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FIRST PROGRESS REPORT
INDIAN POINT FLUME STUDY

CONSOLIDATED EDISON COMPANY
OF NEW YORK, INC.

August 1975

STONE & WEBSTER ENGINEERING CORPORATION
BOSTON, MASSACHUSETTS

TABLE OF CONTENTS

TABLE OF CONTENTS (CONT'D)

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (CONT'D)

LIST OF FIGURES (CONT'D)

SECTION I

INTRODUCTION

In April, 1974, Stone & Webster Engineering Corporation (S&W) submitted a proposal to Consolidated Edison Company of New York, Inc. (Con Edison), for designing test facilities and conducting an experimental program to evaluate the effectiveness and applicability of various fish diversion devices with regard to their potential for alleviating the problem of fish entrapment at Indian Point and other Hudson River sites. Alden Research Laboratories (ARL) in Holden, Massachusetts was chosen as the site for the study program in order to make use of existing facilities.

The following is a list of the objectives of the study program:

(1) Determine the feasibility of transporting and holding Hudson River fish species at ARL.

(2) Review all literature pertaining to fish protection at water intakes, fish diversion studies, and life histories and behavioral characteristics of key Hudson River species commonly impinged at Indian Point.

(3) Evaluate the prototype engineering feasibility of various fish guidance structures with respect to their application at Indian Point.

(4) Utilizing information obtained from Objectives 2 and 3, determine fish guidance structures to be tested. In addition, determine the water quality parameters which can be obtained in the test flume and investigate the effect of control limitations on the results of the study.

(5) Test the applicability of specified fish guidance devices on Hudson River species and optimize the effectiveness of protection systems found to be effective and feasible.

Objectives (1) through (4) have been completed and are discussed in this report. Flume testing will proceed according to the study program discussed in Section VI of this report.

The S & W proposal also included limited studies to determine the feasibility of reducing entrainment of fish eggs and larvae in the circulating water system. Based on preliminary investigations, it was determined that since eggs and larvae would have little ability to react to prototype flows and, as such, would necessitate major changes in potential prototype diversion devices for juvenile and adult fish, it was not desirable to pursue experimental studies on larval fish diversion at this time. Instead, experimental efforts are concentrating on alleviating juvenile and adult entrapment problems concurrently with a review of any developments which may make larval diversion feasible for future study.

SECTION II

PRESENT INTAKE DESIGN

2.1 INDIAN POINT GENERATING STATION - UNITS 1, 2 AND 3

The intakes of Units 1, 2 and 3 are located on the shoreline of the Hudson River between river miles 42 and 43, as shown in Figure 2-1. The combined flow rate into the intakes is 2,058,000 gpm (4,594 cfs). Tidal fluctuations in the Hudson River influence the river currents in the vicinity of the intakes and the approach velocities to the intakes.

