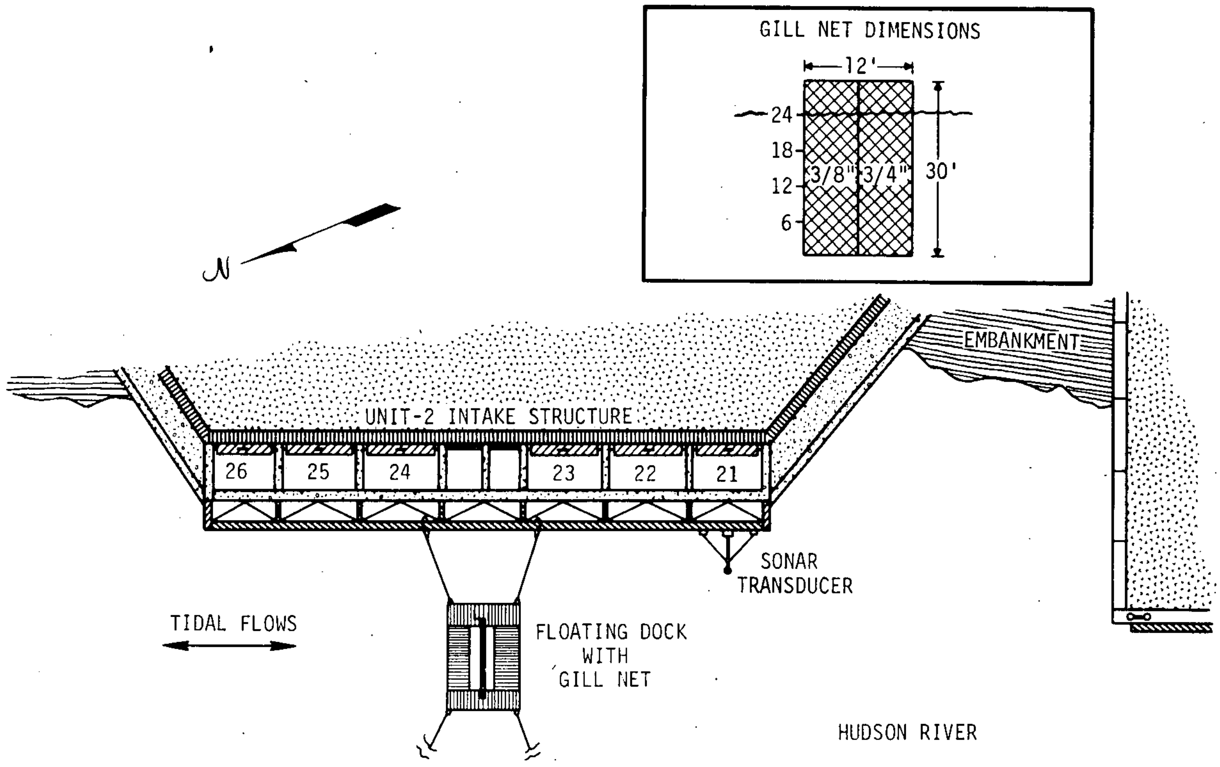

Figure II-6. Vertical Gill Net Placement at Unit 2 for Study of Relative Abundance in Vicinity of Cooling Water Intakes

c. Sonar

A standard commercial echo sounder (Ross Surveyor 200, Table II-2) was used to estimate fish density in the vicinity of Unit 2 intakes. The transducer, depicted in Figure II-7, was deployed on a fixed boom at the center line of the forebay for circulator 21 and approximately 4.6 m in front of the fixed screen (Figures II-6 and II-8). The Ross system was adapted to permit unattended recording of the signal echoes. Appendix I shows redesigned function control sequence and timer/recorder schematics.

Table II-2

Specifications of Ross Surveyor 200 Echo Sounder Used To Evaluate Fish Density at Unit 2

Feature	Specification
Normal depth range	200 ft (full-scale scan of four 50-ft increments)
Operating frequency	200 kHz (nominal)
Soundings	720/min
Keying interval	83.3 msec
Pulse length	Short, 0.1 msec Long, 0.5 msec
Transmitter power	500 w
Transducer voltage ($Z = 100\ \Omega$)	320 v, rms
Receiver sensitivity (for 5 v at detector)	10 μv
Receiver dynamic range	55.5 db
TVG voltage (0.1 msec, min. gain)	-10 v
Power requirement	117 v, 1 ϕ, 60 Hz, 94 w
Beam width	22°

From 8 July to 2 August 1974, 5-min records were made at 4-hr intervals. Total echo counts were estimated from paper strip-chart records and random recounts made to determine the precision of the counting method. Total counts for the six records between 1200 and 0800 inclusive were summed (Table II-3) for comparison with impingement rates determined in subsection B.3. Records from periods during which the air curtain interfered with the transducer were not counted; when air curtain interference voided one record, total sonar counts for that day were not used in analyses. Total sonar counts were not converted to rates, since the sonified volume was a constant; however, counts made by 6-ft depth intervals were volumetrically adjusted to counts per cubic meter (CPUE) per depth interval because of volume differences with depth in the conical sample zone.

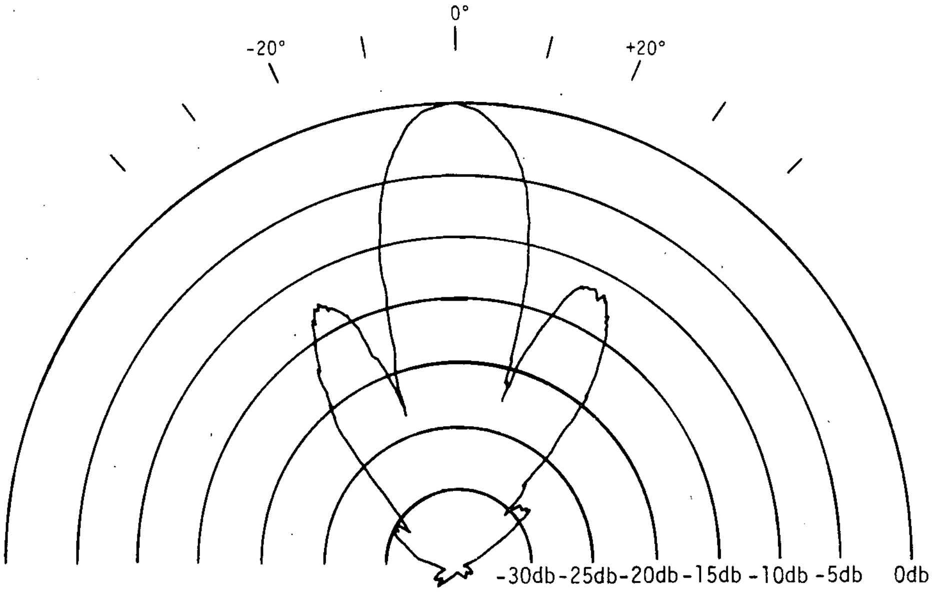

Figure II-7. Average Transducer Pattern Based on One Measurement of Standard Ross "22°" Single-Element Transducer. (Individual transducers may show some variation)

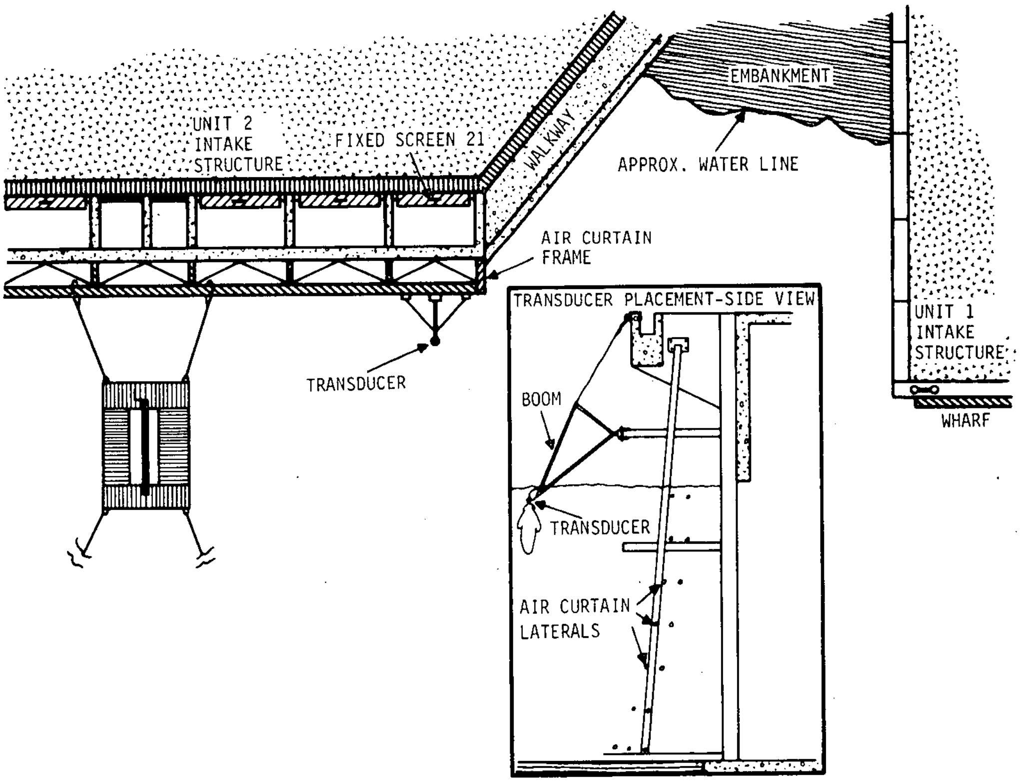

Figure II-8. Placement of Sonar Transducer at Screen 21 for Study of Relative Density

Table II-3

Number of Sonar Counts and Numbers per Cubic Meter
Taken from Sonar Strip Recorder Chart

Date	Total Number	Sonar Counts							
		Surface - 6 Ft		6 - 12 Ft		12 - 18 Ft		18 - 24 Ft	
		No.	No./m^3	No.	No./m^3	No.	No./m^3	No.	No./m^3
7/8/74	102	21	24.4	14	6.0	15	3.3	32	4.3
9	252	37	43.1	33	14.2	76	16.7	106	14.2
10	438	42	48.9	59	25.3	139	30.6	198	26.5
11	552	96	111.8	88	37.8	144	31.7	224	29.9
12	184	28	32.6	52	22.3	54	11.9	50	6.7
17	594	108	125.8	136	58.4	156	34.4	194	25.9
18	763	108	125.8	118	50.6	204	44.9	333	44.5
19	504	34	39.6	47	20.2	154	33.9	269	36.0
20	308	73	85.0	33	14.2	82	18.1	120	16.0
21	557	78	90.8	85	36.5	98	21.6	296	39.6
22	373	40	46.6	58	24.9	100	22.0	175	23.4
24	354	—		76	32.6	88	19.4	190	25.4
26	661	117	136.2	128	54.9	141	31.1	275	36.8
27	890	193	224.7	166	71.2	220	48.5	311	41.6
28	341	46	53.6	57	24.5	90	19.8	148	19.8
29	499	82	95.5	94	40.3	124	27.3	199	26.6
30	579	162	188.6	119	51.1	142	31.3	156	20.9
31	287	72	83.8	67	28.7	59	13.0	89	11.9
8/1/74	284	81	94.3	48	20.6	71	15.6	84	11.2
2	568	131	152.5	103	44.2	124	27.3	210	28.1
3	512	128	149.0	93	39.9	123	27.1	168	22.5
4	494	117	136.2	92	39.5	92	20.3	193	25.8
5	312	111	129.2	56	24.0	46	10.1	99	13.2

Daily Unit 2 and screen 21 impingement rates were used as the independent variables and total daily sonar counts as the dependent variable in linear regression to assess the correlation between sonar and screen counts. Total counts for each record were graphed against 4-hr interval counts at Unit 3 from 18 July to 23 July to determine if similar temporal patterns existed. Percent catch per effort per depth interval was also graphed to permit comparison of depth distribution demonstrated by sonar, screen baskets, and gill nets.

C. RESULTS AND DISCUSSION

1. Impingement Statistics

The total number and weight of impinged fish collected at Indian Point in 1974 was as follows: Unit 1, 138,976 fish for 901 kg (1982 lb); Unit 2, 750,182 fish for 3792 kg (8342 lb); and Unit 3, 35,086 fish for 177 kg (389 lb). The seasonal species composition of impingement collections was similar for all units (Table II-4) during any season, but the composition changed through the year as a function of the life history of the vulnerable species. These trends are related to the migration patterns of certain species. The Hudson River estuary serves as a spawning and nursery ground for several anadromous and resident species, the young-of-the-year and yearlings of which compose a major portion of impingement collections. Young-of-the-year white perch migrate downstream and from the shoals to deep water at an impingeable size in late fall. During winter and spring while concentrated in the channel area, white perch constituted a major portion of impingement collections, reaching maximum levels in winter and spring; white perch impingement rates declined during the summer when they were feeding in the shoals. Young-of-the-year striped bass migrate downstream to deeper water at the edge of the channel during late summer in approximately equal numbers (Texas Instruments, 1974a); however, at no time did striped bass comprise more than a minor portion of impingement collections. Differences in habitat, distribution, or physiological capacity may have accounted for the disproportionate impingement of these two species. Clupeid downstream migration in the fall was reflected by higher impingement rates for clupeids at that time.

Table II-4

Summary of Seasonal Trends in Impingement Rates and Species Composition during 1974

Season	Major Species	Secondary Species	Impingement Rates (No. /10^6 m^3) Unit 1	Unit 2	Unit 3
Winter	White perch		299	1733	95
Spring	White perch	Atlantic tomcod	254	1100	743
Summer	Atlantic tomcod	Bay anchovy	434	860	1075
Fall	White perch	Blueback herring, Atlantic tomcod	512	373	260

Bay anchovies, which spawn in the lower estuary, migrate upstream in the summer and thus were impinged in large numbers at that time. Atlantic tomcod was the major species impinged during the summer, with young-of-the-year comprising a large portion of impingement collections in late spring, summer, and fall and spawning-run adults comprising a large portion of late-fall collections.

Unit 3 circulators were not operated during January, February, and March 1974, but one or two Unit 3 circulators were operated for approximately 1 week per month from April through December 1974. During November and December, concurrent operational testing of several circulators caused fish from different forebays to be mixed and excessive wash water to overflow and collapse the collection box; thus, these fish collections were abnormal and, although recorded in data files, were deleted from various impingement analyses.

Weekly, monthly, seasonal, and annual total numbers and weights of impinged fish are summarized in Appendix B, and plant operational data are summarized in Appendix D. Impingement rates (catch per effort) are presented in Appendix B for the same time periods as are total numbers and weights. Marked fish recovered in support of the population estimate, direct impact assessment, and hatchery striped bass survival programs are listed in Table II-5.

2. Impingement Collection Efficiency Tests

Impingement collection efficiency tests indicated a potential for significant bias in impingement counts at Indian Point Unit 2. The loss of impinged fish may be related to several environmental and operational variables. Interreplicate variation for the tests with dead fish was high when the air curtain was off but negligible when the air curtain was on (Table II-6), indicating that the air curtain is the dominant factor affecting

Table II-5

Number of Marks Recaptured through Impingement during 1974*

Month	Fin Clips				Tags			Hatchery
	Striped Bass	White Perch	Atlantic Tomcod		Striped Bass	White Perch	Atlantic Tomcod	Striped Bass
Jan	0	5	2	Yearling	0	0	0	0
Feb	0	2	0		0	0	0	0
Mar	0	5	0		0	2	0	0
Apr	0	4	0		0	0	0	3†
May	0	18	0		0	0	0	0
Jun	0	8	0		0	7	0	0
Jul	0	0	0		3	3	0	0
Aug	1	0	0		1	6	0	1
Sep	2	0	0	Young-of-the-year	0	5	0	0
Oct	2	0	0		0	5	0	3
Nov	2	11	0		0	4	0	2
Dec	2	6	3		0	4	2	12
Total	9	59	5		4	36	2	21

*Excludes right-pelvic, left-pelvic, and double-pelvic fin clips from white perch marked during fall 1973.
†1973 stocking.

collection efficiency. Without air curtain operation, other variables (tide, freshwater flow, circulator flow, etc.) interacted to influence collection losses. Fish recovery was significantly lower at screen 21 than at 25 when the air curtain was being operated (Table II-7); with the air curtain off, recovery rates were similar for the two screens and overall recovery was significantly increased (Table II-8).

Table II-6

Percent Recovery of Artificially Impinged Fish Summarized by Replicate for Both Modes of Air Curtain Operation

Date	Air Curtain Condition	Percent Recovered	
		Screen 21	Screen 25
Nov 13	On	8.0	16.0
18	Off	69.5	79.5
Dec 4	On	8.0	16.5
9	Off	37.5	36.5

Table II-7

Comparison of Screens 21 and 25 for Recovery Rates from Combined 13 November and 5 December Collection Efficiency Tests
[air curtain was operable during fish release period; difference is significant (χ^2 = 12.78) at α = 0.05 level]

Screen	No. Released	Recovered on All Unit 2 Screens	Percent Recovered
21	400	32	8.00
25	400	65	16.25

Table II-8

Comparison of Screens 21 and 25 for Recovery Rates from Combined 18 November and 9 December Collection Efficiency Tests
[air curtain did not operate during fish release period; difference is not significant (χ^2 = 1.64) at α = 0.05 level]

Screen	No. Released	Recovered on All Unit 2 Screens	Percent Recovered
21	400	214	53.50
25	400	232	58.00

One test with live fish performed under both air curtain conditions produced results similar to those of tests with dead fish. There was no significant difference between results of tests with dead fish and one pair of tests with live fish (Table II-9). It is not known what portion of impinged fish that were lost before collection on the traveling screens were viable specimens, but survival rates in tests at Unit 2 in 1973 (Texas Instruments, 1974b) showed less than 15% survival for fish collected.

Table II-9

Summary of Artificially Impinged Live Fish Recoveries during Various Modes of Air Curtain Operation

Operation Mode	Screen	No. Collected	No. Lost	Percent Recovery
On	21	2	48	4
	25	4	46	8
Off	21	28	22	56
	25	25	25	50

When fixed screens are washed, some fish can be lost when wash water jets blow fish back into the river. The air curtain has been observed to push back into the river the fish removed during fixed screen washings. The air curtain also may actively remove fish from the fixed screen and carry them into the river; fish thus removed are either carried away by the river, reimpinged on the same or adjacent screens, or taken by scavenging sea gulls. The probability of reimpingement depends, in part, on screen location and tidal stage when the fish are being removed from the fixed screens; fish removed from screen 21 during ebb tide, for example, are not exposed to adjacent circulator flow and could be carried away by river flow, and fish removed from fixed screen 25 could be reimpinged at adjacent screens during any tide stage.

Several other factors may effect the low recovery rates: all test fish may not be impinged initially or fish may enter the intake forebay but not be impinged on the traveling screens. Higher recovery rates might be expected with the higher intake velocity associated with 100% circulator flow. Ongoing tests in 1975 will examine these problems.

Although the results of this study indicate the potential for significant bias in the estimates of impingement magnitude, especially during air-curtain operation, they are preliminary and should not be used to quantify such bias or to compute correction factors. To establish correction factors for impingement counts, more tests would be necessary to determine the confidence intervals for efficiency tests under a large number of variable combinations and to verify the impingement of test fish.

3. Relative Abundance

The three methods used to assess relative abundance sampled different portions of the river populations than those collected from Unit 2 screens and, therefore, were considered insensitive tools for predicting impingement peaks or population vulnerability. Weekly standard station CPUE had no apparent relation to impingement rates (Figure II-9). A plot of mean monthly impingement rates (Figure II-10) reflects changes in fish location associated with seasonal migration as indicated by standard station data. The impingement curve shows three periods of increased impingement. White perch was the major species impinged in early spring and late fall when peak bottom trawl catches indicated increased fish density in deep water stations. Impingement decreased as the perch moved into the shoal areas indicated by summer beach seine catch peaks. The summer impingement peak was composed primarily of young-of-the-year tomcod which were collected in higher densities on the east side of the channel near Indian Point.

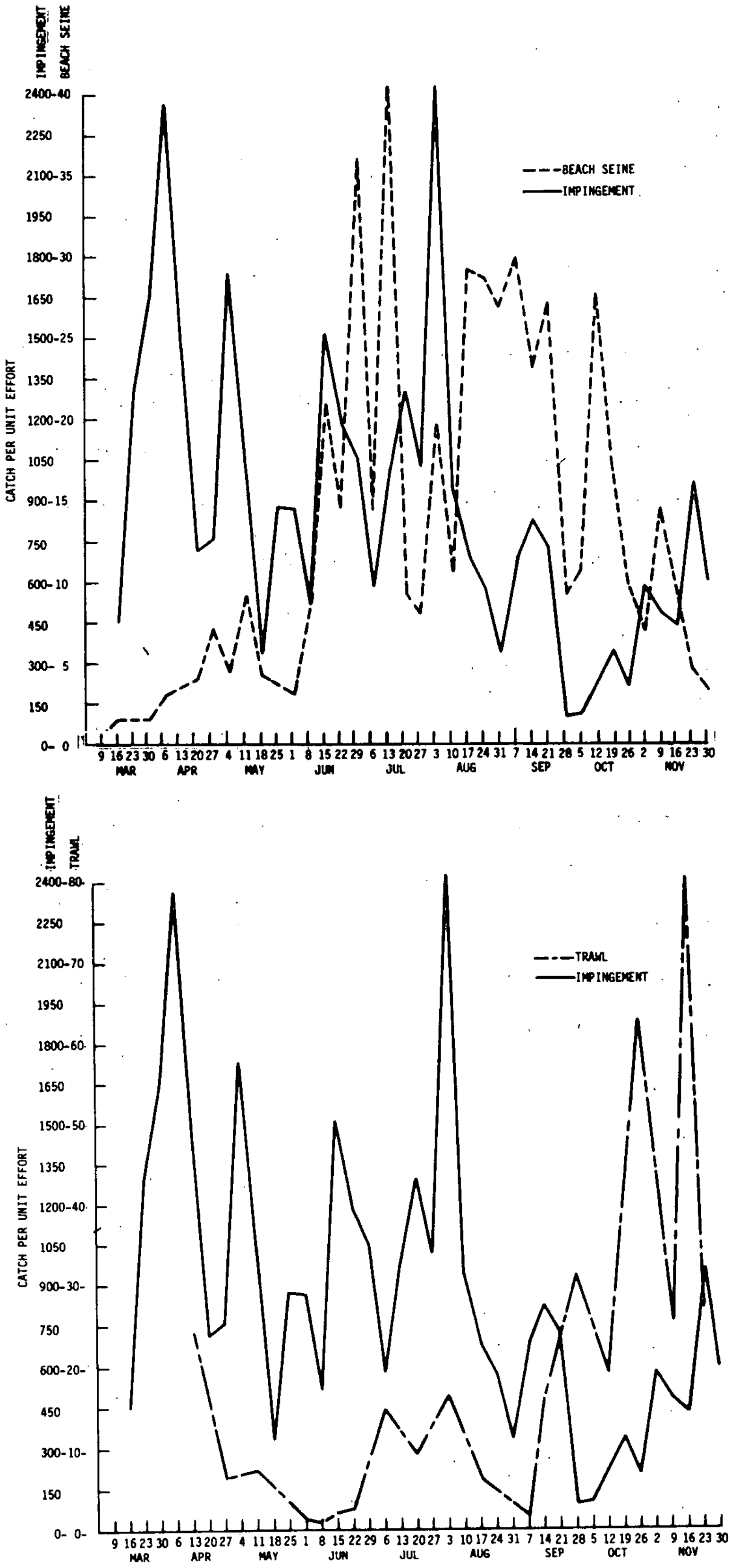

Figure II-9. Beach Seine, Bottom Trawl, and Impingement Catch per Unit Effort Data by Week

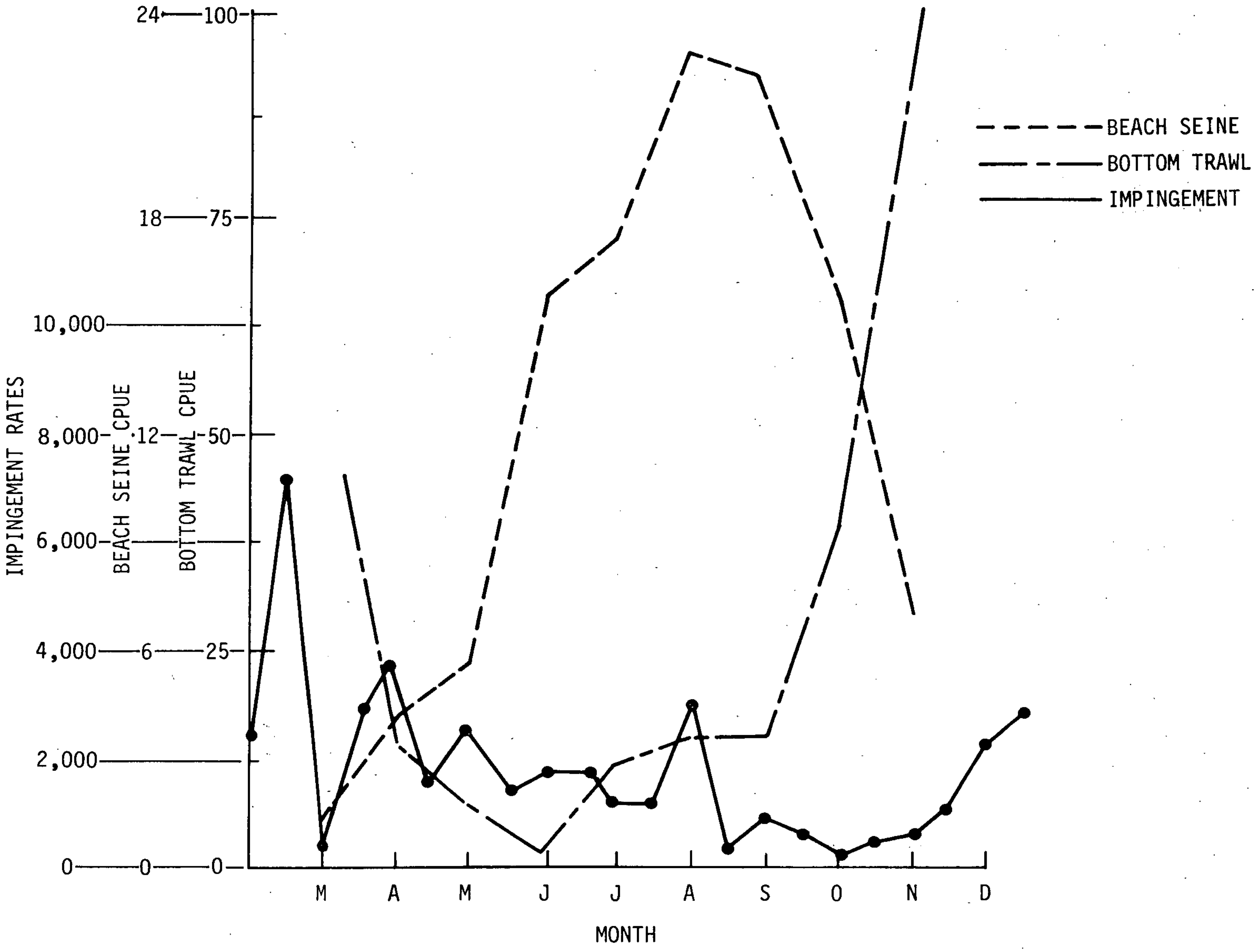

Figure II-10. Monthly Mean Catch per Unit Effort for Standard Station Beach Seine, Trawl, and Impingement Rates

While gill net and impingement collections showed similar monthly trends in catch per unit effort, there was no apparent short-term relationship (Figure II-11). More specifically, the species composition of the two sample populations was very dissimilar (Figure II-12). Striped bass and white perch comprised the major segment of gill net catches, while tomcod catches were negligible; however, during the same period, tomcod formed a large portion of impingement catches with few striped bass impinged. Screens and gill nets do not sample the same portions of the river population, and it cannot be determined from these data which gear more accurately sampled the river community in the immediate vicinity of Unit 2.

A 10% recount showed that the sonar counting estimate procedure was a precise means of establishing the number of echoes recorded by the Ross system (Figure II-13).

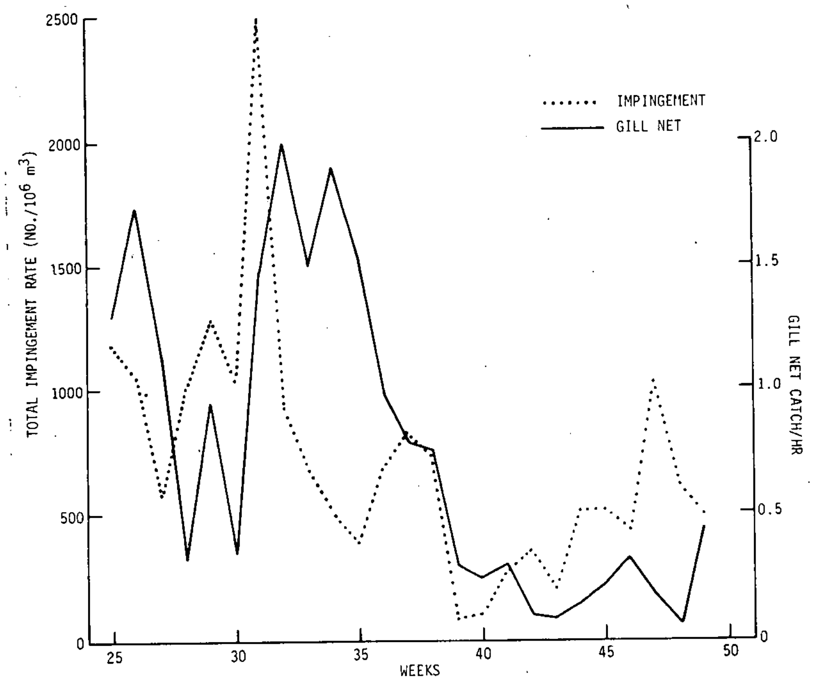

Figure II-11. Weekly Gill Net Catch per Unit Effort (No. /Hr) and Indian Point Unit 2 Impingement Rates (No. / 10^6 m^3)

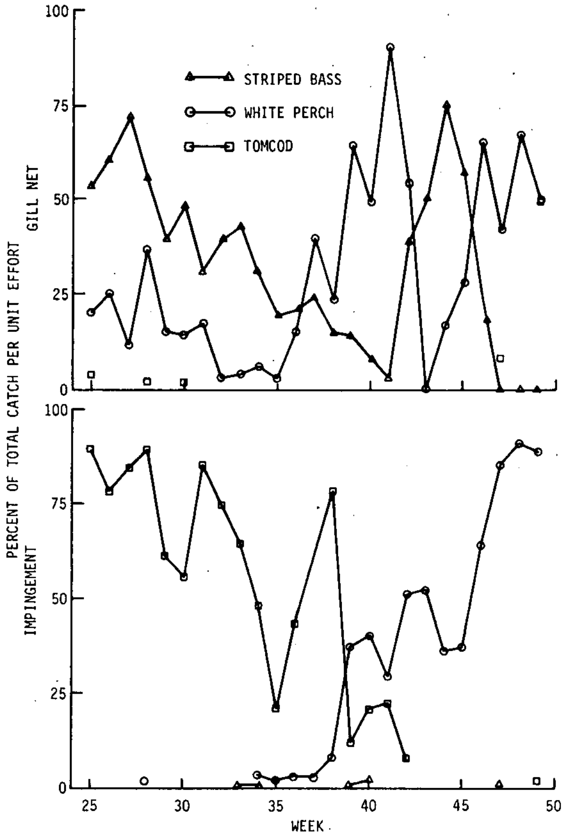

Figure II-12. Percent Catch per Unit Effort Contributed by Striped Bass, White Perch, and Atlantic Tomcod to Gill Nets and Unit 2

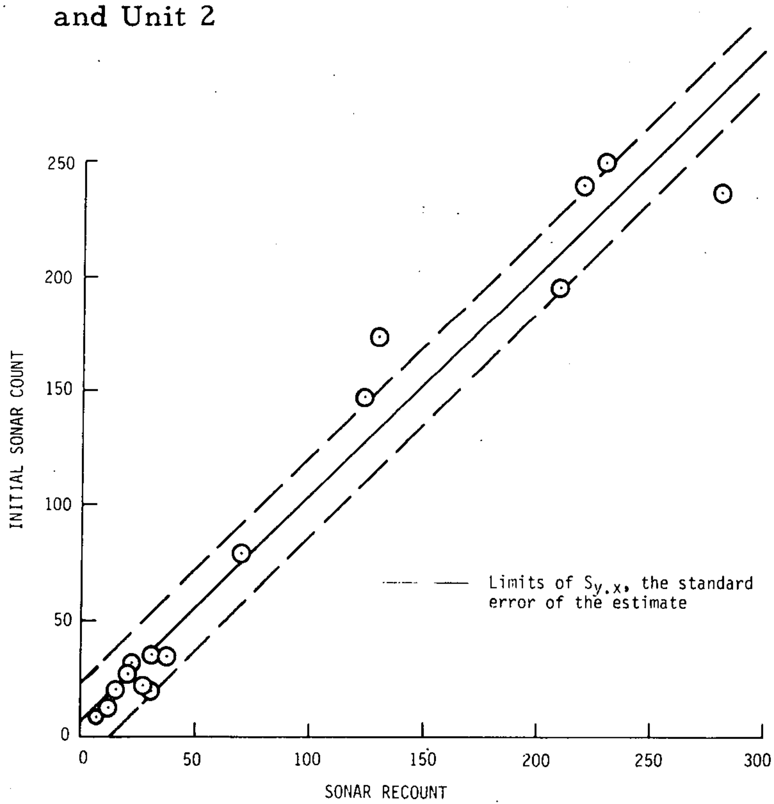

Figure II-13. Scatter Diagram of Sonar Recount Test Results Plotted with Least Squares Best Fit

The accuracy of the echo counts in identifying fish abundance cannot be determined for this system. The only significant correlation (α = 0.05) between sonar and impingement data (Table II-10) was a negative correlation between screen 21 white perch impingement and sonar counts. This may indicate that the sonar was insensitive to targets the size of small young-of-the-year white perch impinged at that time. The general lack of correlation may reflect the selective nature of intake screens and an insensitivity of sonar to a large segment of the vulnerable population.

Graphs of daily Unit 2 impingement and sonar data (Figure II-14) showed no apparent relationship. A 26- to 28- hr cyclic increase in fish density was apparent from graphs of 4-hr interval sonar data (Figure II-15); this cycle does not correlate with an apparent 24-hr impingement cycle (Section III). The pattern of sonar peaks may be a function of the tidal cycle.

Depth interval analysis of impingement (screen 23), sonar, and gill net catches showed no apparent correlation between depths (Figure II-16). Almost 50% of all sonar echoes were counted in the 6-ft deep surface layer; counts at greater depths were uniform and less than 20% of the total. Impingement and gill net catches showed greater variability between depths and weeks.

Table II-10

Results of 12 Regression Analyses Performed on Sonar and Impingement Data Collected between 8 July and 2 August 1974

Variables† X Y	Sample Size N	Y Intercept a	Regression Coef. b	Correlation Coef. r	Std. Error Est. $S_{y \cdot x}$
$U2_T \times S$	23	441.3009	0.0033	0.0627	182.8197
$21_T \times S$	17	475.7576	-0.0101	-0.1078	199.1202
$U2_{SB} \times S$	23	450.1657	0.1296	0.0169	183.1536
$21_{SB} \times S$	23	389.8913	4.5299	0.2604	176.8578
$U2_{WP} \times S$	22	480.5079	-2.0565	-0.1308	181.6064
$21_{WP} \times S$	17	557.4533	-20.0452	-0.4609	177.7494
$U2_{AT} \times S$	23	449.2105	0.0014	0.0216	183.1372
$21_{AT} \times S$	17	469.6298	-0.0079	-0.0772	199.6897
$U2_{BF} \times S$	23	403.4694	1.6210	0.3120	174.0382
$21_{BF} \times S$	17	484.4237	-3.0939	-0.1617	197.6526
$U2_{BA} \times S$	23	432.1807	0.0323	0.1290	181.6484
$21_{BA} \times S$	17	478.7266	-0.0542	-0.1408	198.2922

†Independent variables were: Striped bass (SB), white perch (WP), Atlantic tomcod (AT), bluefish (BF), bay anchovy (BA), and total (T) impingement rates at Unit 2 (U2) and screen 21 (21). Dependent variables were sonar counts (S).

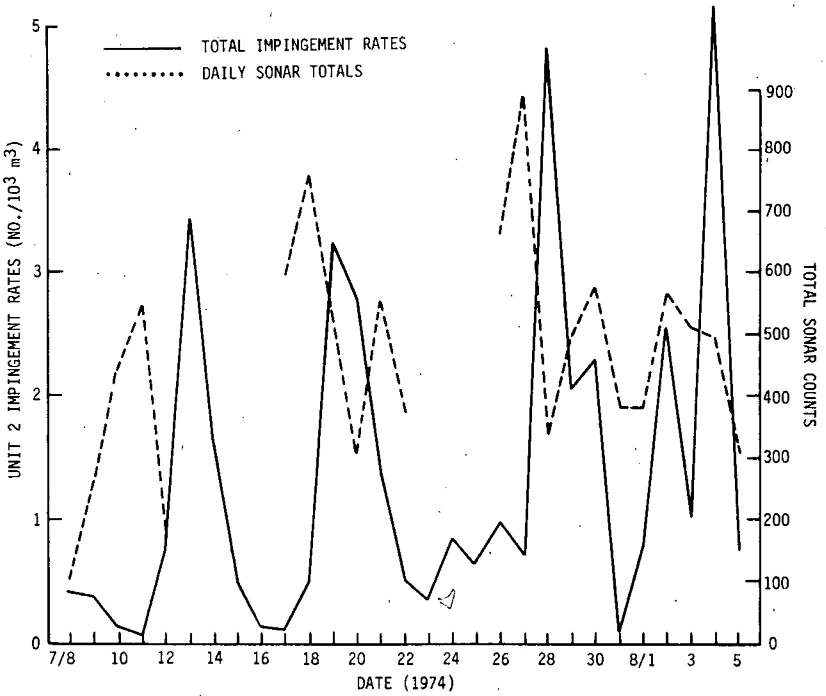

Figure II-14. Daily Sonar Counts and Impingement Rates. (Air curtain interference accounts for missing sonar data)

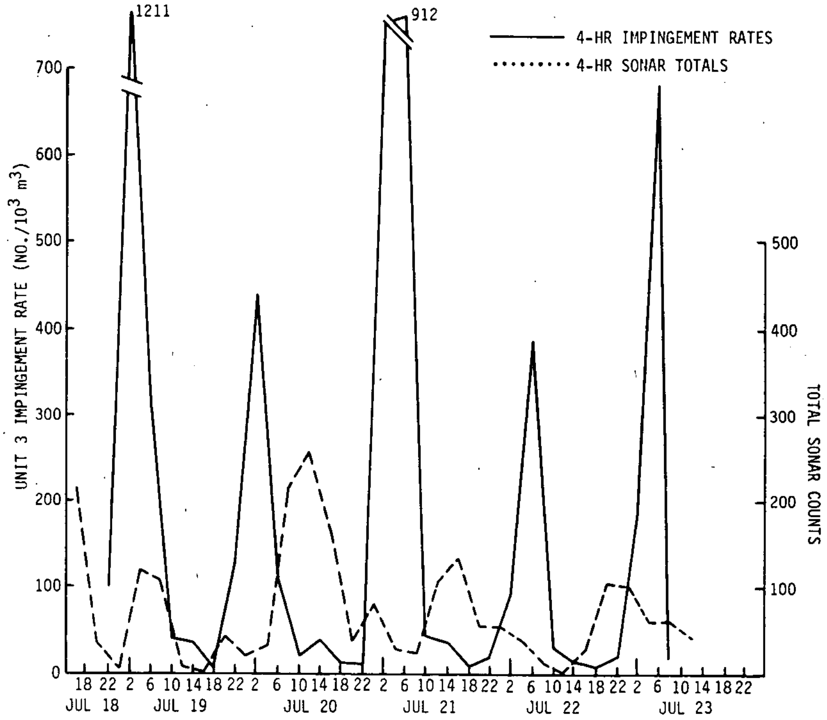

Figure II-15. 4-Hr Interval Data from Sonar and Unit 3 for Week during which Both Systems Were Operational

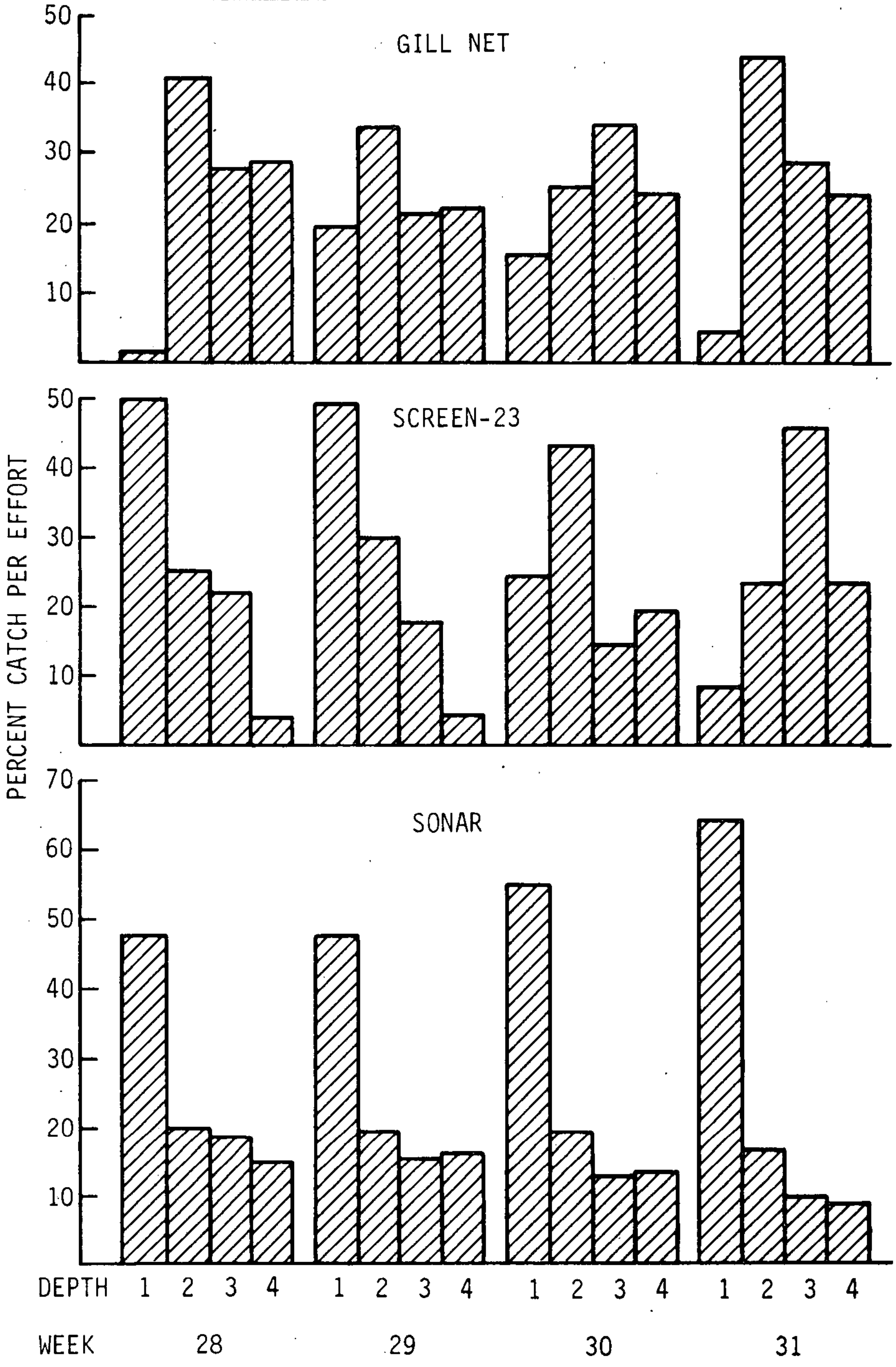

Figure II-16. Depth Distribution Analysis of Sonar, Screen 23, and Gill Nets Used To Determine Relative Density during Testing in Vicinity of Unit 2 Intake Structures. (Depth is in descending 6-ft intervals; 1 is surface layer and 4 is bottom.)

Sonar will record all objects with a density significantly different from the surrounding medium and larger than the lower sensitivity of the hydrophone. Both debris and fish (swim bladders) can be recorded, but very small fish or fish without air bladders are not likely to reflect a detectable sonar signal (echo). At the current level of sophistication and sensitivity, sonar is apparently an ineffective means of sampling intake area density in the assessment of impingement patterns. Differences in selectivity and sensitivity of all four gear and the intake structures indicate that none of these sampling gear are suitable for predictive analysis of impingement.

4. Vertical Distribution of Impinged Fish

Impingement collections from baskets at screens 23 and 26 demonstrated an uneven distribution of impingement over depth. The increased impingement levels near the surface are shown in Figures II-17 through II-22, and seasonal means by species and basket appear in Tables II-11 through II-13. To determine if upwelling currents created by the air curtain were a factor in the vertical distribution of fish on the intake screens, days were separated according to whether the air curtain was on or off (Table II-14). The top two baskets (1 and 2) always had the highest number of fish; basket 1 generally had the most, and basket 4 always had the least. Thus, for all species and seasons examined, impingement primarily occurred on the upper half of the screen. As percentage of total catch, impingement was negligible on the lowest 6 ft of the screens. The air curtain did not alter this pattern to a great extent although, when the air curtain was off, collections were more evenly distributed between the upper three depths.

The causes of these variations in vertical distribution of fish impingement cannot be determined from these data, but one possible controlling factor is uneven approach velocity/intake volume distribution (Section III). Differences in nearfield vertical density indicated by stationary sonar may also account for higher surface impingement. The impingement of higher percentages of bottom-dwelling hogchokers near the surface may indicate the presence of vertical eddy currents displacing fish toward the surface. A more complete understanding of the causes of this vertical distribution is needed before solutions are sought by limiting the vertical zone of water withdrawal.

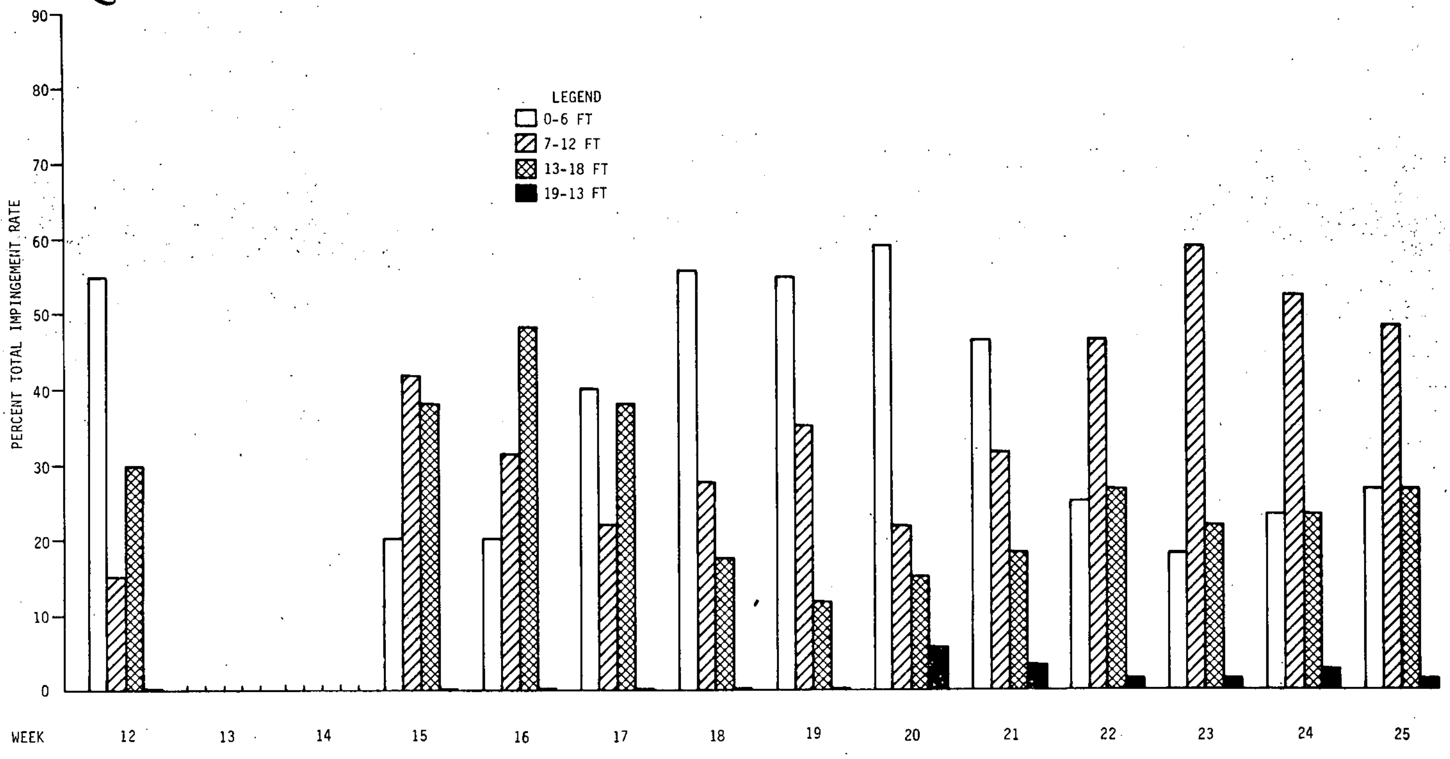

Figure II-17. Mean Percentage of All Fish Collected at Each Depth Basket on Screen 23 during Spring 1974

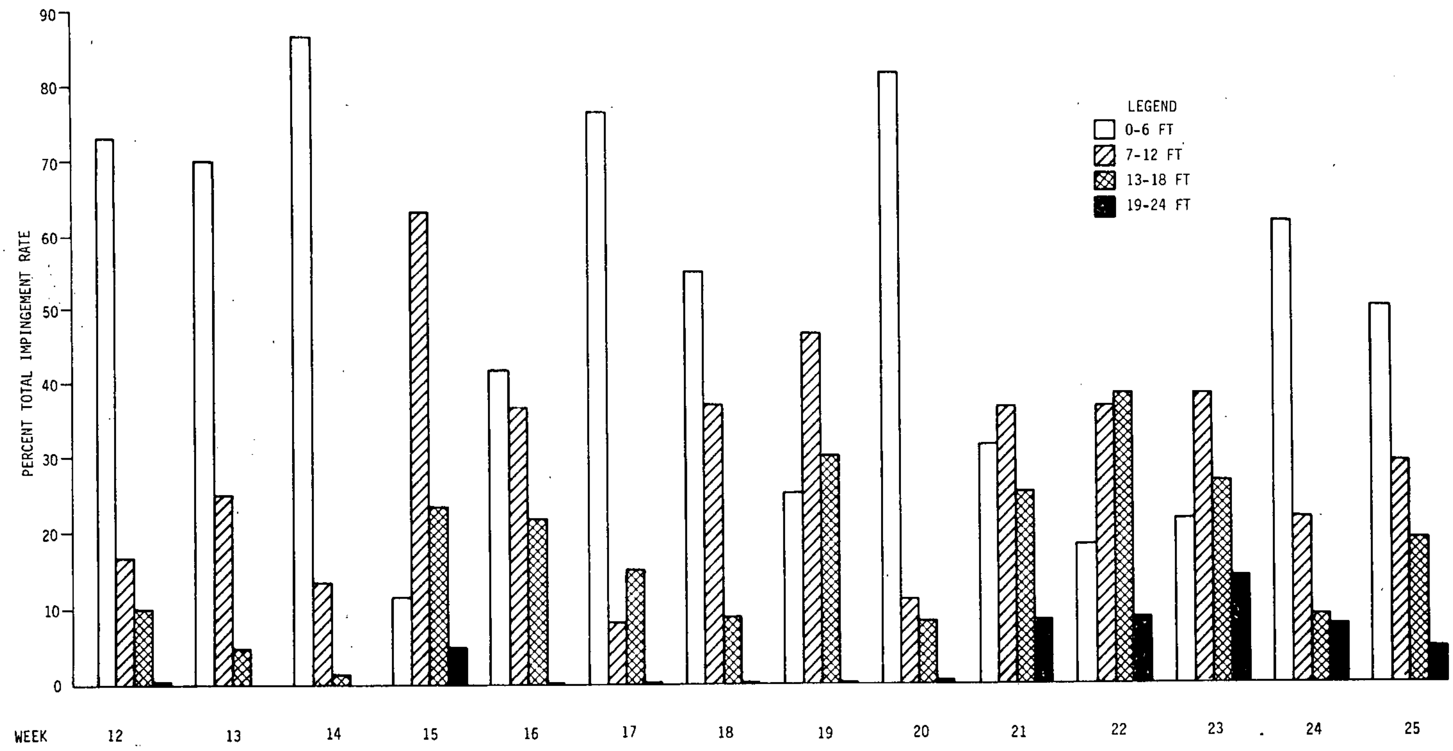

Figure II-18. Mean Percentage of All Fish Collected at Each Depth Basket on Screen 26 during Spring 1974

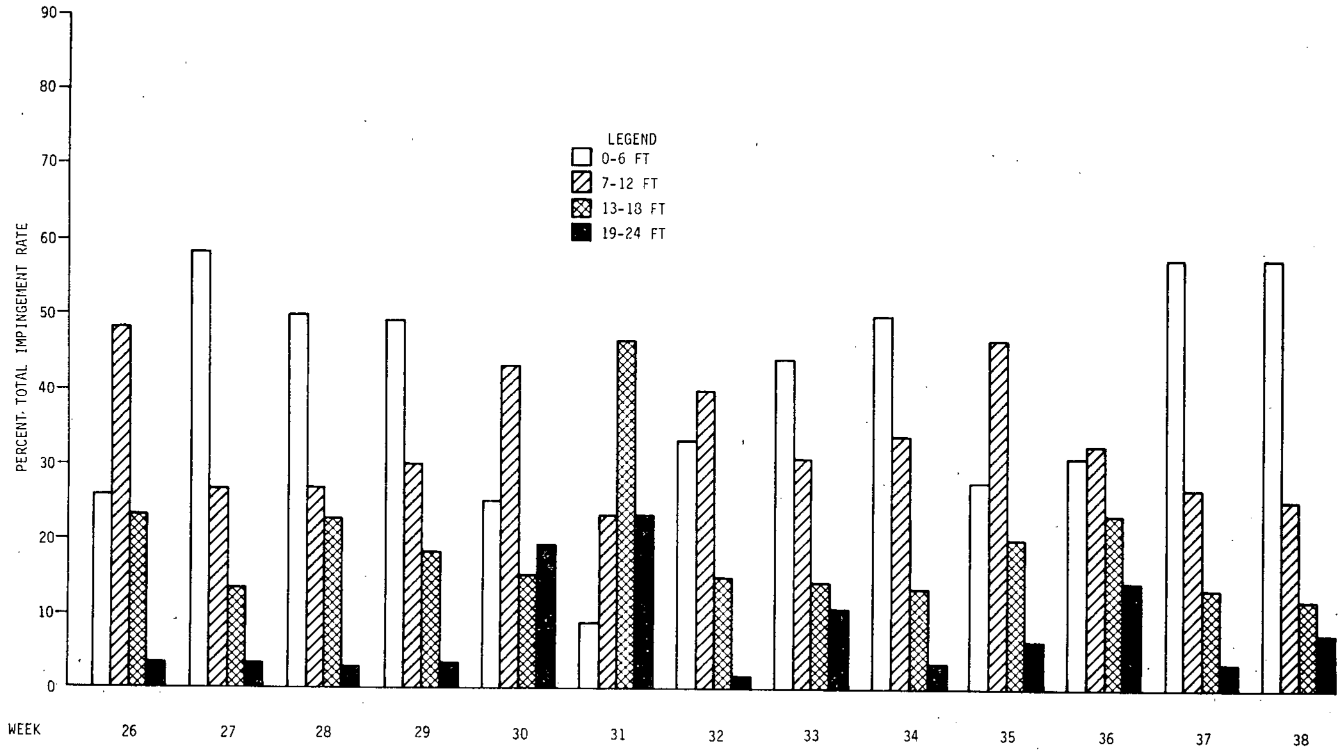

Figure II-19. Mean Percentage of All Fish Collected at Each Depth Basket on Screen 23 during Summer 1974

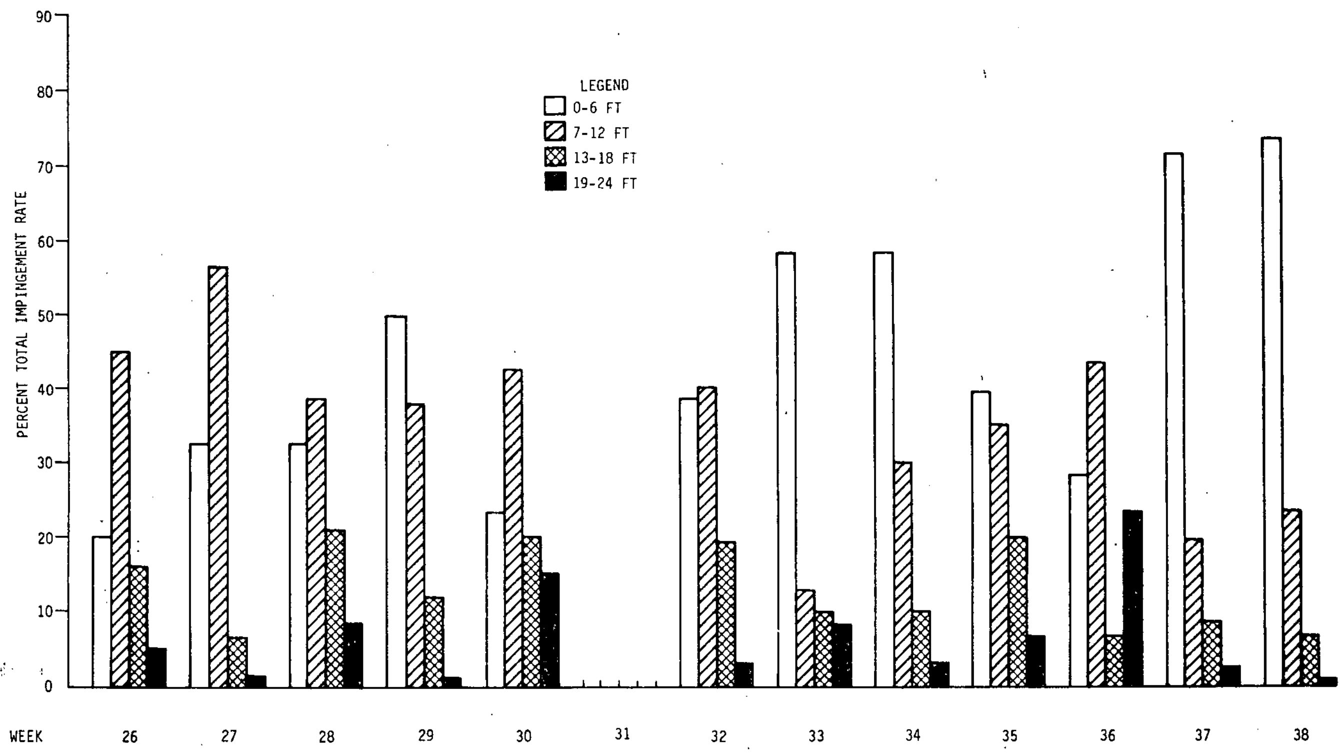

Figure II-20. Mean Percentage of All Fish Collected at Each Depth Basket on Screen 26 during Summer 1974

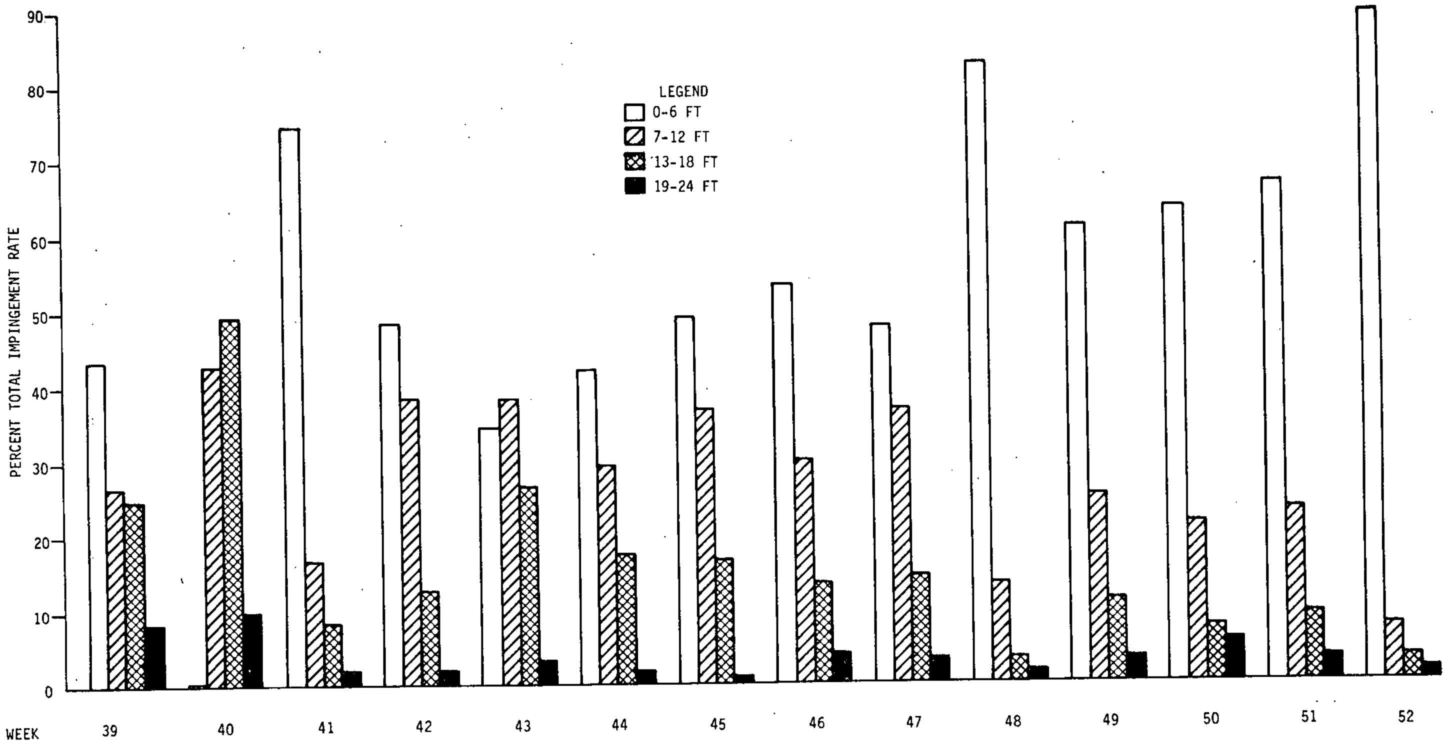

Figure II-21. Mean Percentage of All Fish Collected at Each Depth Basket on Screen 23 during Fall 1974

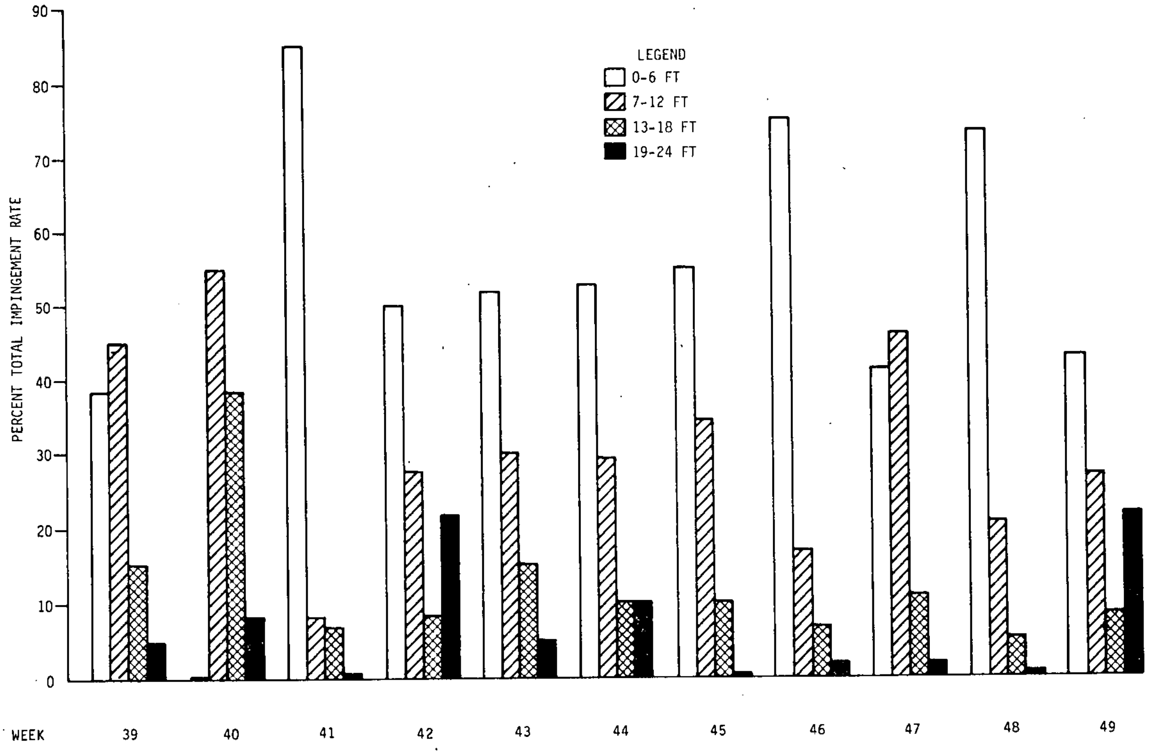

Figure II-22. Mean Percentage of All Fish Collected at Each Depth Basket on Screen 26 during Fall 1974

Table II-11

Mean Percentages of Fish Collected in Each Basket on Screens 23 and 26, Summer 1974

Species	Screen 23 Basket*	Screen 23 Mean (%)	Screen 26 Basket*	Screen 26 Mean (%)
Striped bass	1	38	1	36
	2	35	2	43
	3	17	3	16
	4	10	4	5
Atlantic tomcod	1	42	1	45
	2	35	2	34
	3	17	3	14
	4	6	4	7
White perch	1	41	1	43
	2	34	2	27
	3	18	3	18
	4	7	4	12
Hogchoker	1	52	1	47
	2	22	2	25
	3	16	3	21
	4	10	4	7
All species	1	38	1	41
	2	35	2	33
	3	20	3	18
	4	7	4	7

*Baskets numbered consecutively from top to bottom.

Table II-12

Mean Percentages of Fish Collected in Each Basket on Screens 23 and 26, Fall 1974

Species	Screen 23 Basket*	Screen 23 Mean (%)	Screen 26 Basket*	Screen 26 Mean (%)
Striped bass	1	59	1	48
	2	28	2	28
	3	12	3	18
	4	1	4	8
Atlantic tomcod	1	63	1	67
	2	21	2	23
	3	14	3	8
	4	2	4	2
White perch	1	54	1	52
	2	28	2	31
	3	15	3	10
	4	3	4	7
Hogchoker	1	55	1	50
	2	26	2	24
	3	10	3	23
	4	9	4	3
All species	1	54	1	53
	2	27	2	30
	3	15	3	12
	4	4	4	5

*Baskets numbered consecutively from top to bottom.

Table II-13

Mean Percentages of Fish Collected in Each Basket on Screens 23 and 26, Spring 1974

Species	Screen 23 Basket*	Screen 23 Mean (%)	Screen 26 Basket*	Screen 26 Mean (%)
Striped bass	1	71	1	47
	2	9	2	30
	3	20	3	19
	4	0	4	4
Atlantic tomcod	1	26	1	36
	2	53	2	39
	3	18	3	18
	4	3	4	7
White perch	1	37	1	52
	2	34	2	29
	3	28	3	16
	4	1	4	3
Hogchoker	1	46	1	50
	2	32	2	24
	3	15	3	19
	4	7	4	7
All species	1	38	1	50
	2	35	2	30
	3	26	3	17
	4	1	4	3

*Baskets numbered consecutively from top to bottom.

Table II-14

Seasonal Mean Percent of Total Catch by Depth at Screens 23 and 26 for Spring, Summer, and Fall 1974 [days with different air curtain (AC) modes were separated]

Screen	Depth	Spring AC On	Spring AC Off	Summer AC On	Summer AC Off	Fall AC On	Fall AC Off
23	0-12	79.0	84.1	82.0	54.2	88.7	85.1
	13-24	21.0	15.9	18.0	45.8	11.4	14.9
26	0-12	92.9	67.3	83.2	72.4	89.7	87.9
	13-24	7.1	32.8	16.9	27.6	10.2	12.1

SECTION III

FACTORS AFFECTING IMPINGEMENT

A. INTRODUCTION

To identify major sources of variation in impingement magnitude and species composition, selected plant and environmental variables and indicators of the physical condition of fish were examined. The variables were conductivity, temperature, dissolved oxygen, tide stage, time of day, approach velocity, and thermal recirculation. For indication of physical condition, fish were examined for gill parasite infestation and pathological deterioration of gill, spleen, liver, and kidney.

B. METHODS

1. Water Physical/Chemical Variables

Dissolved oxygen, temperature, and conductivity were examined because 1973 impingement data suggested that they were most likely to affect impingement rates (Texas Instruments, 1974b). Unit 2 studies were designed to examine daily impingement variation with environmental parameters as independent variables; Unit 3 studies examined variations within days. Temperature (°C) and dissolved oxygen (ppm or mg/ℓ) were measured with a YSI Model 54 dissolved oxygen and temperature meter; conductivity (μmhos/cm^2) was measured with a YSI Model 31 SCT meter.

Measurements at Unit 2 intakes were made between 0800 and 1700 at high or low slack tide. Water chemistry was measured at Unit 3 coincidental to 4-hr fish collections. Discharge canal water samples were collected simultaneously with intake measurements at Units 2 and 3. Data from water samples collected at the surface and 2 ft above bottom were averaged for each station. Impingement rates were graphed in conjunction with water chemistry data collected during the same time period. Conductivity, temperature, and dissolved oxygen concentrations were plotted with 4-hr impingement rates for each of the 1-week Unit 3 study periods.

2. Diel and Tide Effects on Impingement

Diel patterns in impingement rates were assessed using Unit 3 fish collections. Total impingement rates were plotted against time for each fish collection period; on the plot, the predominant tide stage for each 4-hr period was indicated in order to identify tidal influence on impingement rates.

3. Plant Operation Variables

a. Thermal Recirculation

Unit 3 intake temperature and tidal stage were used to identify recirculation of the thermal plume and evaluate the influence of recirculation on impingement. As described in Section II, fish were collected and intake temperatures and tidal stage determined and recorded every 4 hr at Unit 3. It was assumed that the thermal plume would be in the vicinity of Unit 3 intakes only at flood or high slack tides. Thermal recirculation was inferred if an intake temperature increase of more than 0.5°C was associated with tide stage changes from ebb or low slack to flood or high slack between successive water chemistry collections. When one sample indicated recirculation, the occurrence of this variable was assumed throughout the period in which consecutive water samples collected at similar tide stages had the same or higher temperatures. Impingement rates were graphed in temporal blocks around periods of recirculation to identify patterns in impingement rates related to recirculation of the thermal plume.

b. Approach Velocity and Head Loss

Plant operational variables and impingement rates recorded at Unit 2 were used to evaluate the effect of approach velocity on impingement.

The accumulation of debris and fish causes a decrease in open screen area and an increase in water level differential across the intake screens. Head loss was determined before each washing; a lead line was lowered from a fixed elevation to the water surface in front of and behind the fixed screens and the difference between elevations from the respective water levels determined. Simultaneously, current velocity was measured (Figure III-1) because head loss was expected to affect current velocity, which could influence fish vulnerability to impingement. Five point measurements were obtained approximately 0.7 m in front of the fixed screen with a Marsh-McBirney Model 711 electromagnetic water current meter. A mean approach velocity was calculated from the five points in each group of measurements. Correlation coefficients were calculated to evaluate the significance of a linear relationship between impingement rates (striped bass, white perch, Atlantic tomcod, and all species combined) and head loss and average approach velocity.

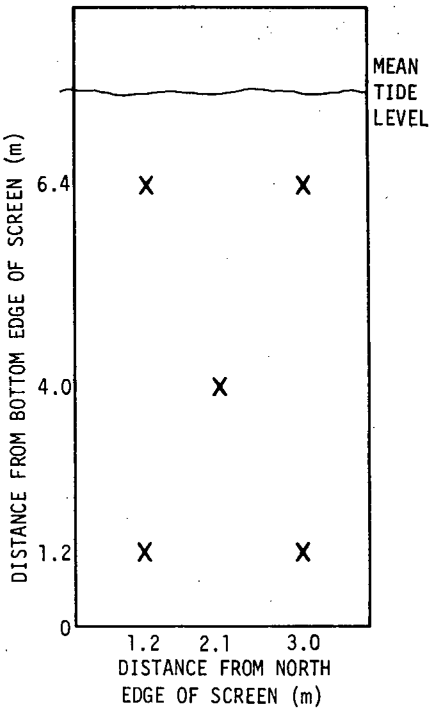

Figure III-1

5-Point Velocity Measurement Locations Used on Unbasketed and Basketed Screens

Current velocity screen profiles might be used to identify the major zone of water withdrawal for evaluation of vulnerability and impingement depth distribution. One set of profile measurements (Figures III-2 and III-3) was made for each of 16 variable combinations at basketed and unbasketed screens (Table III-1). A 2-way analysis of variance ($\alpha = 0.05$) was performed

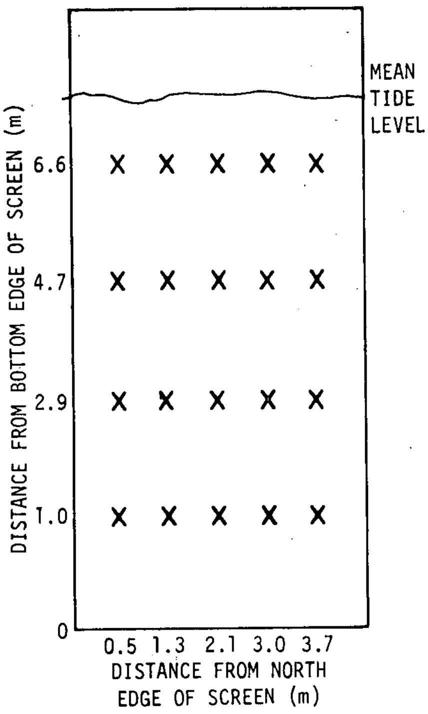

Figure III-2

20-Point Velocity Measurement Locations Used on Basketed Screens 23 and 26 (Refer to Figure II-1)

on data from basketed and unbasketed screens for each combination of variables to determine if significant differences existed between horizontal strata (rows). Replicate measurements under each set of conditions were not made; thus, only one data point existed for each column-row intersection or "cell." No interaction, therefore, was assumed to provide a testing error term. This assumption was tested by Tukey's one degree of freedom test for nonadditivity; when the assumption was not verified, data were appropriately transformed by inversion (i.e., $\frac{1}{\text{data point}}$) before being entered into the analysis of variance (Snedecor and Cochran, 1967).

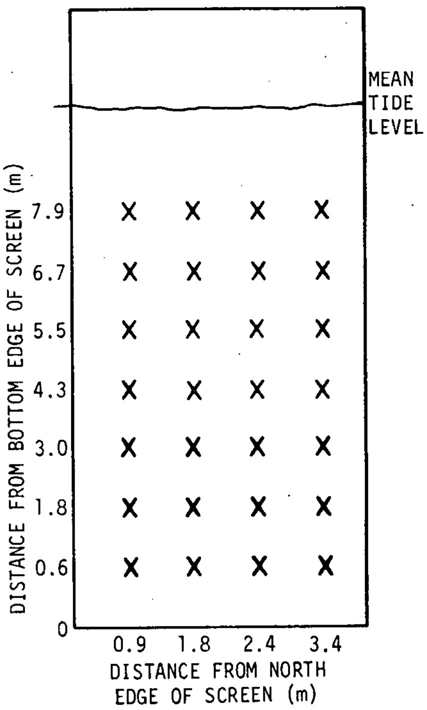

Figure III-3

28-Point Velocity Measurement Locations Used on Unbasketed Screens 21, 22, 24, and 25

Table III-1

Combinations of Tide Stage, Air Curtain, and Flow Conditions under Which Current Velocity Profile Measurements Were Taken on Basketed and Unbasketed Unit 2 Screens in 1974

Slack Tide	Air Curtain Operation	Circulator Flow (%)
High	On	60
High	Off	60
High	On	100
High	Off	100
Low	On	60
Low	Off	60
Low	On	100
Low	Off	100

4. Fish Condition Studies

a. Histopathology Survey

During April and May 1974, 145 white perch were collected and delivered to Pennsylvania State University's histochemical laboratories for histological analysis of pathological condition. Seventy-five live fish (40 fish longer than 100 mm) were collected by beach seine and trawl from Hudson River Region I (Texas Instruments, 1974a) and 69 live fish (31 fish longer than 100 mm) were collected from the Unit 1 intake screens. Preservation and histological techniques, as well as analysis and results, are described in detail in the final report from Dr. William Neff, Pennsylvania State University (Appendix E). Tissue samples from each specimen's gill, spleen, liver, kidney, and buccal roof were examined. To assess the relative severity of the various forms of histopathology encountered, several parameters were examined, including mucous cell counts in the gills, measurements of cysts in spleen and liver, and dimensions of tubules and glomeruli in kidney tissue. A subjective grading system was devised to evaluate such abnormalities as amount of gill congestion and interlamellar debris, hyperplasia (epithelial cell proliferation), presence of parasites, and degree of gill clubbing. The overall numerical rating (Pathological Index) assigned to each fish considered the presence and relative severity of various pathological conditions found in the gill, spleen, liver, and kidney. The Pathological Index (PI) has a range of 1 to 10, where 10 is most severe.

Further statistical analysis was performed on frequency of gas bubble disease (GBD) symptoms. A chi-square test was performed on the data set in a 2 x 2 contingency table to evaluate significant differences between the percent of river and impinged fish demonstrating GBD symptoms. The 95% confidence interval for the probability of GBD symptoms in impinged and seined fish was obtained through the following formula (Conover, 1971):

$$\hat{p} - Z_{1-\frac{\alpha}{2}} \sqrt{\frac{\hat{p}(1-\hat{p})}{n}} < p < \hat{p} + Z_{1-\frac{\alpha}{2}} \sqrt{\frac{\hat{p}(1-\hat{p})}{n}}$$

where

$\hat{p}$ = estimated probability of GBD

$= \frac{\text{number of white perch with GBD}}{\text{total sample size of white perch}}$

$Z_{1-\frac{\alpha}{2}}$ = upper $\frac{\alpha}{2}$ point of standard normal density function

n = sample size

All other identified pathological features were treated descriptively and in terms of percent affected in the subsections for each organ.

b. Gill Parasite Study

Numbers of the isopod *Lironica ovalis* attached to the gills of impinged and river white perch, striped bass, and bluefish were recorded weekly from 18 June through 16 October 1974 as an indicator of the general physical condition of the two groups. Impingement collecting techniques are described in Section II of this report, and Figure III-4 shows where the river fish were collected near Indian Point with 100-ft beach seines (indicated by Xs). Impinged and river fish were sampled on the same day through 19 July; after that date, since impingement occurs during the approximate 24-hr period prior to screen washing and sampling, river fish were examined 1 day prior to impinged fish to reduce the chance that impinged and river fish were from different populations.

The occurrence of *Lironica* on river fish was recorded immediately after seining. Impinged fish were examined during routine laboratory processing, resulting in an approximate 1-hr lag between the collection of impinged fish and the recording of parasite loads. Since the parasite readily detaches from the gills after fish are collected, the parasite load on impinged fish may have an underestimate bias.

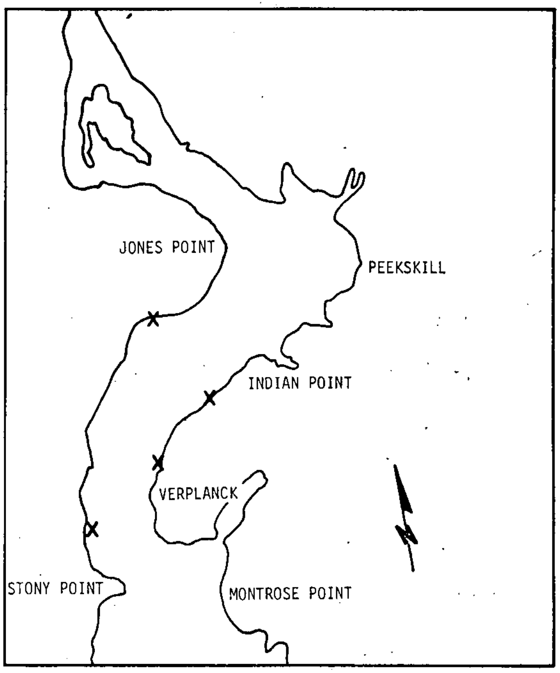

Figure III-4. Locations of Beach Seine Stations Used for Determining *Lironica* Infestation Rates.

Data recorded for both groups of fish (Appendix G) included time, date, and method of capture; total number of white perch and striped bass per length class; total number of bluefish; total number of infested individuals per species; and, when applicable, length class. An individual was condidered infested if at least one *Lironica* was found on a gill or within the opercular cavity. Chi-square tests for 1-sided null hypothesis (Ho: $p_1 \geq p_2$)

were applied to 2 x 2 contingency tables (Conover, 1971) to test differences in percent infestation between collection modes for each species.

c. Dissolved Gas Saturation

Any source of rapid heating or high mixing in an aquatic environment may create an area of dissolved gas supersaturation; under certain seasonal and thermal conditions, the potential exists for fish exposed to these areas to develop gas bubble disease when supersaturated gas in the blood comes out of solution.

To determine if the potential for gas supersaturation exists at Indian Point, dissolved nitrogen and oxygen levels in the Unit 1 intake bay and the effluent canal (Figure I-1) were monitored on a monthly basis from July to December 1974. Monthly sampling periods included 2 days of gas measurement: 1 day with full air curtain operation and 1 day without air curtain operation. Replicate surface and bottom water samples were collected at each sampling site with a 3-ℓ Van Dorn bottle and then transferred to polyethelene bottles. Water temperature and dissolved oxygen concentrations were measured with a YSI Model 54 oxygen meter at the time that the samples were taken. Samples were refrigerated and within 24 hr analyzed for nitrogen concentrations.

The nitrogen analysis technique released nitrogen gas from solution by solubility reduction from heating (Post, 1970). Samples (525 mℓ each) were transferred to an Erlenmeyer flask and treated with 5 mℓ of one normal potassium hydroxide (KOH): sodium sulfite (Na_2SO_3) solution (mixed 1:1 volumetrically) to remove dissolved oxygen and carbon dioxide. Samples then were heated to 95°C for 75-90 min to release all gases from solution. Gases evolved from heating were collected in a 50-mℓ buret and measured by volumetric displacement. All inert gases were contained in the final volume, which was recorded as nitrogen since nitrogen occupies the only significant volume. Nitrogen and oxygen values were measured in milliliters per liter and parts per million respectively and converted to percent saturation utilizing the theoretical saturation formula presented by Weiss (1970). An atmospheric pressure of 760 mm Hg was used for all calculations. The two replicate nitrogen values were averaged for each sample site.

Before each day's samples were run, an air-saturated distilled water sample was analyzed to stabilize the dry system. In addition, a series of saturated distilled water samples were analyzed to standardize the system. The mean nitrogen saturation value of 10 standard samples was 81.0% with standard deviation of 3.4% and standard error of 1.1% (Table III-2). A correction factor (100/81 = 1.2) was applied to all plant intake and effluent sample determinations.

Table III-2

Results of Distilled Water Sample Standard Determination for N_2 Saturation

Series	Standard Sample	Temp (°C)	N_2 (ml)	Saturation Percent	Saturation Mean
1	1	17.0	6.6	99.9*	
1	2	17.2	5.8	88.2	
1	3	17.1	5.4	81.9	81.6
1	4	17.8	5.3	81.5	
1	5	18.4	5.1	79.3	
1	6	18.3	5.4	83.8	
2	1	16.3	6.9	103.1*	
2	2	16.6	5.0	75.1	
2	3	16.8	5.4	81.4	80.1
2	4	16.2	5.3	79.0	
2	5	16.3	5.4	81.7	
2	6	16.4	5.3	79.3	

*First blanks (system stabilization) were not entered in means.

In the discussion of results, the intake and effluent N_2 and O_2 levels are presented as bar graphs to illustrate differences between sample site and air curtain operation. These data are then described in terms of GBD potential at Indian Point.

C. RESULTS AND DISCUSSION

1. Water Physical/Chemical Variables

At Unit 2, there appeared to be no strong daily relationship between impingement rates and either temperature or dissolved oxygen (Figures III-5 and III-6). White perch impingement displayed an inverse relationship with seasonal temperature trends reflecting the movement of perch between shoals and the channel which is keyed to seasonal rise and fall of river temperatures. Minimums in the fluctuating low oxygen levels during the summer occasionally appeared to coincide with young-of-the-year tomcod impingement but no clear consistent relationship was found. Conductivity, dissolved oxygen, and temperature had no effect on the diel impingement patterns at Unit 3.

Conductivity was the only physical variable examined that was found to be strongly related to impingement. Examination of Unit 2 impingement/conductivity data in Figure III-7 reveals that impingement is not directly related to the level of conductivity but to movement of the salt front through the Indian Point region. Similar to previous years' data, impingement peaks correspond to conductivity peaks throughout the year except midsummer to fall, at which time the salt front is located in a semi-stable position north of Indian Point. White perch dominated winter, spring, and late-fall impingement collections, and impingement peaks generally occurred behind the retreating salt front (Table III-3). These periods correlate with data from standard stations which indicate white perch concentrations in the deeper channel water (Texas Instruments, 1974a). Atlantic tomcod impingement peaks in early winter and summer parallelled the movement of the salt front past Indian Point. Adult tomcod peaks generally preceded the incursion of the salt front in winter; young-of-the-year peaks fell in the leading edge of the salt front and were associated with conductivity peaks.

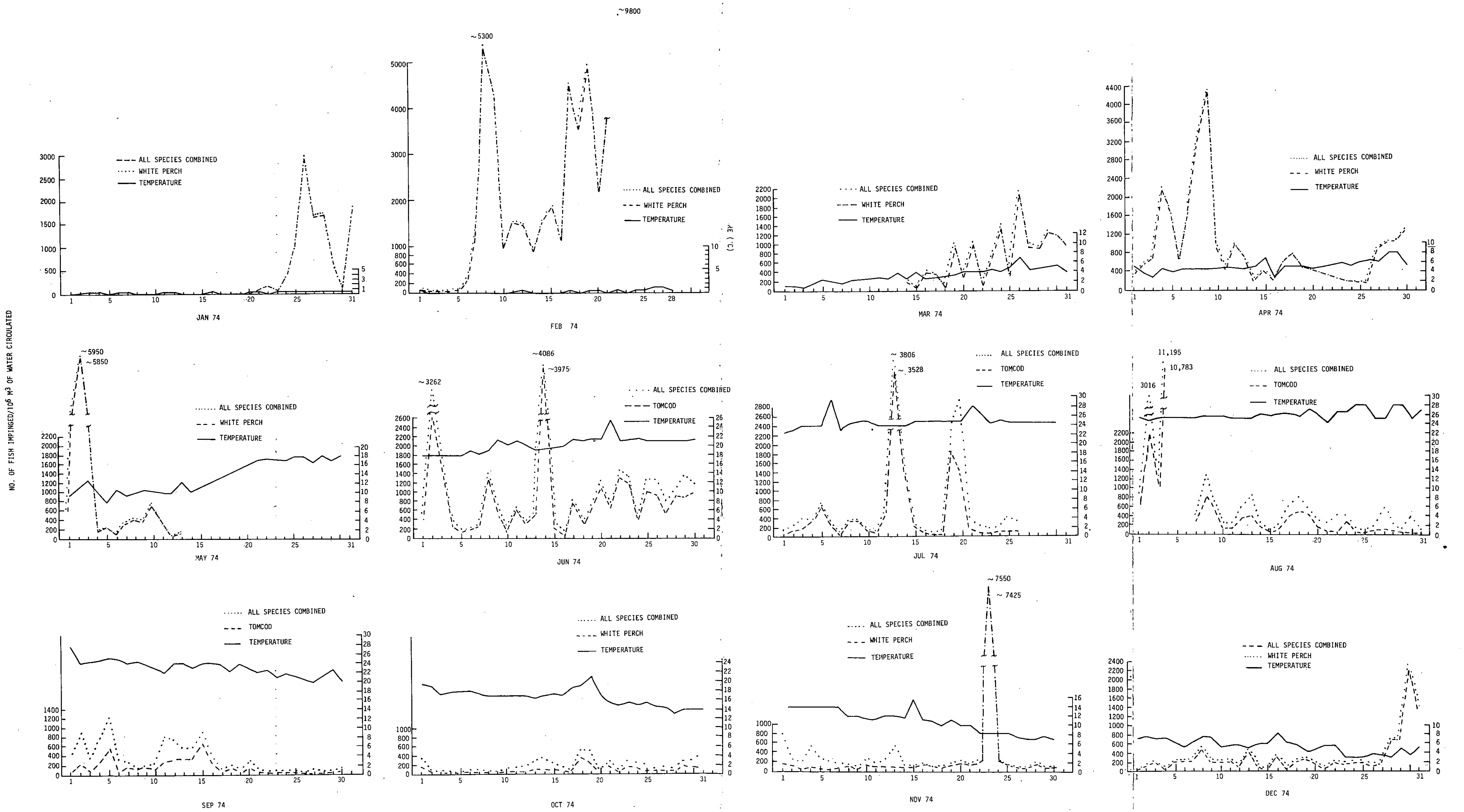

Figure III-5. Fish Impingement Rates and Temperature Measurements at Indian Point Unit 2 during 1974

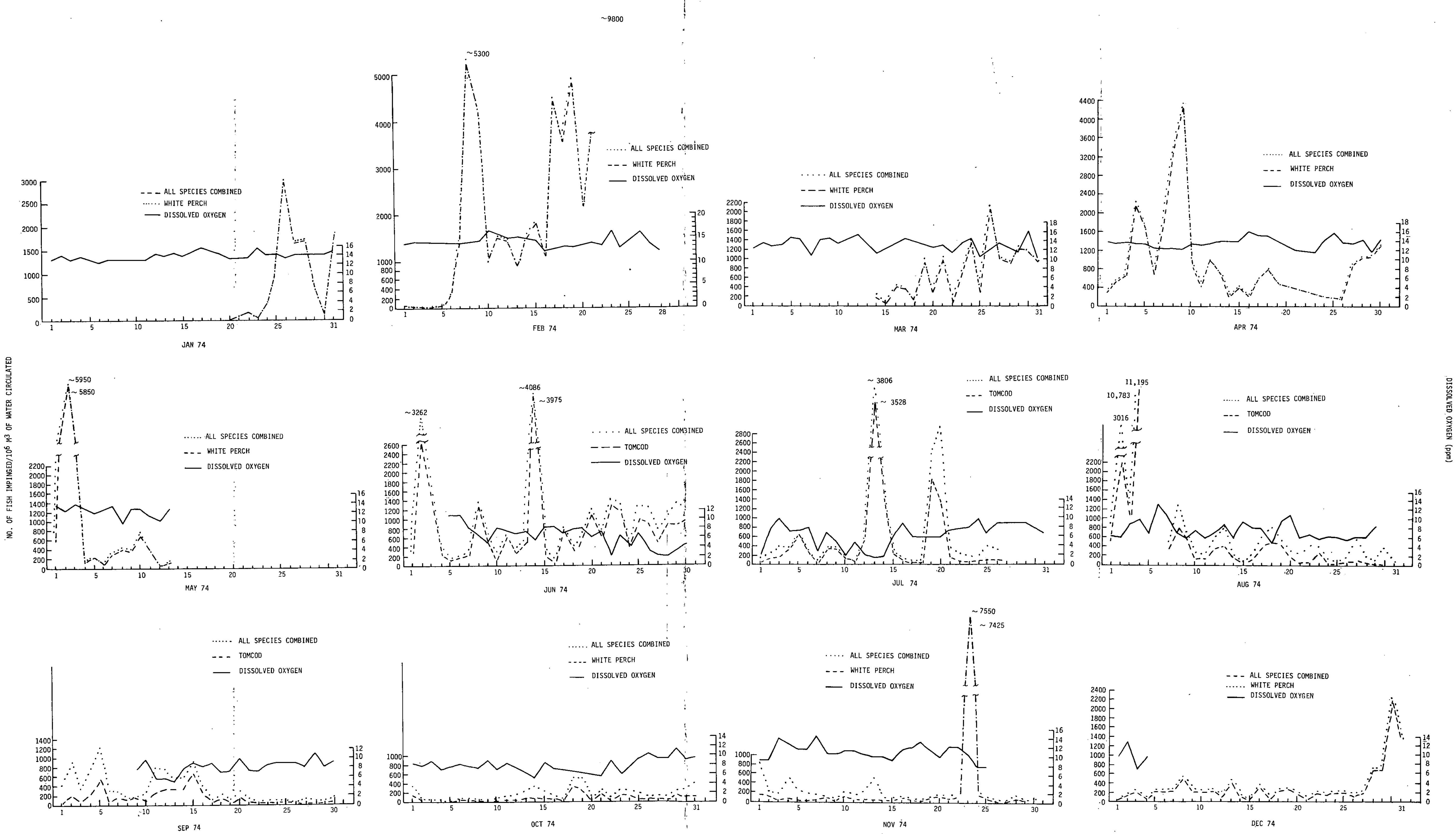

Figure III-6. Fish Impingement Rates and Dissolved Oxygen Measurements at Indian Point Unit 2 during 1974

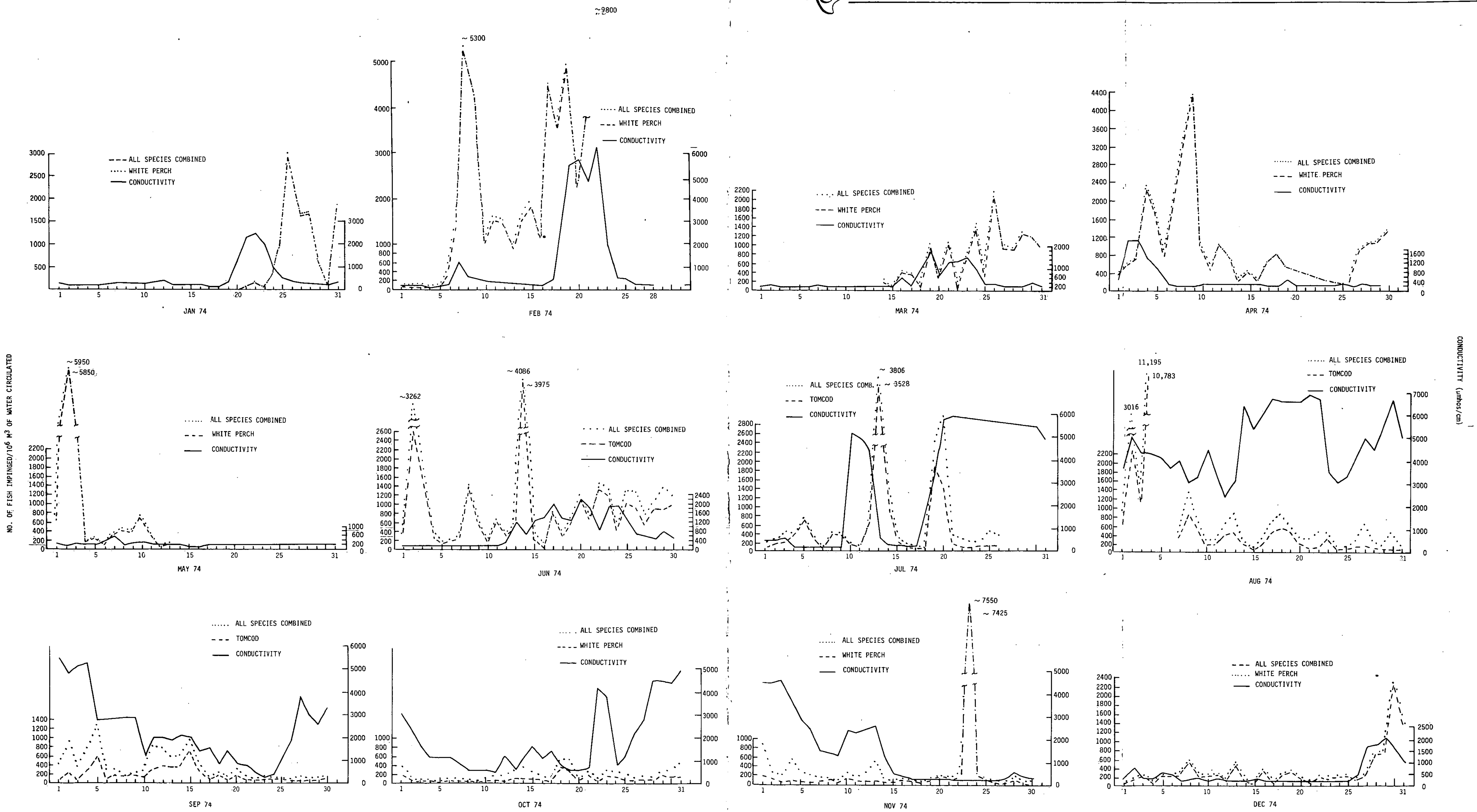

Figure III-7. Fish Impingement Rates and Conductivity Measurements at Indian Point Unit 2 during 1974

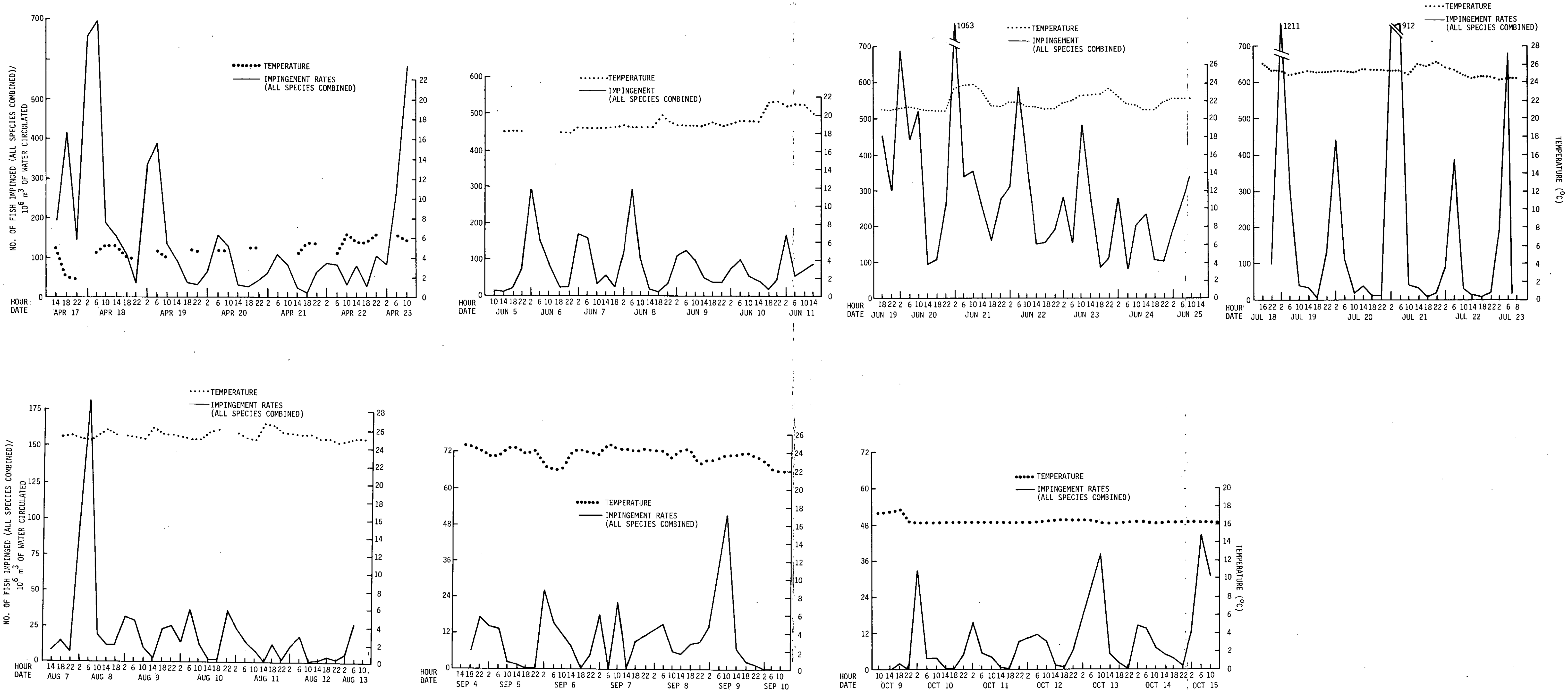

Figure III-8. Fish Impingement Rates and Temperature Measurements at Indian Point Unit 3 during 1974

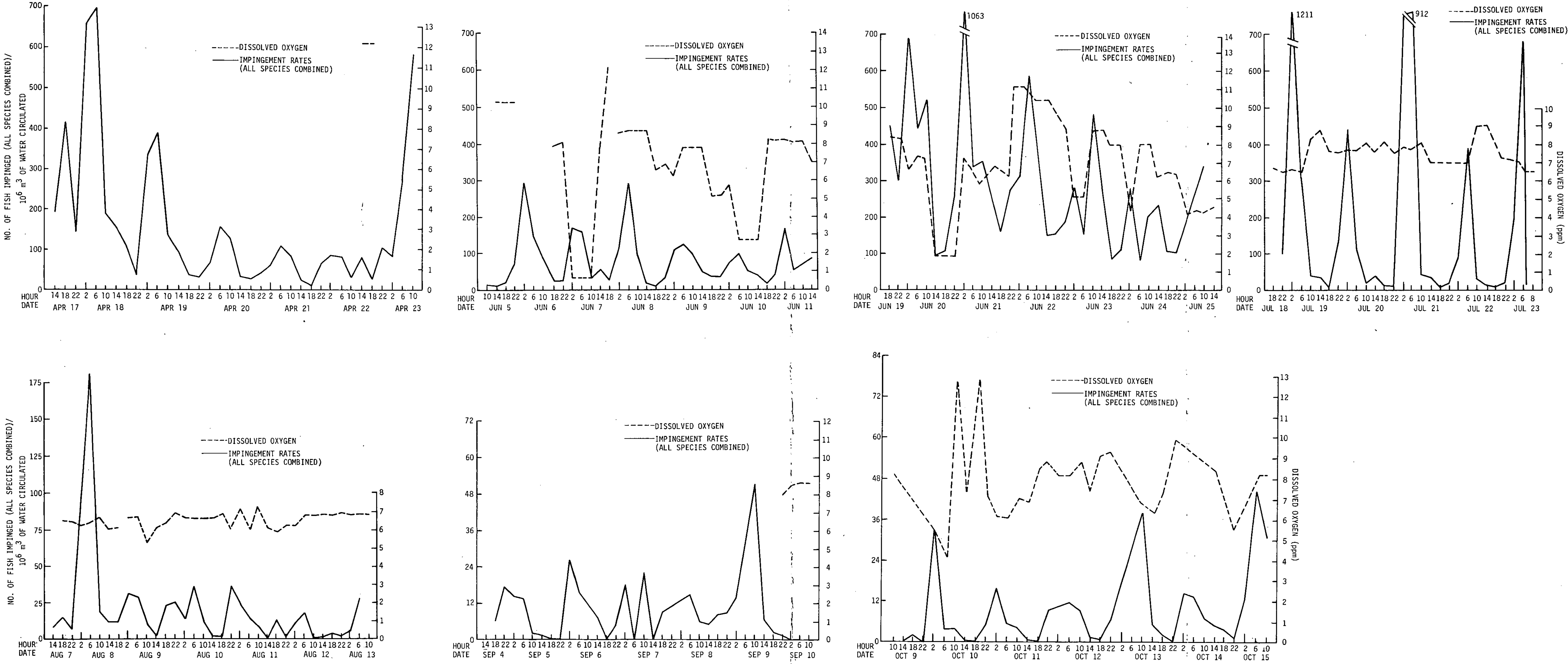

Figure III-9. Fish Impingement Rates and Dissolved Oxygen Measurements at Indian Point Unit 3 during 1974

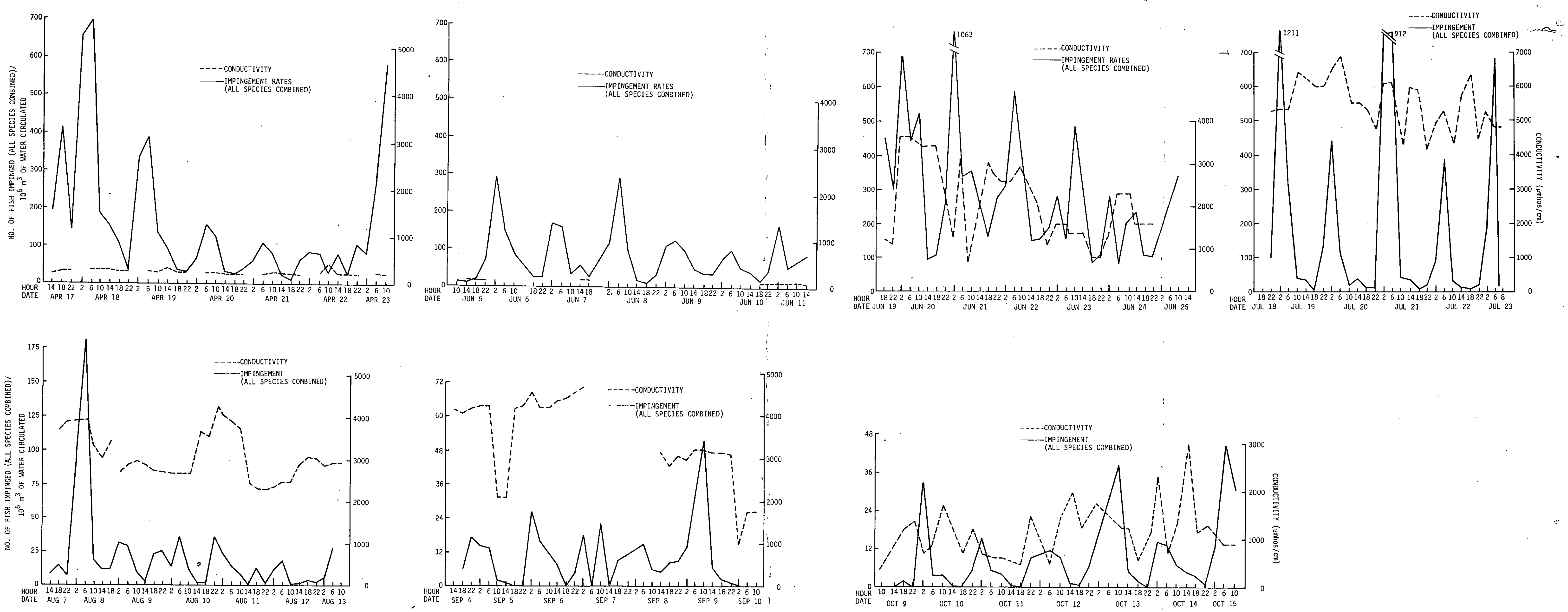

Figure III-10. Fish Impingement Rates and Conductivity Measurements at Indian Point Unit 3 during 1974

Table III-3

Number of Days on Which Major White Perch Impingement Peaks Followed Conductivity Peaks

Month	Impingement Lag (days)
Jan	6
Feb*	Variable
Mar	3
Apr	6
Oct*	Variable
Nov	3
Dec	1

*February and October impingement peaks roughly correspond to conductivity peaks.