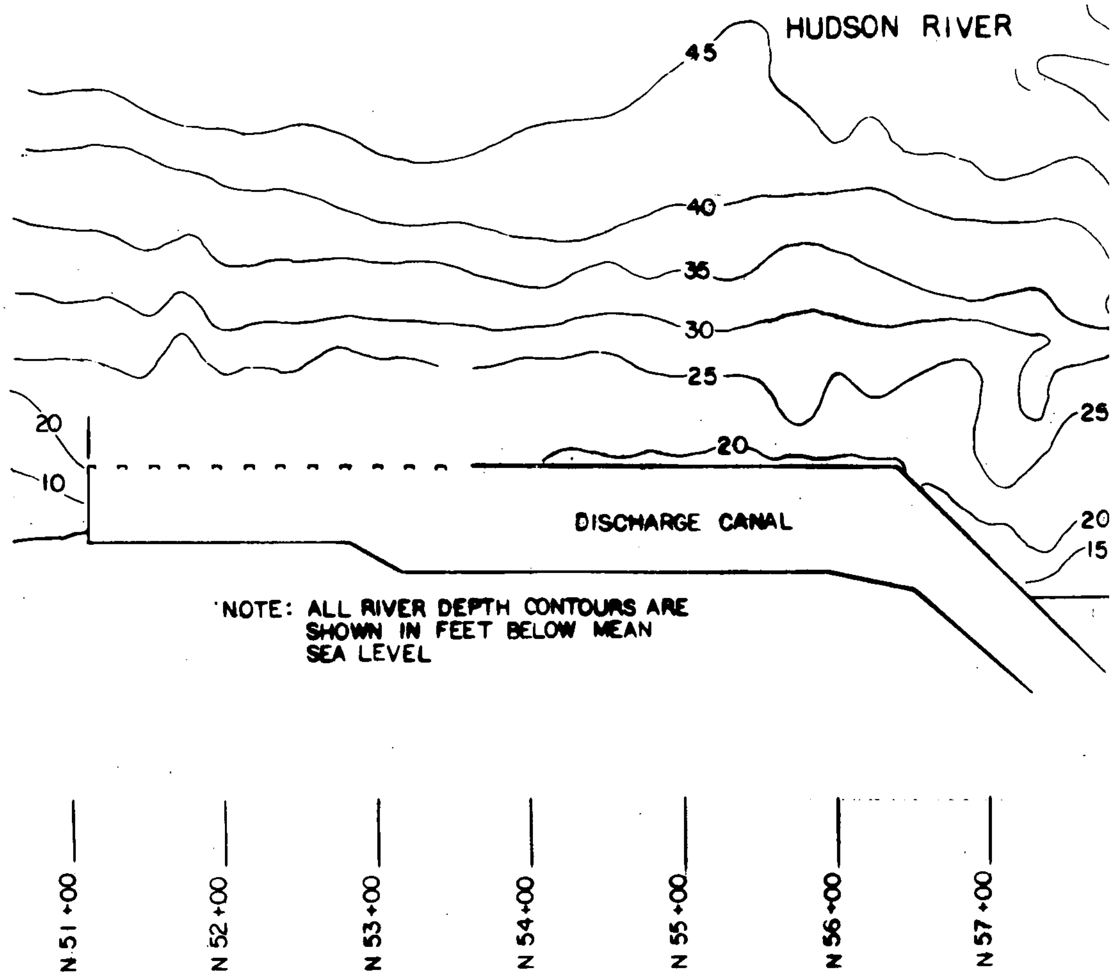
The Unit 1 intake is located between the Units 2 and 3 intakes and behind a barge wharf. The intake structure houses service water pumps and two circulating water pumps, as shown in Figure 2-1. The flow rate into the intake is normally 318,000 gpm (710 cfs) resulting in a design velocity approaching the screens of 0.7 fps. When the ambient river temperature drops below 40°F, the flow rate into the intake is reduced to 60 percent of the normal flow, resulting in an approach velocity of 0.3 fps. The intake structure is equipped with a fixed fine screen with 3/8-inch-square openings placed flush with the face of the intake, vertical trash racks with guided rakes, and traveling water screens with 3/8-inch-square openings, as shown in Figure 2-2. A curtain wall and a warm-water recirculation pipeline upstream of the trash racks provide protection from floating and frazil ice.

The Unit 2 intake is located north of the intakes of Units 1 and 3. The intake structure houses service water pumps and six circulating water pumps, as shown in Figure 2-1. The flow rate into the intake is 870,000 gpm (1,942 cfs), resulting in an approach velocity of approximately 1 fps. At the reduced flow rate of 60 percent of normal flow, the approach velocity is approximately 0.5 fps. Similar to Unit 1, the intake is equipped with fixed fine screens flush with the intake face, a trash rack, a traveling water screen, a curtain wall and a warm-water recirculation line, as shown in Figure 2-2.