The relationship of impingement peaks and the salt front is supported by increased CPUE at standard stations located near the salt front (Texas Instruments, 1974a, 1975b). The influence of conductivity on the concentration of fish and impingement may be related to preference of specific salinity ranges, predation on concentrated food organisms, or a physiological response of the fish to salinity changes.

In summary, it appears that white perch impingement peaks can be expected as the salt front recedes during fall, winter, and early spring. Peaks in tomcod impingement rates can be expected when the salt front approaches or remains in the area of Indian Point during early winter and summer. Dissolved oxygen and water temperature appear to have little effect on impingement. Water physical/chemical variables are not major factors affecting diel variation of impingement rates.

2. Diel and Tide Effects on Impingement

Daily impingement rates at Unit 3 were highest between the hours of 2200 and 0600 (Figure III-11). Tide stage had no apparent impact on impingement. While diel patterns of fish impingement are obvious, the precise nature of those patterns is uncertain. One species generally dominated Unit 3 collections, accounting for the diel impingement peaks (Table III-4). No significant variation in impingement time was found among major species.

Variation in the magnitude of the diel peak was related to the location of the salt front discussed previously. Similar nighttime impingement peaks were identified at Unit 1 by air curtain-associated tests during 1973 (Texas Instruments, 1974b) and at the Albany Steam Electric Generating Station (Lawler et al, 1975). Possible causes of the peaks include movement of fish between channel and shoal, vertical migration, and changes in activity levels.

The results of this study could be of great value when applied to fish protective measures. Effective fish protective devices could be employed for maximum efficiency between the hours of 2200 and 0600, saving fuel and maintenance costs. The data suggest that a fish protective procedure must be effective at night if it is to reduce total impingement significantly.

Table III-4

Major Impinged Species during 1-Week Operation of Indian Point Unit 3 Circulators Each Month of 1974*

Month	Species	Peak Time
Apr	White perch	0600/2200
May	Atlantic tomcod	0600
Jun	Atlantic tomcod	0200/1000
Jul	Atlantic tomcod/bay anchovy	0200
Aug	Atlantic tomcod	0600/2200
Sep	Atlantic tomcod	2200-1000 (erratic)
Oct	Alewife	0200

*Time of major/minor peak also listed.

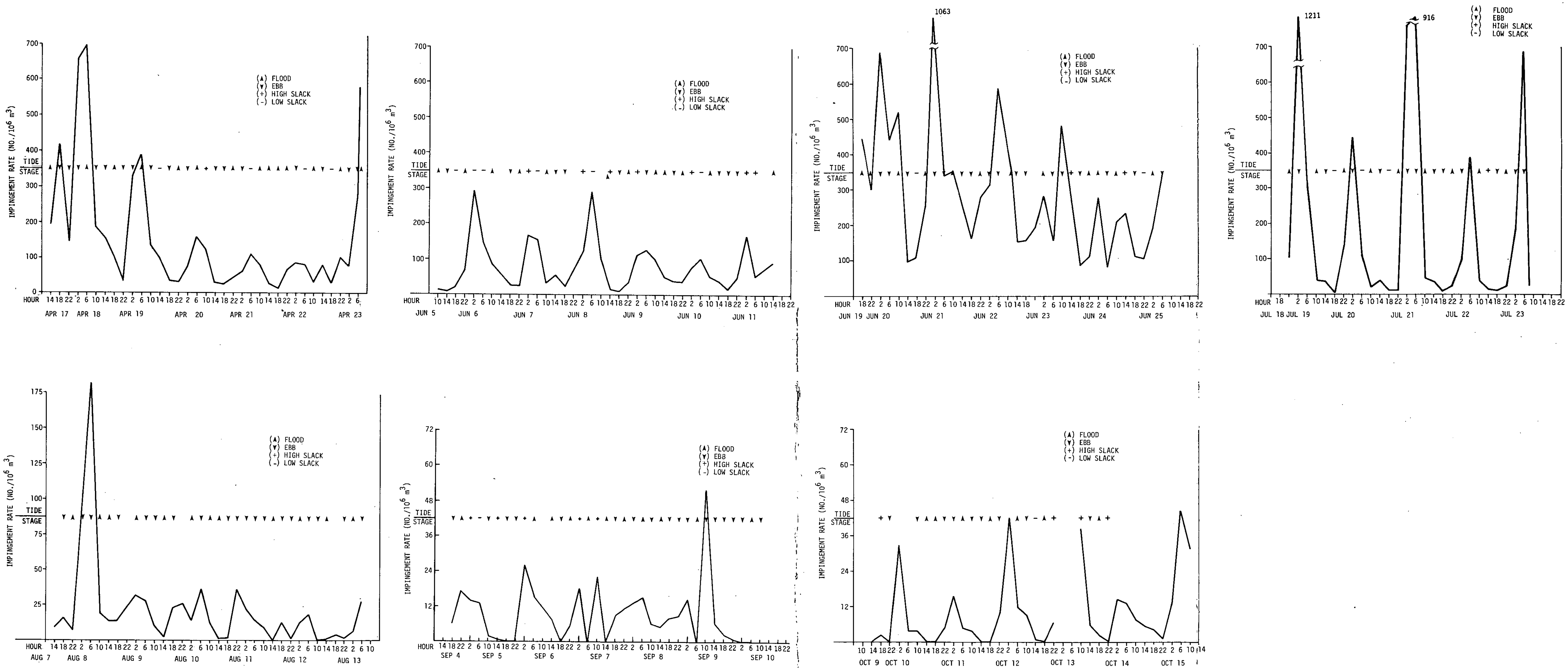

Figure III-11. Diel and Tide Effects on Impingement at Unit 3

3. Plant Operational Variables

a. Thermal Recirculation

Depending on season and thermal history, fish may respond to a thermal plume in one of several ways: avoid or select the plume, show stress and physiological debilitation, or demonstrate no discriminatory reaction. Therefore, the spatiotemporal location of the thermal plume with respect to the water intake structure might influence impingement.

No consistent relationship between impingement and recirculation was found at Unit 3 (Figures III-12 and III-13). Any potential effect of the thermal plume appears to have been superseded by the dominant diel impingement cycle (Figure III-11). Spring and summer thermal recirculation, as defined for this analysis, did not consistently or significantly increase or decrease impingement at Unit 3; however, the influence of thermal recirculation should not be entirely ruled out until a more accurate measure of thermal recirculation can be applied. During the winter, the attractive potential of the thermal plume may be greatest and recirculation could present a problem; Unit 3 data for this period were not available.

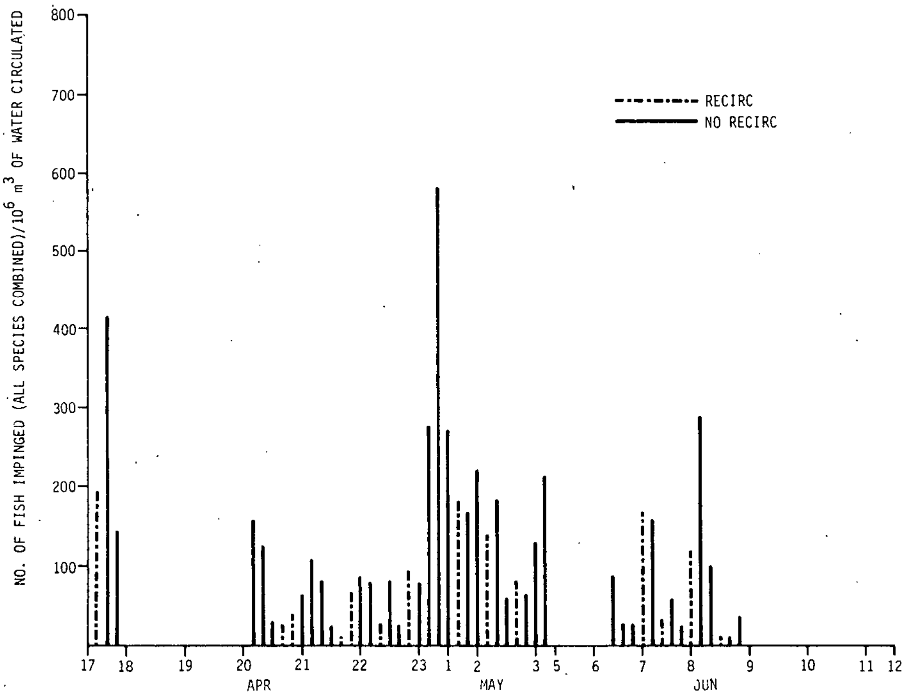

Figure III-12. Impingement Rates at Unit 3 by Washing during Periods of Thermal Recirculation in Spring 1974

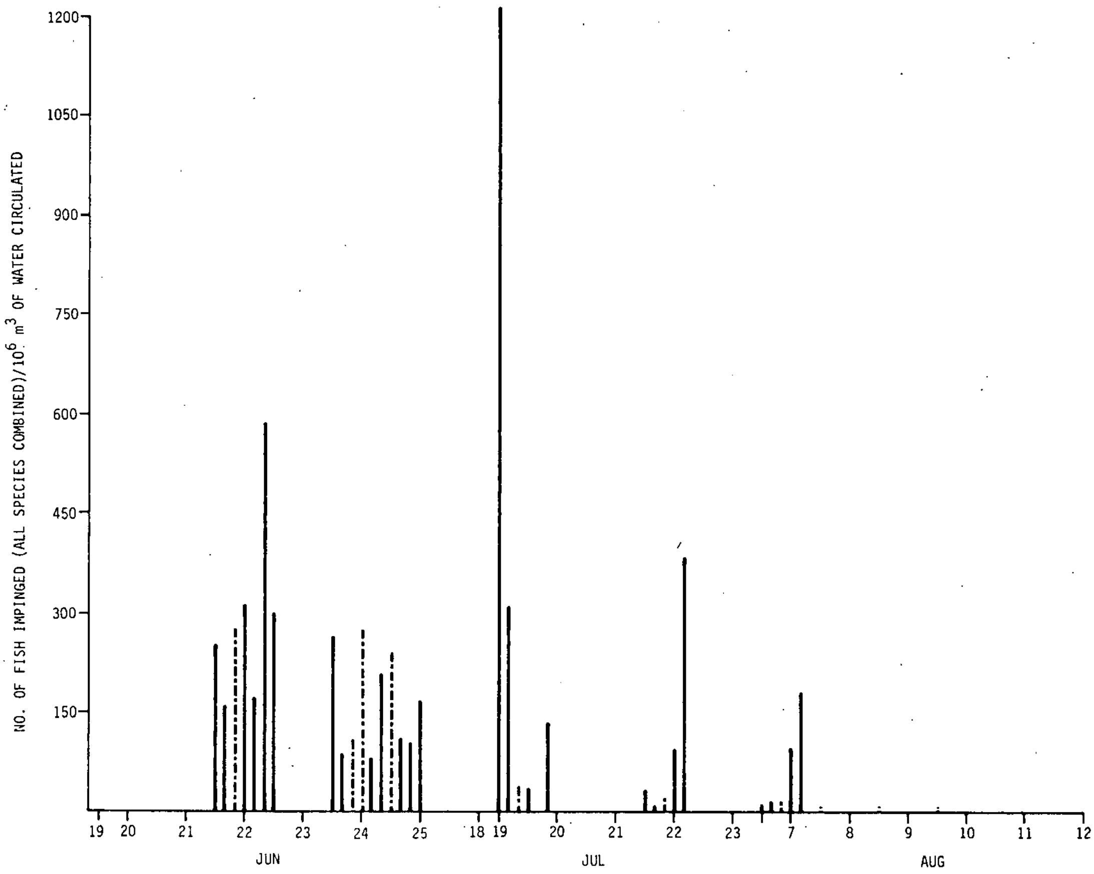

Figure III-13. Impingement Rates at Unit 3 by Washing during Periods of Thermal Recirculation in Summer 1974

b. Approach Velocity and Head Loss

The relationship between theoretical and measured approach velocities and head loss was discussed in the 1972-1973 Impingement Report (Texas Instruments, 1974b). The average velocity measurements taken on all screens are presented in Appendix D.

There were few significant correlations between the independent variables (head loss and measured average approach velocities) and impingement rates of striped bass, white perch, Atlantic tomcod, and all species combined (Table III-5). The most common significant correlations occurred between impingement rates and head loss. Average approach velocities correlated significantly with impingement rates only four times.

Only striped bass (< 1% of the collections) spring impingement rates on the unbasketed screens correlated with both independent variables.

Table III-5

Significant Correlations between Impingement Rates and Head Loss and Average Measured Approach Velocities

Season	Screens	Circulator Flow (%)	Species*	Correlation with Impingement Head Loss (Δh)	Approach Velocities (V_a)
Winter	21, 22, 24, 25	60	SB	No	No
			WP	No	No
			AT	No	No
			AS	No	No
Spring	21, 22, 24, 25	60	SB	Yes	Yes
			WP	No	Yes
			AT	No fish	No fish
			AS	No	Yes
	23, 26		SB	No	No
			WP	No	No
			AT	No fish	No fish
			AS	No	No
	23, 26	100	SB	No	No
			WP	No	No
			AT	No	Yes
			AS	No	No
Summer	21, 22, 24, 25	100	SB	Yes	No
			WP	No	No
			AT	No	No
			AS	No	No
	23, 26		SB	No	No
			WP	No	No
			AT	No	No
			AS	No	No
Fall	21, 22, 24, 25	60	SB	Yes	No
			WP	Yes	No
			AT	Yes	No
			AS	Yes	No
	23, 26		SB	No	No
			WP	No	No
			AT	No	No
			AS	No	No

*SB = striped bass
WP = white perch
AT = Atlantic tomcod
AS = all species combined

The greater number of significant correlations between head loss and impingement rates than between approach velocity and impingement rates may suggest that head loss is, in fact, the dependent variable influenced by numbers of fish impinged on a screen. If impingement rates are independent of head loss and the observed approach velocities, those two variables within the present operational conditions at Indian Point would have little effect on impingement rates.

The range of approach velocities found at Unit 2 appear to have had little influence on impingement rates. The minimum velocities measured may have been above the threshold which commonly impinged species and life stages are able to avoid. It should be noted that high debris loads apparently negate the effect of winter flow reductions on approach velocity. It is also possible that volume and fish abundance are more important factors influencing the magnitude of impingement rates than is velocity. Differences between species composition, life stage, and metabolic activity during winter (60% flow) and the rest of the year (100% flow) make comparisons of velocity effects between the two periods difficult, if not inappropriate.

Velocity measurements showed a high degree of variability over the screen surface, with several high and low velocity regions. There were no significant differences between vertical mean velocities in 10 of the 16 cases tested (Tables III-6 and III-7). Where significant differences occurred at basketed screens, velocities at the surface were generally higher (Figure III-14); unbasketed screens were more variable, but lower velocities occurred near the bottom (Figure III-15). Tide, air curtain, and flow rate did not affect the vertical profiles.

Table III-6

Significant ($\alpha = 0.05$) Differences between Mean Horizontal Velocities Measured on Basketed Screens at Unit 2 in 1974

Tide	Air Curtain Condition	Flow (%)	Distance from River Bottom (ft)	Mean Horizontal Velocity (ft/sec)
High	On	60	21.5	No significant differences between depths
			15.5	
			9.5	
			3.5	
High	On	100	21.5	1.74
			15.5	1.20
			9.5	0.82
			3.5	0.72
High	Off	60	21.5	1.81
			15.5	1.60
			9.5	1.16
			3.5	0.72
High	Off	100	21.5	No significant differences between depths
			15.5	
			9.5	
			3.5	
Low	On	60	21.5	No significant differences between depths
			15.5	
			9.5	
			3.5	
Low	On	100	21.5	2.18
			15.5	1.49
			9.5	0.53
			3.5	0.68
Low	Off	60	21.5	0.84
			15.5	1.32
			9.5	0.80
			3.5	0.62
Low	Off	100	21.5	No significant differences between depths
			15.5	
			9.5	
			3.5	

*Indicates significantly lower mean velocity.

Table III-7

Significant ($\alpha = 0.05$) Differences between Mean Horizontal Velocities Measured on Unbasketed Screens at Unit 2 in 1974

Tide	Air Curtain Condition	Flow (%)	Distance from River Bottom (ft)	Mean Horizontal Velocity (ft/sec)
Low	Off	60	26	0.51
			22	1.25
			18	0.92
			14	1.05
			10	0.82
			6	0.66
			2	0.75
Low	Off	100	26	0.59
			22	0.68
			18	0.55
			14	0.89
			10	1.30
			6	0.83
			2	0.56
Low	On	60	26	No significant differences between depths
			22	
			18	
			14	
			10	
			6	
			2	
Low	On	100	26	No significant differences between depths
			22	
			18	
			14	
			10	
			6	
			2	
High	On	60	26	No significant differences between depths
			22	
			18	
			14	
			10	
			6	
			2	
High	On	100	26	No significant differences between depths
			22	
			18	
			14	
			10	
			6	
			2	
High	Off	60	26	No significant differences between depths
			22	
			18	
			14	
			10	
			6	
			2	
High	Off	100	26	No significant differences between depths
			22	
			18	
			14	
			10	
			6	
			2	

*Indicates significantly lower mean velocity.

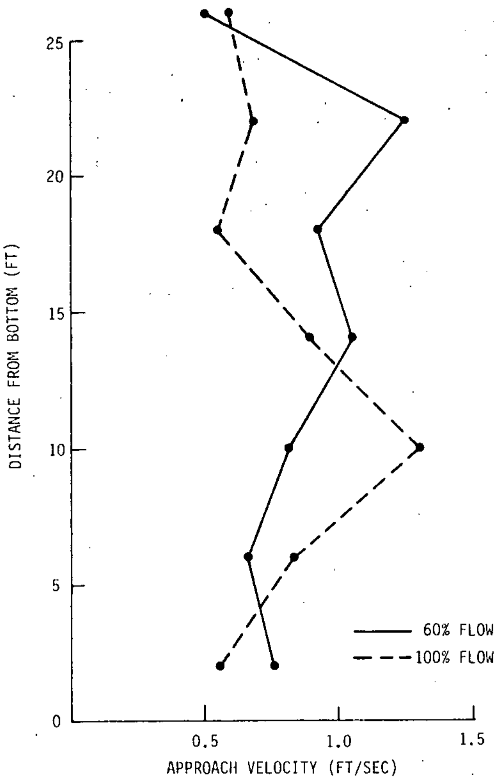

Figure III-14. Vertical Velocity Profiles at Basketed Unit 2 Screens where Variation Was Significant

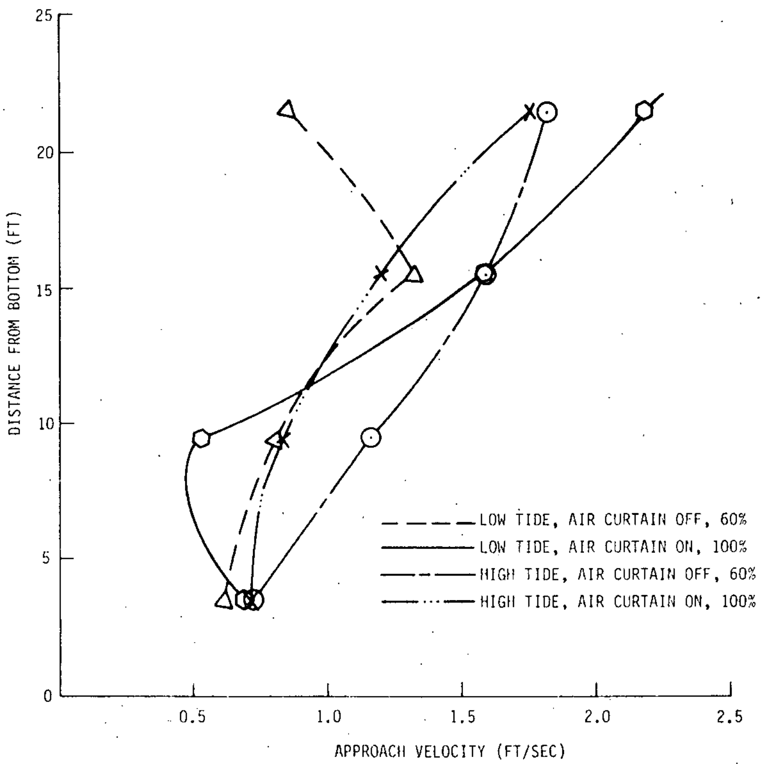

Figure III-15. Vertical Velocity Profiles at Basketed Screens where Significant Variation Occurred. (Both cases are at low tide with air curtain off)

In summary, approach velocities in the Indian Point operational mode and head loss appear to have little effect on impingement rates at Indian Point. The vertical velocity gradient shown by profile measurements may account for the higher impingement rates at the surface, and this may be a function of greater volume filtered at the surface rather than a direct function of velocity. These data indicate that any method employing velocity to reduce impingement might require velocity vector manipulation rather than straightforward velocity reduction.

4. Fish Condition Studies

a. Histopathology Survey

Some form of histopathology occurred in 94% (136) of all fish examined: 58% displayed moderate to severe tissue damage (Tables E-4, E-5, and E-6 of Appendix E). In the 1972-1973 Indian Point Impingement Report (Texas Instruments, 1974b), a lower overall incidence of pathological conditions (67%) and considerably fewer fish with moderate to severe tissue damage (20%) were reported.

Although gill pathology occurred in 46.9% of the fish, none of the observed damage contributed greatly to the Pathological Index (PI) assigned to each animal; gill abnormalities contributed approximately 1.3 units to the PI for each fish with a gill pathology. The incidence of gill pathology in specimens analyzed is summarized in Table III-8.

Table III-8

Incidence of Major Gill Pathology in Seined and Impinged Fish

Population	Total Affected [n(%)]*	Hyperplasia [n(%)]	Congestion [n(%)]	Parasites [n(%)]	Clubbing [n(%)]
Seined	27 (36)	19 (25)	3 (4)	8 (11)	9 (12)
Impinged	31 (45)	22 (32)	9 (13)	14 (20)	5 (7)
Total	58 (40)	41 (28)	12 (8)	22 (15)	14 (10)

*n = number of fish with designated pathology
% = percent of group of fish with designated pathology

Spleen histopathology was observed in 51.7% of the animals analyzed, contributing an average 1.6 units to the assigned PI of each animal. Seined fish showed a higher incidence (63.2%) of spleen pathology than did impinged fish (39.1%). Table III-9 summarizes the incidence of various spleen pathologies. These histopathological conditions of the spleen are symptomatic of poor oxygen supply, stagnation and degeneration of blood, and splenic response to chronic systemic infestation, portal congestion, and tissue-destructive processes.

Table III-9

Incidence of Spleen Pathology in Seined and Impinged Fish

Population	Total Affected [n (%)]*	Necrosis [n (%)]	Vascular Congestion [n (%)]	Amyloidosis [n (%)]	Pigment Deposits [n (%)]
Seined	48 (63)	45 (59)	2 (3)	2 (3)	26 (34)
Impinged	27 (39)	17 (25)	7 (10)	3 (4)	32 (46)
Total	75 (52)	62 (43)	9 (6)	5 (3)	58 (40)

*n = number of fish with designated pathology
%= percent of group of fish with designated pathology

Some form of liver abnormality was found in 76.6% of the fish examined, contributing an average 1.5 units to the assigned PI for each affected specimen. Although there were substantial differences between seined and impinged fish with respect to specific types of histopathology, there was no difference in the overall incidence of liver histopathology between the two groups. The incidence of liver histopathology in specimens examined is summarized in Table III-10. These forms of pathology can result from severe bacterial or viral infection, toxic injury, and ischemia. Cytoplasmic and nuclear degeneration indicated cell death substantially preceding fixation. All fish were alive at the time of preservation. A significant percentage of fish in both the impinged (44.6%) and seined (36.4%) groups showed combinations of common forms of liver histopathology (bizzarre cells, cytoplasmic vacuolation, PAS-positive droplets, and necrosis). Other less frequent forms of pathology included congestion (4.8%), cloudy swelling (2.8%), and edema (6.9%). Although it is suspected that much of the observed liver histopathology is interrelated, there is insufficient confirmation to make any definitive diagnosis.

Table III-10

Incidence of Liver Pathology in Seined and Impinged Fish

Population	Total Affected [n (%)]*	Necrosis [n(%)]	Bizarre Cells [n (%)]	Cytoplasmic Vacuolation [n (%)]	Pigment Deposits [n (%)]
Seined	55 (72)	7 (9)	23 (30)	31 (41)	8 (11)
Impinged	56 (81)	12 (17)	30 (43)	15 (22)	21 (30)
Total	111 (77)	19 (13)	53 (37)	46 (32)	29 (20)

*n = number of fish with designated pathology
%= percent of group of fish with designated pathology

Kidney histopathology was observed in 59.3% of the specimens examined, contributing 2.2 units on the average to the assigned PI for each animal showing kidney damage. Also, there was a substantial difference in the overall incidence of histopathology between seined (53.9%) and impinged (65.2%) fish; this difference, however, does not account for the specific types of abnormalities or the relative severity of any of these conditions. Table III-11 summarizes the incidence of renal pathology in the group of fish examined. As might be expected, a large percentage (approximately 40%) of the fish examined displayed combinations of the more general forms of renal histopathology. These conditions probably are interrelated and, as such, are part of a pathological syndrome. Unfortunately, because of the limitations inherent in histopathologic analyses, the origin of most of the observed pathology cannot be specified.

Table III-11

Incidence of Renal Pathology in Seined and Impinged Fish

Population	Total Affected [n (%)]*	Edema [n (%)]	Cloudy Swelling [n (%)]	Amyloidosis [n (%)]	Casts [n (%)]	Necrosis [n (%)]
Seined	41 (54)	23 (30)	16 (21)	8 (11)	25 (33)	13 (17)
Impinged	45 (65)	9 (13)	28 (41)	12 (17)	34 (49)	2 (3)
Total	86 (59)	32 (22)	44 (30)	20 (14)	59 (41)	15 (10)

*n = number of fish with designated pathology
%= percent of group of fish with designated pathology

The 1974 specimens were comprised of considerably larger fish (average weight, 14.8 g) than those examined in 1972-1973 (Texas Instruments, 1974b) and, although there were exceptions, the larger fish generally showed a consistently higher Pathological Index (Table E-8 in Appendix E). Although the incidence of pathology was somewhat higher in impinged fish (95.7%) than in seined specimens (92.1%), the mean PI for these two groups was identical (PI = 4). Kidney damage was clearly the most severe form of histopathology recorded (Table E-8 in Appendix E), with liver histopathology contributing significantly to the PI, particularly in the larger fish, and gill and spleen damage contributing least.

Excluding the spleen, all organ systems in impinged fish showed a higher percentage of pathology than did those in seined fish (Table III-12), which may indicate that an overall weaker segment of the population is being impinged; however, the high level of pathology in the population as a whole may void the idea of "weaker" or "stronger" in this situation. The use of percentages also neglects the relative severity and synergism of various forms of pathology, which probably confounds any comparative statements about condition.

b. Gill Parasite Study

During the summer salt intrustion, the isopod gill parasite *Lironica ovalis* is introduced into the Hudson with migrating host bluefish.

Table III-12

Incidence and Percent Occurrence of Pathological Symptoms in Fish Examined from Beach Seines and Indian Point Intake Screens

Population	Gill [n (%)]*	GBD [n (%)]	Spleen [n (%)]	Liver [n (%)]	Kidney [n (%)]
Seined	27 (36)	7 (9)	48 (63)	55 (72)	41 (54)
Impinged	31 (45)	31 (45)	27 (39)	56 (81)	45 (65)
Total	58 (40)	38 (26)	75 (52)	111 (77)	86 (59)

*n = number of fish with designated pathology
%= percent of group of fish with designated pathology

While in the river, *Lironica* transfers to the gills of white perch and striped bass, causing hemorrahaging and reducing the area for respiratory gas exchange. This can severely affect the general physiological state and swimming ability. TI first reported on this in the first Indian Point Annual (Texas Instruments, 1973a).

As indicated in Tables III-13, III-14, III-15, and III-16, there were significant differences in parasitic infestation between impinged and seined fish at the 95% confidence level for each species. Impinged white perch and striped bass had a higher incidence of parasitism than did river fish, while the frequency of parasites on impinged bluefish was lower than on river bluefish (Figures III-16, III-17, and III-18). Smaller white perch and striped bass in both groups had fewer parasites than did larger fish of the species (Figure III-19). These results agree closely with the 1973 results (Texas Instruments, 1973a). Parasite frequency was not compared among bluefish size classes since, at any period, almost all bluefish were the same length.

Table III-13

Gill Parasite Infestation in Impinged and Beach Seined Bluefish Collections

Population	No. Infested	No. Not Infested	Total	Percent Infested
Intake screen (impinged)	62	73	135	45.93
Seined river (control)	70	27	97	72.16
Total	132	100	232	

Table III-14

Gill Parasite Infestation in Impinged and Beach Seined Striped Bass Collections

Population	No. Infested	No. Not Infested	Total	Percent Infested
Intake screen (impinged)	15	152	167	8.98
Seined river (control)	5	166	171	2.92
Total	20	318	338	

Table III-15

Gill Parasite Infestation in Impinged and Beach Seined White Perch Collections

Population	No. Infested	No. Not Infested	Total	Percent Infested
Intake screen (impinged)	46	616	662	6.95
Seined river (control)	1	231	232	0.43
Total	47	847	894	

Table III-16

Significant Relationships (α = 0.05 Significance Level) between River and Impinged Fish from 2 x 2 Contingency Tables

Species†	Chi-Square Values*	Site of Higher Infestation
White perch	15.85	Impingement
Striped bass	5.57	Impingement
Bluefish	14.65	River

*One degree of freedom

†Bluefish were of almost homogeneous length at any point in time; striped bass and white perch length classes were combined.

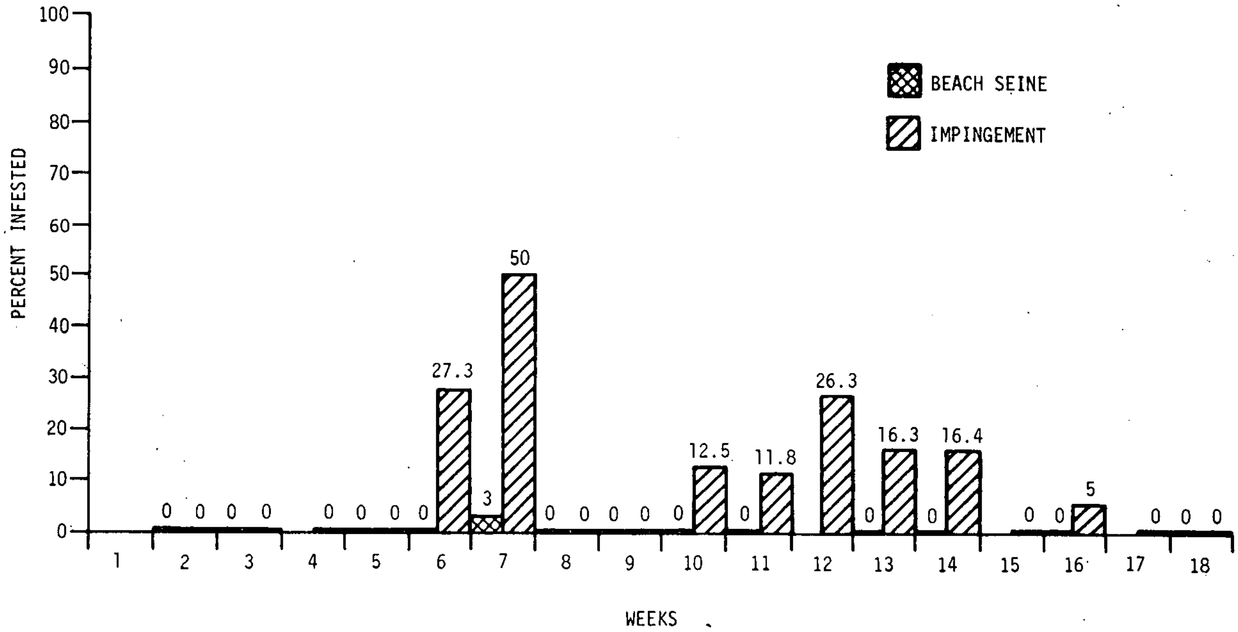

Figure III-16. Percent Infestation for White Perch by Week. (Only samples with at least five fish were plotted)

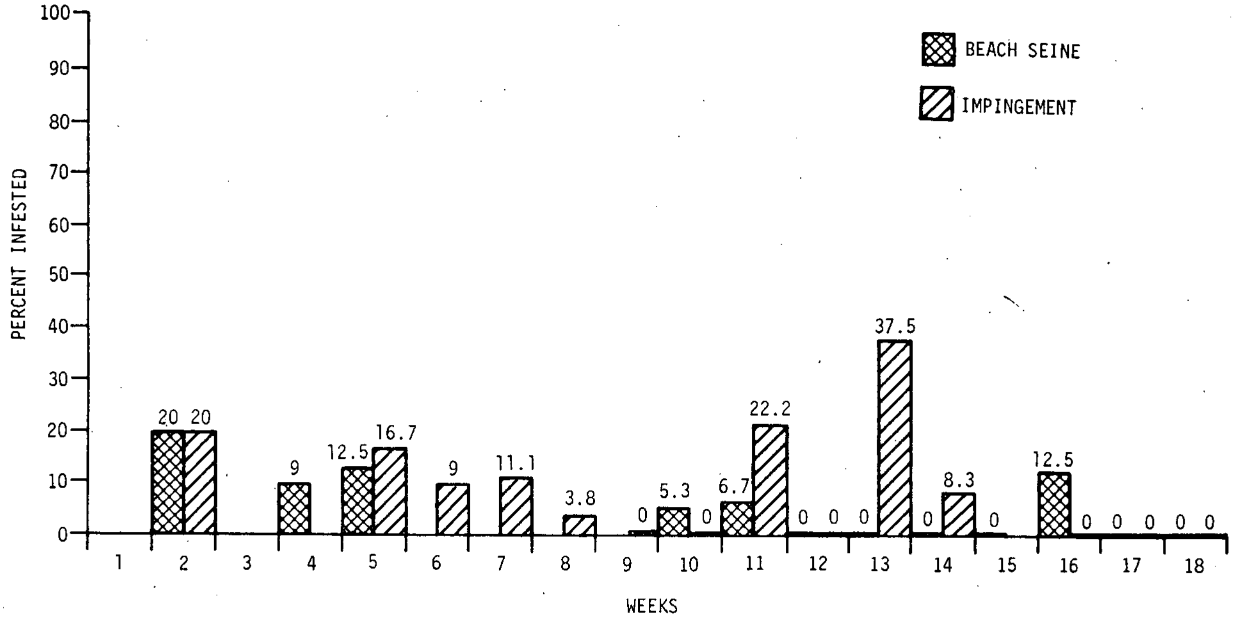

Figure III-17. Percent Infestation for Striped Bass by Week. (Only samples with at least five fish were plotted).

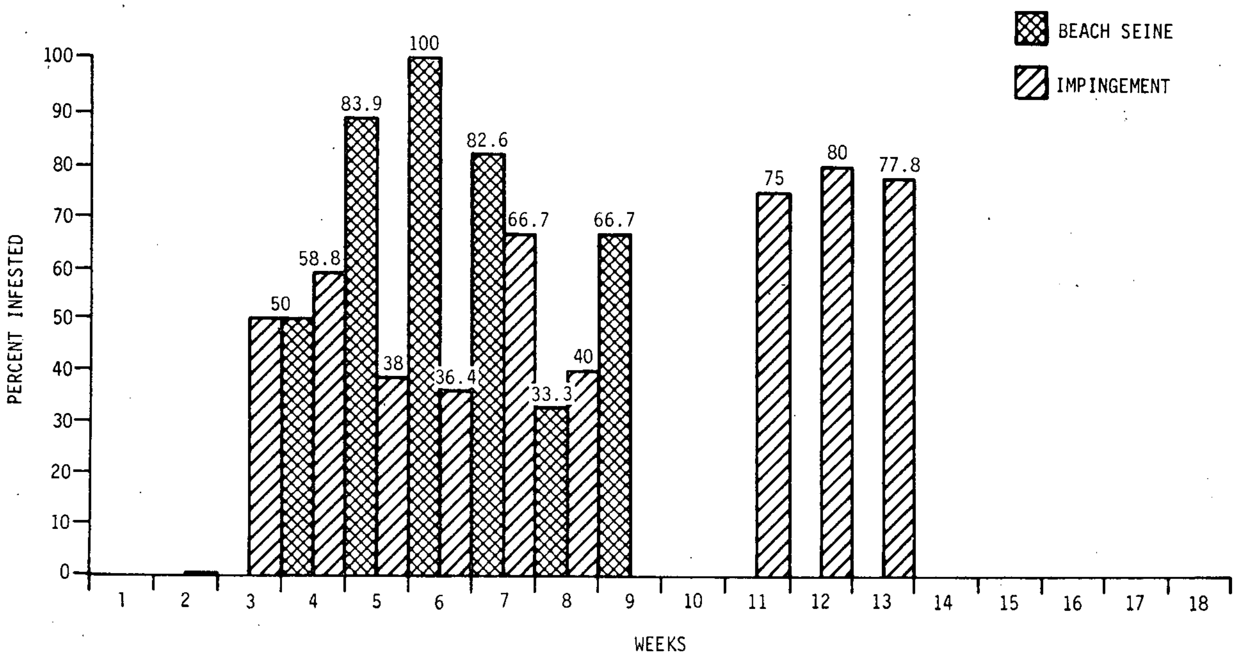

Figure III-18. Percent Infestation for Bluefish by Week. (Only samples with at least five fish were plotted)

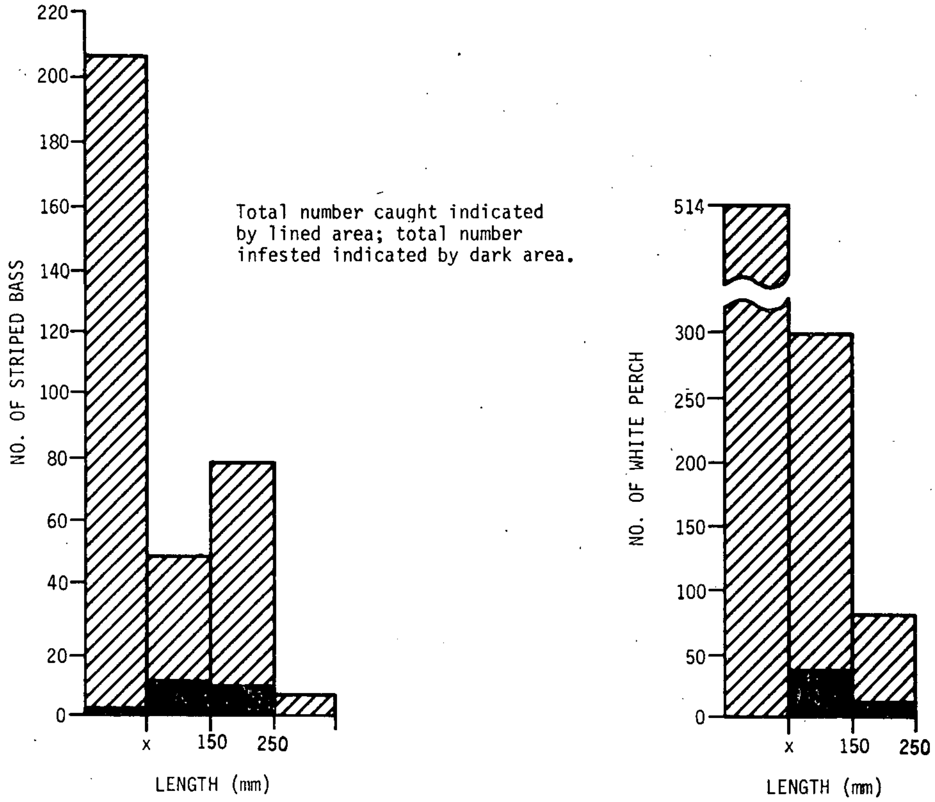

Figure III-19. Catch and Infestation Distribution by Length Class for Striped Bass (left) and White Perch (right)

Since impinged fish had a higher incidence of *Lironica* infestation, it might be inferred that impinged white perch and striped bass populations are generally weaker than "normal" river fish of the same species; however, it has not been established whether the inferred weakened condition increases susceptibility to parasites or whether parasites induce the poor condition. By the same reasoning, it would be inferred that parasite-weakened bluefish are less susceptible to impingement since river fish had a higher incidence of *Lironica* infestation; this so contradicts the inference made for white perch and striped bass that it becomes apparent that the relationships between host, predator, and environment are not entirely understood. Therefore, caution must be exercised in making conclusions concerning impingement and parasitism since the higher parasite infestation of impinged fish may have been an artifact of impingement duration (up to 24 hr). It can be postulated, however, that bluefish, a primary host of *Lironica*, has developed a tolerance for the parasite and that white perch and striped bass, as only incidental hosts, are more stressed by *Lironica* parasitism, which thus contributes to their impingement; i.e., the intake screens may be acting as selective predators on infested white perch and striped bass.

c. Gas Bubble Disease Potential

Histograms of percent nitrogen and oxygen saturation (Figure III-20) show that the effluent saturation levels were consistently higher than the intake levels. (For a list of dissolved nitrogen and oxygen concentrations in intake and effluent water samples, refer to Tables F-1 and F-2 of Appendix F.) Oxygen was never more than 95% saturated at the intakes, but effluent levels surpassed 100% in four of five cases when the air curtain was on and two of five cases when the air curtain was off. Intake and effluent nitrogen concentrations often exceeded 100% saturation.

Intake water subjected to rapid heating becomes supersaturated because gas solubility decreases as water temperature increases and there is no instantaneous gas equilibration (volumetric decrease) to the higher temperature. Supersaturated gas levels may appear in aquatic regions subject to high mixing rates. Fish exposed to critical levels of supersaturated dissolved gases (nitrogen and/or oxygen) may develop gas bubble disease (DeMont and Miller, 1971; Marcello, 1974; Miller, 1973); this occurs when the body fluids of fish become supersaturated and excess gases leave solution during equilibration, forming bubbles in the blood and tissues which accumulate in constricted areas and may be lethal due to circulatory interference.

Conditions conducive to development of gas bubble disease (GBD) in fish ($\geq$110% saturation of dissolved gases) occurred in seven effluent samples. These samples were collected inside the discharge canal, in which case dilution or accelerated equilibration of dissolved gases might have been expected because of release of water through the discharge jets.

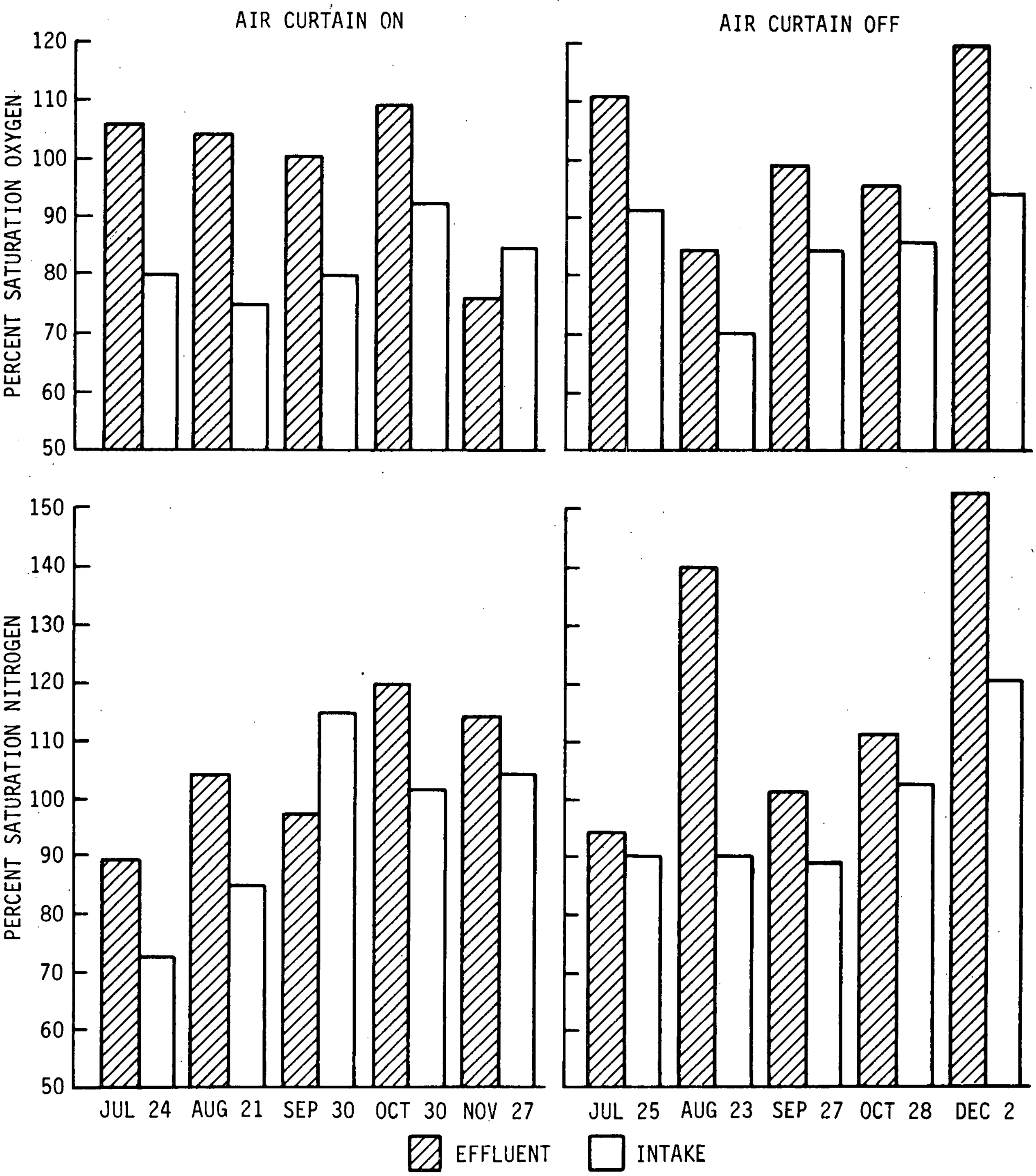

Figure III-20. Dissolved Nitrogen (lower) and Oxygen (upper) in Unit 1 Intake and Effluent Canal. [Data are surface/bottom averages for one monthly sample with air curtain on (left) and off (right)]

Apparent gas accumulation was observed in the gill lamellae of 26% of fish subjected to histopathological analysis (Table E-7, Appendix E). The incidence of lamellar gas bubbles and 95% confidence intervals were 9.2% (5.9-12.5%) for seined fish and 44.9% (33.2-56.7%) for impinged fish. This condition was morphologically distinct and easily identified by separating the respiratory epithelium from the supporting and vascular components of the gill lamellae (Figures III-21 and III-22). The severity of the condition varied not only with the number of lamellae involved but with the extent to which the respiratory epithelium was separated. However, no specimens were included in our count unless numerous lamellae on several filaments were affected and the epithelium was separated along most of the length of involved lamellae. A significant ($\alpha = 0.05$) χ^2 value of 23.87 was obtained for differences in lamellar gas bubble incidence between impinged and seined fish (Table III-17). The presence of gas bubbles in the roof of the mouth (buccal cavity) was extremely difficult to verify because of the natural tendency for separation of epithelium from underlying connective tissue during dissection and processing. Only isolated well-defined epithelial separations were considered to be due to gas accumulation within the tissue. Using these criteria, only 9.0% of the fish had gas bubbles in the buccal roof.

Epithlial separations and accumulation of gas within the gill lamellae and buccal roof are considered to be good diagnostic characteristics of gas bubble disease. Less specific histopathology such as renal tubular necrosis, edema, and abnormal architecture in both spleen and liver have also been associated with this disease. While all of these histopathological changes have been noted in this group of specimens, it should not be assumed that all of them are related and therefore symptomatic of gas bubble disease. Major reservations in making positive diagnosis were that a large percentage (66%) of the fish displaying gas bubbles in the gills did not display buccal roof lesions and there were no observations of gross symptoms, such as exophthalmos

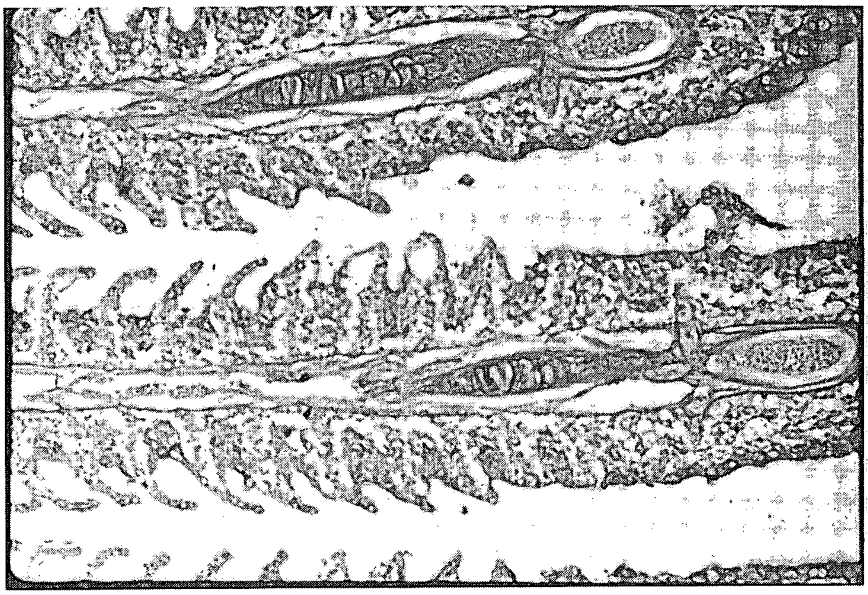

Figure III-21. Gill Filaments (H & E Stained and Based on 50X Magnification) Showing Hyperplasia (Increase in Interlamellar Cells), Partial Clubbing of Gills, and Epithelial Separation

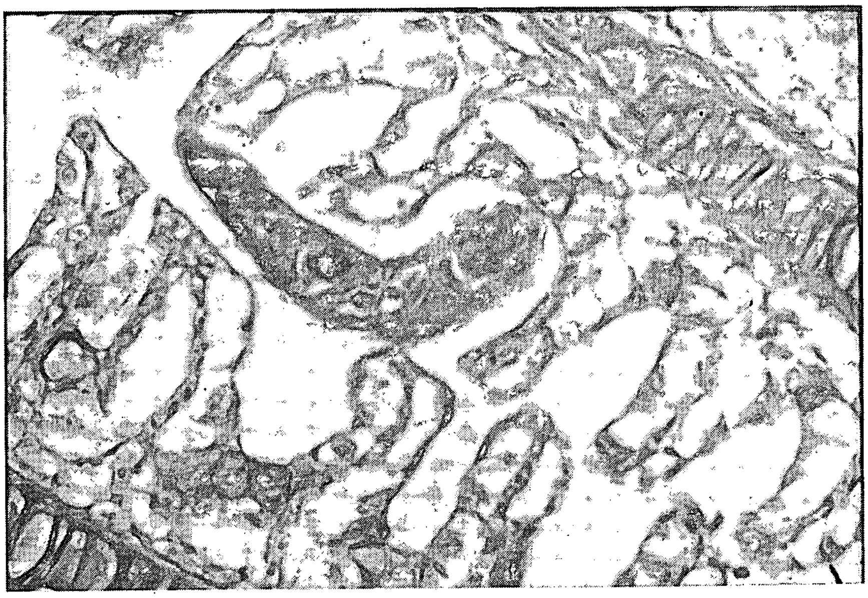

Figure III-22. Trematode Parasite among Lamellae on Sections of Two Filaments (Based on PSA, 250X Magnification) with All Lamellae Showing Extensive Epithelial Separation Due to Gas Accumulation Typical of Gas Bubble Disease

Table III-17

Contingency for Presence/Absence of Gill Gas Bubble Pathology for Two Fish Populations Examined in Histopathology Study

Population	Presence	Absence	Total
Seined	7	69	76
Impinged	31	38	69
Total	38	107	145

or gas bubbles under the skin, which are associated with the disease. It should be noted, however, that lamellar gas bubbles are early-stage symptoms of gas bubble disease, whereas other gross lesions are symptomatic of more advanced stages of gas bubble disease.

The location or cause of supersaturation responsible for the occurrence of gas bubble disease in the river cannot be isolated. Any heat source, under certain thermal conditions, can be a potential source. No information is available, however, about background levels of gas bubble disease in unaltered natural systems or relating background levels in the Hudson River with artificial (man-made) heat discharge.

SECTION IV

FISH PROTECTIVE MEASURES

A. INTRODUCTION

Impingement solutions can be approached from two directions with varying levels of success. This study has addressed both alternatives. The first approach attempts to prevent impingement. This method was evaluated with air curtains and alternate modes of intake screen operation. The second method accepts the fact of impingement and seeks to minimize physical damage and maximize survival of impinged fish. A fish pump was evaluated as part of a bypass system with which to transport impinged fish back to the water source.

B. METHODS

1. Air Curtain Operation

Air bubblers were installed as fish protective devices at all Units 1 and 2 intake screens and at Unit 3 screen 36. The effectiveness of these devices at Unit 1 was evaluated by analysis of covariance (ANOCOVA) with conductivity and temperature as covariates. Impingement rates of striped bass, white perch, tomcod, and all species combined were tested by season for a significant difference between full days of complete air curtain operation and days with no air curtain operation. Screen 14 data were used from days on which intake 13 and 14 air curtains were in the same operational mode; this prevented interference by adjacent air curtains.

ANOCOVA assumes homogeniety of variance and normality of data. These assumptions were tested by Levene's, Cochran's, Bartlett's, and F-Max tests of homogeniety (Brown and Forsythe, 1974; Winer, 1971) and by Anderson-Darling and Shapiro-Wilkes statistics for normality (Stephens, 1974). The assumptions were also tested for transformed data

$[\log_{10}(x+1), \sqrt{x}, {}^{1}/_{x}]$. All species/season combinations except spring and summer striped bass and spring Atlantic tomcod satisfied both assumptions; the large number of zero impingement days accounts for the lack of normality and the rejection of these three data blocks. Other data blocks were rejected when the air curtain was in one mode. The $\log_{10}(x+1)$ transformation of impingement rates uniformly satisfied the assumptions and was used in the analysis of covariance (ANOCOVA-BMDX-64) program). An examination was made of the applicability of the test model/equation

$$\log_{10}(Y_{ij} + 1) = \mu + \alpha_i + \delta_1 + X_{ij} + \delta_2 Z_{ij} + \epsilon_{ij}$$

where

Y_{ij} = impingement rate, j^{th} wash, air curtain $mode_i$

X_{ij} = conductivity ($\mu mho/cm^2$)

Z_{ij} = temperature (°C)

Plots of the residuals ϵ_{ij} against X_{ij} and Z_{ij} demonstrated no spurious results due to the covariates and verified the model. Further tests were performed in which the covariates were also transformed. Impingement rates of striped bass, white perch, tomcod, and all species combined were tested for a significant difference between full days of complete air curtain operation and days with no air curtain operation.

2. Mode of Screen Operation

Differences between continuously operated traveling screens and fixed screens were examined using impingement rates at Units 2 and 3 during 1974. Unit 3 traveling screen 34 was washed continuously for 1-week intervals each month during the spring and summer of 1974; Unit 2 unbasketed fixed screens (21, 22, 24, and 25) were washed once daily and mean daily rates calculated for the same 1-week periods. Differences among impingement rates at the two units were examined with a paired t-test at the 0.05 significance level.

3. Fish Pump Tests

A soft-impeller centrifugal fish pump manufactured by Pacific Pump Company was tested during 1973 and 1974 as a device for transporting fish collected from intake screens back to the river at a point remote from the intakes. Figure IV-1 shows manufacturer-rated pumping capacities.

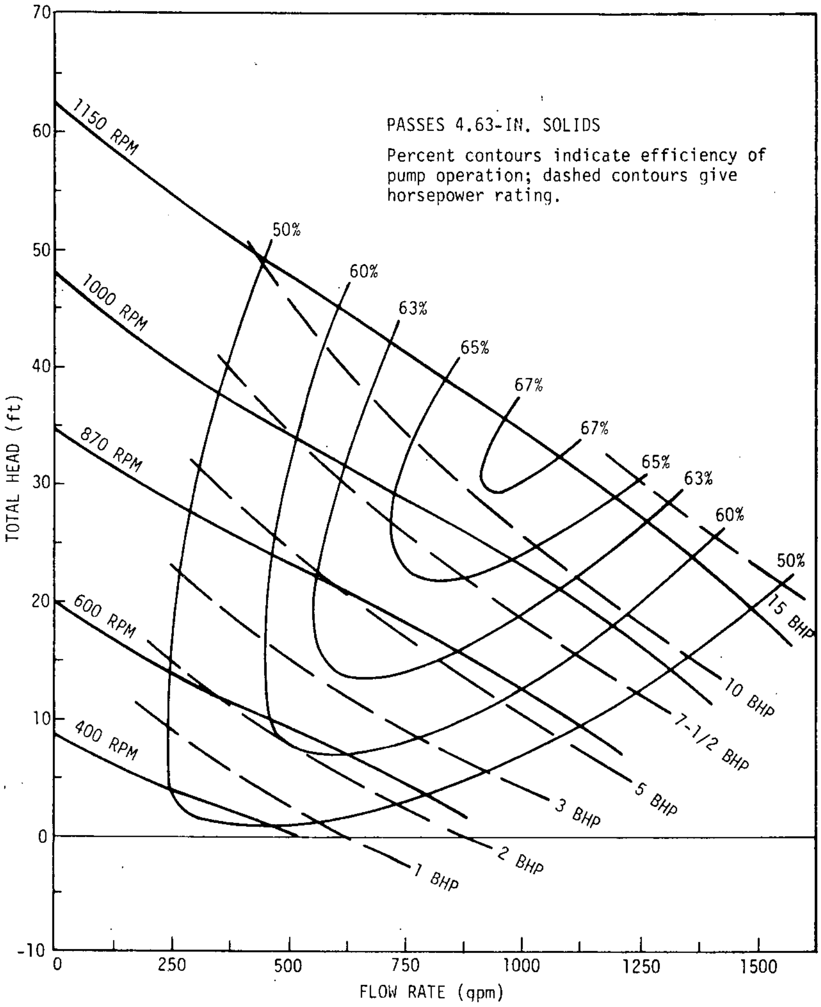

Figure IV-1. Capacities of Fish Pump Used for Testing Fish Transport System. (Courtesy of Pacific Pumping Company)

The pump was installed in a dry pit (Figure IV-2) outside the southwest corner of the Unit 1 pumpwell house. The pump intake was connected to the wet pit by a pipe approximately 6 in. (15.2 cm) in diameter and 12 in. (30.5 cm) in length. Unit 1 service pumps supplied water to the wet pit via the wash-water sluiceway. Water and fish entering the fish pump were discharged through a 6-in. (15.3-cm) diameter pipe 650 ft (198 m) long and received by two 3-m x 0.6-m circular holding pools located near the Unit 3 dock.

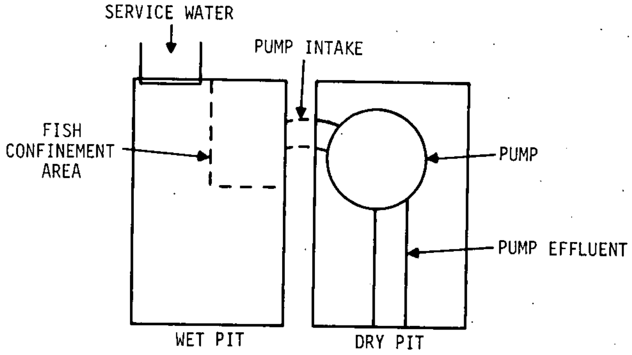

Figure IV-2. Location of Fish Pump with Respect to Wet and Dry Pit for Use in Transporting Fish Away from Intake Area

The fish pump was tested during 1972-1973 (Texas Instruments, 1974b) in the spring at the following pump speeds: 640 to 805 rpm and 850 to 1750 rpm. During 1974, there were two tests under winter temperature conditions (0.5 to 2.5°C): 375 to 450 rpm and 475 to 550 rpm. Con Edison Indian Point performance engineers measured pump speeds (rpm) with a Hasler revolution meter. A range of pump speeds was recorded for each test because fluctuations in hydraulic head in the wet pit produced fluctuations in pump speeds. The 1974 tests used hatchery-reared young-of-the-year striped bass (70 to 110 mm) which, prior to testing, were held in aerated flow-through 400-gal. (1514-ℓ) tanks. Fifty test fish were placed in the wet pit and crowded near the fish pump intake; they passed through the pump and were discharged into the holding pool, a process which took from 15 to 30 min. Simultaneously, as a test control, 50 fish were removed from pretest holding tanks and placed in an adjacent holding facility for handling-induced mortality. Temperature, dissolved oxygen, percent mortality, and the general condition of all fish were recorded immediately after and 24 hr after pumping. Condition was recorded as healthy, damaged, passively alive (floating on side), and dead.

The 24-hr survival rates for the test group (pumped fish) were calculated by the following equation (Bell et al, 1967):

$$P_p = \frac{P_t}{P_c}$$

where

P_p = adjusted proportion surviving pumping

P_t = observed proportion of test group surviving pumping plus 24 hr

P_c = observed proportion of controls surviving 24 hr

C. RESULTS AND DISCUSSION

1. Air Curtain Operation

ANOCOVA results (Table IV-1) showed no significant air curtain effect for any of the data groups tested. While conductivity and temperature effects were occasionally significant ($\alpha = 0.05$), operation of the air curtain apparently did not influence impingement rates as depicted by the covariance model. Further tests of the covariate model with manipulations of the number of covariates and transformations of the covariates indicated no significant effect. Analysis of 1973 impingement rates for air curtain effect showed no significant difference between modes of operation (Texas Instruments, 1974b). Tests at that time also indicated the potential for higher impingement when the air curtain was operating. If initial data from collection efficiency tests prove accurate, it is probable that actual impingement of fish during air curtain operation is increased although collection efficiency is decreased. This potential may be a result of the attraction of fish to current eddies created by the air curtain (Parkinson, Delachanal, 1972).

Studies to evaluate air curtains elsewhere (Bates and VanDer walker, 1969) also show air curtains to be ineffective in turbid water or in darkness. Other studies and TI's Indian Point experience indicate that air curtains are not an effective means of preventing impingement of fish at Indian Point.

Table IV-1

Summary of F Values Derived by ANOCOVA for Air Curtain Operation

		F-Values				
Species	Season	Mean	Air Curtain	Covariance (cond x temp)	Conductivity	Temperature
Striped bass	Fall	34.608	0.343	7.324	5.391	14.049
Atlantic tomcod	Summer	7.503	0.005	2.255	3.194	4.019
	Fall	47.176	0.543	9.147	0.147	16.857
White perch	Spring	151.499	0.176	17.455	6.856	16.412
	Summer	0.583	1.590	0.506	0.329	0.088
	Fall	231.648	0.302	17.313	5.062	34.518
Total impingement	Spring	166.816	0.555	9.199	7.946	4.191
	Summer	9.083	0.178	2.819	5.180	3.748
	Fall	350.924	0.364	20.030	16.811	37.480

2. Mode of Screen Operation

Impingement rates for Units 2 and 3 during 1974 showed no significant difference between fixed and traveling screen impingements (Tables IV-2 and IV-3). When white perch dominated impingement collections in the spring, Unit 3 collections were generally higher; when Atlantic tomcod dominated in the summer, Unit 2 collections were higher. These differences did not result in significant t-values. Data collected during spring 1974 also showed mixed results, but no significant difference between fixed and traveling screens was established (Texas Instruments, 1974b).

On the basis of these results, neither screen design has an apparent advantage in reducing impingement. However, fish removed from continuously washed traveling screens at Unit 3 were apparently in better condition than those removed from Unit 2 fixed screens.

Table IV-2

Comparisons of Spring Impingement Rates on Unit 2 Fixed Screens and Unit 3 Continuously Operated Traveling Screen (34)*

Date (1974)	Impingement Rates (No./10^6 m^3)					
	All Fish		Tomcod		White Perch	
	Unit 2	Unit 3	Unit 2	Unit 3	Unit 2	Unit 3
Apr 17	663	755	0	0	652	680
18	817	1841	0	0	809	1739
19	509	1014	0	0	507	904
Jun 5	138	110	113	81	13	18
6	210	578	177	482	21	56
7	294	708	241	591	24	75
8	1403	750	1304	509	64	107
9	644	755	577	554	52	143
10	174	498	144	430	17	51
11	678	634	622	420	23	43
t value	-1.5290		0.0516		-1.7645	

*Values for paired t-test are also listed, but none were significant.

Table IV-3

Comparisons of Summer Impingement Rates on Unit 2 Fixed Screens and Unit 3 Continuously Operated Traveling Screen (34)*

Date (1974)	Impingement Rates (No./10^6 m^3)			
	All Fish		Tomcod	
	Unit 2	Unit 3	Unit 2	Unit 3
Jul 19	2376	1731	1854	1369
20	2876	628	1356	372
21	327	1782	155	1472
22	233	560	40	342
23	184	887	17	459
Sep 4	845	23	272	16
5	1269	31	526	21
7	248	62	138	43
8	193	45	130	33
9	235	77	173	50
10	253	101	73	55
t value	0.9655		0.2538	

*Values for paired t-test are listed, but none were significant.

3. Fish Pump Tests

Winter fish pump tests (Table IV-4) had significantly higher striped bass survival at low pump speeds (374 to 425 rpm) than at high speeds (475 to 525 rpm). External examination of fish pumped at higher speeds indicated that they were generally in worse physical condition, exhibiting cutaneous hemorrhaging, scale loss, and frayed fins. These results differ from those of spring tests (Texas Instruments, 1974b) in which there were similar white perch survival rates but at higher pump speeds. This variance may be related to seasonal temperatures or species differences. Although variable, these two sets of data indicate that, under the proper speed regime, a fish pump could be employed to transport various fish species.

Table IV-4

Summary of Results of Fish Pump Tests Performed under Winter Conditions To Evaluate Its Use in Fish Bypass System in Association with Traveling Screens

Date	Pump Speed Range (rpm)	No. of Control Fish	Control Fish Surviving at End of 24 Hr (%)	No. of Fish Pumped	Pumped Fish Surviving at End of 24 Hr (%)	Adjusted Survival of Pumped Fish (%)
5/18/73 5/24/73	850-1750	49	67.3	40	40.0	59.4
6/14/73 6/21/73	640-805	190	90.5	173	76.3	84.3
12/11/74	374-425	100	98.0	100	81.0	83.0
3/4/75	475-525	50	92.0	50	44.0	48.0

Although healthy fish were used for these tests, fish in a bypass system will have been subjected to stress from the screen washing procedure before being pumped. To determine the effective value of a fish pump in such a system, fish surviving recent impingement should be used in future pump tests. Survival in such a system might be maximized if pumps were used in conjunction with continuously washed traveling screens, because fish collected from these screens appeared to be in better physical condition than those removed from stationary screens. Fish passed through a pump are often temporarily disoriented, so survival could be enhanced further if fish were returned to the river in an area where they had temporary protection from predators; this would give them time to reorient after being discharged from the pump and before being exposed to environmental selective pressures.

SECTION V

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APPENDIX A

SCOPE OF WORK

APPENDIX A

SCOPE OF WORK

OBJECTIVE 1

Monitor fish collected at Indian Point Units 1 and 2 intakes and record plant operating and river conditions which may be related to impingement.

Purpose

(1) Meet AEC technical specifications and New York State requirements.

(2) Provide data to meet Objectives 2, 3, 6, and 7

Tasks

(1) Wash Units 1 and 2 fixed screens daily. Run the traveling screens at Units 1 and 2 for approximately 15-30 min once every 24 hr.

(2) Record fish collections for each traveling screen washing by intake bay.

(3) Daily, record number, length, weight, and species of fish collected by screen. Subsample the impinged fish population to estimate species number, size, and weight. The subsample will be a size adequate for statistical analyses.

(4) Collect a water sample during slack tide once each day immediately in front of each unit and in the discharge canal at two depths: 2 ft above bottom and 2 ft below the surface. Using accepted test methods, measure the following parameters:

- temperature
- dissolved oxygen
- turbidity
- pH
- salinity (using a recording salinometer)

(5) Obtain plant operational data from the plant performance group and record daily. These data will include:

- hours of circulator pump operation
- flow rate data
- total daily circulator flow by bay
- hours of air curtain operation
- time of fixed and traveling screen washings

(6) Provide data in usable form on computer magnetic tape.

OBJECTIVE 2

Provide data required to evaluate the biological significance of fish impingement at the Indian Point Station.

Purpose

Incorporate accurate impingement counts, along with fish density and chemical and physical data, into a regression model to determine variables significantly affecting impingement and to predict magnitude and timing of high impingement.

Tasks

(1) Examine all white perch and striped bass for internal nose tags and/or external markings (i. e., tags, fin clips).

(2) Generate length and weight frequency distributions from the raw data.

(3) Generate age-growth regression curves monthly for white perch and striped bass and compare with those generated from river data, this knowledge to be incorporated into population dynamics modeling, as appropriate, to evaluate plant effects and determine the ecological role of the plant as a predator.

OBJECTIVE 3

Estimate percentage of impinged fish that are not collected.

Purpose

The accuracy of fish impingement monitoring has recently been questioned by federal and state officials because of observations of impinged fish being forcibly removed from Unit 2 fixed screens by the water spray system during fixed screen washings and the airstreams generated by the air curtain. Conceivably, some impinged fish are never collected on the traveling screens and accurate counts of impinged fish therefore are not achieved. The Hudson River Policy Committee has expressed the need for accurate counts for this program and for evaluation of the biological significance of fish impingement (Objective 1 of the Indian Point Ecological Study). Evaluation of accuracy is also an important consideration in fulfilling all the objectives included in this scope.

Tasks

Artificially impinge tagged young-of-the-year *Morone* sp. at Unit 2 and recover using present monitoring methods in order to determine collecting efficiency of monitoring methods. Perform each of the following tests twice:

(1) Release 100 dead fish at an unbasketed fixed screen at the following times:

(a) Just before the fixed screen is washed

(b) 6 hr before the fixed screen is washed

(c) 12 hr before the fixed screen is washed

(d) 24 hr before the fixed screen is washed

NOTE

In all cases, the air curtain is turned on after washing and remains operating until after the next washing of the screen.

(2) Repeat task 1c with the air curtain turned on after the washing and allowed to operate until just before the next washing of the screen.

(3) Repeat task 2 with the air curtain not operated until after the next screen washing.

(4) Repeat task 3 at a basketed screen.

(5) Repeat task 1c using live fish for the following conditions:

- air curtain operated until after the next screen washing.

- air curtain not operated until after the next screen washing.

OBJECTIVE 4

Correlate Unit 3 impingement to environmental factors.

Purpose

Knowledge of the relationship between impingement and the occurrence of the thermal plume, tide stage, and time of day is essential in providing power plant operational guidelines for fish protection.

Tasks

(1) Monitor impingement at Unit 3 during ten 24-hr periods each month as described in tasks 4-6 of Objective 1, but monitor fish and record every 2-4 hr as necessary.

(2) Analyze data by season to demonstrate any relationship between impingement, tidal stage, salinity, occurrence of thermal plume, and time of day.

(3) Record temperature and salinity immediately before each fish monitoring at depths described in task 4 of Objective 1.

OBJECTIVE 5

Determine and compare the health or condition of impinged and river (control) fish.

Purpose

If extensive pathology and/or a lower condition factor exists in the impinged fish compared with the river fish, the intake screens may be acting as a selective predator on weaker members of the population and thus the impact of impingement would be minimal.

Tasks

(1) For histological analysis, in early winter 1973 collect from both the river and Indian Point Unit 2 young-of-the-year white perch in the following number and of the following two sizes:

– forty 30-100 mm long

– forty > 100 mm long

(2) Submit these fish to histological analysis and compare the two groups for condition.

(3) Compare length/weight regression of striped bass and white perch collected in the river with those impinged on intake screens.

(4) Record gill parasite loads on selected species and compare with those encountered on river fish.

OBJECTIVE 6

Determine if gas bubble disease results from heated discharge and/or air curtain operation.

Purpose

Samples of impinged fish have shown external abnormalities which may be symptomatic of gas bubble disease (GBD). Government officials contend that the air curtain and heating of discharge water (thermal plume) could result in oxygen and nitrogen supersaturation in the intake water.

Such supersaturation may cause fish to be afflicted with GBD, which would make them more susceptible to impingement.

Tasks

(1) Once per month during August, November, February, and May, obtain three water samples at the intake of Unit 1 and three in the discharge canal at two depths each when the air curtain is off and again at the same locations when the air curtain is on.

(2) Analyze these water samples for percentage of oxygen and nitrogen saturation.

(3) Examine the fish described in Objective 5, task 1, for symptoms of gas bubble disease.

OBJECTIVE 7

Evaluate the effectiveness of fish protective devices and modifications of these devices which could result in reductions of fish impingement.

Purpose

Reduce impingement and investigate the degree of impingement at various screen depths, the effectiveness of fixed screen depths, the effectiveness of fixed vs traveling screens at head of forebays, continuous vs periodic operation of traveling screens, and air curtain effectiveness in order to determine whether present devices are reducing impingement.

Tasks

(1) Evaluate the air curtain through statistical comparison (air curtain off vs air curtain on).

(2) Repeat task 1 on only the lower lateral part of the curtain.

(3) Compare intermittent vs continuous traveling screen operation at Unit 3 and fixed screen impingement ratios.

(4) Obtain catch-per-unit-effort data with gill nets in front of Units 2 and 3 and obtain relative abundance data with sonars mounted on the intake structures of Units 2 and 3 to support the above tasks 1, 2, and 3 and Objective 4.

(5) Evaluate the Unit 1 fish pump under winter river conditions.

(6) Determine the vertical distribution of impinged fish. Con Edison will design, construct, and attach four fish baskets as wide as the fixed screens to each of fixed screens 21 and 24 at the following depths: bottom, three-quarters, one-half, and one quarter. When the screens are raised, the catch may be removed; this will be done daily. The catch will be processed as described in tasks 2 and 3 of Objective 1.

(7) Collect current velocity and head loss data. The water velocity profile across Unit 2 fixed screens 22 and 26 should be characterized as full and reduced circulation water flow and should include measurements from the intake forebays made as close as possible to the outer fixed screens and two determinations over a tidal cycle (high and low tide). Once each day immediately before fixed screen washing, measure and record head loss and approach velocity at one bay, preferably forebay 26 unless it is not in operation; otherwise, at a different forebay.

APPENDIX B

FISH MONITORING DATA

Table B-1

Delineation of Weeks by Date

Weeks	Dates	Weeks	Dates
1	Jan 1 - Jan 7	27	Jul 2 - Jul 8
2	Jan 8 - Jan 14	28	Jul 9 - Jul 15
3	Jan 15 - Jan 21	29	Jul 16 - Jul 22
4	Jan 22 - Jan 28	30	Jul 23 - Jul 29
5	Jan 29 - Feb 4	31	Jul 30 - Aug 5
6	Feb 5 - Feb 11	32	Aug 6 - Aug 12
7	Feb 12 - Feb 18	33	Aug 13 - Aug 19
8	Feb 19 - Feb 25	34	Aug 20 - Aug 26
9	Feb 26 - Mar 4	35	Aug 27 - Sep 2
10	Mar 5 - Mar 11	36	Sep 3 - Sep 9
11	Mar 12 - Mar 18	37	Sep 10 - Sep 16
12	Mar 19 - Mar 25	38	Sep 17 - Sep 23
13	Mar 26 - Apr 1	39	Sep 24 - Sep 30
14	Apr 2 - Apr 8	40	Oct 1 - Oct 7
15	Apr 9 - Apr 15	41	Oct 8 - Oct 14
16	Apr 16 - Apr 22	42	Oct 15 - Oct 21
17	Apr 23 - Apr 29	43	Oct 22 - Oct 28
18	Apr 30 - May 6	44	Oct 29 - Nov 4
19	May 7 - May 13	45	Nov 5 - Nov 11
20	May 14 - May 20	46	Nov 12 - Nov 18
21	May 21 - May 27	47	Nov 19 - Nov 25
22	May 28 - Jun 3	48	Nov 26 - Dec 2
23	Jun 4 - Jun 10	49	Dec 3 - Dec 9
24	Jun 11 - Jun 17	50	Dec 10 - Dec 16
25	Jun 18 - Jun 24	51	Dec 17 - Dec 23
26	Jun 25 - Jul 1	52	Dec 24 - Dec 30
		53	Dec 31

Table B-2

Total Numbers and Total Weights of Fish Collected at Unit 1, 1974

		Total Number							Total Weight (gm)						
		All Species Combined	WP†	SB	TC	BH	AL	BA	All Species Combined	WP†	SB	TC	BH	AL	BA
Week	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	23	8	0	10	0	0	0	673	49	0	584	0	0	0
	3	610	177	8	373	0	0	0	25744	2212	76	21024	0	0	0
	4	3988	3897	64	18	0	0	0	55491	54022	489	777	0	0	0
	5	1309	1293	7	6	0	0	0	15882	14287	125	462	0	0	0
	6	841	815	18	3	0	0	0	9426	8910	108	136	0	0	0
	7	2411	2375	23	7	0	0	0	17682	17210	142	301	0	0	0
	8	2097	2041	28	1	2	0	0	21811	21083	188	67	4	0	0
	9	1601	1570	4	3	0	0	0	13880	11837	27	120	0	0	0
	10	396	364	2	8	0	0	0	7768	4523	16	414	0	0	0
	11	198	150	1	0	0	0	0	1440	1292	8	0	0	0	0
	12	3167	3052	88	0	1	1	0	23446	22579	680	0	3	2	0
	13	3173	3090	67	0	0	0	0	20824	20280	408	0	0	0	0
	14	4898	4633	225	0	9	0	0	37379	34591	1594	0	27	0	0
	15	1181	1137	30	0	0	2	0	14345	12459	703	0	0	835	0
	16	840	794	28	1	0	0	0	7496	5595	236	52	0	0	0
	17	910	801	31	0	13	1	0	9333	5340	267	0	35	207	0
	18	1517	1356	24	0	18	7	0	11269	7908	210	0	46	1216	0
	19	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	21	1636	1003	12	346	48	100	14	21657	9118	119	566	2057	7349	47
	22	807	323	9	325	29	59	19	16599	7762	177	782	871	4557	68
	23	4597	505	11	3842	76	94	13	26064	8609	240	9799	1247	3656	38
	24	2568	225	6	1963	73	23	83	20529	5266	79	5998	2111	1811	279
	25	18912	168	20	17573	185	34	395	73548	2171	464	56347	7271	1917	1325
	26	6044	151	12	4295	74	5	1389	30043	4716	159	13395	3493	500	4634
	27	2898	132	11	1990	19	9	659	16702	3586	185	7009	861	450	2346
	28	540	29	6	248	10	4	162	4303	652	163	1415	200	414	477
	29	1469	25	10	619	7	7	678	9911	1080	439	3376	346	140	1868
	30	4988	33	38	1438	11	206	3105	22257	1265	995	6423	56	1296	9241
	31	3317	25	17	1899	6	63	1234	16966	1211	717	9395	40	324	3742
	32	7858	42	33	6244	45	72	1275	37407	702	1298	29120	166	290	3657
	33	1901	38	30	924	27	39	727	13343	1730	1537	5422	178	334	2159
	34	4188	53	22	2304	10	28	1657	22383	855	1110	12980	232	448	5118
	35	1130	20	13	234	7	17	726	6069	480	903	989	70	148	2021
	36	3141	79	28	1598	40	64	1055	17147	1331	1700	7054	432	317	2927
	37	4670	109	39	2616	43	92	1533	24571	1344	1259	11972	589	1264	4584
	38	1371	161	31	683	31	58	365	7925	1670	581	3131	129	467	906
	39	391	94	9	138	21	10	87	2808	628	429	544	246	272	225
	40	1684	785	28	317	49	54	374	10498	4994	859	1912	233	428	1147
	41	6175	1393	49	597	756	260	1422	26435	6873	430	3823	2594	1481	4154
	42	4225	1139	33	52	2179	514	128	19379	7051	227	381	7099	2180	278
	43	3929	757	30	18	2496	408	31	16044	3899	1243	138	7702	1532	65
	44	7393	1109	26	28	5850	132	7	26646	6725	1326	323	15247	634	22
	45	3316	716	16	4	2392	54	0	12996	3473	906	48	5990	283	0
	46	1433	568	8	1	792	7	0	6617	2643	248	23	2138	31	0
	47	231	140	2	0	44	0	0	2085	1422	7	0	109	0	0
	48	638	550	9	0	9	0	0	4389	2987	218	0	24	0	0
	49	1803	1367	46	81	4	4	0	15824	8851	1209	2272	24	147	0
	50	1463	1171	21	168	11	2	0	17910	11006	1175	4050	59	92	0
	51	5100	3691	45	948	9	150	0	58191	29003	943	21488	19	816	0
	52	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	53	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Month	1	5359	4816	74	403	0	0	0	88662	62803	579	22605	0	0	0
	2	6831	6685	76	17	2	0	0	66216	62130	562	793	4	0	0
	3	6738	6482	128	9	1	1	0	54099	48519	937	487	3	2	0
	4	8950	8433	349	1	24	3	0	75134	64202	3012	52	66	1042	0
	5	3344	2352	36	475	80	138	20	41511	19459	323	842	2881	12188	74
	6	32318	1147	55	27771	417	184	1839	154532	24246	1102	85759	14154	8818	6142
	7	11051	236	75	4702	53	254	5239	60016	7354	2271	19932	1543	2477	15888
	8	17267	171	104	11241	92	190	4964	90568	4521	5071	56240	660	1364	14715
	9	9728	446	108	5090	136	225	3114	53383	5119	3974	22944	1399	2323	8843
	10	18800	4534	154	996	7619	1306	1960	83192	25361	3654	6408	23795	5956	5659
	11	9942	2360	45	21	6947	123	2	40464	13607	1800	240	17337	613	7
	12	8648	6492	114	1197	25	156	0	93358	49959	3337	27810	106	1055	0
Season	Winter	15882	15004	226	429	2	1	0	187773	152768	1744	23885	4	2	0
	Spring	22886	14605	460	6477	267	286	129	190965	122164	4148	17197	6397	19631	432
	Summer	61418	925	291	42218	489	659	14658	297111	21454	11307	166026	13950	8001	44312
	Fall	38798	13620	341	2799	14638	1634	2351	225286	90894	9423	37004	41597	8204	6584
Year	1974	138976	44154	1318	51923	15396	2580	17138	901135	387280	26622	244112	61948	35838	51328

†WP = white perch; SB = striped bass; TC = Atlantic tomcod; BH = blueback herring; AL = alewife; BA = bay anchovy

Table B-3

Total Numbers and Total Weights of Fish Collected at Unit 2, 1974

		Total Number							Total Weight (gm)						
		All Species Combined	WP†	SB	TC	BH	AL	BA	All Species Combined	WP†	SB	TC	BH	AL	BA
Week	1	7	2	0	2	0	0	0	212	18	0	183	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	49	40	8	0	0	0	0	324	206	100	0	0	0	0
	4	19236	18804	363	20	1	1	0	109837	104751	3170	1150	2	2	0
	5	3629	3544	35	9	0	0	0	20767	19396	283	486	0	0	0
	6	6690	6483	167	5	0	0	0	40700	39186	1187	155	0	0	0
	7	6868	6731	102	1	0	0	0	41805	40840	752	9	0	0	0
	8	9769	9522	136	0	16	1	0	51378	50075	852	0	37	25	0
	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	11	1963	1821	10	3	0	0	0	12416	11520	71	58	0	0	0
	12	15658	15436	133	0	4	1	0	100486	99068	890	0	9	3	0
	13	22531	22346	117	1	1	1	0	135630	133548	789	131	2	1	0
	14	27815	27392	281	0	7	0	0	167848	163550	1922	0	15	0	0
	15	20860	20682	62	1	2	0	0	126011	123589	414	28	4	0	0
	16	7888	7739	2	0	1	0	0	49279	47212	12	0	3	0	0
	17	9687	8995	24	0	208	2	0	58329	53874	171	0	522	423	0
	18	35744	31747	329	1	441	31	15	239967	198569	2506	44	1146	3144	51
	19	19135	16385	253	27	909	52	8	119229	91240	1801	27	3620	1595	28
	20	3977	3188	69	138	25	13	1	30300	19205	516	140	1309	1490	5
	21	21954	10801	247	9081	234	238	81	109719	62269	1808	12584	4037	7558	261
	22	28641	7424	141	19763	295	121	105	112400	47765	1114	39938	5014	3776	300
	23	15222	1435	52	13026	173	106	43	57050	12701	566	32239	1652	2791	126
	24	34908	438	16	33442	154	86	87	102663	5310	257	89206	1161	2268	232
	25	30149	352	24	26962	182	71	1862	102220	4864	335	76932	3904	4234	5602
	26	30529	429	12	23885	62	12	5624	105023	7412	573	70159	2189	526	19809
	27	18013	277	34	15107	43	10	2345	76256	6223	1057	53909	3235	524	7572
	28	29754	81	45	26508	20	5	2269	121855	2295	1421	102777	519	118	6855
	29	32575	109	55	19916	17	46	11514	136024	2937	1130	88623	308	532	35149
	30	21672	182	135	12181	3	459	8275	92593	4306	2214	54842	80	1857	23929
	31	20875	47	126	17719	6	110	2654	99514	468	2268	87507	116	422	6326
	32	22729	201	163	16848	86	169	4807	104573	2509	1556	79261	264	768	13618
	33	21041	313	161	13741	47	81	5798	107673	5523	2843	74356	385	555	14484
	34	15384	533	152	7475	78	129	5870	80062	6302	2117	37936	355	636	17443
	35	12343	195	55	2635	54	62	8434	53182	3051	1534	11454	613	814	24237
	36	15540	409	105	6916	111	64	5770	81150	6012	2706	28262	547	974	14932
	37	23276	760	140	14257	90	87	6609	106721	7199	1305	61902	392	1264	19076
	38	19316	1461	131	15116	100	90	1540	89585	9329	857	61727	484	1744	4214
	39	2205	817	25	268	40	28	808	12431	3981	145	1100	145	844	2364
	40	882	352	13	189	7	3	211	6286	2253	74	912	27	68	629
	41	3874	1124	32	855	397	354	951	20144	6684	220	5803	1176	1206	2875
	42	10093	5112	89	658	2370	469	669	57344	29904	1691	4743	6830	1703	1420
	43	5592	2951	34	29	1850	363	61	21286	11145	383	225	4678	1023	117
	44	12677	4544	38	133	6992	176	43	53887	22422	759	1620	18661	688	132
	45	7405	2738	9	18	4262	83	8	26905	11391	160	253	10387	356	27
	46	6399	4109	32	7	1921	18	3	29925	17897	874	115	4523	110	5
	47	14136	12069	170	6	474	17	2	157951	145717	2482	166	1103	109	7
	48	7829	7108	37	67	29	0	1	43072	30482	301	1371	108	0	1
	49	5741	5074	36	125	1	0	0	30585	21060	332	3191	3	0	0
	50	15767	15424	24	154	1	2	0	105249	98687	128	3295	2	9	0
	51	4287	3939	10	170	0	0	0	24682	18096	81	3863	0	0	0
	52	25421	24984	123	112	5	0	0	147019	141249	1022	2667	145	0	0
	53	2447	2407	11	5	0	0	0	12856	12415	98	130	0	0	0
Month	1	22657	22172	397	28	1	1	0	129138	122773	3504	1627	2	2	0
	2	23591	22954	414	9	16	1	0	135885	131699	2840	356	37	25	0
	3	39528	38997	254	4	5	2	0	244807	240576	1716	189	11	4	0
	4	72714	70747	398	2	337	10	0	452420	434256	2760	72	844	1048	0
	5	81797	59376	912	12824	1573	409	154	490302	346391	6704	19786	12753	15396	514
	6	131338	7434	207	112952	777	313	7047	435475	59070	2556	299636	10922	11361	23763
	7	105105	713	313	75116	90	574	25806	440814	17245	6234	306438	4305	3125	77926
	8	85037	1224	588	56287	249	478	23191	411165	16351	9121	280700	1506	2933	63069
	9	65865	3504	427	37832	362	288	18321	315206	27942	5807	158321	1689	4994	51341
	10	24737	11367	182	1754	6763	1246	1917	121679	57555	2818	11937	18519	4236	5119
	11	40262	25045	256	157	11537	237	31	276975	205809	3949	2289	28952	1027	93
	12	57551	55523	220	617	9	2	1	338537	306038	1838	14128	172	9	1
Season	Winter	49927	48645	828	40	18	2	0	287554	276011	6457	2041	41	27	0
	Spring	262304	172310	1719	75480	2453	651	340	1398796	1047881	12724	174337	18492	23049	1003
	Summer	296302	4003	1230	206040	806	1314	72078	1278852	60354	21190	835570	12921	13304	209815
	Fall	141649	94098	791	16022	18442	1594	4050	827201	581459	9476	83531	48258	7780	11008
Year	1974	750182	319056	4568	297582	21719	3561	76468	3792403	1965705	49847	1095479	79712	44160	221826

†WP = white perch; SP = striped bass; TC = atlantic tomcod; BH = blueback herring; AL = alewife; BA = bay anchovy

Table B-4

Total Numbers and Total Weights of Fish Collected at Unit 3, 1974

		Total Number							Total Weight (gm)						
		All Species Combined	WP†	SB	TC	BH	AL	BA	All Species Combined	WP†	SB	TC	BH	AL	BA
Week	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	11	14	4	1	0	0	0	0	209	24	9	0	0	0	0
	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	16	3309	2892	19	1	0	16	0	27894	19914	140	119	0	3997	0
	17	275	168	1	0	2	2	0	2879	1519	7	0	5	461	0
	18	907	474	6	0	0	11	0	9627	2579	33	0	0	2067	0
	19	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	23	3838	532	28	3051	84	51	10	16222	3367	268	8003	904	1831	35
	24	1545	69	9	1305	39	6	1	6754	700	81	3625	1232	62	2
	25	18268	383	44	15741	200	111	495	73343	3463	645	49387	8176	4738	1832
	26	977	17	3	696	9	21	95	4411	107	19	2095	70	929	335
	27	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	28	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	29	3601	13	11	2720	2	2	617	15536	540	506	10962	375	43	1975
	30	282	1	2	146	0	9	96	1370	15	106	609	0	198	282
	31	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	32	516	2	9	444	0	9	25	3745	3	481	2205	0	45	81
	33	11	0	0	4	0	0	2	161	0	0	25	0	0	8
	34	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	35	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	36	248	9	9	163	0	2	7	2953	32	780	796	0	6	22
	37	37	0	2	20	0	0	1	428	0	8	152	0	0	4
	38	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	39	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	41	177	53	13	25	11	48	7	982	232	50	195	36	208	21
	42	34	10	5	4	0	10	1	179	46	20	34	0	32	4
	43	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	44	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	45	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	46	224	85	6	0	21	2	1	2236	452	471	0	68	12	4
	47	4	2	1	0	0	0	0	340	5	330	0	0	0	0
	48	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	49	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	51	248	157	4	47	1	0	0	3142	995	16	929	1	0	0
	52	571	458	12	64	1	0	0	4524	2232	72	1490	3	0	0
	53	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Month	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	14	4	1	0	0	0	0	209	24	9	0	0	0	0
	4	3584	3060	20	1	2	18	0	30773	21433	147	119	5	4458	0
	5	907	474	6	0	0	11	0	9627	2579	33	0	0	2067	0
	6	24628	1001	84	20793	332	189	601	100730	7637	1013	63110	10382	7560	2204
	7	3883	14	13	2866	2	11	713	16906	555	612	11571	375	241	2257
	8	527	2	9	448	0	9	27	3906	3	481	2230	0	45	89
	9	285	9	11	183	0	2	8	3381	32	788	948	0	6	26
	10	211	63	18	29	11	58	8	1161	278	70	229	36	240	25
	11	228	87	7	0	21	2	1	2576	457	801	0	68	12	4
	12	819	615	16	111	2	0	0	7666	3227	88	2419	4	0	0
Season	Winter	14	4	1	0	0	0	0	209	24	9	0	0	0	0
	Spring	9874	4135	63	4357	125	86	11	63376	28079	529	11747	2141	8418	37
	Summer	23940	425	80	19934	211	154	1338	101947	4160	2545	66231	8621	5959	4539
	Fall	1258	765	41	140	34	60	9	11403	3962	959	2648	108	252	29
Year	1974	35086	5329	185	24431	370	300	1358	176935	36225	4042	80626	10870	14629	4605

†WP = white perch; SB = striped bass; TC = Atlantic tomcod; BH = blueback herring; AL = alewife; BA = bay anchovy

Table B-5

Numbers and Weights of Fish Collected/1,000,000 m^3 of Water Circulated, Unit 1, 1974

		Total Number*							Total Weight (gm)*						
		All Species Combined	WP†	SB	TC	BH	AL	BA	All Species Combined	WP†	SB	TC	BH	AL	BA
Week	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	118	27	0	80	0	0	0	5835	328	2	5041	0	0	0
	4	872	852	14	80	0	0	0	12133	11812	107	170	0	0	0
	5	334	330	2	2	0	0	0	4050	3643	32	118	0	0	0
	6	127	123	3	0	0	0	0	1422	1344	16	21	0	0	0
	7	333	328	3	1	1	0	0	2444	2378	20	42	0	0	0
	8	288	281	4	0	0	0	0	2999	2899	26	9	1	0	0
	9	218	214	1	0	0	0	0	1894	1615	4	16	0	0	0
	10	62	57	0	1	0	0	0	1223	712	3	65	0	0	0
	11	37	28	0	0	0	0	0	271	243	2	0	0	0	0
	12	598	577	17	0	0	0	0	4430	4266	128	0	1	0	0
	13	591	575	12	0	0	0	0	3875	3774	76	0	0	0	0
	14	725	686	33	0	1	0	0	5531	5119	236	0	4	0	0
	15	159	153	4	0	0	0	0	1928	1674	94	0	0	112	0
	16	114	108	4	0	0	0	0	1020	761	32	7	0	0	0
	17	124	109	4	0	2	0	0	1267	725	36	0	5	28	0
	18	236	211	4	0	3	1	0	1750	1228	33	0	7	189	0
	19	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	21	125	55	1	43	5	12	2	1944	657	13	70	184	846	6
	22	68	27	1	27	2	5	2	1400	655	15	66	73	384	6
	23	406	45	1	340	7	8	1	2304	761	21	866	110	323	3
	24	220	19	1	168	6	2	7	1761	452	7	515	181	155	24
	25	2075	18	2	1928	20	4	43	8070	238	51	6182	798	210	145
	26	530	13	1	377	6	0	122	2637	414	14	1176	307	44	407
	27	288	13	1	198	2	1	65	1658	356	18	696	85	45	233
	28	84	5	1	38	2	1	25	668	101	25	220	31	64	74
	29	124	2	1	52	1	1	57	836	91	37	285	29	12	158
	30	466	3	4	134	1	19	290	2078	118	93	600	5	121	863
	31	285	2	1	163	1	5	106	1458	104	62	808	3	28	322
	32	671	4	3	533	4	6	109	3195	60	111	2487	14	25	312
	33	178	4	3	86	3	4	68	1247	162	144	507	17	31	202
	34	363	5	2	200	1	2	144	1939	74	96	1125	20	39	443
	35	98	2	1	20	1	1	63	526	42	78	86	6	13	175
	36	274	7	2	139	3	6	92	1493	116	148	614	38	28	255
	37	405	9	3	227	4	8	133	2131	117	109	1038	51	110	398
	38	120	14	1	60	3	5	32	693	146	51	274	11	41	79
	39	34	8	4	12	2	1	8	243	54	37	47	21	24	19
	40	214	100	4	40	6	7	48	1336	635	109	243	30	54	146
	41	525	118	4	51	64	22	121	2246	584	37	325	220	126	353
	42	362	98	3	4	187	44	11	1661	604	19	33	608	187	24
	43	344	66	3	2	218	36	3	1404	341	109	12	674	134	6
	44	692	104	2	3	548	12	1	2496	630	124	30	1428	59	2
	45	771	166	4	1	556	13	0	3020	807	211	11	1392	66	0
	46	395	157	2	0	219	2	0	1826	729	68	6	590	9	0
	47	197	119	2	0	37	0	0	1774	1210	6	0	93	0	0
	48	165	142	2	0	2	0	0	1137	773	56	0	6	0	0
	49	475	360	12	21	1	1	0	4171	2333	319	599	6	39	0
	50	368	295	5	42	3	1	0	4508	2770	296	1019	15	23	0
	51	953	675	9	194	2	26	0	11118	5304	170	4425	4	143	0
	52	2120	1820	30	206	1	1	1	21563	15434	382	4856	5	37	3
	53	1106	1031	24	23	0	0	0	9838	8566	231	566	0	0	0
Month	1	617	584	8	24	0	0	0	9275	7592	63	1471	0	0	0
	2	255	249	3	1	0	0	0	2469	2316	21	30	0	0	0
	3	262	252	5	0	0	0	0	2104	1887	36	19	0	0	0
	4	291	274	11	0	1	0	0	2440	2085	98	2	2	34	0
	5	135	89	2	23	4	7	1	1769	779	15	42	115	580	4
	6	687	24	1	590	9	4	39	3284	515	23	1822	301	187	131
	7	251	5	2	107	1	6	119	1362	167	52	452	35	56	361
	8	342	3	2	223	2	4	98	1796	90	101	1115	13	27	292
	9	197	9	2	103	3	5	63	1081	104	80	465	28	47	179
	10	393	95	3	21	159	27	41	1739	530	76	134	497	125	118
	11	568	135	3	1	397	7	0	2313	778	103	14	991	35	0
	12	1129	927	16	127	1	7	0	11727	7625	280	2970	6	58	1
Season	Winter	299	287	4	4	0	0	0	3353	2915	32	253	0	0	0
	Spring	254	160	5	74	3	3	1	2107	1348	47	196	66	217	5
	Summer	434	7	2	298	3	5	104	2100	152	80	1174	99	57	313
	Fall	512	260	5	41	134	15	22	3668	1976	114	708	380	77	60
Year	1974	398	149	4	137	39	7	44	2708	1299	76	701	157	91	131