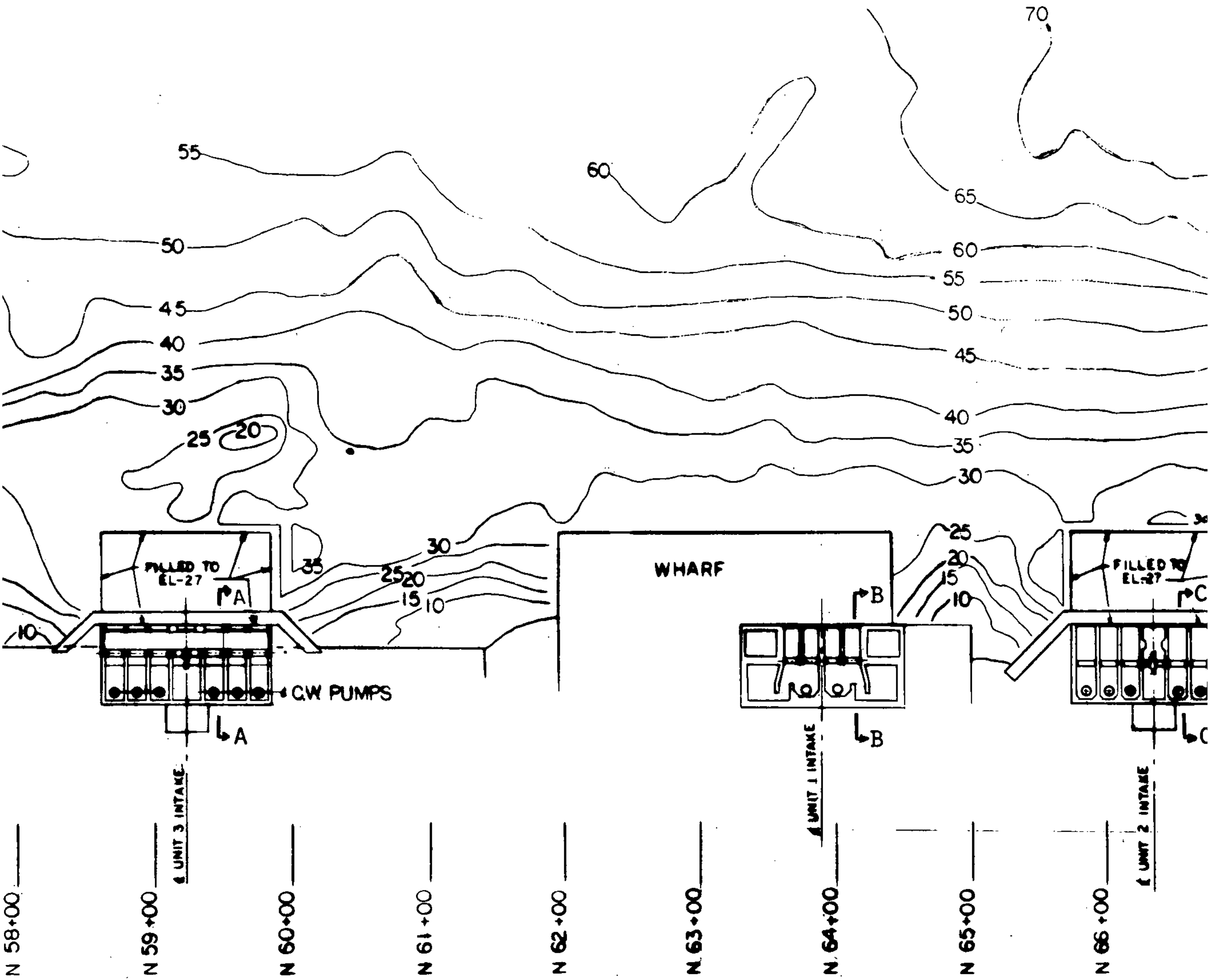
The Unit 3 intake is located south of the intakes of Units 1 and 2. The intake structure houses service water pumps and six circulating water pumps, as shown in Figure 2-1. The flow rate is 870,000 gpm and the design approach velocity to the screens is approximately 1 fps. At the reduced flow rate of 60 percent of normal flow, the approach velocity is approximately 0.5 fps. The intake arrangement is slightly different from that of Units 1 and 2 in that the traveling water screens are set flush with the shoreline with the trash racks protruding into the river allowing a lateral passageway for fish upstream of the traveling screens, as shown in Figure 2-2. A curtain wall ahead of the trash racks and a warm-water recirculation line between the trash racks and screens are provided for protection from ice. Trash racks are also placed at both ends of the lateral passageway.

2.2 CORNWALL PUMPED STORAGE PROJECT

The proposed Cornwall intake will be located on the shoreline of the west bank of the Hudson River, as shown in Figure 2-3. The total intake flow rate, with eight units operating, during the pumping mode ranges between 20,800 cfs (maximum) and 20,000 cfs (minimum), and the total discharge flow rate during the generating mode ranges between 28,800 cfs (maximum) and 23,200 cfs (minimum). The intake opening is about 560 feet wide and extends from elevation -50 feet MSL depth to an ice baffle or curtain wall at elevation -6 feet MSL, as shown in Figure 2-4. The design velocity approaching the screen is approximately 1 fps. The screen will be set flush with the river shoreline and will consist of 1/4-inch-thick bars with 3/8-inch-wide clear spacings to which is attached 3/8-inch woven wire mesh. Should operational experience show a need for bar rack cleaning, manual cleaning or a system of traveling water jets will be used. A tailrace bay extends between the screens and the tailrace tunnels.