*Recorded to the nearest whole number

†WP = white perch; SP = striped bass; TC = Atlantic tomcod; BH = blueback herring; AL = alewife; BA = bay anchovy

Table B-6

Numbers and Weights of Fish Collected/1,000,000 m^3 of Water Circulated, Unit 2, 1974

		Total Number*							Total Weight (gm)*						
		All Species Combined	WP†	SB	TC	BH	AL	BA	All Species Combined	WP†	SB	TC	BH	AL	BA
Week	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	47	47	0	0	0	0	0	232	232	0	0	0	0	0
	4	2365	2311	45	2	0	0	0	13502	12877	390	141	0	0	0
	5	561	548	5	1	0	0	0	3210	2998	44	75	0	0	0
	6	2106	2041	53	2	0	0	0	12813	12336	374	49	0	0	0
	7	2135	2093	32	0	0	0	0	12998	12698	234	3	0	0	0
	8	5352	5217	75	0	9	1	0	28150	27436	467	0	20	14	0
	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	11	447	415	2	1	0	0	0	2839	2636	14	13	0	0	0
	12	1306	1288	11	0	0	0	0	8384	8265	74	0	1	0	0
	13	1638	1624	9	0	0	0	0	9858	9707	57	10	0	0	0
	14	2360	2324	24	0	1	0	0	14240	13875	163	0	1	0	0
	15	1467	1454	4	0	0	0	0	8860	8689	29	2	0	0	0
	16	713	700	0	0	0	0	0	4454	4268	1	0	0	0	0
	17	768	713	2	0	16	0	0	4622	4269	14	0	41	34	0
	18	1718	1526	16	0	21	1	1	11537	9546	120	2	55	151	2
	19	1401	891	14	1	49	3	0	6486	4964	98	1	197	87	2
	20	323	259	6	11	2	1	0	2486	1559	42	11	106	121	0
	21	876	431	10	362	9	9	3	4378	2485	72	502	161	302	10
	22	891	231	4	615	9	4	3	3497	1486	35	1243	156	117	9
	23	509	48	2	436	6	4	1	1909	425	19	1079	55	93	4
	24	1502	19	1	1439	7	4	4	4417	228	11	3838	50	98	10
	25	1181	14	1	1056	7	3	73	4004	191	13	3013	153	166	219
	26	1048	15	0	820	2	0	193	3604	254	20	2408	75	18	680
	27	582	9	1	488	1	0	76	2463	201	34	1742	105	17	245
	28	1001	3	2	892	1	0	76	4101	77	48	3459	17	4	231
	29	1281	4	2	783	1	2	453	5347	115	44	3484	12	21	1382
	30	1039	9	6	584	0	22	397	4441	207	106	2630	4	89	1148
	31	2487	6	15	2111	1	13	316	11855	56	270	10424	14	50	754
	32	927	8	7	687	4	7	196	4266	102	63	3233	11	31	555
	33	669	10	5	437	1	3	184	3423	176	90	2364	12	18	460
	34	491	17	5	238	2	4	187	2554	201	68	1210	11	20	557
	35	386	6	2	82	2	2	264	1664	95	48	358	19	25	758
	36	678	18	5	302	5	3	252	3540	262	118	1233	24	42	651
	37	817	27	5	500	3	3	232	3745	253	46	2172	14	44	669
	38	734	56	5	574	4	3	59	3405	355	33	2346	18	66	160
	39	83	31	1	10	2	1	30	468	150	5	41	5	32	89
	40	150	42	2	22	1	0	25	747	268	9	108	3	8	75
	41	260	76	2	57	27	24	64	1354	449	15	390	79	81	193
	42	347	176	3	23	81	16	23	1970	1027	58	163	235	58	49
	43	198	104	1	1	65	13	2	753	394	14	8	166	36	4
	44	512	183	2	5	282	7	2	2175	905	31	65	753	28	5
	45	516	191	1	1	297	6	1	1876	794	11	18	724	25	2
	46	430	276	2	0	129	1	0	2012	1203	59	8	304	7	0
	47	1027	877	12	0	34	1	0	11475	10586	180	12	80	8	1
	48	611	554	3	5	2	0	0	3360	2378	23	107	8	0	0
	49	488	431	3	11	0	0	0	2598	1789	28	271	0	0	0
	50	1680	1643	3	16	0	0	0	11213	10514	14	351	0	0	0
	51	445	408	1	18	0	0	0	2559	1876	8	401	0	0	0
	52	2481	2439	12	11	0	0	0	14350	13787	100	260	14	0	0
	53	3289	3235	15	7	0	0	0	17278	16686	132	175	0	0	0
Month	1	1968	1927	34	2	0	0	0	11194	10668	296	126	0	0	0
	2	1977	1923	35	1	1	0	0	11387	11036	238	30	3	2	0
	3	1402	1383	9	0	0	0	0	8683	8534	61	7	0	0	0
	4	1310	1275	7	0	6	0	0	8153	7825	50	1	15	19	0
	5	899	653	10	141	17	4	2	5390	3808	74	218	140	169	6
	6	1115	63	2	959	7	3	60	3695	501	22	2543	93	96	202
	7	936	6	3	669	1	5	230	3926	154	56	2729	38	28	694
	8	727	10	5	481	2	4	198	3512	140	78	2398	13	25	539
	9	581	31	4	334	3	3	162	2780	246	51	1396	15	44	453
	10	264	121	2	19	72	13	20	1298	614	30	127	197	45	55
	11	629	392	4	2	180	4	0	4330	3217	62	36	453	16	1
	12	1271	1226	5	14	0	0	0	7478	6760	41	312	4	0	0
Season	Winter	1733	1689	28	1	1	0	0	9973	9583	220	65	1	1	0
	Spring	1110	729	7	319	10	3	1	5920	4435	54	738	78	98	4
	Summer	860	12	4	598	2	4	209	3712	175	62	2425	38	39	609
	Fall	562	373	3	64	73	6	16	3282	2307	38	331	191	31	44
Year	1974	871	370	5	345	25	4	89	4401	2281	58	1271	93	51	257

*Recorded to the nearest whole number

†WP = white perch; SB = striped bass; TC = Atlantic tomcod; BH = blueback herring; AL = alewife; BA = bay anchovy

Table B-7

Numbers and Weights of Fish Collected/1,000,000 m^3 of Water Circulated, Unit 3, 1974

		Total Number*							Total Weight (gm)*						
		All Species Combined	WP†	SB	TC	BH	AL	BA	All Species Combined	WP†	SB	TC	BH	AL	BA
Week	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	11	95	27	7	0	0	0	0	1424	163	61	0	0	0	0
	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	16	809	709	5	0	0	4	0	6840	4883	34	29	0	980	0
	17	935	571	3	0	7	7	0	9788	5164	24	0	17	1567	0
	18	679	355	4	0	0	8	0	7209	1931	25	0	0	1548	0
	19	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	23	612	85	4	486	13	8	2	2586	537	43	1276	144	292	6
	24	1190	53	7	1005	30	5	1	5202	539	62	2792	949	48	2
	25	2313	49	6	1993	25	14	63	9288	439	82	6254	1035	600	232
	26	1263	22	4	900	12	27	123	5701	138	25	2708	90	1201	433
	27	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	28	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	29	1174	4	4	886	1	1	201	5063	176	165	3572	122	14	644
	30	887	3	6	459	0	28	302	4309	47	333	1915	0	623	887
	31	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	32	121	0	2	104	0	2	6	879	1	113	518	0	11	19
	33	86	0	0	31	0	0	16	1266	0	0	197	0	0	63
	34	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	35	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	36	45	2	2	30	0	0	1	540	6	143	146	0	1	4
	37	101	0	5	55	0	0	3	1170	0	22	416	0	0	11
	38	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	39	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	41	40	12	3	6	2	11	2	221	52	11	44	8	47	5
	42	89	26	13	10	0	26	3	469	121	52	89	0	84	10
	43	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	44	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	45	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	46	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	47	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	48	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	49	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	51	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	52	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	53	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Month	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	95	27	7	0	0	0	0	1424	163	61	0	0	0	0
	4	817	700	5	0	0	4	0	7038	4902	34	27	1	1020	0
	5	679	355	4	0	0	8	0	7209	1931	25	0	0	1548	0
	6	1516	62	5	1280	20	12	37	6202	470	62	3886	639	466	136
	7	1147	4	4	846	1	3	211	4992	164	181	3417	111	71	666
	8	120	0	2	102	0	2	6	890	1	110	508	0	10	20
	9	49	2	2	31	0	0	1	579	5	135	162	0	1	4
	10	44	13	4	6	2	12	2	240	58	14	47	7	50	5
	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Season	Winter	95	27	7	0	0	0	0	1424	163	61	0	0	0	0
	Spring	743	311	5	328	9	6	1	4773	2115	40	885	161	634	3
	Summer	1075	19	4	895	9	7	60	4576	187	114	2973	387	267	204
	Fall	260	158	8	29	7	12	2	2359	820	198	548	22	52	6
Year	1974	865	131	5	603	9	7	33	4365	894	100	1989	268	361	114

*Recorded to the nearest whole number

†WP = white perch; SB = striped bass; TC = Atlantic tomcod; BH = blueback herring; AL = alewife; BA = bay anchovy

APPENDIX C

WATER QUALITY DATA

Table C-1

Water Quality, Unit 1 Intake, 1974

Date	DO (ppm)	pH	Conductivity (μmho/cm)	Temperature (°C)
Jan 1	13.0	7.2	302.0	0.7
2	*	7.1	170.5	0.6
3	*	7.2	181.5	0.7
4	*	7.3	192.0	0.8
5	12.9	7.6	164.0	0.3
6	12.4	*	*	0.7
7	13.1	6.8	286.5	0.8
8	13.5	6.9	199.5	0.2
9	13.2	7.0	261.0	0.6
10	*	7.0	274.0	*
11	13.2	7.0	283.0	1.0
12	14.2	7.0	210.0	0.1
13	13.1	7.0	161.5	0.1
14	12.8	7.0	167.0	0.1
15	14.1	6.8	154.5	0.2
16	14.8	7.2	180.5	1.0
17	11.4	7.0	143.0	*
18	*	*	*	*
19	14.5	7.3	560.0	0.9
20	13.5	7.3	1244.5	1.0
21	13.5	7.4	2656.0	0.7
22	13.5	7.1	2708.5	0.7
23	14.7	7.2	1963.0	1.5
24	14.2	7.1	979.5	1.0
25	14.0	7.2	671.5	0.8
26	13.6	7.2	426.5	0.8
27	14.2	7.1	323.5	0.9
28	13.8	7.2	273.5	0.9
29	13.7	6.4	215.5	0.9
30	13.6	7.2	232.0	1.0
31	14.1	7.1	233.5	1.0
Feb 1	14.2	7.4	233.0	0.5
2	*	*	*	0.6
3	*	7.2	240.0	0
4	*	7.2	137.5	*
5	*	7.2	241.0	*
6	*	6.8	485.0	*
7	13.4	6.9	1010.5	0
8	13.6	6.9	689.5	0.4
9	14.5	7.1	375.0	0.1
10	15.6	7.2	317.5	0.3
11	15.9	6.8	256.5	0.4
12	13.8	7.2	275.0	0.8
13	14.8	7.2	268.5	0.5
14	13.2	7.3	301.5	0.6
15	9.4	7.3	154.5	0
16	*	7.0	151.0	0
17	*	7.3	388.0	0.2
18	13.7	7.2	1742.0	0.1
19	13.9	7.4	5005.0	0.3
20	14.0	7.4	6021.5	1.0
21	14.0	7.7	5060.0	0
22	13.4	7.4	6357.0	1.3
23	*	7.3	1794.0	0
24	13.0	7.2	539.0	1.0
25	*	7.3	521.0	1.0
26	15.5	7.4	302.5	1.5
27	13.3	7.3	336.0	1.8
28	12.5	7.5	224.0	2.0

*No data taken

Table C-1 (Contd)

Date	DO (ppm)	pH	Conductivity (μmho/cm)	Temperature (°C)
Mar 1	12.6	7.3	215.0	1.3
2	13.8	7.2	305.5	1.1
3	13.2	7.3	360.0	0.9
4	12.0	7.3	*	1.9
5	14.0	7.5	209.0	2.5
6	14.6	7.6	196.5	1.8
7	13.7	7.4	336.0	2.0
8	14.6	7.2	174.5	3.5
9	14.3	7.2	170.5	3.0
10	13.3	9.5	177.5	2.5
11	14.9	7.0	188.0	3.0
12	15.4	7.1	179.0	3.0
13	13.5	7.5	171.0	3.3
14	11.4	7.5	188.0	3.0
15	12.3	7.7	179.0	4.5
16	13.5	7.4	294.0	3.0
17	14.5	7.2	213.5	2.5
18	*	*	*	*
19	14.7	7.1	1876.5	3.5
20	12.9	7.3	674.0	4.0
21	16.4	7.5	1288.5	4.8
22	10.8	7.4	1649.5	4.0
23	13.4	7.3	1490.0	4.8
24	14.3	7.2	896.5	4.4
25	10.6	7.1	333.0	5.3
26	*	7.2	342.0	6.3
27	13.0	7.2	248.0	5.0
28	12.6	7.6	201.0	5.5
29	12.2	7.6	193.0	5.5
30	16.1	7.0	448.0	5.5
31	12.8	7.0	222.0	3.0
Apr 1	13.7	7.3	564.0	4.5
2	13.4	7.3	2504.0	3.4
3	12.8	*	1656.5	3.7
4	14.2	7.2	1582.5	4.5
5	13.6	7.3	1010.5	4.3
6	11.3	7.4	264.0	4.8
7	12.4	7.2	265.5	4.3
8	12.6	7.0	477.5	4.6
9	13.0	7.4	265.0	4.9
10	12.9	7.4	266.5	4.7
11	12.7	7.4	251.5	5.5
12	13.7	7.4	300.0	5.0
13	14.0	7.5	259.5	4.5
14	*	7.3	290.5	4.8
15	14.2	7.4	294.0	6.8
16	16.4	7.3	286.5	2.5
17	15.0	7.2	213.0	4.3
18	15.0	7.4	213.0	4.3
19	*	7.2	172.5	*
20	12.6	7.2	229.5	4.3
21	12.2	7.3	205.0	4.9
22	12.0	7.2	231.0	5.8
23	12.0	7.3	223.0	6.3
24	14.4	7.2	198.5	5.3
25	16.0	7.3	256.0	6.0
26	13.6	7.1	295.5	7.0
27	13.6	7.4	292.5	6.3
28	*	7.4	248.5	7.5
29	10.4	7.3	231.5	8.5
30	12.7	7.2	*	5.4

*No data taken

Table C-1 (Contd)

Date	DO (ppm)	pH	Conductivity (µmho/cm)	Temperature (°C)
May 1	13.1	6.8	283.5	8.8
2	*	7.0	221.0	*
3	13.3	9.0	276.0	12.3
4	12.6	7.0	507.0	9.8
5	11.9	7.0	272.5	10.7
6	13.1	7.0	415.0	10.5
7	13.9	8.9	591.0	9.5
8	9.6	7.0	215.0	10.0
9	11.9	7.3	234.5	10.3
10	13.0	8.8	257.0	10.5
11	11.3	7.2	190.0	10.3
12	9.8	7.8	232.5	10.0
13	12.7	7.3	212.0	11.3
14	*	8.1	215.0	10.0
15	*	7.2	201.5	*
16	*	7.0	141.0	*
17	*	7.2	147.5	*
18	*	7.2	152.5	*
19	*	7.1	157.5	*
20	*	7.1	160.0	*
21	*	7.2	190.0	16.8
22	*	6.9	157.0	18.5
23	*	7.9	159.0	17.0
24	10.0	7.2	178.0	17.0
25	*	7.2	155.0	18.3
26	*	7.3	160.0	18.3
27	*	7.2	164.0	16.5
28	*	7.2	156.5	17.5
29	*	7.2	166.0	17.0
30	*	7.0	160.0	18.3
31	*	7.2	162.0	17.3
Jun 1	*	7.2	172.5	18.1
2	*	7.2	174.5	17.6
3	*	7.1	175.0	18.0
4	*	8.2	169.5	18.0
5	10.8	7.1	168.5	19.3
6	11.0	7.1	172.5	18.2
7	7.1	8.9	172.0	18.3
8	6.9	7.2	171.5	19.3
9	5.4	7.1	172.5	18.9
10	9.2	7.2	163.5	21.5
11	*	7.2	252.5	20.5
12	*	7.2	355.5	20.2
13	6.6	7.2	1269.5	20.1
14	5.6	7.4	597.0	20.0
15	7.3	8.2	1280.5	19.9
16	7.0	7.3	1352.5	20.0
17	7.6	7.4	1506.0	20.5
18	8.2	7.6	1402.0	21.3
19	8.1	7.6	1024.0	26.0
20	4.7	7.1	2518.5	21.8
21	6.9	7.4	2228.0	25.5
22	2.3	7.4	862.0	21.3
23	5.1	7.3	2362.0	23.3
24	5.4	7.5	1801.0	21.4
25	7.0	7.7	1783.0	21.0
26	4.6	7.6	628.5	21.0
27	1.9	7.5	603.5	20.9
28	1.4	7.4	428.5	21.0
29	2.0	7.5	793.0	21.3
30	3.3	7.3	584.5	21.5

*No data taken

Table C-1 (Contd)

Date	DO (ppm)	pH	Conductivity (μmho/cm)	Temperature (°C)
Jul 1	2.6	7.2	483.0	22.0
2	5.1	7.5	531.5	23.0
3	10.2	7.7	573.5	22.0
4	6.8	6.9	257.0	23.6
5	7.7	7.4	235.0	24.0
6	8.2	7.4	199.5	25.1
7	5.5	7.2	207.5	23.1
8	7.1	7.2	200.5	24.3
9	6.3	7.2	196.0	25.4
10	2.3	7.3	4280.0	24.8
11	5.1	7.2	5415.5	23.9
12	1.3	7.2	4118.0	24.2
13	1.5	7.6	659.0	23.9
14	2.1	7.4	327.5	23.9
15	5.6	7.4	310.0	25.0
16	8.3	7.4	205.0	25.0
17	6.0	7.2	178.0	25.5
18	6.6	*	*	25.3
19	6.4	7.4	3899.0	25.0
20	6.6	7.4	5793.0	25.1
21	7.3	7.5	5938.5	25.5
22	7.7	*	*	25.5
23	7.1	*	*	24.5
24	9.2	*	*	32.1
25	8.5	*	*	25.1
26	9.9	*	*	24.8
27	9.6	*	*	24.4
28	9.7	*	*	24.5
29	9.6	*	*	24.8
30	10.3	*	5932.5	24.8
31	6.6	7.5	5378.5	24.8
Aug 1	6.1	7.4	3652.0	24.3
2	7.0	7.3	4622.0	24.8
3	9.3	7.5	4471.5	24.8
4	8.5	7.4	4622.5	24.8
5	6.1	7.5	4055.5	25.6
6	10.0	7.3	3899.0	25.0
7	11.3	7.3	3945.0	25.1
8	6.3	7.2	3771.5	25.1
9	6.0	7.1	3365.0	25.7
10	7.0	7.2	3968.0	25.2
11	6.3	7.2	3083.0	24.9
12	6.9	7.3	2352.0	26.0
13	9.3	7.6	5195.0	26.0
14	6.5	7.6	6140.5	26.0
15	10.2	7.5	5450.5	25.5
16	6.7	5.6	*	21.6
17	7.9	7.4	6558.5	28.9
18	6.8	7.2	6755.0	25.3
19	11.8	7.3	6959.0	26.0
20	10.8	7.6	6418.5	26.4
21	6.0	7.3	6831.5	25.5
22	6.6	7.3	6746.0	26.5
23	5.5	7.5	4045.0	27.5
24	5.6	*	3966.0	27.9
25	6.0	7.4	3135.5	27.9
26	5.2	7.5	4133.0	26.0
27	7.1	7.7	4704.5	25.5
28	6.5	7.3	4430.0	28.0
29	7.7	7.2	5052.5	27.9
30	*	7.5	5035.5	25.0
31	*	7.3	4915.5	26.9

*No data taken

Table C-1 (Contd)

Date	DO (ppm)	pH	Conductivity (μmho/cm)	Temperature (°C)
Sep 1	*	7.3	5561.0	28.0
2	*	*	4624.5	24.7
3	*	7.5	4458.0	25.8
4	*	7.3	4371.5	24.8
5	*	7.3	2663.5	25.2
6	*	7.1	*	24.5
7	*	7.4	*	23.8
8	*	7.2	3129.5	24.1
9	7.4	7.3	2983.5	24.0
10	9.7	7.4	1049.0	23.8
11	4.0	7.7	2012.0	23.1
12	7.6	7.6	2001.5	24.0
13	7.0	7.5	2000.0	24.4
14	8.6	7.3	2065.0	23.8
15	8.6	7.5	1974.5	24.1
16	8.4	7.8	1418.0	24.7
17	8.6	7.5	1497.0	24.4
18	7.3	7.4	793.5	22.5
19	8.1	7.6	1425.5	23.0
20	9.1	7.1	907.0	23.8
21	8.6	7.5	709.0	24.9
22	8.4	7.4	393.5	25.0
23	8.5	7.5	230.5	24.0
24	8.3	7.5	427.5	21.7
25	7.9	7.5	854.5	21.8
26	8.5	7.5	1846.5	21.6
27	7.5	7.5	3586.0	20.5
28	11.6	7.6	3358.0	22.0
29	7.9	7.4	3346.5	22.0
30	7.1	7.7	2723.0	20.8
Oct 1	7.8	7.5	2841.0	19.7
2	8.0	6.9	2511.0	18.9
3	8.4	7.4	1738.5	17.5
4	8.1	7.2	1230.0	17.8
5	6.9	7.1	1098.5	18.2
6	6.4	7.2	1103.0	18.5
7	9.1	7.3	1004.8	17.9
8	8.4	7.4	649.5	17.0
9	8.0	7.6	554.0	17.0
10	6.8	7.5	613.0	17.2
11	6.5	7.6	548.5	17.0
12	8.1	7.5	1302.0	18.5
13	6.5	*	511.0	16.7
14	5.6	7.7	1248.5	17.1
15	8.1	7.6	1630.5	17.3
16	7.3	7.6	1184.5	17.3
17	*	7.5	1340.0	20.4
18	*	8.0	768.5	19.0
19	*	7.3	617.5	21.1
20	*	7.3	609.0	17.0
21	6.6	7.6	713.0	15.5
22	8.1	7.6	4177.5	15.2
23	5.9	7.6	3740.0	15.3
24	*	7.8	490.5	15.3
25	8.9	7.5	1129.0	13.8
26	9.4	7.5	2108.0	13.5
27	15.3	7.6	3038.0	13.9
28	8.3	7.6	4497.0	13.2
29	11.1	7.6	4588.0	13.6
30	10.2	7.4	4175.5	13.9
31	9.0	7.7	4646.0	13.9

*No data taken

Table C-1 (Contd)

Date	DO (ppm)	pH	Conductivity (μmho/cm)	Temperature (°C)
Nov 1	9.1	7.8	4835.0	13.9
2	*	7.6	3992.5	*
3	13.3	7.6	4392.5	13.9
4	*	7.6	4667.0	14.0
5	11.2	7.7	2775.0	14.0
6	11.1	7.6	2616.0	13.5
7	10.4	7.8	1672.0	12.5
8	11.1	7.8	1348.5	12.0
9	10.9	7.8	1309.0	12.0
10	12.1	7.7	1609.5	11.5
11	9.5	7.8	2043.0	11.1
12	10.5	7.6	2445.5	12.0
13	10.1	7.9	2842.5	12.0
14	9.7	7.9	1173.5	11.7
15	9.5	7.9	538.5	11.8
16	9.5	7.9	388.0	11.0
17	11.9	8.0	344.5	10.6
18	11.8	7.8	319.5	10.8
19	7.0	7.7	279.5	10.3
20	11.0	7.4	252.0	10.9
21	13.0	7.7	250.0	10.0
22	10.5	*	249.0	8.0
23	9.3	*	224.0	8.5
24	9.2	*	244.5	8.0
25	9.4	*	227.0	8.0
26	9.1	*	235.5	7.4
27	8.3	*	345.0	7.1
28	9.8	*	678.0	7.0
29	4.8	*	376.0	7.1
30	*	*	343.0	7.0
Dec 1	8.8	*	317.0	6.9
2	12.1	*	790.5	7.4
3	6.9	*	274.5	8.0
4	9.4	*	247.5	7.1
5	*	*	701.0	*
6	*	*	392.0	5.1
7	*	*	195.0	*
8	*	*	357.0	6.0
9	*	*	231.0	6.0
10	*	*	220.5	5.5
11	*	*	253.5	6.1
12	*	*	220.5	5.5
13	*	*	229.5	5.9
14	*	*	232.0	6.1
15	*	*	253.5	5.5
16	*	*	159.5	8.0
17	*	*	208.5	7.5
18	*	*	206.5	5.5
19	*	*	224.0	5.0
20	*	*	193.5	5.5
21	*	*	185.0	5.6
22	*	*	187.0	5.5
23	*	*	196.0	3.0
24	*	*	213.0	3.0
25	*	*	215.5	3.0
26	*	*	389.5	3.9
27	*	*	1661.0	4.1
28	*	*	1755.0	3.6
29	*	*	1918.0	5.0
30	*	*	1485.0	4.0
31	*	*	1079.0	5.0

*No data taken

Table C-2

Water Quality, Unit 2 Intake, 1974

Date	DO (ppm)	pH	Conductivity (umho/cm)	Temperature (°C)
Jan 1	13.1	7.1	282.5	0.4
2	13.9	7.1	184.0	0.6
3	13.0	7.2	175.5	1.3
4	13.7	7.2	212.5	0.8
5	12.8	7.4	160.0	0.2
6	12.4	*	*	1.0
7	13.1	6.6	268.5	1.2
8	13.3	6.9	264.0	0.6
9	13.4	6.8	248.0	0.3
10	*	6.9	149.5	*
11	13.2	7.0	273.5	0.9
12	14.4	7.0	368.5	1.0
13	13.9	6.9	227.0	0.6
14	14.6	6.9	248.0	0.5
15	14.3	6.9	156.0	0.6
16	10.0	7.2	178.0	0.8
17	15.5	7.0	140.0	0.5
18	*	7.5	149.0	*
19	14.5	7.2	261.0	0
20	13.6	7.3	1315.0	1.5
21	13.3	7.4	2464.5	0.7
22	13.5	7.0	2711.5	0.5
23	15.5	7.2	1949.5	1.0
24	14.1	7.0	968.5	0.9
25	14.1	7.0	592.5	1.2
26	13.3	7.1	365.5	1.0
27	13.9	7.2	315.0	1.6
28	14.2	7.1	342.0	1.5
29	13.9	6.8	207.0	1.5
30	14.1	7.0	231.5	1.5
31	14.4	7.3	248.0	1.0
Feb 1	14.3	7.2	242.5	1.1
2	14.5	7.3	195.0	0.2
3	*	7.3	244.5	0
4	*	7.2	137.0	*
5	*	7.2	194.5	*
6	*	6.9	312.5	*
7	14.0	7.0	1104.0	0
8	14.2	7.1	558.0	0.1
9	14.6	7.1	481.0	0.6
10	16.7	7.2	396.0	0.3
11	*	*	*	*
12	14.9	7.2	264.5	0.8
13	15.5	7.3	262.5	0.5
14	14.9	7.3	264.5	0.3
15	14.5	7.5	243.0	0.3
16	12.6	7.2	251.5	0.3
17	*	7.3	483.5	1.0
18	13.5	7.4	2907.0	0.3
19	13.2	7.4	5591.0	0.9
20	13.9	7.5	5690.5	0.9
21	14.1	7.5	4793.0	0
22	13.6	7.4	6201.5	1.0
23	16.5	7.2	1886.0	0
24	13.0	7.5	539.0	1.0
25	*	7.2	539.0	1.0
26	16.5	7.0	347.0	1.6
27	13.8	7.3	329.5	1.8
28	12.0	7.3	234.0	1.4

*No data taken

Date	DO (ppm)	pH	Conductivity (μmho/cm)	Temperature (°C)
Mar 1	12.5	7.3	220.0	1.1
2	13.5	7.3	295.5	1.2
3	12.9	7.3	191.0	0.7
4	13.3	7.4	209.0	1.5
5	14.7	7.7	217.5	2.4
6	14.3	7.5	252.0	2.0
7	10.7	7.2	319.0	1.8
8	14.3	*	183.5	2.3
9	14.5	7.2	173.0	2.5
10	13.2	7.2	168.5	2.5
11	14.3	7.1	173.0	3.0
12	15.3	7.1	173.0	2.5
13	13.8	7.4	166.0	3.8
14	11.6	7.5	188.5	2.9
15	12.3	7.7	177.0	4.0
16	13.2	7.3	628.0	2.8
17	14.6	7.2	211.5	2.8
18	*	*	*	*
19	13.1	7.4	1812.0	3.4
20	12.5	7.3	677.0	4.1
21	13.1	7.4	1237.5	4.0
22	11.5	7.4	1320.0	4.0
23	13.4	7.3	1490.0	4.8
24	14.3	7.2	969.0	4.0
25	11.4	7.1	350.0	5.0
26	*	7.2	312.0	7.0
27	13.6	7.2	235.5	4.5
28	12.2	7.4	208.0	4.8
29	11.7	7.6	208.0	5.0
30	16.2	7.2	443.5	5.3
31	11.9	7.1	226.5	4.0
Apr 1	13.9	7.3	507.0	5.0
2	13.6	7.3	2162.5	3.5
3	13.8	7.3	2194.0	2.8
4	13.6	7.2	1389.5	4.7
5	13.5	7.4	1031.0	4.0
6	12.7	7.3	270.0	4.3
7	12.4	7.3	253.0	4.5
8	12.7	7.2	252.5	4.5
9	12.5	7.3	259.5	4.6
10	13.8	7.5	262.0	4.8
11	13.6	7.3	263.0	5.1
12	13.7	7.4	306.0	4.8
13	14.2	7.5	263.5	4.5
14	*	7.3	304.0	5.0
15	14.2	7.4	278.5	7.0
16	16.1	7.3	301.0	2.8
17	15.3	7.2	232.0	5.0
18	15.3	7.3	232.0	5.0
19	*	7.2	459.5	4.9
20	13.1	7.6	214.0	4.8
21	12.3	7.2	209.0	4.9
22	12.1	7.2	228.5	5.6
23	11.8	7.2	226.0	5.9
24	14.3	7.3	198.5	5.3
25	16.0	7.3	260.0	6.0
26	13.9	7.0	244.5	6.5
27	13.7	7.4	325.5	6.0
28	14.2	7.3	240.0	8.3
29	11.4	7.3	242.0	8.0
30	14.3	7.2	*	5.4

*No data taken

Table C-2 (Contd)

Date	DO (ppm)	pH	Conductivity (μmho/cm)	Temperature (°C)
May 1	13.5	6.8	297.5	9.3
2	12.5	7.0	234.5	11.0
3	13.9	7.1	250.0	12.8
4	12.9	7.1	231.0	9.9
5	12.0	7.1	241.0	8.0
6	12.9	7.1	354.5	10.8
7	13.5	8.9	584.5	9.3
8	9.9	7.0	219.0	10.0
9	13.0	7.2	249.5	10.7
10	13.0	8.7	265.5	10.3
11	11.6	7.1	223.5	10.0
12	10.5	7.4	208.5	10.0
13	12.7	7.2	219.5	12.3
14	*	7.2	221.0	10.3
15	*	7.2	141.5	*
16	*	7.1	143.5	*
17	*	7.1	151.0	*
18	*	7.1	150.5	*
19	*	7.1	157.5	*
20	*	7.1	156.5	*
21	*	7.1	189.0	17.0
22	*	7.2	157.5	17.5
23	*	7.5	160.5	17.3
24	9.8	7.0	177.0	17.1
25	*	7.3	156.5	17.8
26	*	7.2	159.5	17.8
27	*	7.2	167.0	16.3
28	*	7.2	160.5	18.0
29	*	7.2	159.5	16.8
30	*	7.1	159.0	18.0
31	*	7.2	160.0	17.3
Jun 1	*	7.0	173.5	18.0
2	*	7.1	174.5	17.8
3	*	7.2	173.0	18.0
4	*	7.2	173.0	18.0
5	11.0	7.1	174.0	17.8
6	10.9	7.1	170.0	18.9
7	7.9	7.5	172.0	18.3
8	6.7	7.2	175.0	18.8
9	4.9	7.2	165.0	21.3
10	8.2	7.2	169.0	20.0
11	*	7.4	213.0	21.3
12	7.1	7.4	247.5	20.0
13	7.4	7.3	1221.5	18.8
14	5.6	7.4	714.5	19.2
15	8.3	7.7	1297.0	19.6
16	8.6	7.2	1361.0	20.0
17	7.0	7.2	1957.5	21.5
18	8.0	7.5	1436.0	21.0
19	8.1	7.5	1290.0	21.4
20	6.1	7.2	2255.0	21.5
21	7.5	7.4	1782.0	25.5
22	1.8	7.3	862.0	21.3
23	6.3	7.4	1931.0	21.5
24	4.0	7.5	1856.0	21.5
25	6.9	7.5	1295.5	21.0
26	2.8	7.4	741.0	21.1
27	2.1	7.4	626.0	21.0
28	1.8	7.4	487.5	21.1
29	3.1	7.4	758.5	21.0
30	4.4	7.2	589.5	21.4

*No data taken

Table C-2 (Contd)

Date	DO (ppm)	pH	Conductivity (μmho/cm)	Temperature (°C)
Jul 1	2.3	7.4	494.0	22.5
2	7.8	7.3	520.0	23.0
3	10.3	7.3	561.0	24.0
4	7.2	7.2	241.5	24.1
5	7.3	7.2	231.0	23.8
6	8.2	7.3	188.5	29.6
7	3.2	7.2	204.5	23.2
8	7.0	7.2	192.5	24.4
9	5.0	7.3	184.5	25.2
10	1.7	7.7	5159.5	24.9
11	5.1	7.6	5099.0	24.0
12	1.8	7.3	4376.5	24.1
13	1.6	8.0	591.0	24.0
14	1.9	7.2	327.5	23.8
15	6.2	8.3	306.0	24.9
16	9.2	7.2	200.5	24.9
17	6.3	7.3	180.0	25.0
18	5.9	*	*	25.3
19	6.1	7.4	3402.5	25.0
20	6.1	7.4	5830.5	25.2
21	7.4	7.7	5891.0	27.9
22	*	*	*	*
23	8.1	*	*	24.5
24	9.8	*	*	24.9
25	6.8	*	*	24.4
26	9.3	*	*	24.5
27	8.9	*	*	24.5
28	9.0	*	*	24.3
29	9.3	*	*	24.5
30	7.8	*	5452.5	24.5
31	6.9	7.4	4909.0	24.9
Aug 1	6.3	7.7	3665.5	24.8
2	5.7	7.4	4949.0	24.5
3	8.9	7.5	4426.0	24.7
4	9.9	7.5	4278.0	25.3
5	6.7	7.5	4091.0	25.1
6	13.2	7.2	3749.0	25.0
7	10.9	7.2	3949.0	25.0
8	7.3	7.3	2967.5	25.6
9	6.3	7.2	3257.0	25.7
10	7.7	7.4	4507.5	25.5
11	5.9	7.1	3273.5	24.9
12	7.2	7.1	2474.0	25.0
13	8.9	7.6	3049.0	25.0
14	6.2	7.4	6433.5	25.9
15	9.4	7.5	5346.5	25.5
16	8.3	7.5	*	26.0
17	7.9	7.3	6714.0	26.0
18	5.2	7.2	6645.5	25.4
19	9.6	7.2	6599.0	27.3
20	10.9	7.6	6554.0	26.1
21	5.9	7.3	6882.5	24.0
22	6.8	7.1	6685.5	26.6
23	5.8	7.5	3542.5	26.5
24	6.2	*	3137.0	28.0
25	6.2	7.4	3342.5	28.1
26	5.4	7.4	4237.5	25.2
27	6.1	7.5	4998.0	25.0
28	6.4	7.3	4477.0	28.0
29	8.4	7.1	5561.0	28.0
30	*	7.6	6498.0	25.0
31	*	7.2	4969.0	26.8

*No data taken

Table C-2 (Contd)

Date	DO (ppm)	pH	Conductivity (µmho/cm)	Temperature (°C)
Sep 1	*	7.3	5475.5	27.5
2	*	*	4767.5	24.0
3	*	7.6	5134.5	24.5
4	*	7.5	5258.0	24.9
5	*	7.3	2807.5	25.3
6	*	7.2	*	24.8
7	*	7.5	*	24.1
8	*	7.3	2908.5	24.4
9	7.9	7.4	2850.5	23.7
10	10.0	7.4	1155.0	22.9
11	5.7	7.6	2040.0	22.4
12	5.7	7.6	2036.0	24.1
13	5.0	7.5	1941.5	23.9
14	7.8	7.6	2107.0	23.0
15	9.0	7.5	1954.0	24.3
16	8.3	7.6	1437.0	24.3
17	8.9	7.7	1495.0	23.5
18	7.1	7.5	840.5	22.2
19	7.6	7.6	1383.0	23.8
20	9.9	7.2	893.5	23.7
21	7.5	7.4	752.0	23.3
22	7.2	7.4	530.5	23.5
23	8.4	7.5	328.5	20.8
24	8.9	7.5	364.0	21.7
25	8.9	7.5	1113.0	20.9
26	8.8	7.5	1914.0	20.4
27	8.1	7.4	3823.0	19.3
28	11.2	7.5	3005.0	21.5
29	8.2	7.4	2623.5	22.5
30	8.9	7.7	3330.0	20.3
Oct 1	8.3	7.5	3062.5	19.7
2	7.8	7.1	2372.5	18.9
3	8.8	7.4	1608.5	17.6
4	7.1	7.2	1200.0	18.0
5	7.8	7.3	1181.5	18.1
6	8.2	7.2	1178.0	18.2
7	*	*	*	*
8	7.6	7.6	580.0	16.9
9	8.9	7.6	554.0	17.0
10	7.1	7.5	642.5	17.0
11	8.4	7.6	540.0	17.0
12	7.4	7.5	1247.5	17.1
13	6.2	*	572.0	16.5
14	5.4	7.7	1182.0	16.9
15	8.4	7.6	1552.0	17.5
16	7.2	7.7	1132.0	17.0
17	*	7.7	1389.0	18.7
18	*	8.0	779.5	19.0
19	*	7.4	638.0	21.1
20	*	7.5	613.0	17.0
21	5.7	7.5	682.0	15.6
22	8.9	7.8	4225.0	14.7
23	5.7	7.7	3846.0	15.5
24	*	7.9	758.0	15.0
25	9.3	7.7	1209.0	15.5
26	10.6	7.7	2218.5	14.4
27	9.6	7.7	2838.0	14.0
28	9.7	7.9	4507.0	13.1
29	11.4	7.5	4530.0	14.1
30	9.0	7.6	4405.0	13.8
31	9.5	7.7	4893.0	14.0

*No data taken

Table C-2 (Contd)

Date	DO (ppm)	pH	Conductivity (umho/cm)	Temperature (°C)
Nov 1	9.2	7.9	4497.5	13.8
2	8.9	8.7	4498.5	14.1
3	14.0	7.5	4598.0	13.8
4	*	*	*	*
5	11.4	7.9	2775.0	14.0
6	11.4	7.6	2527.0	15.0
7	14.3	7.8	1542.5	13.9
8	10.6	7.9	1375.0	12.0
9	10.7	7.8	1262.5	12.0
10	11.2	7.8	2375.5	11.5
11	11.2	7.8	2258.5	11.2
12	10.5	7.6	2478.5	12.0
13	10.2	7.9	2578.0	12.0
14	10.0	7.9	1271.0	11.5
15	9.3	7.9	481.5	15.5
16	11.5	7.9	356.0	11.0
17	11.9	8.0	329.0	10.7
18	12.9	7.8	306.5	10.0
19	11.6	7.6	267.5	11.0
20	9.8	7.5	256.0	10.2
21	12.2	7.6	250.0	10.0
22	12.1	*	243.5	8.3
23	10.4	*	225.5	8.3
24	7.7	*	241.0	7.9
25	7.9	*	227.5	7.9
26	11.2	*	233.5	7.5
27	10.4	*	328.0	7.0
28	6.0	*	617.0	7.0
29	7.4	*	364.5	7.4
30	9.6	*	330.0	6.9
Dec 1	9.5	*	318.5	7.0
2	13.0	*	784.5	7.6
3	6.5	*	309.5	7.0
4	9.6	*	246.5	7.1
5	*	*	608.5	*
6	*	*	450.0	5.0
7	*	*	170.0	*
8	*	*	334.5	7.5
9	*	*	245.0	7.0
10	*	*	206.5	5.2
11	*	*	260.5	5.4
12	*	*	221.0	5.4
13	*	*	228.0	5.1
14	*	*	232.5	5.7
15	*	*	247.0	6.0
16	*	*	164.5	8.0
17	*	*	216.0	6.0
18	*	*	205.0	5.5
19	*	*	229.5	4.0
20	*	*	190.5	4.8
21	*	*	182.5	5.5
22	*	*	182.5	5.5
23	*	*	192.0	3.0
24	*	*	210.5	2.9
25	*	*	208.5	2.9
26	*	*	498.5	3.8
27	*	*	1685.0	3.4
28	*	*	1772.5	3.0
29	*	*	2067.5	4.9
30	*	*	1595.0	3.5
31	*	*	994.0	4.9

*No data taken

Table C-3

Water Quality, Unit 3 Intake, 1974

Date	DO (ppm)	pH	Conductivity (µmho/cm)	Temperature (°C)
Jan	*	*	*	*
Feb 1-6				
7	14.1	*	892.0	0
8-28	*	*	*	*
Mar	*	*	*	*
Apr 1-16	*	*	*	*
17	13.1	7.5	247.8	3.4
18	13.1	7.3	263.3	4.7
19	*	7.2	239.1	4.5
20	10.3	7.3	218.4	4.2
21	12.5	7.3	218.7	4.3
22	12.2	7.3	252.6	5.6
23	*	*	219.0	6.0
24-30	*	*	*	*
May 1	12.9	7.5	250.8	8.9
2	13.1	7.0	248.2	10.8
3	13.4	9.0	267.3	10.3
4	12.7	7.1	241.0	9.5
5	12.2	7.2	230.5	10.0
6	14.0	7.0	454.5	18.2
7-31	*	*	*	*
Jun 1-4	*	*	*	*
5	10.4	7.1	172.5	18.1
6	9.3	7.1	172.0	18.1
7	7.0	7.2	175.0	18.6
8	7.5	7.2	169.0	19.2
9	6.0	7.2	169.0	19.0
10	6.8	7.3	157.3	20.5
11	7.8	7.2	181.3	20.7
12	8.5	7.3	268.0	20.4
13	8.0	7.3	883.7	20.0
14-18	*	*	*	*
19	8.5	7.4	955.1	21.0
20	5.5	7.2	2083.7	21.2
21	6.5	7.3	2209.4	24.2
22	8.7	7.5	2005.8	22.4
23	6.6	7.4	1719.4	22.3
24	6.2	*	1627.6	22.0
25	4.2	*	*	21.5
26-30	*	*	*	*
Jul 1-17	*	*	*	*
18	6.7	7.2	5296.3	25.7
19	7.1	7.3	5600.8	26.0
20	7.8	7.4	5801.8	25.4
21	7.4	7.3	5549.7	25.6
22	7.9	7.3	5926.6	18.7
23	6.8	7.5	5056.3	24.4
24-31	*	*	*	*
Aug 1-6	*	*	*	*
7	6.6	7.1	3886.8	25.2
8	6.3	7.2	3408.5	23.6
9	6.3	7.3	2846.1	25.5
10	6.7	7.2	3540.2	23.8
11	6.3	7.2	3117.5	25.6
12	7.0	*	2768.9	25.1
13	6.8	*	2876.8	25.0
14-31	*	*	*	*

*No data taken

Table C-3 (Contd)

Date	DO (ppm)	pH	Conductivity (µmho/cm)	Temperature (°C)
Sep 1-3	*	*	*	*
4	*	7.2	4138.7	24.6
5	*	7.5	3621.5	24.2
6	*	7.4	4392.8	23.7
7	*	7.4	4691.0	24.3
8	*	7.3	2990.5	24.3
9	7.9	7.3	3149.6	23.6
10	8.6	7.5	1365.3	22.7
11-30	*	*	*	*
Oct 1-8	*	*	*	*
9	8.1	7.6	1100.8	16.9
10	8.6	7.5	1034.4	17.3
11	8.4	7.6	924.8	16.7
12	8.3	7.5	1339.7	17.0
13	8.5	7.5	1062.9	16.9
14	7.3	7.5	1641.9	17.0
15	8.4	7.6	1031.5	17.3
16-31	*	*	*	*
Nov 1-12	*	*	*	*
13	10.1	7.8	2922.1	12.2
14	10.5	7.9	1299.0	11.2
15	10.6	7.8	535.8	10.8
16	11.0	7.8	353.4	10.5
17	11.9	7.9	306.4	10.9
18	11.8	7.7	367.0	10.6
19	11.8	7.5	276.3	10.5
20-30	*	*	*	*
Dec 1-17	*	*	*	*
18	*	*	221.1	5.7
19	*	*	237.5	3.9
20-26	*	*	*	*
27	*	*	1037.5	4.8
28	*	*	1737.0	4.2
29	*	*	2156.1	4.3
30-31	*	*	*	*

*No data taken

Table C-4

Water Quality, Discharge Canal, 1974

Date	DO (ppm)	pH	Conductivity (μmho/cm)	Temperature (°C)
Jan 1	13.0	6.9	290.0	0.6
2	13.6	7.1	177.5	0.7
3	*	7.2	186.5	1.0
4	13.1	7.5	186.5	0.8
5	11.8	7.3	211.5	0.7
6	12.6	*	*	1.1
7	13.0	6.7	266.5	1.1
8	13.5	6.8	261.0	0.7
9	12.1	6.9	252.5	0.7
10	*	6.9	155.0	*
11	12.9	6.9	281.0	1.2
12	15.0	7.0	289.5	1.1
13	13.1	7.0	326.5	0
14	11.9	6.9	323.0	0.7
15	15.1	6.9	184.0	0.9
16	13.8	7.0	146.5	8.1
17	15.1	6.9	155.0	0.2
18	*	*	*	*
19	15.0	7.3	455.5	0.4
20	12.1	7.4	846.0	10.8
21	12.6	7.5	1962.5	12.3
22	11.5	7.1	2156.5	8.9
23	14.8	7.1	1520.0	8.5
24	14.9	7.0	817.0	7.5
25	14.0	7.3	620.5	1.5
26	13.0	7.2	313.5	6.1
27	13.9	7.1	284.0	4.6
28	14.1	7.1	221.5	8.0
29	13.2	7.0	215.0	1.5
30	13.4	7.1	224.5	0.7
31	14.4	7.2	233.0	1.3
Feb 1	15.2	7.1	224.5	0.9
2	12.9	7.1	218.0	4.0
3	*	7.2	210.5	4.2
4	*	7.2	138.0	*
5	*	7.2	215.0	*
6	*	7.0	240.0	*
7	13.5	7.0	935.0	2.5
8	12.4	7.0	527.0	7.0
9	10.6	7.1	442.0	6.0
10	14.5	7.1	331.5	7.0
11	15.3	7.0	238.0	5.3
12	15.3	7.2	227.5	6.8
13	14.5	7.2	229.5	6.5
14	14.5	7.2	242.5	6.5
15	12.4	7.4	227.5	5.5
16	11.2	7.3	258.0	2.5
17	*	7.3	445.5	3.7
18	12.8	7.5	2676.0	3.0
19	11.9	7.5	5114.5	5.0
20	13.2	7.5	5193.5	6.0
21	15.0	7.4	4802.5	0
22	13.1	7.4	4970.0	7.0
23	*	7.2	1372.0	10.5
24	13.8	7.5	401.5	11.5
25	*	7.2	409.0	10.8
26	17.7	7.4	283.0	10.3
27	14.8	7.3	244.5	11.0
28	13.2	7.3	206.0	11.1

*No data taken

Table C-4 (Contd)

Date	DO (ppm)	pH	Conductivity (μmho/cm)	Temperature (°C)
Mar 1	12.7	7.3	206.0	8.5
2	13.3	7.3	225.0	10.7
3	12.4	7.5	299.0	11.3
4	12.3	7.5	564.0	11.4
5	13.5	7.6	266.0	12.3
6	14.7	7.5	213.0	11.0
7	8.3	7.2	250.5	12.0
8	15.6	*	181.0	14.5
9	14.3	7.2	179.0	13.5
10	14.1	7.0	182.0	13.5
11	6.3	7.1	184.0	15.3
12	18.0	7.1	181.0	13.0
13	14.3	7.4	175.5	10.5
14	13.2	7.5	173.0	8.3
15	12.7	7.7	241.5	10.0
16	12.3	7.3	327.0	7.5
17	15.0	7.2	214.5	7.0
18	*	*	*	*
19	13.5	7.4	1447.5	5.3
20	12.8	7.3	677.0	8.3
21	10.6	7.3	1259.0	5.5
22	11.3	7.4	954.0	11.5
23	11.9	7.3	1226.0	10.8
24	9.5	7.2	857.0	12.1
25	12.7	7.2	332.0	12.5
26	*	7.2	325.5	10.0
27	13.1	7.3	242.5	13.5
28	11.7	7.6	182.0	18.0
29	11.2	7.7	191.0	17.3
30	18.4	7.4	445.0	14.3
31	13.1	7.2	228.0	12.0
Apr 1	13.7	7.3	598.5	15.7
2	12.4	7.3	2278.5	16.9
3	13.3	7.3	2283.0	15.0
4	13.7	7.3	1018.5	16.0
5	13.9	7.3	969.0	16.7
6	12.1	7.1	252.0	17.5
7	12.0	7.3	246.0	8.5
8	12.5	7.3	455.5	15.7
9	10.9	7.4	245.5	19.6
10	12.3	7.4	304.0	16.5
11	13.2	7.3	252.5	13.5
12	13.5	7.4	265.0	15.0
13	14.2	7.3	511.5	11.5
14	*	7.3	256.5	13.5
15	13.5	7.3	219.5	27.8
16	16.2	7.2	212.0	19.0
17	14.8	7.3	235.8	12.7
18	11.2	7.2	288.4	12.9
19	*	7.2	225.6	15.0
20	13.0	7.4	204.6	9.4
21	12.9	7.2	215.2	8.2
22	12.1	7.2	223.6	8.9
23	12.3	7.2	213.2	8.7
24	13.8	7.3	260.5	10.0
25	16.3	7.3	228.0	13.8
26	14.3	7.3	265.5	9.3
27	14.1	7.2	284.5	10.0
28	13.9	7.4	242.0	10.8
29	11.5	7.3	199.0	14.7
30	11.5	7.3	*	8.6

*No data taken

Table C-4 (Contd)