[COURTESY OF CONSOLIDATED EDISON CO. OF N.Y., INC.]



PLAN

SEE FIGURE 2-2
FOR ELEVATION VIEWS
A-A, B-B & C-C

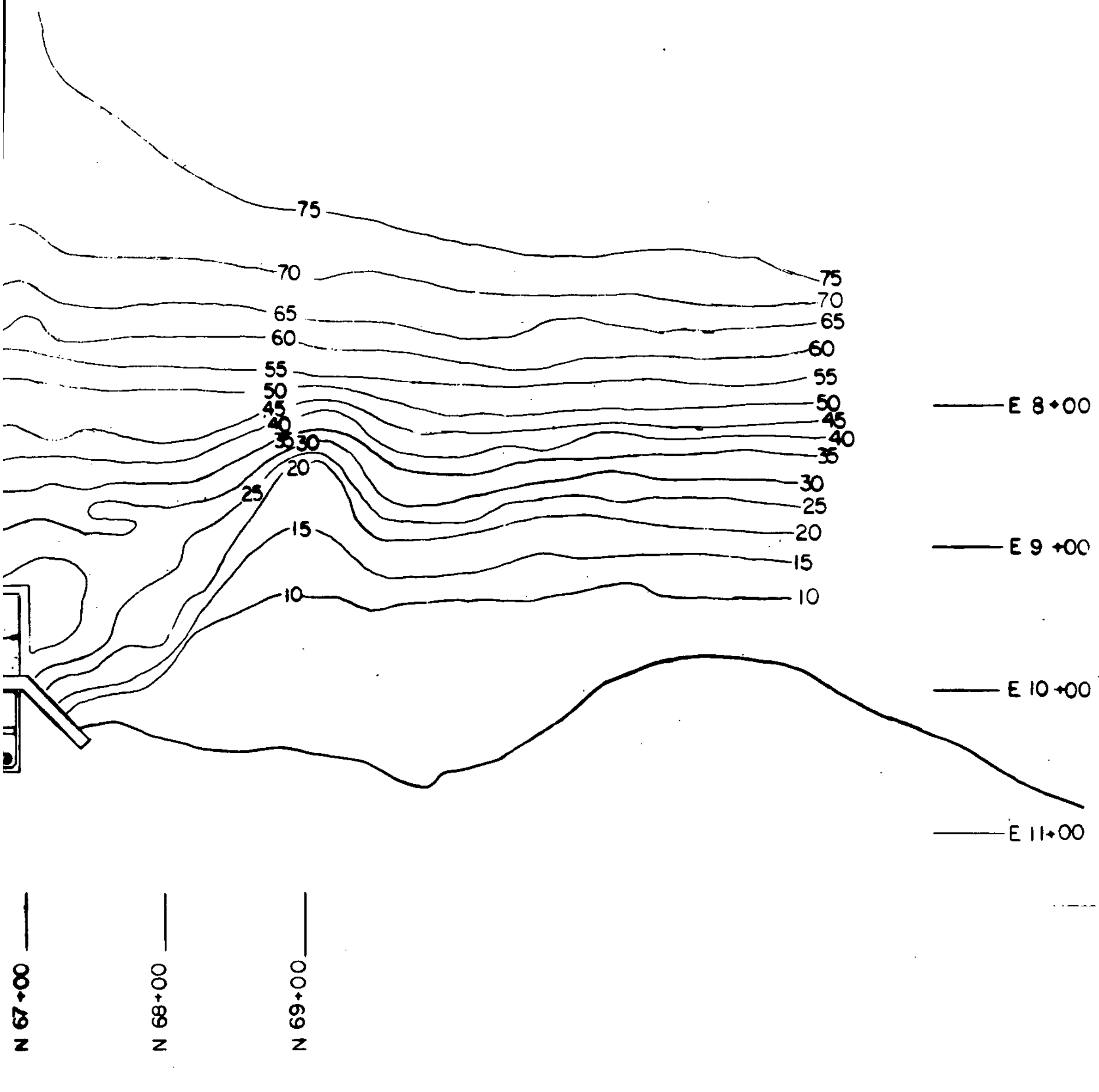


FIGURE 2-1.

PLAN OF EXISTING INTAKES

INDIAN POINT FLUME STUDY
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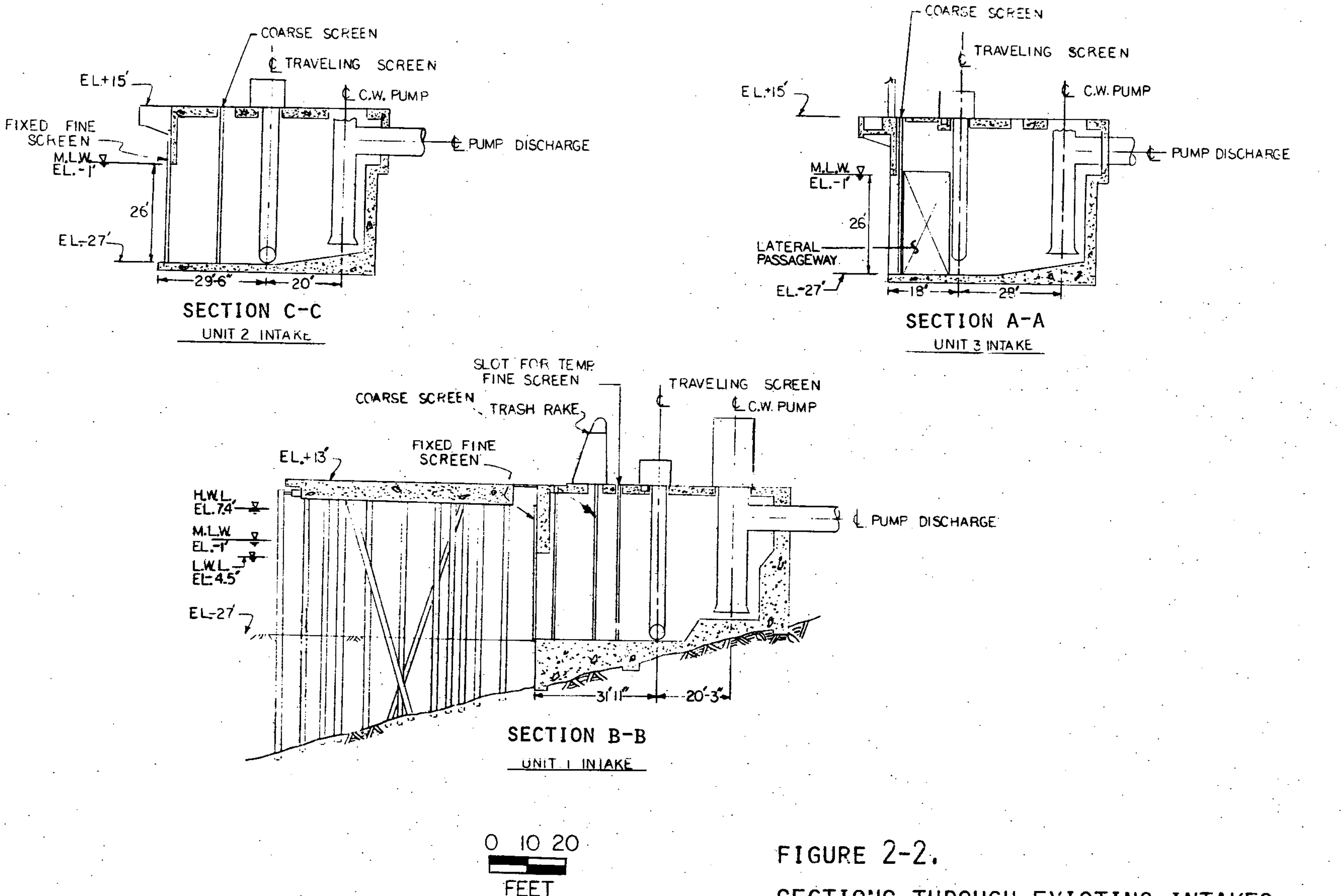