Date	DO (ppm)	pH	Conductivity (μmho/cm)	Temperature (°C)
May 1	12.7	7.1	231.8	19.0
2	13.1	7.1	333.6	16.9
3	12.1	7.1	353.2	18.2
4	13.1	7.0	258.0	12.5
5	11.9	7.0	219.5	15.0
6	11.9	7.0	219.5	15.0
7	13.4	7.0	224.5	20.5
8	9.8	9.3	178.5	18.2
9	12.6	7.1	258.0	19.9
10	12.8	7.3	231.5	16.8
11	12.0	7.8	213.5	10.0
12	10.1	7.2	222.0	10.0
13	12.8	7.2	245.0	10.0
14	*	7.3	215.0	10.0
15	*	7.2	142.5	*
16	*	7.1	143.5	*
17	*	7.0	150.0	*
18	*	7.2	153.5	*
19	*	7.2	157.5	*
20	*	7.2	160.0	*
21	*	7.2	177.0	20.0
22	*	7.3	183.5	13.3
23	*	7.3	148.0	21.0
24	10.1	7.1	164.0	24.2
25	*	7.2	139.0	24.0
26	*	7.4	134.0	24.0
27	*	7.2	145.5	22.7
28	*	7.2	138.5	24.3
29	*	7.3	143.5	22.5
30	*	7.2	138.5	25.3
31	*	7.1	150.0	25.0
Jun 1	*	7.1	156.0	23.0
2	*	7.1	157.0	22.7
3	*	7.3	149.5	25.0
4	*	7.2	144.5	26.0
5	11.8	7.1	146.5	26.3
6	11.7	7.1	148.5	24.8
7	7.7	7.3	155.0	23.3
8	6.4	7.1	152.5	23.6
9	4.2	7.3	151.0	25.0
10	6.8	7.3	150.9	24.1
11	8.6	7.3	159.1	25.4
12	9.3	7.3	290.0	25.8
13	8.2	7.3	826.7	27.1
14	7.2	7.4	588.0	27.3
15	8.5	7.5	1207.5	23.1
16	9.0	7.4	1282.5	23.0
17	8.0	7.6	1564.5	26.1
18	10.5	7.5	1372.0	26.0
19	8.8	7.4	957.8	27.5
20	4.9	7.3	2125.4	29.4
21	7.2	7.3	2150.7	28.6
22	5.6	7.4	3345.0	29.1
23	6.4	7.3	1603.8	30.9
24	5.9	7.3	2303.8	28.2
25	8.1	7.4	1856.0	23.3
26	5.3	7.3	597.5	26.8
27	5.0	7.5	563.5	29.1
28	1.6	7.3	418.0	28.8
29	3.2	7.4	623.0	31.0
30	5.4	7.4	451.0	29.2

*No data taken

Table C-4 (Contd)

Date	DO (ppm)	pH	Conductivity (μmho/cm)	Temperature (°C)
Jul 1	4.5	7.2	428.5	30.0
2	6.2	7.9	520.0	25.9
3	10.3	7.2	501.5	32.0
4	7.4	7.3	240.0	26.1
5	7.5	7.4	187.5	32.1
6	8.4	7.4	173.0	32.5
7	6.2	7.3	191.5	27.1
8	6.8	7.4	184.0	30.7
9	4.6	7.2	177.0	32.6
10	1.9	7.3	4740.5	31.7
11	4.3	7.4	4288.5	32.4
12	3.7	8.3	3725.0	29.9
13	5.4	8.6	405.0	30.4
14	4.5	7.3	271.0	31.1
15	6.8	7.6	260.5	31.4
16	9.8	7.2	178.5	30.8
17	7.1	7.4	173.5	31.1
18	6.9	7.3	4536.8	33.3
19	7.8	7.4	5592.1	31.6
20	7.7	7.4	5254.6	30.6
21	7.6	7.5	4957.2	32.2
22	7.6	7.5	4298.5	32.6
23	8.4	7.4	4386.8	30.8
24	8.8	*	*	39.6
25	9.6	*	*	33.3
26	9.7	*	*	32.1
27	9.5	*	*	32.4
28	9.6	*	*	32.3
29	10.6	*	*	24.8
30	10.2	*	6520.5	26.8
31	7.7	7.5	4948.5	28.0
Aug 1	5.8	7.5	3329.5	28.3
2	6.5	7.4	4524.0	28.0
3	9.3	7.5	4357.5	27.8
4	10.1	7.8	2300.0	29.3
5	6.4	7.5	3588.5	29.3
6	10.3	7.4	3785.0	26.5
7	11.2	7.7	3469.3	32.5
8	6.2	7.3	3547.3	28.1
9	6.4	7.5	2733.4	32.1
10	6.7	7.3	3367.4	31.8
11	6.9	7.5	5128.5	30.9
12	7.2	7.5	2691.8	32.0
13	8.4	7.6	3311.2	32.7
14	6.8	7.6	5063.0	32.4
15	10.1	7.6	5101.0	32.5
16	9.4	7.3	*	34.5
17	8.1	7.3	5890.5	34.6
18	8.1	7.4	5851.5	35.0
19	10.3	7.4	5922.0	34.0
20	11.1	7.5	6048.0	34.0
21	7.3	7.2	6020.5	33.5
22	8.3	7.4	6050.5	32.5
23	6.3	7.6	3364.0	35.3
24	5.8	*	2828.5	34.4
25	5.1	7.6	3204.5	35.3
26	6.3	7.4	4226.0	32.8
27	6.6	7.6	4843.0	32.0
28	6.2	7.4	4830.0	34.0
29	8.8	7.4	4528.5	36.0
30	*	7.5	4738.5	29.8
31	*	7.4	4703.0	32.1

*No data taken

Table C-4 (Contd)

Date	DO (ppm)	pH	Conductivity (μmho/cm)	Temperature (°C)
Sep 1	*	7.4	5158.5	31.9
2	*	7.6	4879.5	26.4
3	*	7.5	5152.5	25.7
4	*	7.4	5017.0	27.8
5	*	7.5	3979.6	32.6
6	*	7.4	4228.8	32.4
7	*	7.6	4378.5	31.3
8	*	7.4	2865.0	28.5
9	8.8	7.3	3119.9	25.7
10	9.3	7.5	1581.0	25.0
11	8.3	7.6	1726.5	29.7
12	6.7	7.6	1832.5	32.0
13	7.4	7.6	1823.5	29.9
14	8.3	7.6	1815.5	30.3
15	8.1	7.6	1740.5	33.8
16	8.4	7.6	1286.5	31.9
17	8.5	7.6	1253.5	31.8
18	9.0	7.6	679.5	31.1
19	8.3	7.8	1431.5	31.5
20	10.3	7.4	784.5	31.5
21	6.5	7.5	616.5	33.2
22	7.3	7.3	352.0	33.5
23	8.8	7.5	296.0	29.2
24	10.2	7.4	359.5	30.6
25	8.3	7.5	941.5	30.6
26	9.8	7.5	1671.0	29.0
27	7.6	7.5	2964.0	28.1
28	10.6	7.6	2865.5	31.5
29	7.5	7.5	4461.0	28.0
30	8.4	7.8	3228.0	22.2
Oct 1	8.8	7.5	2959.5	21.4
2	8.6	6.7	2340.5	19.2
3	10.1	7.3	1576.0	18.2
4	9.6	7.5	1154.0	18.0
5	7.1	7.2	1149.5	18.2
6	9.6	7.3	1123.0	20.3
7	8.6	7.6	880.5	20.3
8	8.7	7.6	611.0	19.0
9	9.1	7.5	1176.7	19.2
10	7.9	7.6	973.4	19.4
11	9.8	7.5	929.4	19.5
12	10.1	7.6	1153.0	23.5
13	9.2	7.5	861.8	25.3
14	7.0	7.6	1412.7	24.4
15	7.3	7.6	1066.3	25.6
16	7.6	7.7	1025.0	25.3
17	*	7.8	1029.5	26.6
18	*	8.0	686.5	26.0
19	*	7.5	585.0	26.1
20	*	7.5	513.0	25.5
21	10.0	7.6	633.5	23.9
22	8.1	7.8	3731.0	23.2
23	8.7	7.7	3579.0	23.2
24	*	7.9	615.0	22.9
25	12.3	7.6	1030.0	23.0
26	9.0	7.7	2037.5	22.2
27	11.2	7.7	3178.5	22.1
28	9.5	7.8	3838.5	21.8
29	10.4	7.7	3993.0	22.5
30	10.5	7.5	4070.5	20.0
31	8.7	7.9	4423.0	20.8

*No data taken

Table C-4 (Contd)

Date	DO (ppm)	pH	Conductivity (μmho/cm)	Temperature (°C)
Nov 1	9.2	7.8	4457.5	20.6
2	10.4	7.7	4527.5	20.1
3	11.6	7.7	4581.0	23.8
4	13.9	7.7	4811.0	22.0
5	10.6	7.9	2655.0	18.0
6	10.1	7.6	2323.5	20.0
7	11.7	7.9	1454.0	18.0
8	11.1	8.0	1135.5	22.5
9	10.1	7.9	1348.0	12.0
10	12.6	7.8	1586.0	12.0
11	12.1	7.9	1846.5	12.1
12	10.7	7.6	1823.5	21.5
13	10.2	7.8	2520.0	18.2
14	10.3	7.9	1154.8	17.5
15	9.9	7.8	452.8	20.4
16	11.5	7.8	309.2	19.1
17	10.2	7.9	258.2	18.9
18	10.1	7.9	292.8	18.6
19	11.6	7.7	268.2	19.3
20	11.0	7.5	209.0	22.8
21	9.8	7.5	217.0	21.0
22	12.1	*	188.0	19.3
23	10.0	*	193.0	21.5
24	10.4	*	220.5	18.3
25	12.1	*	210.0	16.3
26	7.3	*	193.0	17.8
27	8.9	*	279.5	17.1
28	6.6	*	555.5	14.5
29	3.9	*	316.0	19.5
30	*	*	294.0	19.0
Dec 1	8.6	*	300.5	18.8
2	8.5	*	729.5	19.3
3	8.1	*	258.5	13.0
4	6.0	*	236.0	15.5
5	*	*	536.5	*
6	*	*	340.5	19.0
7	*	*	317.5	*
8	*	*	377.0	7.0
9	*	*	199.0	22.0
10	*	*	163.0	21.0
11	*	*	181.0	22.0
12	*	*	149.0	22.0
13	*	*	174.5	19.3
14	*	*	191.0	20.8
15	*	*	183.5	21.1
16	*	*	179.0	19.5
17	*	*	168.5	18.5
18	*	*	185.3	14.3
19	*	*	179.4	15.6
20	*	*	176.0	16.0
21	*	*	176.5	14.1
22	*	*	170.5	14.6
23	*	*	187.5	11.5
24	*	*	191.0	14.3
25	*	*	190.0	14.8
26	*	*	317.5	12.0
27	*	*	1174.3	10.9
28	*	*	1470.8	11.8
29	*	*	1650.4	11.6
30	*	*	1211.0	14.0
31	*	*	802.5	19.7

*No data taken

APPENDIX D

PLANT OPERATIONAL VARIABLES FOR UNITS 1, 2, AND 3

Table D-1

Unit 1 Operational Variables, 1974

Date	No. of Circulators Operating	Avg. Time Circulators Operating (hr)	Avg. Flow Rate (gpm x 10^3)	Avg. Head Loss (ft)	Avg. Measured Approach Velocity (fps)	Avg. Time Air Curtain Operating (hr)	Avg. AES Measured Tide (ft)	Total Flow (10^6 m^3)
Jan 1	1	*	52.0	*	*	*	-0.85	*
2	1	*	52.0	*	*	*	-1.60	*
3	1	*	43.0	*	*	*	-0.75	*
4	1	*	43.0	*	*	*	-0.28	*
5	1	*	43.0	*	*	*	1.05	*
6	1	*	43.0	*	*	*	1.14	*
7	1	*	52.0	*	*	*	0.48	*
8	1	*	52.0	*	*	*	0.29	*
9	1	*	52.0	*	*	*	0.48	*
10	1	*	52.0	*	*	*	-1.13	*
11	1	*	43.0	*	*	*	-1.13	*
12	1	*	43.0	*	*	*	-1.32	*
13	1	*	43.0	*	*	*	-1.60	*
14	1	*	43.0	*	*	*	-0.56	*
15	1	*	43.0	*	*	*	-0.56	*
16	2	*	47.5	*	*	*	0.19	*
17	2	22.1	47.5	*	*	*	0.76	0.957
18	2	21.8	47.5	*	*	*	*	0.474
19	2	24.7	47.5	*	*	*	1.05	0.247
20	2	25.8	47.5	*	*	*	-1.32	0.257
21	2	22.2	47.5	*	*	*	0.38	0.222
22	2	24.4	47.5	*	*	*	-1.23	0.244
23	2	24.8	47.5	*	*	*	-1.51	0.248
24	2	18.3	47.5	*	*	*	-1.60	0.409
25	2	26.1	47.5	*	*	15.4	-0.09	1.125
26	2	20.9	47.5	*	*	20.9	-0.85	0.903
27	2	26.8	47.5	*	*	26.8	-0.66	1.159
28	1	24.8	43.0	*	*	24.8	-0.37	0.485
29	1	20.8	43.0	*	*	20.8	-0.28	0.407
30	1	23.1	43.0	*	*	20.8	-0.18	0.452
31	1	24.5	43.0	*	*	24.5	-0.10	0.479
Feb 1	1	26.4	43.0	*	*	26.4	-0.66	0.515
2	2	21.8	47.5	*	*	21.8	0.55	0.426
3	2	24.0	47.5	*	*	24.0	1.42	0.240
4	2	44.5	47.5	*	*	44.5	0.95	1.404
5	2	33.3	47.5	*	*	33.3	1.71	1.485
6	1	22.3	43.0	*	*	22.3	-0.66	0.436
7	2	24.3	47.5	*	*	*	-0.47	0.474
8	2	26.2	47.5	*	*	*	-0.85	1.140
9	2	23.5	47.5	*	*	23.5	*	1.018
10	2	23.7	47.5	*	*	23.7	*	1.022
11	2	24.4	47.5	*	*	24.6	*	1.055
12	2	25.3	47.5	*	*	25.3	*	1.092
13	2	22.6	47.5	*	*	22.6	*	0.974
14	2	24.0	47.5	*	*	24.0	*	1.037
15	2	24.9	47.5	*	*	24.8	*	1.072
16	2	*	47.5	*	*	*	*	*
17	2	47.6	47.5	*	*	*	*	2.053
18	2	23.4	47.5	*	*	23.4	*	1.008
19	2	24.3	47.5	*	*	24.3	*	1.049
20	2	24.4	47.5	*	*	24.4	1.33	1.052
21	2	24.4	47.5	*	*	24.3	-1.04	1.053
22	2	24.2	47.5	*	*	24.2	-0.66	1.041
23	2	23.5	47.5	*	*	23.5	-2.17	1.014
24	2	23.6	47.5	*	*	23.6	-1.41	1.020
25	2	24.2	47.5	*	*	24.2	-1.41	1.042
26	2	23.9	47.5	*	*	23.9	-1.13	1.032
27	2	23.7	47.5	*	*	23.7	-1.13	1.024
28	2	24.3	47.5	*	*	24.3	-0.66	1.046

*No data taken.

Table D-1 (Contd)

Date	No. of Circulators Operating	Avg. Time Circulators Operating (hr)	Avg. Flow Rate (gpm x 10^3)	Avg. Head Loss (ft)	Avg. Measured Approach Velocity (fps)	Avg. Time Air Curtain Operating (hr)	Avg. AES Measured Tide (ft)	Total Flow (10^6 m^3)
Mar 1	2	24.0	48.0	*	*	24.0	-0.56	1.047
2	2	25.0	48.0	*	*	25.0	-0.47	1.088
3	2	23.4	48.0	*	*	2344	0.29	1.019
4	2	24.6	48.0	*	*	24.6	1.14	1.072
5	2	24.9	48.0	*	*	24.9	0.95	1.084
6	2	21.8	48.0	*	*	21.8	0.29	0.953
7	2	21.8	48.0	*	*	24.1	0.29	0.684
8	2	29.9	48.0	*	*	29.9	-0.66	1.323
9	2	25.2	48.0	*	*	*	0.10	0.800
10	2	22.9	48.0	*	*	23.0	-0.66	1.323
11	2	24.5	48.0	*	*	24.5	-2.17	0.780
12	2	23.1	48.0	*	*	23.1	-0.73	0.736
13	2	24.3	48.0	*	*	24.3	-2.17	0.774
14	2	23.4	48.0	*	*	23.4	-0.85	0.745
15	2	25.9	48.0	*	*	25.9	0.10	0.825
16	2	22.9	46.0	*	*	23.0	0.76	0.685
17	2	24.5	48.0	*	*	24.5	1.14	0.778
18	2	24.2	48.0	*	*	24.2	-0.66	0.770
19	2	25.1	48.0	*	*	25.1	1.23	1.096
20	2	23.0	48.0	*	*	23.0	1.99	0.731
21	2	24.0	48.0	*	*	24.0	1.61	0.764
22	2	24.2	48.0	*	*	24.2	-0.28	0.768
23	2	23.8	48.0	*	*	23.8	1.99	0.758
24	1	24.4	52.0	*	*	24.4	-0.09	0.288
25	2	28.1	48.0	*	*	28.1	-1.41	0.887
26	2	23.4	48.0	*	*	23.4	-0.94	0.739
27	2	23.1	48.0	*	*	23.1	-1.51	0.734
28	2	24.2	48.0	*	*	24.2	-0.85	0.768
29	2	23.9	48.0	*	*	23.9	-0.37	0.760
30	2	23.9	48.0	*	*	23.9	0.57	0.759
31	2	24.3	48.0	*	*	24.3	0.19	0.772
Apr 1	2	26.5	48.0	*	*	*	1.23	0.842
2	2	23.4	48.0	*	*	*	1.99	0.743
3	2	24.3	48.0	*	*	*	1.52	0.774
4	2	25.3	48.0	*	*	25.3	1.33	1.101
5	2	23.1	48.0	*	*	23.1	1.05	1.010
6	2	24.5	48.0	*	*	24.5	0.00	1.070
7	2	23.5	48.0	*	*	*	-0.56	1.026
8	2	23.7	48.0	*	*	23.7	*	1.034
9	2	25.0	48.0	*	*	*	-1.13	1.091
10	2	23.8	52.0	*	*	23.8	-1.23	1.125
11	2	23.8	48.0	*	*	23.8	-1.04	1.039
12	2	23.9	48.0	*	*	23.9	-1.32	1.041
13	2	24.0	48.0	*	*	24.0	-0.37	1.047
14	2	24.4	48.0	*	*	*	0.19	1.064
15	2	23.7	48.0	*	*	*	0.76	1.034
16	2	24.6	48.0	*	*	24.7	0.03	1.072
17	2	24.0	48.0	*	*	*	0.57	1.043
18	2	24.0	48.0	*	*	24.0	0.76	1.047
19	2	24.0	48.0	*	*	24.0	0.67	1.045
20	2	24.5	48.0	*	*	24.0	0.76	1.070
21	2	25.5	48.0	*	*	*	*	1.112
22	2	22.0	48.0	*	*	*	-0.47	0.959
23	2	28.5	48.0	*	*	*	-0.75	1.243
24	2	19.8	48.0	*	*	*	1.71	0.862
25	2	23.8	48.0	*	*	*	2.46	1.036
26	2	23.5	48.0	*	*	23.5	1.99	1.024
27	2	24.3	48.0	*	*	24.3	-0.37	1.057
28	2	24.7	48.0	*	*	*	-0.56	1.076
29	2	24.5	48.0	*	*	*	1.05	1.070
30	2	23.6	48.0	*	*	23.6	1.42	1.029

*No data taken.

Table D-1 (Contd)

Date	No. of Circulators Operating	Avg. Time Circulators Operating (hr)	Avg. Flow Rate (gpm x 10^3)	Avg. Head Loss (ft)	Avg. Measured Approach Velocity (fps)	Avg. Time Air Curtain Operating (hr)	Avg. AES Measured Tide (ft)	Total Flow (10^6 m^3)
May 1	2	24.1	62.0	*	*	*	2.37	1.358
2	2	26.1	62.0	*	*	*	*	1.244
3	2	22.1	62.0	*	*	22.1	0.10	1.244
4	2	23.8	62.0	*	*	23.8	1.52	1.339
5	2	*	62.0	*	*	*	0.19	*
6	2	*	66.0	*	*	*	0.10	*
7	1	*	66.0	*	*	*	0.00	*
8	1	*	75.0	*	*	*	*	*
9	1	*	75.0	*	*	*	-0.37	*
10	1	*	71.0	*	*	*	0.00	*
11	1	*	71.0	*	*	*	-0.37	*
12	1	*	71.0	*	*	*	0.57	*
13	1	*	71.0	*	*	*	1.42	*
14	1	*	75.0	*	*	*	1.05	*
15	1	*	75.0	*	*	*	1.52	*
16	1	*	75.0	*	*	*	0.95	*
17	1	*	75.0	*	*	*	1.90	*
18	1	*	75.0	*	*	*	1.61	*
19	2	*	75.5	*	*	*	1.61	*
20	2	*	75.5	*	*	*	0.95	*
21	2	*	75.5	*	*	*	*	*
22	2	*	75.5	*	*	*	0.19	*
23	2	22.0	75.5	*	*	*	-0.47	1.507
24	2	24.9	75.5	*	*	*	2.65	1.709
25	2	21.4	75.5	*	*	*	-0.18	1.467
26	2	24.0	75.5	*	*	*	-0.09	1.644
27	2	24.3	75.5	*	*	*	0.76	1.663
28	2	26.4	75.5	*	*	*	1.42	1.814
29	2	22.5	75.5	*	*	*	1.71	1.539
30	2	23.5	75.5	*	*	*	1.90	1.611
31	2	24.0	75.5	*	*	24.0	1.80	1.648
Jun 1	2	25.2	75.5	*	*	*	1.90	1.734
2	2	27.0	75.5	*	*	*	0.76	1.852
3	2	24.2	75.5	*	*	*	0.48	1.658
4	2	21.8	75.5	*	*	*	0.19	1.496
5	2	23.6	75.5	*	*	*	0.76	1.619
6	2	24.6	75.5	*	*	26.9	-0.66	1.690
7	2	20.5	75.5	*	*	20.5	1.52	1.406
8	2	26.0	75.5	*	*	26.0	-0.56	1.783
9	2	22.3	75.5	*	*	*	0.29	1.526
10	2	26.1	75.5	*	*	*	0.95	1.793
11	2	22.3	75.5	*	*	*	-0.09	1.529
12	2	23.6	75.5	*	*	*	-0.18	1.621
13	2	25.6	75.5	*	*	*	0.48	1.754
14	2	24.3	75.5	*	*	21.6	1.33	1.668
15	2	22.5	76.0	*	*	*	1.61	1.554
16	2	22.3	76.0	*	*	*	2.28	1.536
17	2	28.9	76.0	*	*	*	1.42	1.993
18	2	23.3	76.0	*	*	*	1.33	1.188
19	2	29.8	76.0	*	*	*	0.76	2.075
20	2	22.0	76.0	*	*	*	-0.09	1.159
21	2	27.5	76.0	*	*	*	-0.94	1.449
22	2	21.5	76.0	*	*	*	-1.70	1.133
23	2	23.5	76.0	*	*	*	-1.70	1.238
24	2	24.0	76.0	*	*	24.0	-0.09	0.872
25	2	22.4	76.0	*	*	*	-0.94	1.554
26	2	23.0	76.0	*	*	*	-1.51	1.588
27	2	23.5	76.0	*	*	*	-1.04	1.623
28	2	23.5	76.0	*	*	*	-0.66	1.623
29	2	24.0	76.0	*	*	24.0	-0.94	1.657
30	2	24.5	76.0	*	*	24.5	1.33	1.692

*No data taken.

Table D-1 (Contd)

Date	No. of Circulators Operating	Avg. Time Circulators Operating (hr)	Avg. Flow Rate (gpm x 10^3)	Avg. Head Loss (ft)	Avg. Measured Approach Velocity (fps)	Avg. Time Air Curtain Operating (hr)	Avg. AES Measured Tide (ft)	Total Flow (10^6 m^3)
Jul 1	2	24.0	76.0	*	*	*	0.67	1.657
2	2	22.5	76.0	*	*	*	2.18	1.554
3	2	25.0	76.0	*	*	*	-0.56	1.726
4	2	23.8	76.0	*	*	23.8	-0.18	1.640
5	2	24.0	76.0	*	*	24.0	0.00	1.657
6	2	25.0	76.0	*	*	25.0	-1.60	1.726
7	1	*	80.0	*	*	*	-1.79	*
8	1	48.8	80.0	*	*	*	-1.70	1.772
9-11	0	*	*	*	*	*	*	*
12	2	23.6	76.0	*	*	*	0.48	1.628
13	2	21.0	76.0	*	*	*	1.05	1.450
14	2	24.3	76.0	*	*	*	1.23	1.674
15	2	24.5	76.0	*	*	*	1.99	1.692
16	2	23.3	76.0	*	*	*	2.09	1.605
17	2	23.3	76.0	*	*	*	1.52	1.605
18	2	25.5	76.0	*	*	*	1.33	1.761
19	2	27.0	76.0	*	*	*	0.76	1.864
20	2	20.0	76.0	*	*	20.0	-0.47	1.381
21	2	27.3	76.0	*	*	*	2.18	1.881
22	2	25.5	76.0	*	*	*	-0.75	1.761
23	2	19.8	76.0	*	*	*	-0.37	1.364
24	2	25.5	76.0	*	*	*	0.10	1.761
25	2	22.5	76.0	*	*	*	*	1.554
26	2	24.0	76.0	*	*	*	0.76	1.657
27	2	24.0	76.0	*	*	*	0.76	1.657
28	2	23.0	70.0	*	*	*	1.71	0.993
29	2	25.0	76.0	*	*	*	1.71	1.726
30	2	24.0	76.0	*	*	*	1.61	1.657
31	2	24.0	76.0	*	*	*	0.38	1.657
Aug 1	2	24.5	76.0	*	*	16.0	0.67	1.692
2	2	24.0	76.0	*	*	24.0	0.29	1.657
3	2	25.0	76.0	*	*	25.0	-0.37	1.726
4	2	23.0	76.0	*	*	00.0	-1.32	1.588
5	2	24.0	76.0	*	*	00.0	-2.83	1.657
6	2	23.0	76.0	*	*	00.0	-3.07	1.588
7	2	24.5	76.0	*	*	00.0	-1.13	1.692
8	2	25.0	76.0	*	*	25.0	0.76	1.726
9	2	23.6	76.0	*	*	23.5	-1.13	1.623
10	2	25.5	80.0	*	*	00.0	0.38	0.927
11	2	35.8	76.0	*	*	*	-0.09	2.428
12	2	25.0	76.0	*	*	00.0	1.14	1.726
13	2	24.0	76.0	*	*	*	1.80	1.657
14	2	24.0	76.0	*	*	*	2.18	1.657
15	2	11.5	76.0	*	*	23.5	*	0.794
16	2	24.0	76.0	*	*	20.0	1.61	1.657
17	2	24.3	76.0	*	*	24.3	1.14	1.674
18	2	24.0	76.0	*	*	24.0	-0.18	1.657
19	2	23.3	76.0	*	*	00.0	-1.32	1.605
20	2	25.3	72.0	*	*	00.0	-0.75	1.652
21	2	23.3	76.0	*	*	00.0	-0.75	1.605
22	2	24.0	76.0	*	*	00.0	-0.28	1.657
23	2	24.5	76.0	*	*	00.0	-0.47	1.692
24	2	23.5	76.0	*	*	00.0	0.57	1.623
25	2	25.0	76.0	*	*	00.0	1.14	1.726
26	2	23.0	76.0	*	*	00.0	1.52	1.588
27	2	12.3	74.0	*	*	00.0	0.24	1.663
28	2	24.0	76.0	*	*	00.0	0.19	1.657
29	2	24.0	76.0	*	*	00.0	-0.66	1.657
30	2	24.5	72.0	*	*	00.0	-0.28	1.603
31	2	22.8	76.0	*	*	00.0	-0.56	1.571

*No data taken.

Table D-1 (Contd)

Date	No. of No. Circulators Operating	Avg. Time Circulators Operating (hr)	Avg. Flow Rate (gpm x 10^3)	Avg. Head Loss (ft)	Avg. Measured Approach Velocity (fps)	Avg. Time Air Curtain Operating (hr)	Avg. AES Measured Tide (ft)	Total Flow (10^6 m^3)
Sep 1	2	24.8	76.0	*	*	00.0	-1.60	1.709
2	2	23.0	80.0	*	*	00.0	-2.36	1.672
3	2	24.0	76.0	*	*	00.0	-2.36	1.657
4	2	21.4	76.0	*	*	00.0	-2.74	1.472
5	2	24.0	76.0	*	*	19.5	-1.98	1.657
6	2	24.5	76.0	*	*	24.5	-2.17	1.692
7	2	25.0	76.0	*	*	25.0	-2.64	1.726
8	2	21.0	76.0	*	*	00.0	-1.89	1.450
9	2	26.5	76.0	*	*	00.0	0.86	1.830
10	2	24.0	76.0	*	*	00.0	-1.89	1.657
11	2	24.0	76.0	*	*	00.0	-1.32	1.657
12	2	24.5	76.0	*	*	22.5	-0.28	1.692
13	2	21.0	76.0	*	*	21.0	0.38	1.450
14	2	25.5	76.0	*	*	25.5	0.67	1.761
15	2	25.0	76.0	*	*	3.0	-0.18	1.726
16	2	23.0	76.0	*	*	2.0	0.48	1.588
17	2	25.0	76.0	*	*	00.0	-0.94	1.726
18	2	24.0	76.0	*	*	00.0	-1.13	1.657
19	2	24.0	76.0	*	*	22.0	-1.13	1.657
20	2	23.5	76.0	*	*	23.5	-1.13	1.623
21	2	24.5	76.0	*	*	24.5	1.71	1.692
22	2	23.5	76.0	*	*	2.0	0.38	1.623
23	2	21.0	76.0	*	*	00.0	0.76	1.454
24	2	24.5	76.0	*	*	00.0	-0.09	1.692
25	2	26.0	76.0	*	*	00.0	1.90	1.795
26	2	23.8	76.0	*	*	00.0	1.61	1.640
27	2	21.3	76.0	*	*	21.9	1.71	1.467
28	2	24.5	76.0	*	*	24.5	1.90	1.692
29	2	23.5	76.0	*	*	23.5	1.42	1.623
30	2	24.0	76.0	*	*	24.0	0.48	1.657
Oct 1	2	24.5	76.0	*	*	24.5	0.67	1.692
2	2	12.3	76.0	*	*	22.5	-0.47	0.809
3	1	23.8	72.0	*	*	23.8	0.10	0.777
4	1	24.5	72.0	*	*	24.5	-1.51	0.801
5	1	22.2	70.0	*	*	25.4	-1.41	0.705
6	2	20.3	76.0	*	*	00.0	-1.41	1.419
7	2	24.0	76.0	*	*	00.0	-0.66	1.657
8	2	23.5	76.0	*	*	00.0	-0.37	1.623
9	2	25.0	76.0	*	*	00.0	-0.37	1.726
10	2	24.5	76.0	*	*	00.0	0.86	1.692
11	2	24.5	76.0	*	*	00.0	1.80	1.692
12	2	24.5	76.0	*	*	19.5	1.80	1.692
13	2	24.0	76.0	*	*	24.0	2.18	1.657
14	2	24.5	76.0	*	*	24.5	1.52	1.692
15	2	22.5	76.0	*	*	00.0	1.52	1.692
16	2	23.5	76.0	*	*	00.0	1.61	1.623
17	2	26.0	76.0	*	*	00.0	2.56	1.795
18	2	24.0	76.0	*	*	00.0	-0.94	1.657
19	2	25.0	76.0	*	*	21.0	2.37	1.726
20	2	24.0	76.0	*	*	24.0	2.28	1.657
21	2	24.0	76.0	*	*	00.0	0.86	1.657
22	2	24.0	76.0	*	*	00.0	0.57	1.657
23	2	21.5	76.0	*	*	00.0	0.29	1.484
24	2	24.0	76.0	*	*	00.0	1.42	1.657
25	2	25.5	76.0	*	*	00.0	1.99	1.761
26	2	24.0	76.0	*	*	00.0	1.42	1.657
27	2	22.0	76.0	*	*	00.0	1.80	1.519
28	2	24.5	76.0	*	*	00.0	2.18	1.692
29	2	23.5	76.0	*	*	00.0	2.18	1.623
30	2	26.5	76.0	*	*	00.0	2.18	1.830
31	2	24.0	76.0	*	*	00.0	0.29	1.657

*No data taken.

Table D-1 (Contd)

Date	No. of Circulators Operating	Avg. Time Circulators Operating (hr)	Avg. Flow Rate (gpm x 10^3)	Avg. Head Loss (ft)	Avg. Measured Approach Velocity (fps)	Avg. Time Air Curtain Operating (hr)	Avg. AES Measured Tide (ft)	Total Flow (10^6 m^3)
Nov 1	2	25.0	76.0	*	*	22.5	0.29	1.726
2	2	19.5	76.0	*	*	19.5	1.23	1.346
3	2	23.5	76.0	*	*	00.0	0.00	1.623
4	1	24.0	80.0	*	*	00.0	-0.37	0.872
5	1	24.5	80.0	*	*	00.0	-1.13	0.890
6	1	24.0	52.0	*	*	00.0	0.86	0.567
7	1	24.0	52.0	*	*	00.0	-0.18	0.567
8	1	22.0	52.0	*	*	00.0	0.57	0.520
9	1	27.0	52.0	*	*	00.0	0.76	0.638
10	1	21.0	52.0	*	*	00.0	2.84	0.496
11	1	26.5	52.0	*	*	18.5	3.32	0.626
12	1	21.5	52.0	*	*	00.0	3.13	0.508
13	1	5.3	52.0	*	*	00.0	1.80	0.126
14	1	37.7	52.0	*	*	00.0	1.61	0.890
15	1	21.0	52.0	*	*	16.0	0.95	0.496
16	1	24.0	52.0	*	*	24.0	-0.56	0.567
17	1	24.0	52.0	*	*	24.0	1.80	0.567
18	1	13.0	52.0	*	*	00.0	33.88	0.471
19	1	24.0	52.0	*	*	00.0	-1.04	0.567
20-23	1	*	*	*	*	*	*	*
24	1	3.3	52.0	*	*	00.0	0.29	0.077
25	1	22.5	52.0	*	*	00.0	1.99	0.531
26	1	25.0	52.0	*	*	16.0	-0.28	0.591
27	1	24.0	51.0	*	*	24.0	1.42	0.556
28	1	24.0	51.0	*	*	00.0	2.37	0.556
29	1	24.0	51.0	*	*	16.0	1.80	0.556
30	1	24.5	51.0	*	*	24.0	2.46	0.568
Dec 1	1	25.0	48.0	*	*	25.0	1.71	0.545
2	1	22.5	48.0	*	*	22.5	2.84	0.491
3	1	23.5	48.0	*	*	19.8	-0.37	0.512
4	1	24.5	48.0	*	*	12.3	-1.70	0.534
5	1	24.0	48.0	*	*	12.0	0.67	0.523
6	1	24.0	51.0	*	*	12.0	-0.37	0.556
7	1	24.0	51.0	*	*	20.0	0.95	0.556
8	1	23.0	51.0	*	*	00.0	2.28	0.533
9	1	25.0	51.0	*	*	00.0	*	0.579
10	1	*	51.0	*	*	*	2.46	*
11	1	48.0	51.0	*	*	00.0	*	1.112
12	1	24.0	51.0	*	*	00.0	*	0.556
13	1	24.0	51.0	*	*	16.0	*	0.556
14	1	24.0	51.0	*	*	24.0	1.14	0.556
15	1	24.0	51.0	*	*	24.0	1.90	0.556
16	1	27.5	51.0	*	*	27.5	1.52	0.637
17	1	21.0	51.0	*	*	21.0	*	0.486
18	1	15.8	49.0	*	*	18.0	-0.37	0.351
19	1	24.0	49.0	*	*	24.0	-0.75	0.534
20	2	25.3	49.0	*	*	8.0	-0.66	1.124
21	2	23.5	49.0	*	*	19.8	0.38	1.046
22	2	24.5	49.0	*	*	00.0	0.19	1.091
23	2	24.0	49.0	*	*	00.0	00.95	1.068
24	2	24.0	49.0	*	*	00.0	1.42	1.068
25	2	24.0	49.0	*	*	00.0	*	1.068
26	2	26.0	49.0	*	*	00.0	1.61	1.157
27	2	22.0	49.0	*	*	00.0	2.75	0.979
28	2	23.0	49.0	*	*	00.0	1.42	1.024
29	2	25.0	49.0	*	*	00.0	2.09	1.113
30	2	24.0	49.0	*	*	16.0	2.65	1.068
31	2	24.0	49.0	*	*	24.0	*	1.068

*No data taken.

Table D-2

Unit 2 Operational Variables, 1974

Date	No. of Circulators Operating	Avg. Time Circulators Operating (hr)	Avg. Flow Rate (gpm x 10^3)	Avg. Head Loss (ft)	Avg. Measured Approach Velocity (fps)	Avg. Time Air Curtain Operating (hr)	Avg. AES Measured Tide (ft)	Total Flow (10^6 m^3)
Jan 1	1	*	84.0	0.7000	*	*	-0.85	*
2-16	0	*	*	*	*	*	*	*
17	1	*	84.0	0.2000	*	*	0.76	*
18	1	*	84.0	*	*	*	*	*
19	1	*	84.0	*	*	*	1.05	*
20	1	32.1	84.0	0.0000	*	*	-1.32	0.612
21	0	*	*	*	*	*	*	*
22	1	14.5	84.0	*	*	*	-1.23	0.276
23	1	23.0	84.0	0.0000	*	*	-1.51	0.439
24	1	25.2	84.0	0.0000	*	*	-1.60	0.480
25	3	23.8	84.0	0.0333	*	11.6	-0.09	0.908
26	6	14.8	84.0	0.1500	0.4000	17.5	-0.85	1.970
27	6	19.4	84.0	0.2500	0.9000	23.8	-0.66	2.224
28	4	24.1	84.0	0.0250	1.1000	24.1	-0.37	1.838
29	4	23.6	84.0	0.0000	1.0000	23.6	-0.28	1.800
30	1	24.0	84.0	0.1000	0.9000	24.0	-0.18	0.458
31	3	26.0	84.0	0.0000	*	*	0.10	0.496
Feb 1	2	30.0	84.0	0.0000	*	*	-0.66	1.143
2	2	21.0	84.0	0.0000	*	21.0	0.67	0.800
3	2	23.3	84.0	0.0000	*	23.3	1.42	0.889
4	2	23.2	84.0	0.0000	*	23.2	0.95	0.884
5	1	23.0	84.0	0.0000	*	23.0	1.71	0.439
6	1	23.8	84.0	0.0000	*	23.8	-0.66	0.455
7	1	25.1	84.0	0.0000	*	25.1	-0.47	0.479
8	2	22.1	84.0	0.0000	*	22.1	-0.85	0.421
9	1	26.0	84.0	0.0000	*	26.0	*	0.496
10	1	22.8	84.0	0.0000	*	22.8	*	0.434
11	1	23.8	84.0	0.0000	*	23.8	*	0.453
12	1	24.1	84.0	0.0000	*	24.1	*	0.459
13	1	23.7	84.0	0.0000	*	23.7	*	0.452
14	1	24.1	84.0	0.0000	*	24.1	*	0.459
15	1	24.7	84.0	0.0000	*	24.7	*	0.471
16	1	24.3	84.0	0.0000	*	24.3	*	0.464
17	1	23.8	84.0	0.0000	*	23.8	*	0.453
18	1	24.0	84.0	0.0000	*	24.0	*	0.458
19	1	24.0	84.0	0.0000	*	24.0	*	0.458
20	1	23.8	84.0	0.0000	*	23.8	1.33	0.453
21	1	24.0	84.0	0.0000	*	*	-1.04	0.458
22	1	23.9	84.0	0.0000	*	23.9	-0.66	0.456
23-28	0	*	*	*	*	*	*	*
Mar 1-12	0	*	*	*	*	*	*	*
13	1	3.3	84.0	0.0000	*	4.2	-0.61	0.127
14	2	6.3	84.0	0.0800	*	11.8	0.48	0.601
15	2	7.8	84.0	0.0000	0.9000	7.8	-.16	0.895
16	2	8.1	84.0	0.3333	*	8.0	0.45	0.932
17	2	7.9	84.0	0.0000	1.7000	7.9	-0.28	0.906
18	2	7.9	84.0	0.0000	*	7.9	-1.16	0.901
19	2	8.7	84.0	0.0000	*	8.7	0.62	0.994
20	2	8.0	84.0	0.0000	*	8.0	0.57	0.917
21	5	10.0	84.0	0.0200	*	10.0	1.58	1.143
22	5	13.2	84.0	0.0000	0.9000	13.2	0.23	2.274
23	5	14.0	84.0	0.0067	*	14.0	0.70	2.402
24	5q	9.9	84.0	0.0000	*	9.9	1.59	2.275
25	5	10.4	84.0	0.0000	*	10.4	-0.33	1.981
26	5	11.9	84.0	0.3333	0.8000	11.9	-0.94	2.493
27	5	8.6	84.0	0.1571	0.8000	8.8	-0.12	2.287
28	5	9.1	84.0	0.539	0.8000	9.1	-0.07	1.738
29	4	11.4	84.0	0.0000	*	11.4	-0.04	1.744
30	4	9.8	84.0	0.0000	*	10.6	1.30	1.684
31	4	11.0	84.0	0.0000	0.8000	11.0	0.67	1.895

*No data taken.

Table D-2 (Contd)

Date	No. of Circulators Operating	Avg. Time Circulators Operating (hr)	Avg. Flow Rate (gpm x 10^3)	Avg. Head Loss (ft)	Avg. Measured Approach Velocity (fps)	Avg. Time Air Curtain Operating (hr)	Avg. AES Measured Tide (ft)	Total Flow (10^6 m^3)
Apr 1	4	25.1	84.0	0.0000	*	25.1	1.23	1.917
2	4	23.8	84.0	0.0750	1.4000	23.8	1.99	1.817
3	4	24.6	84.0	0.0250	1.1500	24.6	1.52	1.878
4	4	23.6	84.0	0.0750	3.0500	23.6	1.33	1.800
5	4	23.9	84.0	1.1000	0.9500	23.9	1.05	1.820
6	4	24.2	84.0	0.3750	0.9000	24.2	0.00	1.844
7	3	23.8	84.0	0.0000	0.8333	23.8	-0.56	1.364
8	3	22.1	84.0	1.1667	*	22.1	*	1.264
9	4	16.7	84.0	0.1500	*	16.7	-1.13	1.908
10	4	11.3	84.0	0.0000	*	12.4	-0.52	1.725
11	5	12.3	84.0	*	0.7000	12.2	0.03	1.870
12	5	11.9	84.0	0.0111	0.7600	11.9	-0.50	2.049
13	5	11.2	84.0	0.0000	0.7833	11.2	-0.28	2.130
14	5	11.9	84.0	0.0100	0.8000	11.9	-0.14	2.262
15	5	11.9	84.0	0.0111	*	11.9	0.15	2.278
16	5	11.1	84.0	0.0143	*	11.6	-0.52	2.540
17	5	12.0	84.0	0.0000	0.9250	12.0	-0.42	2.286
18	5	12.0	84.0	0.0000	*	12 0	0.00	2.293
19	6	23.1	84.0	0.0000	0.7000	23.1	0.67	2.641
20	1	10.2	84.0	0.0000	*	10.2	0.76	0.388
21	1	12.0	84.0	0.0000	*	12.0	-1.32	0.458
22	1	12.0	84.0	0.0000	*	12.0	-0.47	0.458
23	1	12.0	84.0	0.0000	*	12.0	0.76	0.458
24	3	11.5	121.3	0.0000	*	8.5	0.62	1.966
25	2	14.6	102.7	0.0000	*	14.6	-0.44	1.086
26	3	9.4	140.0	0.0000	*	5.2	0.90	1.792
27	3	9.4	140.0	0.0667	*	9.4	0.90	1.789
28	3	12.0	140.0	0.0167	*	12.0	0.53	2.287
29	5	11.6	134.4	0.0200	*	11.6	1.05	3.242
30	5	12.2	140.0	0.1200	*	12.2	1.42	3.882
May 1	5	12.7	140.0	0.0333	*	14.8	0.86	3.643
2	5	23.6	140.0	0.0000	*	23.6	*	3.755
3	4	24.3	140.0	0.1000	*	24.3	2.09	3.095
4	1	23.6	140.0	0.1000	*	23.6	1.52	0.750
5	4	20.9	140.0	0.0000	*	20.6	0.19	2.655
6	4	23.8	140.0	0.1250	0.8000	23.1	0.15	3.021
7	4	24.1	140.0	0.6000	*	24.8	0.00	3.063
8	4	20.8	140.0	0.4000	*	*	*	3.302
9	4	23.0	140.0	0.1500	*	*	-0.37	2.920
10	5	23.5	140.0	0.0800	*	24.4	0.00	3.743
11	2	23.0	140.0	0.5000	*	23.0	-0.37	1.465
12	2	24.0	140.0	0.0000	*	24.0	0.57	1.529
13	5	14.8	140.0	0.0000	*	24.6	1.42	2.359
14	1	23.4	140.0	0.1000	1.0000	23.4	1.05	0.745
15	2	24.1	140.0	0.0500	*	24.1	1.52	0.766
16	1	23.9	140.0	0.1000	*	23.9	0.95	0.760
17	1	24.0	140.0	0.1000	*	*	1.90	0.763
18	1	24.0	140.0	0.1000	*	*	1.61	0.763
19	5	29.2	140.0	0.0800	*	*	1.61	4.649
20	5	24.4	140.0	0.1000	*	*	0.95	3.876
21	5	23.8	140.0	0.1000	*	*	*	3.023
22	5	23.9	140.0	0.2400	*	*	0.19	3.802
23	5	24.1	140.0	0.1400	1.0000	*	-0.47	3.071
24	5	24.4	140.0	0.1000	*	*	-0.47	3.882
25	5	24.2	140.0	0.0400	1.2000	*	-0.18	3.840
26	5	23.3	140.0	0.1400	*	*	-0.09	3.710
27	5	23.5	140.0	0.2200	*	*	0.76	3.731
28	6	24.6	140.0	0.1167	*	*	1.42	4.701
29	6	23.5	140.0	0.0500	*	*	1.71	4.491
30	6	23.8	140.0	0.1833	0.9500	*	1.90	4.550
31	6	23.8	140.0	0.1000	1.2333	*	1.80	4.539

*No data taken.

Table D-2 (Contd)

Date	No. of Circulators Operating	Avg. Time Circulators Operating (hr)	Avg. Flow Rate (gpm x 10^3)	Avg. Head Loss (ft)	Avg. Measured Approach Velocity (fps)	Avg. Time Air Curtain Operating (hr)	Avg. AES Measured Tide (ft)	Total Flow (10^6 m^3)
Jun 1	6	24.2	140.0	0.1500	*	*	1.90	4.624
2	6	24.2	140.0	0.2833	*	*	0.76	4.616
3	6	24.2	140.0	0.1333	*	*	0.48	4.621
4	5	23.9	140.0	0.0200	*	21.8	0.19	3.805
5	5	23.2	140.0	0.1400	*	23.2	-0.18	3.686
6	6	21.8	140.0	0.0333	*	*	-0.66	4.158
7	6	23.5	140.0	0.0000	*	23.5	-0.09	4.475
8	6	24.7	140.0	0.0000	*	*	-0.56	4.717
9	6	23.3	140.0	0.0167	*	9.3	-0.66	4.454
10	6	24.1	140.0	0.0500	*	15.7	-0.66	4.589
11	6	24.2	140.0	0.0333	*	24.2	0.29	4.613
12	6	24.0	140.0	0.0000	*	24.0	0.38	4.574
13	5	23.5	140.0	0.0000	*	23.5	0.57	3.739
14	5	24.0	140.0	0.0000	*	24.0	1.23	3.818
15	2	23.4	140.0	0.0000	*	23.3	1.61	1.487
16	2	24.1	140.0	0.0000	*	24.1	2.28	1.534
17	6	21.9	140.0	0.0000	*	24.8	1.42	3.480
18	6	24.0	140.0	0.0167	*	24.0	1.33	4.574
19	6	24.3	140.0	0.0333	*	24.3	0.76	4.627
20	5	24.0	140.0	0.0200	*	24.0	-0.66	3.816
21	4	24.0	140.0	0.0250	*	24.0	-0.94	3.053
22	5	25.5	140.0	0.0200	*	34.1	-1.70	4.048
23	4	22.7	140.0	0.0250	*	23.5	-1.70	2.886
24	4	19.9	140.0	0.0250	*	24.0	-0.09	2.528
25	6	19.8	140.0	0.3400	*	*	-0.94	3.769
26	5	24.0	140.0	0.0400	*	*	-1.51	3.816
27	6	24.1	140.0	0.0000	*	24.0	-1.04	4.603
28	6	24.0	140.0	0.0667	1.3000	24.0	-0.66	4.579
29	5	24.0	140.0	0.0000	1.1000	24.0	-0.94	3.816
30	6	24.8	140.0	0.0167	*	28.0	1.33	4.740
Jul 1	5	24.0	140.0	0.0000	*	24.0	0.57	3.816
2	6	29.7	140.0	0.0333	*	29.0	0.76	5.671
3	6	19.8	140.0	0.0000	*	19.8	-0.56	3.784
4	6	23.8	140.0	0.0000	*	*	-0.18	4.531
5	4	23.8	140.0	0.0000	0.8000	*	0.00	3.021
6	6	24.4	140.0	0.0000	*	*	-1.60	4.648
7	6	24.3	140.0	0.0500	*	*	-1.79	4.627
8	6	24.5	140.0	0.1500	0.7000	*	-1.70	4.674
9	6	24.0	140.0	0.2000	*	*	0.00	4.579
10	6	23.5	140.0	0.2500	*	*	-0.18	4.483
11	6	24.0	140.0	0.1500	0.9500	*	-0.37	4.579
12	6	24.3	140.0	0.2000	*	*	0.48	4.627
13	6	24.0	140.0	0.3833	*	*	1.05	4.579
14	5	24.0	140.0	0.4000	*	*	1.23	3.816
15	4	24.0	140.0	0.4250	*	24.0	1.99	3.053
16	5	23.7	140.0	0.1200	*	24.0	2.09	3.772
17	5	24.0	140.0	0.1200	*	24.0	1.52	3.816
18	5	24.2	140.0	0.2200	0.7000	*	1.33	3.840
19	5	25.0	140.0	0.3800	0.8000	*	0.76	3.975
20	5	23.5	140.0	0.0400	*	23.5	-0.47	2.989
21	5	25.4	140.0	0.0800	*	24.0	2.18	4.044
22	4	23.6	140.0	0.0750	*	32.0	-0.75	3.004
23	6	25.5	140.0	0.0833	1.5000	24.0	-0.37	4.866
24	6	24.0	140.0	0.0000	1.6000	24.0	0.10	4.579
25	6	23.5	140.0	0.0000	*	23.5	*	4.483
26	6	24.5	140.0	0.4167	*	*	0.76	4.674
27	1	22.7	140.0	0.1000	*	*	0.76	0.721
28	1	24.0	140.0	3.0000	*	*	1.71	0.763
29	1	24.0	140.0	0.5000	*	*	1.61	0.763
30	1	23.5	140.0	0.8000	0.9000	*	1.61	0.747
31	1	24.0	140.0	0.0000	*	*	0.38	0.763

*No data taken.

Date	No. of Circulators Operating	Avg. Time Circulators Operating (hr)	Avg. Flow Rate (gpm x 10^3)	Avg. Head Loss (ft)	Avg. Measured Approach Velocity (fps)	Avg. Time Air Curtain Operating (hr)	Avg. AES Measured Tide (ft)	Total Flow (10^6 m^3)
Aug 1	2	24.5	140.0	0.0500	1.2000	00.0	0.67	1.558
2	2	23.5	140.0	0.0000	*	00.0	0.29	1.494
3	2	24.3	140.0	0.1500	*	*	-0.37	1.542
4	2	24.3	140.0	0.1000	*	00.0	-1.32	1.542
5	1	23.5	140.0	0.1000	1.2000	23.5	-2.83	0.747
6	1	24.0	140.0	0.1000	*	24.0	-1.89	0.763
7	6	24.8	140.0	0.0000	*	24.8	-1.13	4.738
8	6	24.0	140.0	0.0167	0.2000	24.0	-0.85	4.579
9	5	24.5	140.0	0.2000	*	24.5	-1.13	3.895
10	4	22.9	140.0	0.1000	*	24.0	-0.94	2.909
11	5	23.5	140.0	0.0400	*	23.5	-1.70	2.989
12	6	20.9	140.0	0.0333	*	21.7	1.14	4.642
13	6	22.3	140.0	0.7333	*	22.3	1.80	4.257
14	6	21.7	140.0	0.2167	1.0000	21.7	2.18	4.144
15	6	23.3	140.0	0.4333	*	24.0	*	4.451
16	6	25.5	140.0	0.8000	3.2000	25.5	1.61	4.865
17	6	24.0	140.0	0.6000	*	24.0	1.14	4.579
18	6	24.0	140.0	0.7500	*	24.0	-0.18	4.579
19	6	24.0	140.0	0.6667	*	24.0	-1.32	4.579
20	6	21.8	140.0	0.2333	1.1000	21.8	-0.75	4.168
21	6	24.0	140.0	0.1000	*	24.0	-0.75	4.579
22	6	24.0	140.0	0.1000	*	24.0	-0.28	4.579
23	6	24.0	140.0	0.0500	*	24.0	-0.47	4.579
24	6	23.1	140.0	0.2333	*	23.1	-0.75	4.410
25	6	23.3	140.0	0.2333	*	23.3	-0.66	4.450
26	6	24.0	140.0	0.4667	*	00.0	1.52	4.579
27	6	12.8	140.0	0.0000	*	12.8	0.24	4.865
28	6	22.0	140.0	0.0333	*	22.0	0.19	4.197
29	6	24.5	140.0	0.1333	*	24.5	-0.66	4.674
30	6	23.0	140.0	0.0167	1.9000	23.0	-0.28	4.388
31	6	24.8	140.0	0.3500	0.8000	24.8	-0.56	4.722
Sep 1	6	24.3	140.0	0.2500	*	24.3	-1.60	4.627
2	6	23.5	140.0	0.4667	*	23.5	-2.36	4.483
3	6	24.0	140.0	0.0833	*	24.0	-2.36	4.579
4	6	24.0	140.0	0.8333	*	24.0	-2.74	4.579
5	6	24.0	140.0	0.3167	1.2000	24.0	-1.98	4.579
6	6	24.0	140.0	0.0167	*	24.0	-2.17	4.579
7	2	24.0	140.0	0.8500	*	24.0	-2.64	1.526
8	2	24.0	140.0	0.0500	0.9000	24.0	-1.89	1.526
9	2	24.5	140.0	0.0500	*	24.5	-0.85	1.558
10	6	10.1	140.0	0.0333	*	10.1	-1.89	1.929
11	6	24.0	140.0	0.0167	*	24.0	-1.32	4.579
12	6	23.3	140.0	0.0167	*	23.3	-0.28	4.452
13	6	24.0	140.0	*	1.2000	24.0	0.38	4.579
14	6	24.0	140.0	0.0833	*	24.0	0.67	4.579
15	6	23.5	140.0	0.1833	1.9000	23.5	-0.18	4.483
16	5	24.5	140.0	0.8600	*	24.5	0.48	3.895
17	5	24.0	140.0	0.0600	*	24.0	-0.94	3.816
18	5	23.2	140.0	0.4200	1.9000	23.6	-1.13	3.688
19	4	22.0	140.0	0.1000	*	22.0	-1.13	3.498
20	5	24.0	140.0	0.1200	*	24.0	-1.13	3.816
21	5	24.5	140.0	0.1200	0.9000	24.5	-1.70	3.895
22	5	24.0	140.0	0.0800	*	24.0	-1.41	3.816
23	5	23.5	140.0	1.9200	*	12.5	-1.79	3.784
24	5	24.0	140.0	0.0400	*	24.0	0.67	3.816
25	5	23.0	140.0	0.0000	*	23.0	1.90	3.657
26	5	25.0	140.0	0.0000	1.6000	25.0	1.61	3.975
27	5	23.0	140.0	0.0400	*	23.0	1.71	3.657
28	5	24.0	140.0	0.0200	*	24.0	1.90	3.816
29	5	24.0	140.0	0.0400	*	24.0	1.42	3.816
30	5	24.0	140.0	0.0600	*	24.0	0.48	3.816

*No data taken.

Table D-2 (Contd)

Date	No. of Circulators Operating	Avg. Time Circulators Operating (hr)	Avg. Flow Rate (gpm x 10^3)	Avg. Head Loss (ft)	Avg. Measured Approach Velocity (fps)	Avg. Time Air Curtain Operating (hr)	Avg. AES Measured Tide (ft)	Total Flow (10^6 m^3)
Oct 1	2	24.0	140.0	0.3000	*	24.0	0.67	1.526
2	2	24.0	140.0	0.0000	*	24.0	-0.47	1.526
3	2	24.0	140.0	0.0000	*	24.0	-0.09	1.526
4	2	24.3	140.0	0.0000	*	24.0	-1.51	1.542
5	1	24.0	140.0	0.0000	*	24.0	-1.41	0.763
6	1	24.0	140.0	0.0000	*	24.0	-1.41	0.763
7	1	24.0	140.0	0.0000	1.2000	24.0	-0.66	0.763
8	1	24.0	140.0	0.0000	*	24.0	-0.37	0.763
9	1	24.0	140.0	0.0000	*	24.0	-0.37	0.763
10	1	24.0	140.0	0.1000	*	24.0	1.42	0.763
11	5	7.2	140.0	0.0200	*	7.2	1.80	1.145
12	5	22.0	140.0	0.0200	*	22.0	1.80	3.498
13	5	27.0	140.0	0.0000	*	27.0	2.18	4.293
14	5	23.0	140.0	0.0000	*	23.0	1.52	3.657
15	5	24.0	140.0	0.0000	1.7000	24.0	1.52	3.816
16	5	17.0	140.0	*	*	17.0	1.61	5.962
17	5	24.8	140.0	0.0400	*	24.8	2.56	3.935
18	5	23.9	140.0	0.0400	*	23.9	-0.94	3.793
19	5	25.0	140.0	0.1600	*	25.0	-0.75	3.975
20	5	23.0	140.0	0.0000	*	23.0	0.10	3.657
21	5	25.0	140.0	0.0000	*	25.0	-0.37	3.975
22	5	24.0	140.0	0.0000	*	24.0	0.46	3.816
23	5	23.0	140.0	0.0000	*	23.0	0.29	3.657
24	5	24.0	140.0	0.0400	*	24.0	1.42	3.816
25	5	25.0	140.0	0.0200	*	25.0	1.99	3.975
26	5	21.1	140.0	0.2800	*	21.1	1.42	5.358
27	5	17.8	140.0	0.0900	*	17.8	1.80	5.644
28	5	12.5	140.0	0.0000	*	12.5	2.18	1.987
29	5	24.0	140.0	0.4600	*	24.0	2.18	3.816
30	5	24.0	140.0	0.0600	1.3500	24.0	2.18	3.816
31	5	17.1	156.1	1.1667	*	26.1	3.66	5.488
Nov 1	5	11.5	140.0	0.5000	1.3000	11.5	0.29	3.657
2	5	14.0	112.0	0.3000	1.1000	14.0	-0.56	2.805
3	5	10.5	95.2	0.1600	*	10.5	0.34	2.270
4	5	13.5	95.2	0.3000	*	13.5	0.19	2.919
5	5	12.5	95.2	0.0000	*	12.5	-1.13	2.703
6	5	9.0	87.2	0.2800	*	9.0	0.86	0.891
7	5	19.0	84.0	0.0000	0.8500	19.0	-0.18	3.625
8	5	12.0	84.0	0.1800	*	12.0	0.57	2.289
9	5	12.1	84.0	0.0000	*	12.1	1.14	1.851
10	3	12.0	84.0	0.0000	*	12.0	2.84	1.374
11	5	10.6	84.0	0.0000	*	11.8	3.07	1.612
12	5	11.4	84.0	0.0000	*	11.4	3.13	1.087
13	5	21.3	84.0	0.4000	*	21.3	1.96	2.432
14	5	17.0	84.0	0.8000	0.8000	17.0	1.80	3.243
15	5	12.0	84.0	0.0000	*	12.0	0.95	2.289
16	5	13.0	84.0	0.0000	*	13.0	-0.56	1.240
17	5	24.0	84.0	0.0400	*	24.0	-0.75	2.289
18	5	20.3	84.0	0.0600	*	20.3	-0.47	2.289
19	5	13.0	84.0	0.0000	*	13.0	-1.04	1.240
20	5	24.5	84.0	0.1000	0.4500	00.0	0.00	2.337
21	5	23.5	84.0	0.0800	*	00.0	0.48	2.242
22	5	21.9	84.0	0.1400	*	1.9	-0.85	2.509
23	4	20.7	84.0	0.1500	*	00.0	2.09	1.975
24	4	19.0	84.0	0.0000	0.5000	15.0	2.18	1.812
25	4	21.6	84.0	0.4000	*	21.6	1.99	1.650
26	4	24.0	84.0	0.2500	*	24.0	-0.28	1.832
27	4	24.0	84.0	0.2000	*	24.0	1.42	1.832
28	4	23.5	84.0	0.4500	*	23.5	2.37	1.793
29	4	22.4	84.0	0.5000	*	22.4	1.80	2.137
30	4	18.3	84.0	0.2600	*	18.5	1.00	1.746

*No data taken.

Table D-2 (Contd)

Date	No. of Circulators Operating	Avg. Time Circulators Operating (hr)	Avg. Flow Rate (gpm x 10^3)	Avg. Head Loss (ft)	Avg. Measured Approach Velocity (fps)	Avg. Time Air Curtain Operating (hr)	Avg. AES Measured Tide (ft)	Total Flow (10^6 m^3)
Dec 1	4	19.6	84.0	0.2000	1.4000	19.6	1.94	1.870
2	4	21.1	84.0	1.2500	*	21.1	2.75	1.612
3	4	7.6	84.0	0.4000	*	7.6	1.38	2.308
4	4	16.8	84.0	0.0250	*	16.8	-1.70	2.242
5	4	15.5	84.0	0.0000	*	15.5	-0.28	1.183
6	3	18.4	84.0	0.0333	*	18.4	0.48	2.103
7	3	11.3	84.0	0.0000	*	11.3	0.95	0.644
8	3	23.5	84.0	0.0000	*	23.5	2.28	1.345
9	3	17.0	84.0	0.0000	*	17.0	0.57	1.946
10	3	17.3	84.0	0.0000	*	00.0	2.46	0.992
11	3	20.4	84.0	0.0000	*	20.4	1.05	1.555
12	3	14.6	84.0	0.0000	*	14.6	0.48	1.116
13	3	14.3	84.0	0.4333	*	4.8	*	1.631
14	3	24.0	84.0	0.2000	*	14.5	1.14	1.374
15	3	24.0	84.0	0.1000	0.9000	24.0	0.67	1.374
16	3	23.5	84.0	0.0333	*	23.5	1.52	1.345
17	3	24.5	84.0	0.3333	0.7000	24.5	*	1.402
18	3	23.5	84.0	0.2667	*	23.5	-0.37	1.345
19	3	24.0	84.0	0.2000	*	24.0	-0.75	1.374
20	3	24.5	84.0	0.1000	*	24.5	-0.94	1.402
21	3	23.5	84.0	0.0000	*	23.5	0.38	1.345
22	3	24.5	84.0	0.0000	*	24.5	0.86	1.402
23	3	24.0	84.0	0.0000	*	24.0	0.95	1.374
24	3	24.0	84.0	0.0000	*	24.0	1.42	1.374
25	3	24.0	84.0	0.0000	*	24.0	*	1.374
26	3	23.5	84.0	0.0000	1.0000	23.5	1.61	1.345
27	3	24.5	84.0	0.0000	0.9000	24.5	2.75	1.402
28	3	24.0	84.0	0.0000	*	24.0	1.42	1.374
29	3	24.0	84.0	0.1000	*	24.0	2.09	1.374
30	3	17.5	84.0	2.0000	0.6000	17.5	2.65	2.003
31	3	6.5	84.0	0.0000	*	6.5	*	0.744

*No data taken.

Table D-3

Unit 3 Operational Variables, 1974

Date	No. of Circulators Operating	Avg. Time Circulators Operating (hr)	Avg. Flow Rate (gpm x 10^3)	Avg. Head Loss (ft)	Avg. Measured Approach Velocity (fps)	Avg. Time Air Curtain Operating (hr)	Avg. AES Measured Tide (ft)	Total Flow (10^6 m^3)
Apr 1-16	0	*	*	*	*	*	*	*
17	1	4.0	140.0	*	*	*	0.76	0.254
18	1	4.0	140.0	0.0000	*	*	0.16	0.763
19	1	4.0	140.0	*	*	*	0.65	0.763
20	1	4.0	140.0	*	*	*	0.83	0.768
21	1	4.0	140.0	*	*	*	0.10	0.758
22	1	4.0	140.0	*	*	*	0.57	0.771
23	1	3.1	140.0	*	*	*	0.62	0.294
24-30	0	*	*	*	*	*	*	*
May 1	1	3.3	140.0	*	*	*	0.51	0.318
2	1	4.0	140.0	*	*	*	0.53	0.763
3	1	4.0	140.0	*	*	*	-0.09	0.254
4-17	0	*	*	*	*	*	*	*
Jun 1- 4	0	*	*	*	*	*	*	*
5	1	4.0	140.0	*	*	*	0.38	0.509
6	1	4.8	140.0	*	*	*	0.61	0.763
7	1	4.1	140.0	*	*	*	1.14	0.390
8	2	4.0	140.0	*	*	*	0.97	1.542
9	2	4.0	140.0	*	*	*	0.49	1.542
10	2	4.0	140.0	*	*	*	0.34	1.526
11	2	4.1	140.0	*	*	*	1.39	0.784
12	2	4.0	140.0	*	*	*	1.14	0.514
13-18	*	*	*	*	*	*	*	*
19	2	4.0	140.0	*	*	*	0.92	0.254
20	2	4.0	140.0	*	*	*	0.12	1.526
21	2	4.0	140.0	*	*	*	0.24	1.537
22	2	4.0	140.0	*	*	*	-0.12	1.526
23	2	4.0	140.0	*	*	*	-0.50	1.526
24	2	4.0	140.0	*	*	*	0.60	1.526
25	2	4.1	140.0	*	*	*	0.86	0.774
26-30	0	*	*	*	*	*	*	*
Jul 18	1	4.0	140.0	*	*	*	1.00	0.127
19	1	4.0	140.0	*	*	*	0.38	0.763
20	1	4.0	140.0	*	*	*	0.23	0.763
21	1	4.1	140.0	*	*	*	0.78	0.652
22	1	4.0	140.0	*	*	*	1.06	0.763
23	1	3.3	140.0	*	*	*	1.05	0.318
24-31	0	*	*	*	*	*	*	*
Aug 1-6	0	*	*	*	*	*	*	*
7	1	3.5	140.0	*	*	*	1.01	0.445
8	1	4.0	140.0	*	*	*	0.62	0.763
9	1	4.0	140.0	*	*	*	0.18	0.763
10	1	4.0	140.0	*	*	*	0.65	0.763
11	1	4.0	140.0	*	*	*	0.95	0.763
12	1	4.0	140.0	*	*	*	1.09	0.763
13	1	4.0	140.0	*	*	*	1.80	0.127
14-17	0	*	*	*	*	*	*	*
Sep 1-3	0	*	*	*	*	*	*	*
4	1	8.0	140.0	*	*	*	-0.18	1.018
5	1	7.3	140.0	*	*	*	-0.37	1.399
6	1	4.0	140.0	*	*	*	-0.60	0.763
7	1	4.0	140.0	*	*	*	-0.18	0.763
8	1	4.0	140.0	*	*	*	0.53	0.763
9	1	4.0	140.0	*	*	*	0.25	0.763
10	1	3.8	140.0	*	*	*	-1.07	0.366
11-17	1	*	*	*	*	*	*	*
Oct 1-8	0	*	*	*	*	*	*	*
9	1	4.0	140.0	*	*	*	0.92	0.509
10	1	4.0	140.0	*	*	*	0.71	0.763
11	1	4.0	140.0	*	*	*	0.68	0.763
12	1	4.0	140.0	*	*	*	1.01	0.763
13	1	4.0	140.0	*	*	*	1.10	0.890
14	1	4.0	140.0	*	*	0.0	*	0.763
15	1	4.0	140.0	*	*	0.0	-1.04	0.382
16-17	0	*	*	*	*	*	*	*

*No data taken.

APPENDIX E

HISTOPATHOLOGY

PENNSYLVANIA STATE UNIVERSITY

HISTOPATHOLOGY SURVEY

TEXAS INSTRUMENTS PROJECT

February 1975

The following report deals with the post-mortem examination of fish collected from the vicinity of the water intakes of Consolidated Edison Generating Stations on the Hudson River.

The primary aim of the study was to identify pathological changes, if any, in the white perch population found in these areas. More specifically, our aim was to describe and evaluate the various types of histopathology observed in gill, spleen, liver, kidney and buccal roof with respect to incidence, severity and possible etiology. Our study groups included specimens removed from water intake screens as well as seined fish collected outside the intake currents.

Methodology

The 145 white perch examined in this study were collected during April and May of 1974. The specimens ranged in length from 59 mm to 212 mm and weighed from 3.0 to 134.3 g. All of the specimens were delivered to our laboratory fixed in either 10% neutral formalin or Bouins fluid (see Table 1, Appendix B). The tissue processing techniques employed were described in previous reports and are included in Appendix A of this report.

Tissue samples of gill, spleen, liver, kidney and buccal roof were removed from each fish, processed (paraffin technique) and sectioned for microscopic examination. Sections of each tissue type were stained with hematoxylin and eosin (h & e) and with periodic acid - Schiff reagent (PAS). Several special staining procedures were also employed where more definitive analysis was desirable. The previously employed pathological parameters, grading system and overall numerical rating scheme (Pathological Index) were used in assessing the incidence and severity of the histopathology observed in each specimen.

Results and Analysis

The major histopathological findings observed in gill, spleen, liver, kidney and buccal roof from "seined" (shipped specimens marked no. FR, BR) and "impinged" (specimens designated as no. FS, FEX, BEX) fish are summarized in Tables I and II, Appendix B.

It is interesting to note that of the entire group of 145 fish examined in this study, 136 (94%) showed some form of histopathology. This is especially noteworthy since 58% of the animals displayed moderate to severe degrees (P.I., 4-9) of tissue damage (Table III, Appendix B). In our previous survey, not only was the overall incidence of pathology lower (67%) but considerably fewer fish displayed moderate to severe degrees of tissue damage (ca. 20%). It should be noted, however, that this current group of shipped specimens was comprised of considerably larger fish (ave. wt. 30.3 g) than the previous study group (ave. wt. 14.8 g). And, although there were exceptions, the larger fish generally showed a consistently higher pathological index (see Table V, Appendix B).

Although the incidence of histopathology was somewhat higher in impinged fish (95.7%) than in seined specimens (92.1%), the mean P.I. for these two groups was identical (P.I., 4). As expected, kidney damage was clearly the most severe form of histopathology recorded for all size categories except group B (see Table V, Appendix B). Liver histopathology also contributed significantly to the P.I., particularly in the larger weight categories (groups C, D & E), while gill and spleen damage contributed least to the mean P.I. in all size categories.

Detailed analyses of major tissues are summarized in succeeding subsections.

Gill

Gill (n)*	Congestion (n)	Hyperplasia (n)	Parasites (n)	Clubbing (n)
Seined (27)	(3)	(19)	(8)	(9)
Impinged (31)	(9)	(22)	(14)	(5)
Total (68)	(12)	(41)	(22)	(14)

n = number of fish showing designated histopathology in each study group.

Although gill pathology occurred in 46.9% of the fish examined, none of the observed damage contributed greatly to the pathological index assigned to each animal. On the average, considering all types of histopathology, gill abnormalities contributed only 1.3 units to the pathological index for each fish which displayed gill pathology.

Hyperplasia was the most common form of tissue abnormality found in the gill. This condition was observed in 28.3% of the fish examined, and was most evident in the interlamellar areas. Epithelial cell proliferation at these points, including mucous cells, substantially added to the thickness of the gill filament and tended to occlude the interlamellar spaces. No significant differences were observed between seined and impinged fish with respect to the incidence or severity of hyperplasia. As with most of the histopathology observed in this survey, hyperplasia does not result from any one specific pathological stimulus.

Gill parasites were observed in 15.2% of the fish examined. Encysted spores (Microsporidia) were found within the tips of the filaments and mature parasites (monogenetic trematodes) were seen in the interlamellar area of the gill. It should be noted that the incidence of gill parasite infestations reported in this survey would undoubtedly be low, since our screening procedure involved the examination of only small representative areas of gill tissue from each specimen. In addition, mature parasites would be easily lost from the interlamellar area during the collection and processing of tissues. Impinged fish showed a higher incidence of gill parasites but as mentioned previously such differences may not be significant because of the limitations in our screening procedure.

Gill clubbing was observed in only 10% of the fish (See Slide # 1). This condition appeared to be the result of excessive proliferation of cells (hyperplasia) within the interlamellar area. Although lamellar supporting tissue and vascular elements were always discernible, severe clubbing resulted in complete loss of interlamellar spaces. This condition is known to occur in response to a wide variety of environmental irritants.

Vascular congestion (hyperemia) was observed in 8% of the fish examined and generally occurred in conjunction with the previously noted histopathology.

In appendix C several slides (numbers 1 through 4) illustrate examples of common pathologies observed.*

Slide 1. Gill filaments (H & E stained, magnified 50X) Note hyperplasia (increase in interlamellar cells; partial clubbing of gill marked by epithelial separation

Slide 2. High power view (400X) of two lamellae showing separation of epithelial cell elements suggestive of gas accumulation

Slide ~~3~~ 4. High power (PAS, 250X) showing trematode embedded among lamellae. Lamellae illustrate more extensive epithelial separation which has been described by some workers as typifying gas bubble disease

Black and white polaroid pictures of a gill lamellae with gas bubble type pathology and degenerating epithelial cells is shown in figure 1 (magnified 1000X) and a large lamellar cyst photographed using Nomarski interference optics in figure 2 (magnified 1000X).

Gas Bubble Analysis

Apparent gas accumulation was observed in the gill lamellae of 26% of the fish examined. (See Table IV, Appendix C). The incidence of gas bubbles was substantially higher in impinged fish (44.9%) than in the

*All slides and photos referenced in this report are included in documentation package for 1974 Impingement Study.

seined group (9.2%). This condition was morphologically distinct and easily identified by separation of the respiratory epithelium from the supporting and vascular components of the gill lamellae. The severity of the condition varied not only with the number of lamellae involved but also with the extent to which the respiratory epithelium was separated. However, no specimens were included in our count unless numerous lamellae on several filaments were affected and unless the epithelium was separated along most of the length of involved lamellae.

The presence of gas bubbles in the roof of the mouth was extremely difficult to verify because of the natural tendency for separation of epithelium from underlying connective tissue during dissection and processing. Only isolated, well defined epithelial separations were considered to be due to gas accumulation within the tissue. Using these criteria, only 9.0% of the fish displayed gas bubbles in the buccal roof. There was no marked hydropic degeneration in surface epithelial cells in any of the specimens examined.

Epithelial separations and accumulation of gas within the gill lamellae and buccal roof are considered to be good diagnostic characteristics of "gas bubble" disease. Less specific histopathology such as renal tubular necrosis, edema and abnormal architecture in both spleen and liver have also been associated with this disease. While all of these histopathological changes have been noted in this group of specimens, it is dangerous to assume that they are necessarily related and therefore symptomatic of "gas bubble" disease.

Our major reservations in making any positive diagnosis focus on the following points:

- a large percentage (66%) of the fish which displayed gas bubbles in the gill did not display the buccal roof lesions
- no attempt was made to correlate less specific histopathology with gas bubble symptoms
- no gross lesions of the disease such as exophthalmos or gas bubbles in the skin were observed

Slide no 5 in Appendix C (PAS stain, 50X) shows typical separation of surface stratified epithelium (which contains 6 dark staining goblet cells) from the underlying connective tissue of the submucosa. Refer to slides numbers 2 and 3 for gill changes typically occurring in gas bubble disease.

<u>Spleen</u>

Spleen (n)*	Necrosis (n)	Vascular Congestion (n)	Amyloidosis (n)	Deposits (n)
Seined (48)	(45)	(2)	(2)	(26)
Impinged (27)	(17)	(7)	(3)	(32)
Total (75)	(62)	(9)	(5)	(58)

*(n) = number of fish showing designated histopathology for each study group

Spleen histopathology was observed in 51.7% of the animals analyzed. Seined fish showed a higher incidence (63.2%) of spleen pathology than impinged fish (39.1%). Spleen pathology contributed on the average, considering all forms of histopathology, 1.6 units to the assigned pathological index of each animal.

Necrosis was the most prevalent form of regressive change observed in the spleen (42.8%). Although multiple necrosis involving large areas of the spleen were observed in a few animals; most necrotic areas were microscopic in size (focal necrosis) and confined to the pulp area of the organ. In addition to the usual degenerative changes within the cells, these necrotic areas for the most part were readily identified by their PAS-positive reaction and their increased eosinophilia. Seined fish showed a much higher incidence of necrosis (59.2%) than impinged fish (24.6%). However, in a number of the specimens from both groups the degree of necrosis as well as the absence of any inflammatory response suggests that the necrosis occurred after the death of the animals.

Since necrosis may be caused by almost any type of severe injury (i.e., physical agents, chemical agents, bacterial toxins or interruptions in circulation) no definitive statement can be made with respect to possible etiology.

Abnormal pigmentation within the spleen was another common form of histopathology observed in this current group of specimens. Approximately 40% of the animals examined showed abnormally large amounts of pigmentation. However, there was only a slight difference between seined fish (34.2%) and impinged fish (46.3%) with respect to this parameter. All pigments observed were tentatively identified as hemoglobin-derived pigments.

The most frequent form of pigment deposition was brown, PAS-negative, intracellular and extracellular, and most abundant in the area of red pulp sinusoids and surrounding vessels within the trabeculae. We suggest that these deposits may be hematoidin (bilirubin) or other bile pigments. Such pigments are often found where good oxygen supply is lacking, i.e., where blood is undergoing breakdown in dead or dying tissues.

The other major possibility which fits this set of characteristics is the so called acid hematin or formalin pigmentation. This substance is not a normal breakdown product of hemoglobin but occurs most frequently as a fixation artifact due to improper buffering of the formalin fixative. However, it has also been associated with such pathological situations as intravascular hemolysis and hemoglobinemia.

Spleen tissue from a few animals in both seined and impinged groups displayed intracellular, brown deposits which gave a PAS-positive reaction. These deposits were found within the phagocytic cells of the pulp and sinuses, and were tentatively identified as hemosiderin. This pigment is usually found within the phagocytic reticuloendothelial cells whenever there is an excessive breakdown of blood, i.e. hemorrhage, hemolytic anemias and passive congestions of organs in which stagnation of blood occurs in the capillaries.

It should be re-emphasized that our identification of these spleen deposits is only tentative and that further chemical analyses would be required to make a positive identification of these substances. For example, both hematin and hematoidin can be distinguished from hemosiderin by the prussian blue test. Hematin can be further distinguished by the benzidine test as well as its acid solubility.

Less frequent forms of histopathology observed in spleen tissue include congestion (6.2%) and amyloidosis (3.4%). Invariably, these conditions appeared to be part of a more general pathological picture. For example vascular congestion (hyperemia) was generally accompanied by various amounts of pigmentation and when amyloidosis was observed in the spleen it was also present in other organs such as liver and kidneys.

Vascular congestion observed in the spleen was most frequently characterized by dilation and engorgement of veins and sinusoids. There was always a marked increase in the number and variety of pulp cells, particularly leukocytes, and various amounts of cellular necrosis within the follicles and pulp. While hyperemia may be caused by a variety of pathologic stimuli, the changes described above are more typical of the splenic response to systemic infections or portal congestion.

Amyloidosis in the spleen was characterized by the deposition of relatively small amounts of amyloid found beneath the endothelium of arterioles and sinusoids. The amyloid was easily identified by its red, homogeneous appearance when stained with hematoxylin and eosin. Congo red was also employed as a confirmatory stain for amyloid.

Amyloid deposits are hyaline-like, apparently protein in nature and are transported to the site of deposition by the circulatory system. While amyloidosis has been characterized as a degenerative change, its pathological significance is not completely understood. It is thought to result primarily from long-continued, infective, tissue destructive processes.

Slides 6, 7, 8, 9, 10, 11 (Appendix C) show various types of spleen pathology.

Slide 6. Spleen (Papanicolaou stain, 50X) Massive degeneration of red and white pulp, i.e. extensive necrosis

Slide 7. Spleen (H & E . stain, 50X) illustrates the focal necrosis. Necrotic areas occur throughout splenic tissue (and are PAS-positive when stained with Schiff reagent)

Slide 8. Spleen (PAS stain, 50X) shows a different type of deposit which is PAS-negative. These often occur in necrotic areas

Slide 9. Spleen (Papanicolaou stain, 250X) Shows amyloid deposits in splenic parenchyma. Amyloid appears red to orange

Slide 10. Spleen (Papanicolaou stain, 50X) Vascular congestion; note markedly dilated blood vessel in center and dilated or engorged pulp sinusoids throughout the section

Slide 11. Spleen (PAS stain, 50X) shows parasitic cyst. Focal necrosis can be evidenced in surrounding splenic tissue

Figure 3 shows a photomicrograph of a clump of inclusion bodies in spleen tissue (Nomarski interference). These proved to be PAS-negative. Tentatively these were identified as hemoglobin derived (hematoidin).

Liver

Liver (n)*	Necrosis (n)	Bizarre Cells (n)	Cytoplasmic Vacuolization (n)	Deposits (n)
Seined (55)	(7)	(23)	(31)	(8)
Impinged (56)	(12)	(30)	(15)	(21)
Total (111)	(19)	(53)	(46)	(29)

(n) = number of fish showing designated histopathology in each category

Approximately seventy-seven percent (76.6%) of the fish showed some form of liver abnormality. In this group of fish, liver histopathology contributed, on the average, 1.5 units to the assigned pathological index for each animal which displayed liver damage. Although there were substantial differences between seined and impinged fish with respect to specific types of histopathology, there was no difference in the overall incidence of liver histopathology between the two groups.

The most prevalent form of liver histopathology was marked by the presence of hepatic cells with abnormally large nuclei. These cells were observed in 36.6% of the animals examined, and were found more frequently in impinged fish (43.5%) than in seined fish (30.3%). These cells were characterized by extremely large nuclei with prominent, hypertrophied, dark staining nucleoli. Condensed chromatin in many of these nuclei was dispersed along the inner surface of the nuclear membrane (margination) and around the nucleolus thus giving the appearance of a polyploid cell. Such cells are typically found in regenerating liver tissue following injury. Bizarre cells, having a similar appearance have been associated with viral infections and neoplasms. Light microscopy and H & E staining are simply not adequate to fully characterize these cells.

This group of specimens also displayed a relatively high incidence (31.7%) of cytoplasmic vacuolization. This condition was observed most often in seined fish (40.8%).

In general, the vacuoles were characterized by having ragged, indistinct borders and tended to impart an open meshwork appearance to the tissue. Nuclei in these cells remained prominent and did not appear to be displaced as in fatty degeneration. Hematoxylin and eosin staining displayed the intracytoplasmic vacuoles as poorly defined, clear areas. The degree of vacuolization was evident from the general appearance of the cytoplasm, and ranged from a typical foamy appearance (numerous small vacuoles) to cells in which the cytoplasm was completely lacking. Although cytoplasmic degeneration does occur as a result of pathogenic stimuli, particularly metabolic disorders, it is also clearly part of the sequence of events which follows cell death. In a considerable number of the specimens the marked cytoplasmic vacuolization and disintegration, involving virtually the entire organ, suggests cell death prior to fixation.

Abnormal cellular deposits occurred in 20.0% of the specimens. These deposits were more frequently observed in impinged fish (30.4%) than in seined fish (10.5%). With few exceptions these deposits appeared as very dense, PAS-positive (magenta) droplets of various sizes. The droplets were located both intracellularly and extracellularly and predominantly within the more central regions of the tissue. Duplicate sections of liver tissue gave negative reactions to colloidal iron, alcian blue and sudan staining. On the basis of the staining response, the droplets can be broadly categorized (glycogen, neutral mucopolysaccharide, mucoprotein), however further histochemical analyses would be required to make a positive identification. Of course, it is impossible to assess the pathological significance of these deposits until they can be positively identified.

Hepatic cell necrosis was found in 13.1% of the fish analyzed. This condition was more prevalent in the impinged group of fish (17.4%) than in seined fish (9.2%). It should be emphasized that the term necrosis as used in this context refers in all cases to cells displaying nuclear degeneration. This is in contrast to the cytoplasmic breakdown described previously in which nuclear degeneration was not evident.

Focal necrosis in the liver bore no relationship to any particular part of the lobule. The necrotic areas were small and contained hepatic cells in various stages of degeneration. The inflammatory response was weak with leukocytic infiltration generally limited to the periportal areas. Necrotic cells were readily identified by their darkly staining, pyknotic nuclei and acidophilic cytoplasm. A few hepatic cells appear to have undergone hyaline degeneration with the formation of councilman bodies. Swollen Kupffer cells and histocytes were also prominent in necrotic foci. This type of necrosis can occur in a variety of severe infections as well as ischemia and toxic injury.

In summary, much of the liver tissue analyzed was characterized by atypical architecture. For example, a normal lobular pattern was frequently absent. Hepatic cells in such tissue were not arranged in regular cords and while sinusoids could be discerned, they lacked the typical radiating pattern. There were also relatively few central veins and periportal regions.

Abnormal architecture is frequently seen in regenerating liver tissue in which the reticulum of the organ has been disrupted. However, regeneration is generally confined to small areas of the organ and is marked by mitotic activity. In contrast, our examination revealed massive areas of the liver showing abnormal architecture and without evidence of mitosis.

It should be pointed out that a significant number of fish in both the impinged (44.6%) and seined (36.4%) groups showed combinations of the more frequently observed forms of histopathology (bizarre cells, cytoplasmic vacuolization, PAS-positive droplets and necrosis). Other less frequent forms of pathology included: congestion (4.8%), cloudy swelling (2.8%) and edema (6.9%). Although we suspect that much of the observed liver histopathology is interrelated, we lack sufficient confirmation to make any definitive diagnosis.

Slides 12, 13, 14 and 15 depict examples of different forms of cytopathology in liver tissue.

Slide 12. (Papanicolaou stain, 400X) Liver parenchymal cords of cells. Individual nuclei exhibit very prominent nucleoli resembling "inclusion bodies" frequently associated with virus infections. Cytoplasm exhibits very slight vacuolization. Cords of cells are less organized than in normal liver, i.e. integrity of microarchitecture is disrupted

Slide 13. (H & E, 250X) Extensive vacuolization and atrophy of liver parenchymal cells. Nuclei irregular, often pycnotic. Such cytopathology can stem from toxic infections but can also result from autolysis during postmortem degeneration

Slide 14. (PAS stain, 400X) Nuclei of liver cells very difficult to see in view of extensive deposits of PAS-positive droplets and tentatively identified as polysaccharide in nature

Slide 15. (Papanicolaou stain, 50X) Extensive amyloidosis. Complete loss of cord arrangement of hepatocytes which are in degenerative state

Figures 4 and 5 are photomicrographs of liver pathology.

A "bizarre" cell with extremely large nucleus (center of field) is shown in figure 4. Surrounding this are parenchymal cells all exhibiting various degrees of degeneration, i.e. cloudy swelling of cytoplasm and smaller, irregularly shaped nuclei.

Figure 5 depicts a more advanced degenerative state of hepatic tissue. Cells are shrunken, cytoplasm vacuolated and nuclei pycnotic.

Kidney

Kidney (n)*	Edema	Cloudy Swelling (n)	Amyloidosis (n)	Casts (n)	Necrosis (n)
Seined (41)	(23)	(16)	(8)	(25)	(13)
Impinged (45)	(9)	(28)	(12)	(34)	(2)
Total (86)	(32)	(44)	(20)	(59)	(15)

(n) = number of fish showing designated histopathology in each study group

Kidney histopathology was observed in 59.3% of the specimens examined. In this group of fish, kidney pathology contributed, on the average, 2.2 units to the assigned pathological index for each animal which showed kidney damage. Also, there was a substantial difference in the overall incidence of histopathology between seined (53.9%) and impinged (65.2%) fish. However, this difference would not take into account specific types of abnormalities or the relative severity of any of these conditions.

Tubular casts were the most common form of renal disturbance (46.7%). These casts ranged from deeply staining, hyaline type to casts of granular and/or cellular nature. Although specific types of casts are frequently associated with well defined renal disorders, they are usually not, by themselves, considered adequate diagnostic criteria. Tubular casts, however, can someimes be analyzed and directly related to some causative factor. For example, eosinophilic colloid casts were generally observed in severe amyloidosis of the kidney while cellular casts were nearly always the result of desquamation of tubular epithelium associated with necrotic tubules. Casts consisting of cellular debris, desquamated cells and inflammatory cells were also observed and were undoubtedly a sequel to the inflammatory process.

Cloudy swelling of tubular epithelium was frequently observed during the course of our analysis (30.3%). The incidence of cloudy swelling was considerably higher in impinged fish (40.6%) as compared to seined specimens (21.1%). This condition (cloudy swelling) is one of the most frequently observed and perhaps mildest form of degenerative change. Microscopically the epithelial lining cells appeared swollen with cloudy or granular cytoplasm. The nuclei of these cells were sometimes obscure but did not appear to be displaced or damaged. Cloudy swelling is a nonspecific degenerative change which may result from a variety of injurious conditions such as acute infections, poisons and anoxemia. It should be emphasized that early autolytic changes simulate the anatomic appearance of cloudy swelling.

Marked interstitial edema was found in 22.1% of the fish, with the highest incidence occurring in the seined group (30.3%). This condition was characterized by excessive separation of renal tubules. The intertubular area contained relatively few formed elements (i.e., fibroblasts, fibers or vascular elements) and appeared for the most part as open space. Where the edematous condition existed along with tubular necrosis, inflammatory cells were also present in large numbers. In this latter situation, the edema was undoubtedly part of the inflammatory process.

Amyloid deposition appeared in the kidneys of 13.8% of the animals examined. Marked amyloid infiltration of glomeruli was the most pronounced feature of this condition, and ranged from minor involvement of a few capillary tufts (nodules) to complete obliteration of the glomerulus. With H & E staining, glomeruli appeared to be filled with "soft" eosinophilic material and displayed virtually no nuclei. Occasionally, small arteries and arterioles were thickened as a result of amyloid infiltration. Renal tubules contained various amounts of amyloid depending upon the severity of the condition but no cases were observed in which amyloid deposits were found within the interstitial tissue. The glomerular capsule and intracapsular area appeared normal, and there was no apparent reduction in the number of tubules.

Amyloidosis observed in the fish kidney is most likely the so-called secondary form which occurs as a sequel to various disease processes.

Tubular necrosis was seen in a small number of specimens (10.3%). Among the most readily indentifiable features of this condition were the dilated, irregularly shaped tubules. These tubules were lined with very low epithelium which showed increased basophilia and deep staining oval nuclei. Mitotic figures were also observed in the tubular lining cells, giving the general appearance of regeneration. Amorphous, eosinophilic material as well as desquamated cells were frequently found within the tubular lumen. Death and desquamation of tubular epithelium is typically associated with many renal disorders, including acute tubular necrosis, pyelonephritis, amyloidosis, and toxic nephrosis. It is also typically found as a result of post-mortem degeneration of kidney tissue.

As expected, a large percentage (ca. 40%) of the fish examined displayed combinations of the more general forms of histopathology described in this section. It is likely that these conditions are interrelated and are, as such part of a pathological syndrome. Unfortunately, because of the limitations inherent in histopathologic analyses and more specifically the approach employed in this study, we are unable to specify the origin of most of the observed pathology. Accordingly, we have observed such conditions as amyloidosis, tubular necrosis and a variety of cellular changes which apparently stem from severe infections and/or exposure to toxic substance. However, we cannot be certain of the precise etiology of any of these conditions. Moreover, we cannot adequately assess the influence of autolytic tissue damage.

Slides 16 through 20 and three photomicrographs (figures 6, 7 and 8) illustrate various types of kidney pathology.

Slide 16. (H & E stain, 250X) This shows extensive degenerative changes in tubules (central region of slide) and some amyloidosis of a glomerulus. Marked separation of glomerular and tubular elements from surrounding connective tissue (evidenced by spaces between structures) suggest an edematous state. One large swollen tubule has a clump of cellular debris (cellular "cast")

Slides 17 & 18. (H & E stain, 400X and 250X) Slightly higher magnification of renal tubule showing cast in lumen; also desquamation of pycnotic epithelial cells lining the lumen. Tubular cells exhibit normal vesicular nuclei with cloudy cytoplasm

Figure 6 (1000X) exhibits a similar type of tubular necrosis with desquamated cells in the lumen and low cuboidal epithelial cells lining the lumen of the tubule

Slide 19. (Papanicolaou stain, 50X) Illustrates eosinophilic amyloidosis of glomerular units

Slide 20. (Papanicolaou stain, 400X) Section through tubules showing cloudy swelling and separation of tubules from surrounding connective tissue

Figures 7 & 8. Show same cells viewed by Normarski interference (figure 7) and ordinary light microscopy (figure 8) of an H & E stained kidney section (1600X)

Central proximal tubule exhibits cloudy swelling of cytoplasm although nuclei appear normal. Other tubules in section contain disrupted epithelial cell linings with degenerating cells (pycnotic nuclei).

APPENDIX E

HISTOPATHOLOGY

Table E-1

Fixing Procedure, Autotechnicon Ultra, 4-hr Schedule*

Process	Duration (min)
95% alcohol	10
95% alcohol	10
95% alcohol	10
Absolute alcohol	20
Absolute alcohol	20
Absolute alcohol	20
Clearing agent**	10
Clearing agent	15
Clearing agent	25
Paraffin (56-58°C M.P.)	20
Paraffin	40

*All specimens processed according to thickness of tissue. In this study, tissue specimens were cut at 4-mm thickness and processed on corresponding 4-hr schedule, beginning with step 2.

**Technicon U. C. 670, xylene or amyl acetate.

Table E-2

Procedure 1, Hematoxylin and Eosin*

Process	Duration (min)	Comments
Xylene	3	
Xylene	3	To remove paraffin
100% alcohol	2	
100% alcohol	2	
95% alcohol	2	Hydration
70% alcohol	2	
Water	3	
Hematoxylin (aqueous solution)	0.5	Check after 0.5 min; if too light, stain for additional 0.5-1 min
Running water	3-5	
Ammonia water	3	Use 1 drop NH_4Oh in tap water
Running water	3-5	
Eosin in 70% alcohol	1	As counterstain
70% alcohol	1 or 2 dips†	
95% alcohol	1 or 2 dips†	
100% alcohol	3	Dehydration
100% alcohol	3	
Xylene	3	
Xylene	3 or more	
Permount, cover slip		Keep sections wet with xylene while putting on Permount; tissue must not dry CAUTION Tissue must <u>never</u> be allowed to dry during staining procedure.

*Results

Nuclei and other basophilic components - dark blue
Cytoplasm and other acidophilic components - pink

†These steps control intensity of counterstain (eosin) and must be rinsed very quickly or too much eosin is lost.

Table E-3

Procedure 2, Periodic Acid-Schiff Reaction, Aqueous Method

Process	Duration (min)
Xylene	5
Xylene	2
Absolute ethanol	2
Absolute ethanol	2
95% ethalon	2
70% ethanol	1
Distilled water	Rinse
Periodic acid (aqueous)	5
Running tap water	5
Schiff reagent	10
0.5% sodium metabisulfite	2
0.5% sodium metabisulfite	2
0.5% sodium metabisulfite	2
Running tap water	5
Harris hematoxylin	0.5
Running tap water	5
Scott's solution	3
Distilled water	Rinse
70% ethanol	Rinse
95% ethanol	Rinse
Absolute ethanol	Rinse
Xylene	2
Xylene	2
Permount	
Total time	~1 hr

Table E-4

Data Forming Bases for Pathological Indices

Fish No.	Weight (g)	Length (mm)	Gill: Congestion Interlamellar Debris	Gill: Hyperplasia	Gill: Parasites	Gill: Mucous Cells Proliferation 100/mm^2	Gill: Clubbing	Spleen: Cysts, Fecal Necrosis	Liver: Cysts, Fecal Necrosis	Kidney: Cysts, Fecal Necrosis Edema	Patho-logical Index
FR	134.1	212	-	+	-	-	-	+	+++	-	5(6)
FR2	72.4	163	-	-	-	-	-	++	++	+	5
FR3	51.4	140	-	-	-	-	-	-	++	+	3
FR4	96.2	176	-	-	-	-	-	+	++	+++	6
FR5	29.5	127	-	+	+	+	-	-	++	-	5
FR6	60.3	152	-	-	-	-	-	+	+	+	3
FR7	76.9	162	-	+	-	-	+	+	+++	+	7
FR8	71.6	157	-	-	-	-	-	-	+	+++	4
FR9	27.6	125	-	-	-	-	-	-	+	-	1
FR10	45.4	140	-	-	-	-	-	-	++	+	3
FR11	134.3	195	-	-	-	-	-	+	+	+++	5
FR12	69.9	162	-	+	-	-	-	+	+	+	4
FR13	27.9	125	-	-	-	-	-	-	+	++	3
FR14	27.3	126	-	-	+	-	-	-	+	++	4
FR15	37.4	130	-	-	-	-	-	-	+	-	1
FR16	26.5	120	-	-	-	-	-	+	+	-	2
FR17	104.0	185	-	-	-	-	-	-	+	++	3
FR18	44.4	142	-	-	-	-	+	+	++	-	4
FR19	50.0	148	-	-	-	-	+	-	-	++	3
FR20	54.0	146	-	-	-	-	-	+	+	+	3
FR21	52.7	155	-	+	-	-	-	+	-	+	3
FR22	79.2	172	-	+	-	+	+	+	+	-	5
FR23	67.1	160	+	-	-	-	-	+	+	-	3
FR24	34.5	135	-	-	-	-	-	+	+	-	2
FR25	42.4	136	-	-	-	-	-	+	+	-	2
FR26	54.8	148	-	+	-	-	-	-	-	-	1
FR27	51.2	152	-	-	-	-	-	+	+	+	3
FR28	49.4	150	-	-	-	-	-	+	-	+++	4
FR29	48.9	136	-	-	-	-	-	+	+	+++	5
FR30	49.7	146	-	-	-	-	-	+++	+	-	4
FR31	49.0	146	-	-	-	-	-	-	-	-	0
FR32	30.8	131	-	-	-	-	-	+	-	+++	4
FR33	53.5	151	-	+	-	-	+	+++	-	-	5(6)
FR34	68.0	157	-	+	+	-	-	+	+	-	4
FR35	41.7	140	-	+	-	-	+	+	+	+	5
FR36	69.4	165	-	-	-	-	-	+	+	-	2
FR81	9.1	90	-	-	-	-	-	+++	+	++	6
FR83	9.5	85	-	-	-	-	-	-	+	++	3
FR84	5.2	75	-	-	-	-	-	+++	+	+++	7(8)
FR85	7.2	83	-	-	-	-	-	+++	-	+++	6
FR86	5.0	74	-	-	-	-	-	+++	+	-	4
FR87	6.8	82	-	-	-	-	-	+++	+	++	6
FR90	6.3	82	+	-	+	-	-	+++	+	+++	9
FR91	3.8	69	-	-	-	-	-	++	-	+++	5
FR92	4.7	73	-	-	-	-	-	-	+	+++	4
FR93	5.5	75	-	-	-	-	-	-	+	-	1
FR94	8.5	88	-	+	-	-	-	-	+	+++	5(7)
FR95	9.0	86	-	-	-	-	-	-	+	-	1
FR97	6.3	80	-	-	-	-	-	-	-	-	0
FR98	5.7	77	-	-	-	-	-	+++	+	-	4
FR99	5.2	75	-	-	-	-	-	-	-	-	0
FR100	4.5	75	-	-	-	-	-	-	-	-	0
FR101	9.2	88	-	+	-	-	-	+	++	+	5
FR102	6.4	78	-	-	-	-	-	-	-	+++	3
FR103	7.0	81	-	-	-	-	-	+	-	-	1
FR104	8.8	86	-	-	-	-	-	+++	+	-	4
FR105	10.3	92	-	+	-	-	+	-	-	-	2
FR106	9.3	90	-	+	-	-	-	+++	-	-	4
FR107	7.4	85	-	-	-	-	-	+++	+	-	4
FR108	5.4	78	+	-	+	-	-	+++	+	-	6
FR109	4.6	74	-	-	-	-	-	+++	-	+++	6
FR110	11.4	97	-	-	+	-	-	+++	+	+++	8
FR111	5.8	81	-	+	-	-	-	-	-	-	1
FR112	8.0	86	-	+	+	-	+	-	+	++	6
FR113	8.1	89	-	-	-	-	-	-	++	++	4
FR114	7.9	86	-	-	-	-	-	-	-	-	0
FR115	10.2	92	-	-	+	-	-	-	-	++	3
FR116	8.0	85	-	+	-	-	-	+	++	++	6
BR37	90.6	165	-	-	-	-	-	+	++	-	3(5)
BR38	66.2	148	-	+	-	-	-	++	+	+	5(7)
BR39	98.3	176	-	-	-	-	-	+	++	+	4(5)
BR40	60.7	160	-	-	-	-	-	++	+++	+++	8
BR117	4.4	65	-	-	-	-	+	+	+	-	3
BR118	6.0	76	-	-	-	-	-	+	+	+	3
BR119	8.8	81	-	-	-	-	-	-	-	-	0
BR120	6.5	78	-	+	-	-	-	+	+++	++	7

F = formalin preservation.
B = Bovin's solution preservation.
R = river collection.
EX + S = impingement collection.