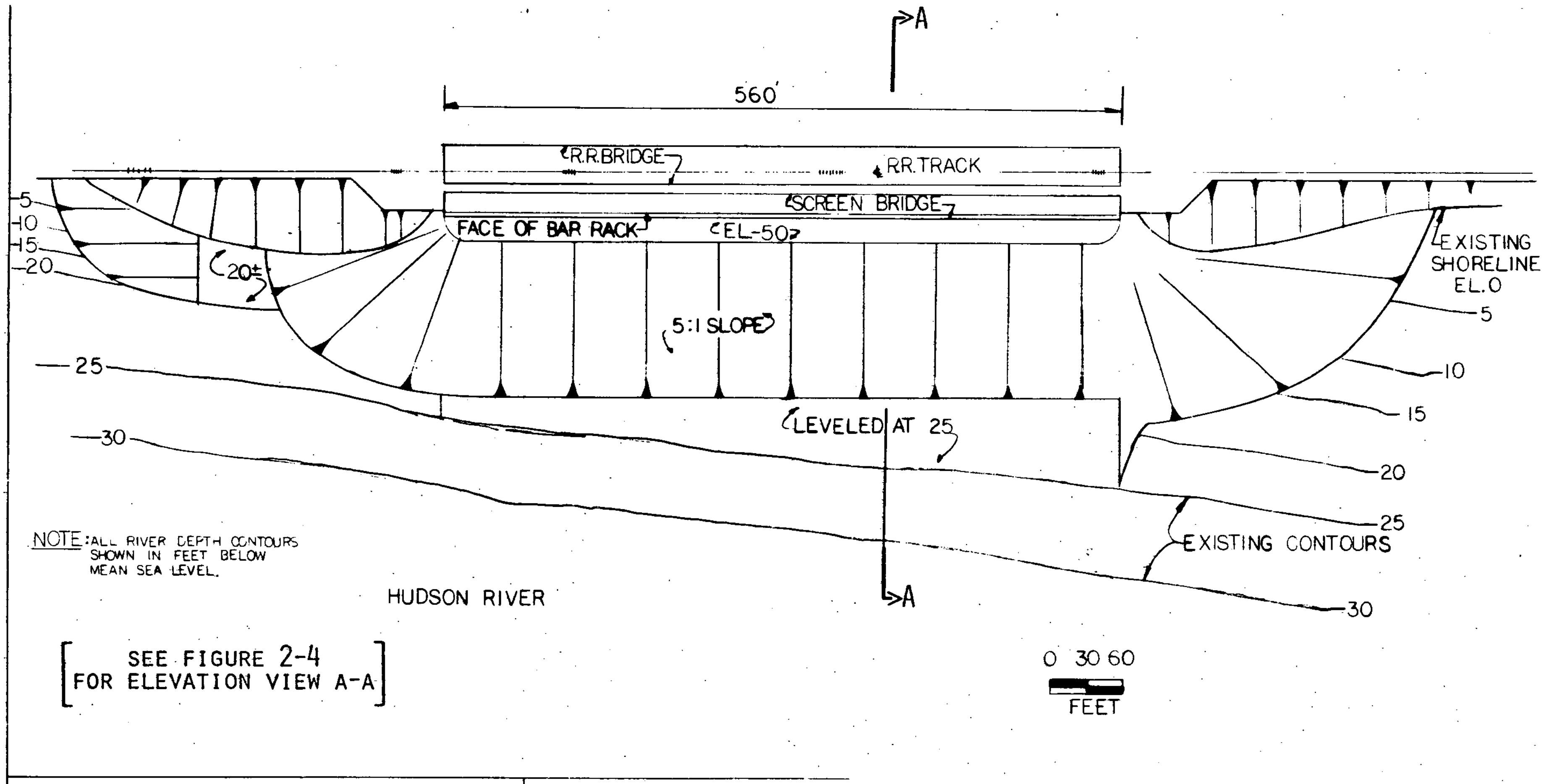
[COURTESY OF CONSOLIDATED EDISON CO. OF N.Y., INC.]

FIGURE 2-2.

SECTIONS THROUGH EXISTING INTAKES

INDIAN POINT FLUME STUDY
CONSOLIDATED EDISON CO. OF NEW YORK, INC.