Table E-4 (Contd)

Fish No.	Weight (g)	Length (mm)	Gill: Congestion Interlamellar Debris	Gill: Hyperplasia	Gill: Parasites	Gill: Mucous Cells Proliferation 100/mm^2	Gill: Clubbing	Spleen: Cysts, Fecal Necrosis	Liver: Cysts, Fecal Necrosis	Kidney: Cysts, Fecal Necrosis Edema	Pathological Index
FS41	69.4	160	-	+	-	-	-	+	-	+++	5(7)
FS42	51.1	150	-	-	-	-	-	+	-	-	1(2)
FS43	23.1	112	-	-	-	-	-	+	-	-	1(3)
FS44	28.3	122	-	-	-	-	-	-	+	-	1(3)
FS45	110.4	191	-	-	-	-	-	+	+	+++	5
FS46	82.6	162	-	-	-	-	-	+	+	+	3
FS47	37.5	126	+	+	-	-	-	+	+	+++	7(9)
FS48	23.4	119	-	+	+	-	-	-	+	++	5(6)
FS50	31.7	126	-	+	-	-	-	+	-	-	2(3)
FS51	59.3	150	-	-	-	-	-	-	+++	+++	6(7)
FS52	30.1	130	-	-	-	-	-	+	-	+	2
FS53	31.6	122	-	-	-	-	-	+++	+++	+++	9(10)
FS54	38.8	128	-	-	-	-	-	-	+++	+++	6
FS55	41.2	125	+	-	+	-	-	-	++	+++	7(8)
FS59	30.4	120	-	-	-	-	-	+	+++	-	4(5)
FS60	8.5	105	-	-	-	-	-	-	+++	-	3
FEX62	22.8	116	-	-	-	-	-	-	-	++	2
FEX64	53.0	152	+	+	-	-	-	-	++	+	5
FEX66	97.4	184	-	-	-	-	-	+	+	+++	5
FEX67	22.9	116	-	-	+	-	-	+	+++	+++	8
FEX68	15.3	98	+	+	+	-	-	-	+	+	5
FEX69	30.7	125	-	+	+	-	-	+	+	+++	7
FEX70	25.0	125	+	+	-	-	+	+	+++	++	9
FEX71	60.8	156	-	-	-	-	-	-	-	-	0
FEX72	50.8	146	-	-	-	-	-	++	+	+++	6
FEX73	28.9	134	-	+	+	-	+	+++	+	-	7
FEX74	22.6	120	-	-	-	-	-	-	-	++	2
FEX75	22.2	120	-	+	+	-	-	+	+++	+++	9(10)
FEX76	14.0	100	-	-	-	-	-	-	+++	++	5
FEX121	8.5	85	-	+	-	-	-	-	+	++	4(5)
FEX122	10.1	90	-	-	-	-	-	-	++	++	4(5)
FEX123	10.5	90	-	+	-	-	-	-	+	+++	5(6)
FEX124	7.8	82	-	-	-	-	-	+	++	++	5
FEX125	4.9	70	-	-	-	-	-	-	++	+++	5
FEX126	5.3	73	-	+	+	-	-	-	++	-	4(5)
FEX127	5.3	72	-	+	-	-	-	-	+	++	4(5)
FEX129	6.3	75	-	-	-	-	-	-	+	-	1(2)
FEX130	4.5	67	-	-	+	-	-	-	+	-	2
FEX132	9.1	78	-	-	-	-	-	-	++	-	2
FEX133	6.0	73	-	-	-	-	-	-	-	-	0(1)
FEX134	6.9	78	-	-	+	-	-	-	-	+	2
FEX135	5.9	75	-	-	-	-	-	-	+	-	1(2)
FEX136	6.9	78	-	-	-	-	-	-	++	-	2
FEX137	7.7	75	-	-	-	-	-	-	++	+++	5
FEX138	12.1	85	-	-	-	-	-	-	++	+	3(5)
FEX139	8.1	81	-	-	-	-	-	+	++	-	3
FEX140	7.4	73	-	-	-	+	-	+++	+	-	5
FEX141	10.7	91	-	-	-	-	-	-	++	-	2
FEX142	9.1	83	-	-	-	-	-		+	++	3(4)
FEX143	11.3	84	-	-	+	-	-	+++	+++	++	9
FEX144	6.4	75	-	-	-	-	-	+	-	+++	4(5)
FEX146	5.0	72	-	-	-	-	-	-	+++	++	5
FEX147	3.8	65	-	-	-	-	-	-	+	+++	4
FEX148	10.0	86	-	+	-	-	-	-	+	++	4(5)
FEX149	7.0	76	-	-	+	-	-	-	++	-	3(4)
FEX150	7.1	77	-	-	-	-	-	-	+	++	3
FEX151	10.4	88	+	-	+	-	-	-	++	-	4(6)
FEX152	6.1	68	-	-	-	-	-	-	-	-	0
FEX153	8.0	82	-	-	-	-	-	-	+	-	1
FEX154	10.6	87	+	-	-	-	-	-	++	-	3(4)
FEX155	8.7	85	-	+	-	+	+	-	+	+	5
FEX156	3.0	59	-	-	-	-	-	-	-	++	2
BEX78	77.0	163	+	+	-	+	-	-	+	-	4
BEX79	30.0	120	-	-	-	-	-	+	+++	+++	7
BEX80	72.3	170	-	+	-	-	-	+	+	++	5
BEX157	7.0	81	+	+	+	-	+	-	+	+++	8(10)
BEX158	7.0	76	-	+	-	-	+	+	+	++	6(8)
BEX159	4.2	68	-	+	-	-	-	+	+	++	5(7)
BEX160	11.3	88	-	+	-	+	-	+	++	+++	8(10)

F = formalin preservation.
B = Bovin's solution preservation.
R = river collection.
EX + S = impingement collection.

Table E-5

Gas Bubble Analysis

Fish No.	Weight (g)	Length (mm)	Gill Epithelial Separation	Buccal Roof Epithelial Separation, Vesicles
FR	134.1	212	+	-
FR2	72.4	163	-	-
FR3	51.4	140	-	-
FR4	96.2	176	-	-
FR5	29.5	127	-	-
FR6	60.3	152	-	-
FR7	76.9	162	-	-
FR8	71.6	157	-	-
FR9	27.6	125	-	-
FR10	45.4	140	-	-
FR11	134.3	195	-	-
FR12	69.9	162	-	-
FR13	27.9	125	-	-
FR14	27.3	126	-	-
FR15	37.4	130	-	-
FR16	26.5	120	-	-
FR17	104.0	185	-	-
FR18	44.4	142	-	-
FR19	50.0	148	-	-
FR20	54.0	146	-	-
FR21	52.7	155	-	-
FR22	79.2	172	-	-
FR23	67.1	160	-	-
FR24	34.5	135	-	-
FR25	42.4	136	-	-
FR26	54.8	148	-	-
FR27	51.2	152	-	-
FR28	49.4	150	-	-
FR29	48.9	136	-	-
FR30	49.7	146	-	-
FR31	49.0	146	-	-
FR32	30.8	131	-	-
FR33	53.5	151	+	-
FR34	68.0	157	-	-
FR35	41.7	140	-	-
FR36	69.4	165	-	-
FR81	9.1	90	-	-
FR83	9.5	85	-	-
FR84	5.2	75	+	-
FR85	7.2	83	-	-
FR86	5.0	74	-	-
FR87	6.8	82	-	-
FR90	6.3	82	-	-
FR91	3.8	69	-	-
FR92	4.7	73	-	-
FR93	5.5	75	-	-
FR94	8.5	88	+	+
FR95	9.0	86	-	-

Table E-5 (Contd)

Fish No.	Weight (g)	Length (mm)	Gill	Buccal Roof
			Epithelial Separation	Epithelial Separation, Vesicles
FR97	6.3	80	-	-
FR98	5.7	77	-	-
FR99	5.2	75	-	-
FR100	4.5	75	-	-
FR101	9.2	88	-	-
FR102	6.4	78	-	-
FR103	7.0	81	-	-
FR104	8.8	86	-	-
FR105	10.3	92	-	-
FR106	9.3	90	-	-
FR107	7.4	85	-	-
FR108	5.4	78	-	-
FR109	4.6	74	-	-
FR110	11.4	97	-	-
FR111	5.8	81	-	-
FR112	8.0	86	-	-
FR113	8.1	89	-	-
FR114	7.9	86	-	-
FR115	10.2	92	-	-
FR116	8.0	85	-	-
BR37	90.6	165	+	+
BR38	66.2	148	+	+
BR39	98.3	176	+	-
BR40	60.7	160	-	-
BR117	4.4	65	-	-
BR118	6.0	76	-	-
BR119	8.8	81	-	-
BR120	6.5	78	-	-
FS41	69.4	160	+	+
FS42	51.1	150	+	-
FS43	23.1	112	+	+
FS44	28.3	122	+	+
FS45	110.4	191	-	-
FS46	82.6	162	-	-
FS47	37.5	126	+	+
FS48	23.4	119	+	-
FS50	31.7	126	+	-
FS51	59.3	150	+	-
FS52	30.1	130	-	-
FS53	31.6	122	+	-
FS54	38.8	128	-	-
FS55	41.2	125	+	-
FS59	30.4	120	+	-
FS60	8.5	105	-	-
FEX62	22.8	116	-	-
FEX64	53.0	152	-	-
FEX66	97.4	184	-	-
FEX67	22.9	116	-	-

Table E-5 (Contd)

Fish No.	Weight (g)	Length (mm)	Gill	Buccal Roof
			Epithelial Separation	Epithelial Separation, Vesicles
FEX58	15.3	98	-	-
FEX69	30.7	125	-	-
FEX70	25.0	125	-	-
FEX71	60.8	156	-	-
FEX72	50.8	146	-	-
FEX73	28.9	134	-	-
FEX74	22.6	120	-	-
FEX75	22.2	120	+	-
FEX76	14.0	100	-	-
FEX121	8.5	85	+	-
FEX122	10.1	90	+	-
FEX123	10.5	90	+	-
FEX124	7.8	82	-	-
FEX125	4.9	70	-	-
FEX126	5.3	73	+	-
FEX127	5.3	72	+	-
FEX129	6.3	75	+	-
FEX130	4.5	67	-	-
FEX132	9.1	78	-	-
FEX133	6.0	73	+	-
FEX134	6.9	78	-	-
FEX135	5.9	75	+	-
FEX136	6.9	78	-	-
FEX137	7.7	75	-	-
FEX138	12.1	85	+	+
FEX139	8.1	81	-	-
FEX140	7.4	73	-	-
FEX141	10.7	91	-	-
FEX142	9.1	83	+	-
FEX143	11.3	84	-	-
FEX144	6.4	75	+	-
FEX146	5.0	72	-	-
FEX147	3.8	65	-	-
FEX148	10.0	86	+	-
FEX149	7.0	76	+	-
FEX150	7.1	77	-	-
FEX151	10.4	88	+	+
FEX152	6.1	68	-	-
FEX153	8.0	82	-	-
FEX154	10.6	87	+	-
FEX155	8.7	85	-	-
FEX156	3.0	59	-	-
BEX78	77.0	163	-	-
BEX79	30.0	120	-	-
BEX80	72.3	170	-	-
BEX157	7.0	81	+	+
BEX158	7.0	76	+	+
BEX159	4.2	68	+	+
BEX160	11.3	88	+	+

Table E-6

Pathological Index*

	N	Weight (g)	Length (mm)	0 No Damage n (%)	1-3 Slight Damage n (%)	4-6 Moderate Damage n (%)	7-9 Severe Damage n (%)
Total fish	145	30.3	111.6	9(6.2)	52(35.9)	66(45.5)	18(12.4)
Impinged	69	24.4	104	3(4.3)	24(34.8)	30(43.5)	12(17.4)
FS	16						
FEX	46						
BEX	7						
Seined	76	35.7	118	6(7.9)	28(36.8)	36(47.4)	6(7.9)
FR	68						
BR	8						

*Pathological index does not include gas-bubble analysis of gill or buccal roof. N = number of fish collected for tissue processing; n=number showing designated severity of pathology; (%)=percentage of fish collected in designated groups in each pathology index category. Average weight of fish collected was recorded in grams (g); average length was recorded in millimeters (mm). See Table D-4 for summary of raw data forming basis for designated pathological indices represented in columns 2, 3, and 4.

Table E-7

Gas Bubble Analysis

	N	Weight (g)	Length (mm)	Gill n (%)	Buccal Roof n (%)
Total fish	145	30.3	111.6	38(26.2)	13(9.0)
Impinged	69	24.4	104	31(44.9)	10(14.5)
FS	16				
FEX	46				
BEX	7				
Seined	76	35.7	118	7(9.2)	3(3.9)
FR	68				
BR	8				

*N=number of fish collected for tissue processing; n=number of specimens showing gas-bubble pathology for designated tissue and group; (%)=percentage of fish showing gas-bubble pathology for designated tissue and group. Average weight of fish collected was recorded in grams (g); average length was recorded in millimeters (mm). See Table D-5 for summary of raw data and explanation of fish numbers and groups.

Table E-8

Mean Pathological Indices ($\bar{x}$ PI) By Weight Categories

	N	Weight (g)	Length (mm)	($\bar{x}$ PI)	Weight Category (g): 1-5 n(%)	1-5 ($\bar{x}$ PI)	5.1-10 n(%)	5.1-10 ($\bar{x}$ PI)	10.1-20 n(%)	10.1-20 ($\bar{x}$ PI)	20.1-50 n(%)	20.1-50 ($\bar{x}$ PI)	50.1+ n(%)	50.1+ ($\bar{x}$ PI)
Seined	76	35.7	118	(4)	6(7.9)	(3)	27(35.5)	(4)	3(3.9)	(4)	17(22.4)	(3)	23(30.3)	(4)
Impinged	69	24.4	104	(4)	6(8.7)	(4)	24(34.8)	(3)	10(14.5)	(5)	18(26.1)	(5)	11(15.9)	(4)
Total	145	30.3	112	(4)	12(8.3)	(3)	51(35.2)	(3)	13(9.0)	(5)	35(24.1)	(4)	34(23.4)	(4)

*N = number of fish collected for tissue processing; n = number in each designated weight category; (%) = percentage of fish showing designated mean pathological index ($\bar{x}$ PI) for each weight category. Average weight of fish collected was recorded in grams (g); average length was recorded in millimeters (mm). See Table D-4 for summary of raw data forming basis for designated pathological indices.

APPENDIX F

COMMON EFFLUENT WATER CHEMISTRY DATA

Table F-1

Data Summary for Unit 1 Intake Water Chemistry Taken for Dissolved Gas Saturation Study

Date (1974)	Depth*	Temp (°C)	DO (ppm)	O_2 (%)	N_2 (mℓ) Rep 1	Rep 2	N_2 (%) Rep 1	Rep 2	$\bar{x}$	N_2 Corrected (%)	N_2 $\frac{S+B}{2}$
Jul 24†	S	24.5	6.8	80.0	3.3	3.3	57.0		57.0	76.0	79.9
	B	25.1	6.5	79.0	3.7	3.6	64.7	63.0	63.8	82.8	
Jul 25	S	24.2	7.8	93.3	4.2	4.0	72.4	69.0	70.7	89.7	92.9
	B	24.5	7.5	90.1	4.5	4.4	77.9	76.2	77.1	96.1	
Aug 21†	S	26.0	5.8	71.8	4.0		71.0		71.0	90.0	86.6
	B	25.0	6.4	77.6	3.7	3.9	64.6	68.1	66.3	83.3	
Aug 23	S	27.5	5.5	70.0	4.5	4.6	81.9	83.7	82.8	101.8	104.5
	B	27.5	5.6	71.2	4.7	5.0	85.5	91.0	88.2	107.2	
Sep 27	S	20.5	7.0	77.9	4.9	4.7	79.2	75.9	77.5	96.5	91.7
	B	20.0	8.2	90.4	4.1	4.4	65.6	70.4	68.0	87.0	
Sep 30†	S	21.0	8.2	92.1	6.5	5.2	105.9	84.7	95.3	114.3	112.3
	B	20.5	6.2	69.0	5.7	5.6	92.1	90.5	91.3	110.3	
Oct 28	S	13.4	9.3	89.2	5.9	6.0	83.2	84.6	83.9	102.9	102.9
	B	13.4	8.8	84.4	5.9	6.0	83.2	84.6	83.9	102.9	
Oct 30†	S	14.7	8.8	86.9	5.6	5.8	81.1	84.0	82.5	101.5	101.8
	B	14.7	9.9	97.7	5.6	5.9	81.1	85.4	83.2	102.2	
Nov 27†	S	7.8	10.5	88.3	7.0	7.0	87.5	87.5	87.5	106.5	103.2
	B	7.0	7.6	62.7	6.4	6.8	78.6	83.5	81.0	100.0	
Dec 2	S	7.1	11.2	92.6	8.2	8.2	100.9	100.9	100.9	119.9	117.3
	B	7.3	11.4	94.8	7.6	7.9	93.9	97.7	95.8	114.8	

*S = surface; B = bottom.

†Days on which air curtain was operated.

Table F-2

Data Summary for Common Effluent Water Chemistry Taken for Dissolved Gas Saturation Study

Date (1974)	Depth*	Temp (°C)	ΔT (°C)	DO (ppm)	O_2 (%)	N_2 (mℓ) Rep 1	N_2 (mℓ) Rep 2	N_2 (%) Rep 1	N_2 (%) Rep 2	$\bar{x}$	N_2 Corrected (%)	N_2 $\frac{S+B}{2}$
Jul 24†	S	30.5	6.0	7.3	97.7	3.7	3.5	70.5	66.7	68.6	87.6	90.7
	B	30.9	5.8	8.6	115.9	4.1	3.7	78.6	71.0	74.8	93.8	
Jul 25	S	32.2	8.0	7.9	109.3	4.0	4.0	78.3	78.1	78.2	97.2	95.8
	B	33.0	8.5	8.1	118.8	3.7	3.9	73.3	77.3	75.3	94.3	
Aug 21†	S	33.0	7.0	7.1	99.7	4.3	4.4	85.2	87.2	86.2	105.2	103.4
	B	34.0	9.0	7.6	109.0	4.1		82.6		82.6	101.6	
Aug 23†	S	39.5	12.0	5.9	95.3	4.9	5.3	108.8	117.7	113.2	132.2	131.9
	B	40.2	12.7	6.4	74.4	4.9	5.1	110.2	114.7	112.4	131.4	
Sep 27	S	28.0	7.5	7.0	89.7	4.2	4.8	77.1	88.1	82.6	101.6	101.3
	B	28.0	8.2	8.3	106.8	4.4	4.5	81.0	82.8	81.9	100.9	
Sep 30†	S	22.3	1.3	8.6	99.2	4.2	5.6	70.1	93.4	81.7	100.7	98.1
	B	22.0	1.5	9.0	103.1	4.5	4.7	74.7	78.0	76.3	95.3	
Oct 28	S	21.8	8.4	8.4	95.9	5.4	5.4	89.3	89.3	89.3	108.3	109.9
	B	20.8	7.4	8.6	96.3	5.5	5.9	89.3	95.8	92.8	111.5	
Oct 30†	S	24.9	10.2	8.6	104.1	5.5	5.5	95.9	95.9	95.9	114.9	116.9
	B	25.2	10.5	9.4	114.9	5.7	5.7	99.9	99.9	99.9	118.9	
Nov 27†	S	19.0	11.2	7.8	84.2	5.8	6.1	91.2	95.9	93.5	112.5	111.5
	B	16.5	9.5	6.8	69.7	6.2	6.0	93.0	90.0	91.5	110.5	
Dec 2	S	19.8	12.7	11.3	123.9	7.9	8.2	126.0	130.8	128.4	147.4	143.1
	B	17.4	10.6	11.2	117.0	7.4	8.3	112.9	126.6	119.7	138.7	

*S = surface; B = bottom.
†Days on which air curtain was operated.

APPENDIX G
GILL PARASITE DATA

Table G-1

Weekly Summary of Gill Parasite (*Lironica ovalis*) Infestation of Bluefish from Beach Seine and Impingement Samples

Week No.	Impingement			Beach Seine		
	No. Caught	No. Infested	% Infested	No. Caught	No. Infested	% Infested
0	–	–	–	3	2	66.67
1	15	0	0.00	4	1	25.00
2	8	4	50.00	1	0	0.00
3	17	10	58.82	10	5	50.00
4	21	8	38.10	9	8	88.89
5	22	8	36.36	5	5	100.00
6	6	4	66.67	46	38	82.61
7	15	6	40.00	6	2	33.33
8	1	1	100.00	6	4	66.67
9	4	2	50.00	0	0	0.00
10	8	6	75.00	2	2	100.00
11	5	4	80.00	1	0	0.00
12	9	7	77.78	1	1	100.00
13	3	2	66.67	0	0	0.00
14	0	0	0.00	1	0	0.00
15	1	0	0.00	2	2	100.00
16	0	0	0.00	0	0	0.00
17	0	0	0.00	0	0	0.00
Total	135	62	45.93	97	70	72.17

Table G-2

Weekly Summary of Gill Parasite (*Lironica ovalis*) Infestation of Striped Bass from Beach Seine and Impingement Samples

Week No.	Impingement			Beach Seine		
	No. Caught	No. Infested	% Infested	No. Caught	No. Infested	% Infested
0	–	–	–	0	0	0.00
1	5	1	20.00	5	1	20.00
2	1	0	0.00	3	0	0.00
3	3	0	0.00	11	1	9.09
4	6	1	16.67	8	1	12.50
5	22	2	9.09	–	–	–
6	9	1	11.11	–	–	–
7	26	1	3.85	–	–	–
8	8	0	0.00	–	–	–
9	9	0	0.00	19	1	5.26
10	9	2	22.22	15	1	6.67
11	12	0	0.00	7	0	0.00
12	16	6	37.50	18	0	0.00
13	12	1	8.33	21	0	0.00
14	2	0	0.00	14	0	0.00
15	6	0	0.00	16	2	12.50
16	7	0	0.00	6	0	0.00
17	14	0	0.00	20	0	0.00
Total	167	15	7.35	163	7	4.30

Table G-3

Weekly Summary of Gill Parasite (*Lironica ovalis*) Infestation of White Perch from Beach Seine and Impingement Samples

Week No.	Impingement			Beach Seine		
	No. Caught	No. Infested	% Infested	No. Caught	No. Infested	% Infested
0	–	–	–	0	0	0.00
1	12	0	0.00	8	0	0.00
2	18	0	0.00	21	0	0.00
3	10	0	0.00	1	0	0.00
4	7	0	0.00	5	0	0.00
5	11	3	27.27	20	0	0.00
6	8	4	50.00	35	1	2.86
7	28	0	0.00	11	0	0.00
8	18	0	0.00	8	0	0.00
9	24	3	12.50	18	0	0.00
10	34	4	11.76	6	0	0.00
11	38	10	26.32	4	0	0.00
12	49	8	16.33	5	0	0.00
13	67	11	16.42	28	0	0.00
14	28	0	0.00	3	0	0.00
15	60	3	5.00	22	0	0.00
16	67	0	0.00	0	0	0.00
17	183	0	0.00	37	0	0.00
Total	662	46	6.95	232	1	0.43

APPENDIX H

VERTICAL GILL NET DATA

Table H-1

Weekly Means of Fish Numbers Collected in Gill Nets

		Mean Number per Hour					Mean Percentage				
Week	Depth	Striped Bass	White Perch	Tomcod	Hogchoker	All Species Combined	Striped Bass	White Perch	Tomcod	Hogchoker	All Species Combined
25	1	0.435	0	0	0	0.435	62.50	0	0	0	33.33
	2	0.174	0.217	0.043	0	0.522	25.00	83.33	100.00	0	40.00
	3	0.087	0	0	0	0.217	12.50	0	0	0	16.67
	4	0	0.043	0	0	0.130	0	16.67	0	0	10.00
26	1	0.320	0.071	0	0	0.413	30.20	16.13	0	0	23.77
	2	0.626	0.121	0	0	0.904	59.06	27.42	0	0	52.05
	3	0.071	0.135	0	0	0.228	6.71	30.65	0	0	13.11
	4	0.043	0.114	0	0	0.192	4.03	25.81	0	0	11.07
27	1	0.285	0.012	0	0	0.360	34.75	8.33	0	0	31.79
	2	0.424	0.047	0	0	0.517	51.77	33.33	0	0	45.64
	3	0.110	0.064	0	0	0.221	13.48	45.83	0	0	19.49
	4	0	0.017	0	0	0.035	0	12.50	0	0	3.08
28	1	0.006	0	0	0	0.006	3.33	0	0	0	1.85
	2	0.078	0.042	0.006	0	0.133	43.33	35.00	100.00	0	40.74
	3	0.054	0.030	0	0	0.090	30.00	25.00	0	0	27.78
	4	0.042	0.048	0	0	0.096	23.33	40.00	0	0	29.63
29	1	0.040	0.020	0	0	0.185	10.71	14.29	0	0	19.44
	2	0.159	0.013	0	0	0.344	42.86	9.52	0	0	36.11
	3	0.073	0.060	0	0	0.205	19.64	42.86	0	0	21.53
	4	0.099	0.046	0	0	0.219	26.79	33.33	0	0	22.92
30	1	0.035	0.021	0	0	0.056	20.83	42.86	0	0	16.00
	2	0.049	0	0.007	0	0.092	29.17	0	100.00	0	26.00
	3	0.063	0.007	0	0	0.120	37.50	14.29	0	0	34.00
	4	0.021	0.021	0	0	0.085	12.50	42.86	0	0	24.00
31	1	0.032	0	0	0	0.063	6.90	0	0	0	4.30
	2	0.261	0.008	0	0	0.648	56.90	3.23	0	0	44.09
	3	0.126	0.055	0	0	0.403	27.59	22.58	0	0	27.42
	4	0.040	0.182	0	0	0.356	8.62	74.19	0	0	24.19
32	1	0.336	0.010	0	0	0.839	43.24	20.00	0	0	41.88
	2	0.273	0.010	0	0	0.734	35.14	20.00	0	0	36.65
	3	0.094	0	0	0	0.241	12.16	0	0	0	12.04
	4	0.073	0.031	0	0	0.189	9.46	60.00	0	0	9.42
33	1	0.167	0	0	0	0.297	25.69	0	0	0	19.76
	2	0.274	0.006	0	0	0.725	42.20	9.09	0	0	48.22
	3	0.155	0.024	0	0	0.357	23.85	36.36	0	0	23.72
	4	0.054	0.036	0	0	0.125	8.26	54.55	0	0	8.30
34	1	0.066	0.006	0	0	0.305	11.58	5.23	0	0	16.09
	2	0.216	0	0	0	0.701	37.89	0	0	0	36.91
	3	0.228	0.036	0	0	0.689	40.00	31.58	0	0	36.28
	4	0.060	0.072	0	0	0.204	10.53	63.16	0	0	10.73
35	1	0.042	0	0	0	0.102	14.29	0	0	0	6.63
	2	0.170	0	0	0	0.892	57.14	0	0	0	58.01
	3	0.076	0.008	0	0	0.365	25.71	16.67	0	0	23.76
	4	0.008	0.042	0	0.017	0.178	2.86	83.33	0	100.00	11.60
36	1	0.036	0.004	0	0	0.170	17.24	2.38	0	0	17.03
	2	0.127	0.011	0	0	0.546	60.34	7.14	0	0	54.71
	3	0.029	0.033	0	0	0.108	13.79	21.43	0	0	10.87
	4	0.018	0.105	0	0.004	0.174	8.62	69.05	0	100.00	17.39

Table H-1 (Contd)

		Mean Number per Hour					Mean Percentage				
Week	Depth	Striped Bass	White Perch	Tomcod	Hogchoker	All Species Combined	Striped Bass	White Perch	Tomcod	Hogchoker	All Species Combined
37	1	0.022	0	0	0	0.094	11.43	0	0	0	11.89
	2	0.110	0.039	0	0	0.292	57.14	12.73	0	0	37.06
	3	0.044	0.105	0	0	0.209	22.86	34.55	0	0	26.57
	4	0.017	0.160	0	0	0.193	8.57	52.73	0	0	24.48
38	1	0.029	0.017	0	0	0.203	26.32	6.12	0	0	27.34
	2	0.070	0.064	0	0	0.278	63.16	22.45	0	0	37.50
	3	0.012	0.110	0	0	0.157	10.53	38.78	0	0	21.09
	4	0	0.093	0	0	0.104	0	32.65	0	0	14.06
39	1	0	0	0	0	0.029	0	0	0	0	9.52
	2	0.029	0.021	0	0	0.079	66.67	11.11	0	0	26.19
	3	0.007	0.086	0	0	0.093	16.67	44.44	0	0	30.95
	4	0.007	0.086	0	0	0.100	16.67	44.44	0	0	33.33
40	1	0.006	0.006	0	0	0.018	33.33	4.76	0	0	6.98
	2	0.006	0	0	0	0.094	33.33	0	0	0	37.21
	3	0.006	0.035	0	0	0.053	33.33	28.57	0	0	20.93
	4	0	0.083	0	0	0.088	0	66.67	0	0	34.88
41	1	0	0	0	0	0	0	0	0	0	0
	2	0.005	0.010	0	0.005	0.026	50.00	3.85	0	100.00	8.62
	3	0.005	0.150	0	0	0.160	50.00	55.77	0	0	53.45
	4	0	0.108	0	0	0.113	0	40.38	0	0	37.93
42	1	0.016	0	0	0	0.024	40.00	0	0	0	23.08
	2	0.008	0	0	0	0.008	20.00	0	0	0	7.69
	3	0.016	0.024	0	0	0.040	40.00	42.86	0	0	38.46
	4	0	0.032	0	0	0.032	0	57.14	0	0	30.77
43	1	0	0	0	0	0	0	0	0	0	0
	2	0.043	0	0	0	0.086	100.00	0	0	0	100.00
	3	0	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0
44	1	0	0	0	0	0	0	0	0	0	0
	2	0.077	0	0	0	0.089	72.22	0	0	0	62.50
	3	0.024	0.018	0	0	0.041	22.22	75.00	0	0	29.17
	4	0.006	0.006	0	0	0.012	5.56	25.00	0	0	8.33
45	1	0.021	0	0	0	0.021	15.38	0	0	0	9.52
	2	0.083	0.010	0	0	0.104	61.54	16.67	0	0	47.62
	3	0.010	0.021	0	0	0.042	7.69	33.33	0	0	19.05
	4	0.021	0.031	0	0	0.052	15.38	50.00	0	0	23.81
46	1	0.007	0	0	0	0.014	9.09	0	0	0	4.35
	2	0.034	0	0	0	0.041	45.45	0	0	0	13.04
	3	0.034	0.090	0	0	0.138	45.45	43.33	0	0	43.48
	4	0	0.117	0	0	0.124	0	56.67	0	0	39.13
47	1	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0.074	0	0	0	0	41.67
	3	0	0.015	0.015	0	0.045	0	20.00	100.00	0	25.00
	4	0	0.059	0	0	0.059	0	80.00	0	0	33.33
48	1	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0.021	0	0	0	0	33.33
	3	0	0	0	0	0	0	0	0	0	0
	4	0	0.043	0	0	0.043	0	100.0	0	0	66.67
49	1	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0
	3	0	0	0.045	0	0.045	0	0	20.00	0	10.00
	4	0	0.227	0.182	0	0.409	0	100.00	80.00	0	90.00

APPENDIX I

SONAR EQUIPMENT DESIGN AND WIRING

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SONAR EQUIPMENT DESIGN AND WIRING

In Table H-1 are the controlled functions and their status during a complete system cycle. Initially, the system is in a "standby" phase with only filament power applied. Upon receipt of the initiating pulse from the main control timer, the 0- to 6-sec system timer 5S turns "on" and applies power to the recorder paper-drive motor and the stylus belt-drive motor. This gives the stylus plenty of time to reach full operating speed and advances the paper a slight amount to put a black separator between consecutive records. After 5 sec of operation in this mode, timer 5S resets and, in the process, sends a pulse to the 0- to 5-min timer 5M which then holds the paper and belt motors on, applies B+ to the transceiver, and closes the connection between the stylus and the "mark" signal input.

In the schematic of the recorder, Figure H-1, the additional wiring is indicated (heavy lines); it is seen that the relay system merely acts in parallel with the recorder function switch SW9 (which must be in the OFF position during automatic operation of the system). The paper-drive motor is activated by application of power from the arm of switch SW10. The stylus motor is turned on by simply returning its low side to ground. The B+ is controlled by a set of contacts in the power transformer ground return, which closes upon activation of the 5M timer. Figures H-2 and H-3 show the relay system wiring, and Figure H-4 shows the actual hardwiring to the recorder. The internal wiring was redesigned to utilize the Cramer™ timer (5S and 5M) in this application. The final wiring diagrams appear in Figure H-5.

Table I-1

Timing System Control Function Sequence for Unattended Interval Recording of Sonar Transducer Signals

Function	Standby	Warm Up*	Record On (II)**
Filaments	On	On	On
B+	Off	Off	On
"Mark signal"	Off	Off	On
Belt drive	Off	On	On
Paper drive	Off	On	On

* 0-5 sec times; warm-up, paper advance

** 0-5 min times; recording

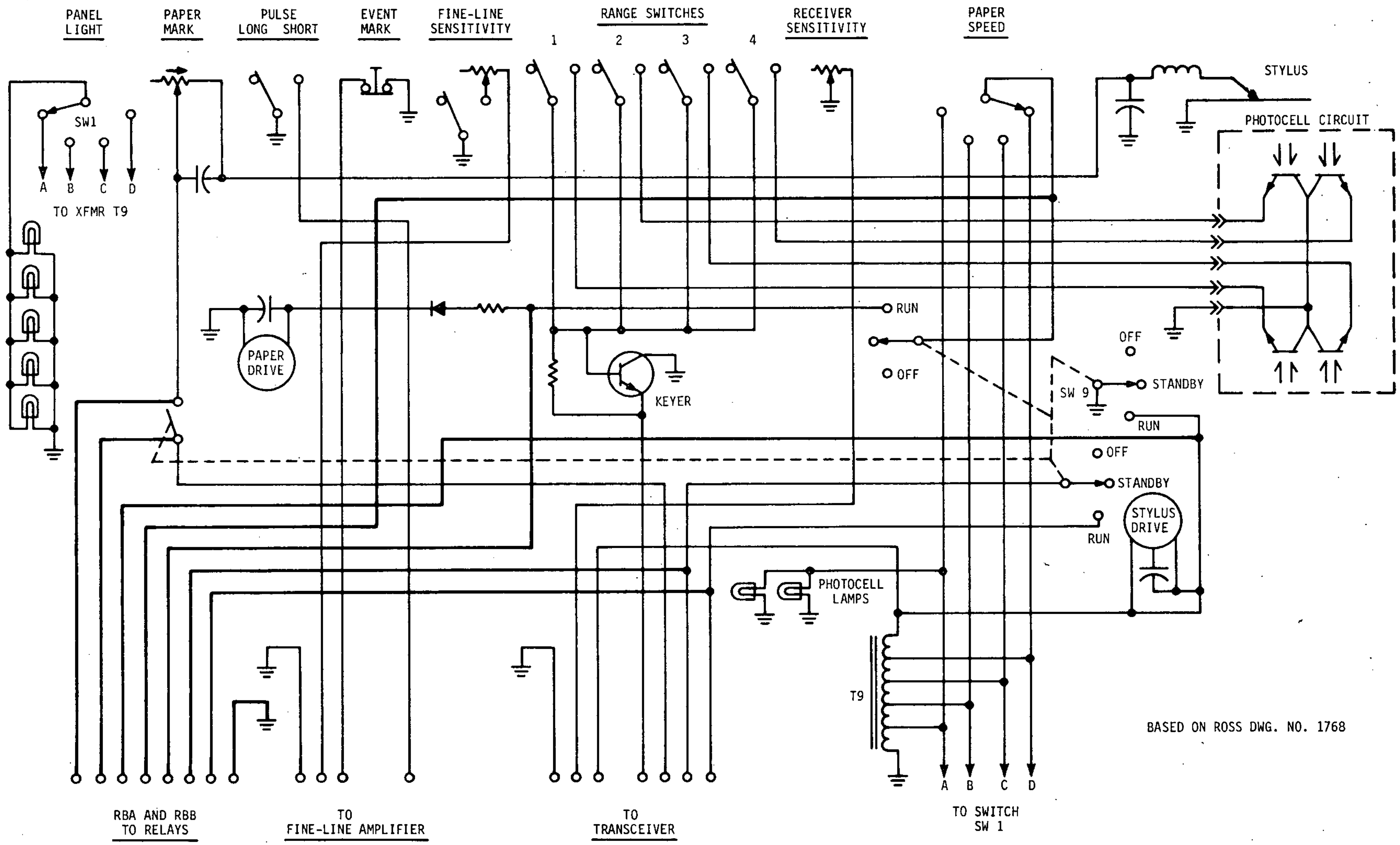


Figure I-1. Sonar Recorder Wiring Schematic. (Heavy lines were accessory wiring required to integrate interval recording sequence)

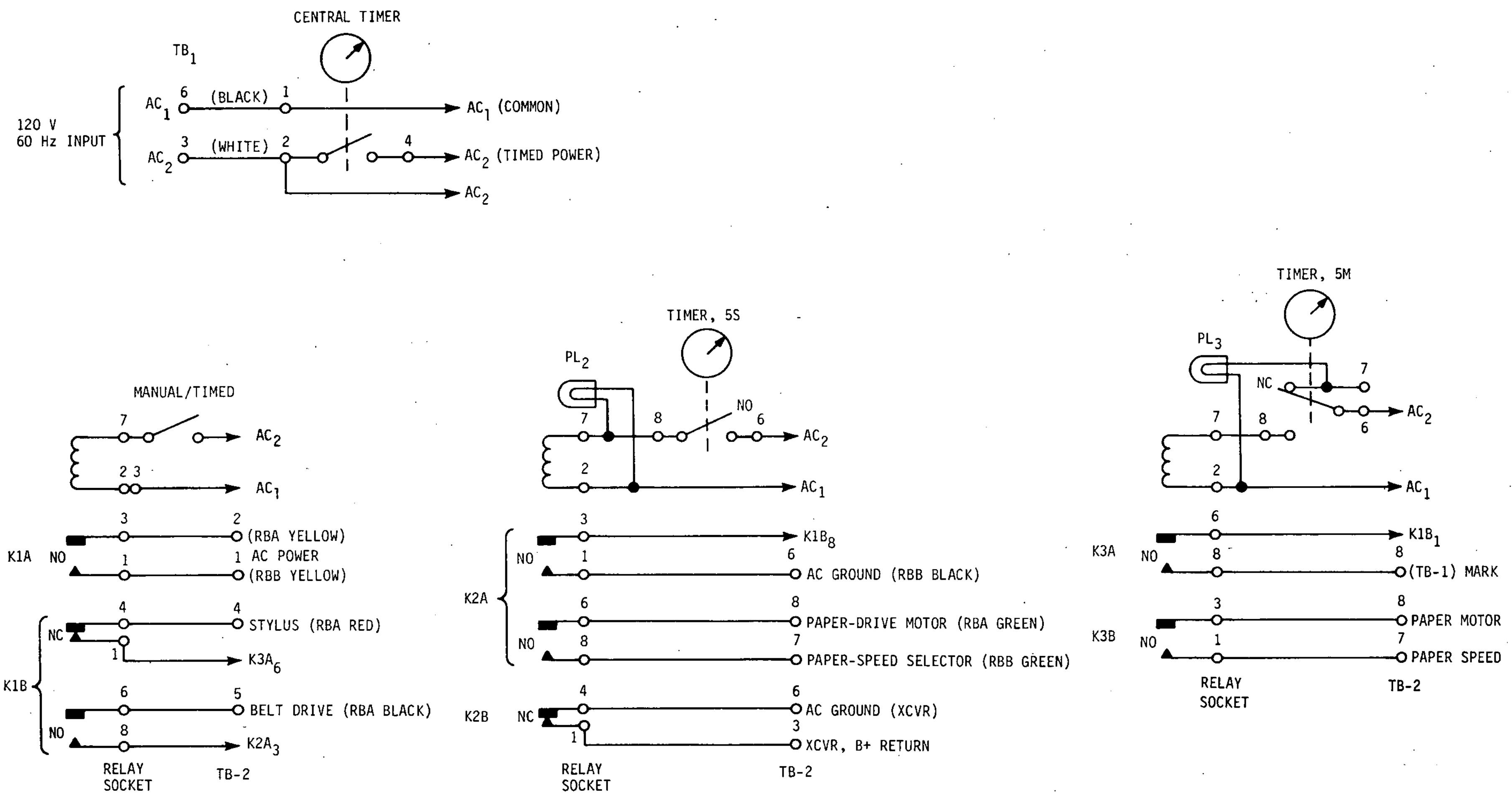


Figure I-2. Blueprint of Timing Control Relay System Handwiring Hookup for Unattended Recording of Sonar Transducer Input

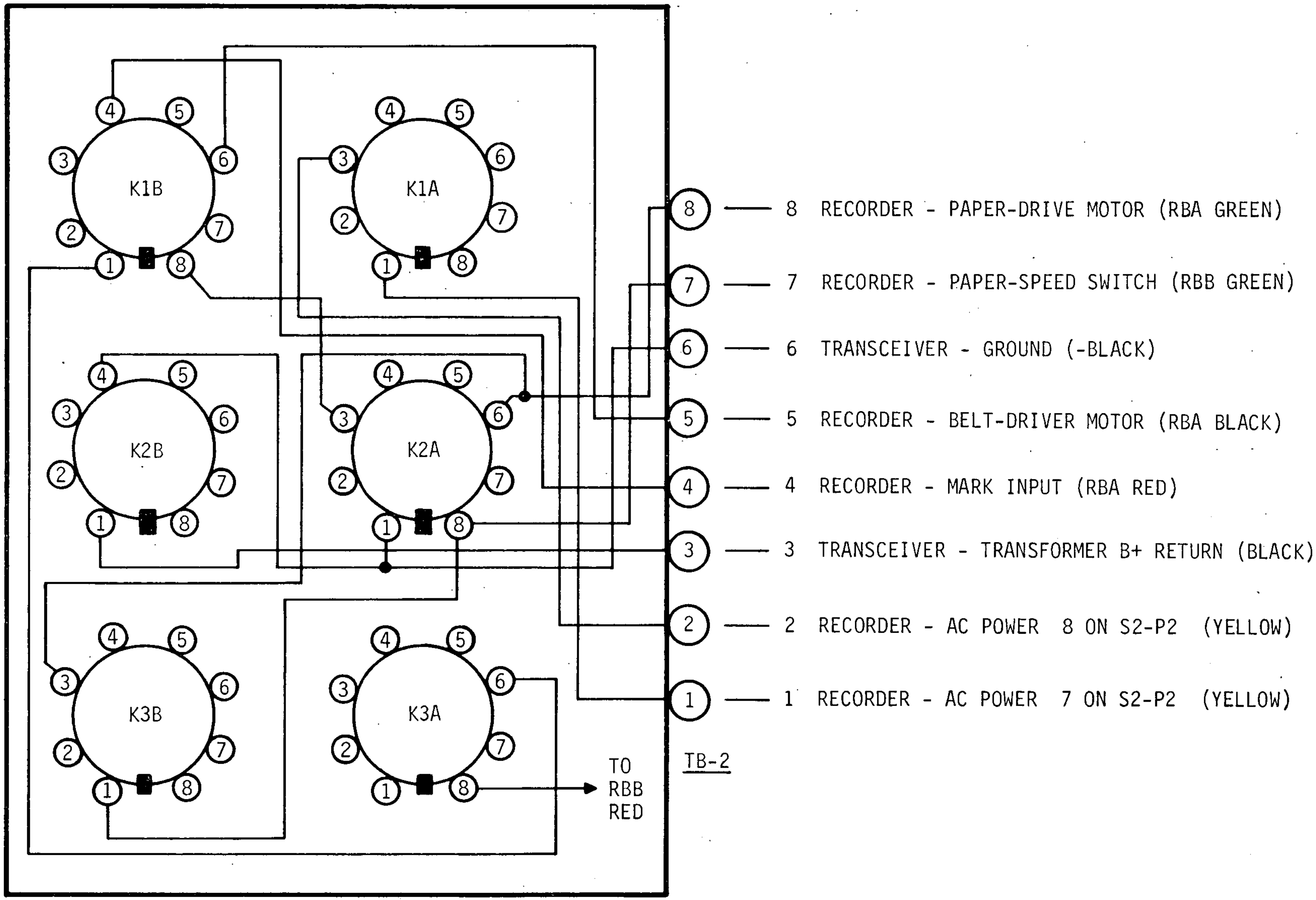


Figure I-3. Relay Control System Wiring for Unattended Recording of Sonar Transducer Input

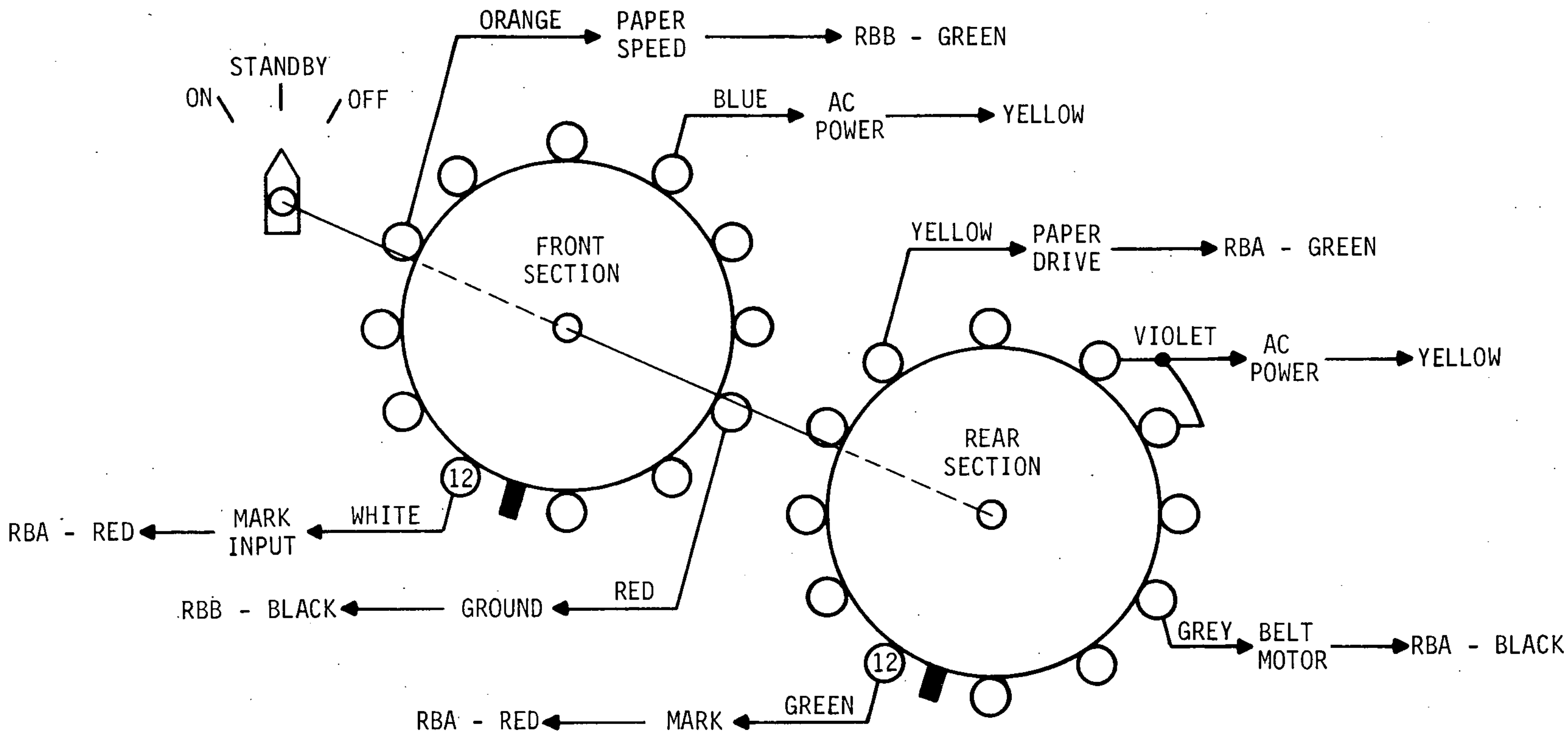
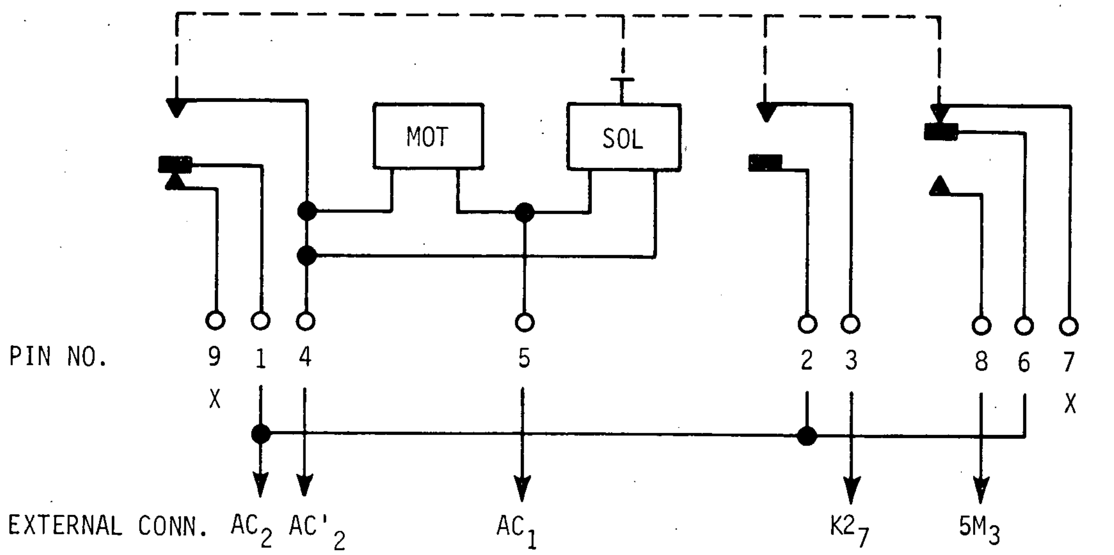


Figure I-4. Recorder Power Switch (Rear View) Wired for Interval Recording of Sonar Transducer Input

5 SECOND WARMUP



5 MINUTE RECORD

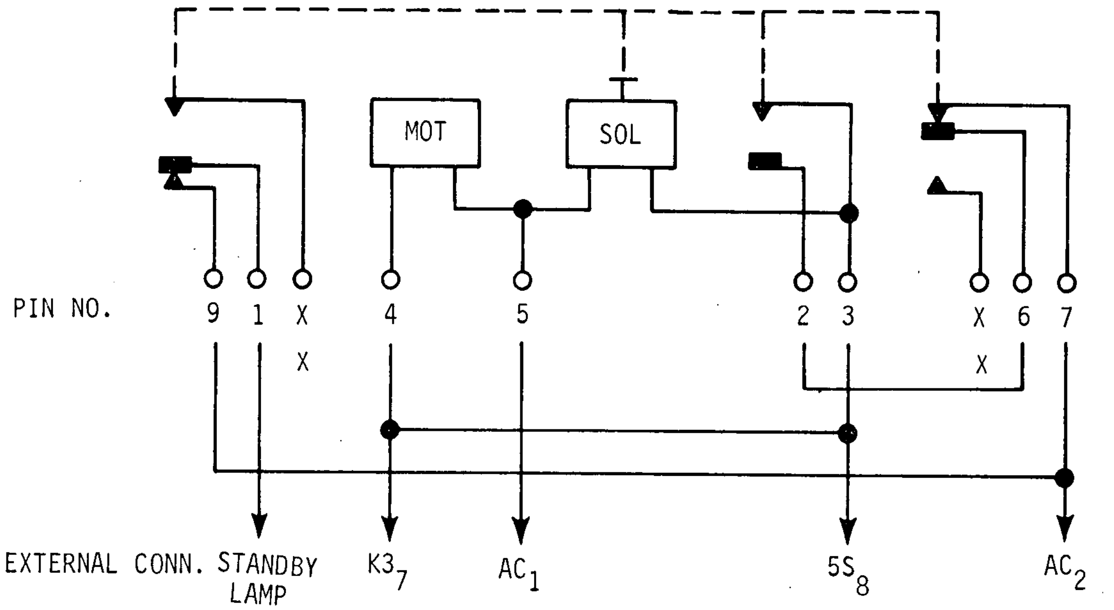


Figure I-5. Cramer[TM] Timer Wiring after Redesign for Interval Recording of Sonar Transducer Input