STONE & WEBSTER ENGINEERING CORPORATION

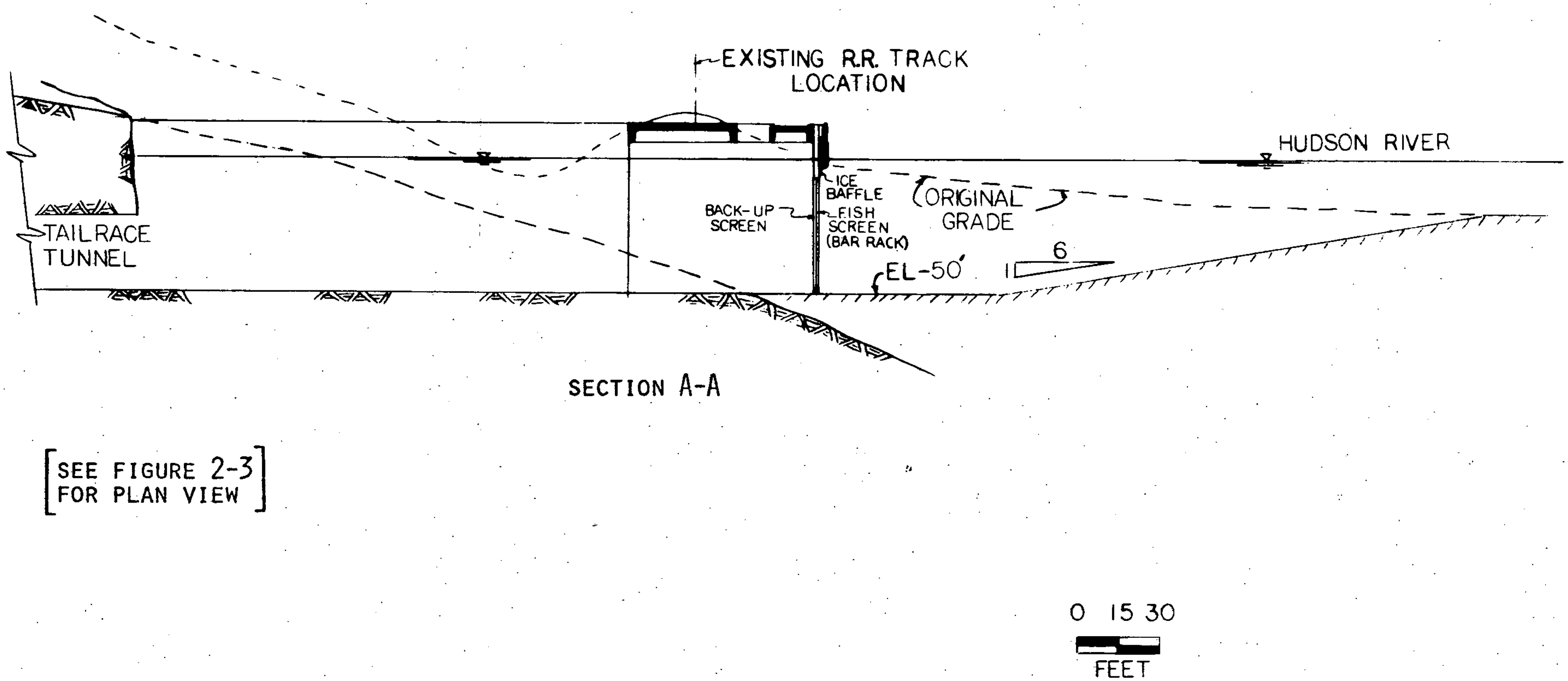


[SEE FIGURE 2-4 FOR ELEVATION VIEW A-A]

[COURTESY OF CONSOLIDATED EDISON CO. OF N.Y., INC.]

FIGURE 2-3.
PLAN OF CORNWALL INTAKE

CORNWALL PUMPED STORAGE PROJECT
INDIAN POINT FLUME STUDY
CONSOLIDATED EDISON CO. OF NEW YORK, INC.
STONE & WEBSTER ENGINEERING CORPORATION



[SEE FIGURE 2-3 FOR PLAN VIEW]

[COURTESY OF CONSOLIDATED EDISON CO. OF N.Y., INC.]

FIGURE 2-4.

SECTION THROUGH CORNWALL INTAKE

CORNWALL PUMPED STORAGE PROJECT
INDIAN POINT FLUME STUDY
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SECTION III

INDIAN POINT IMPINGEMENT HISTORY AND DESCRIPTION OF TEST SPECIES

3.1 IMPINGEMENT STUDIES AT INDIAN POINT

Various regulatory agencies have been concerned with fish impingement at Indian Point since Unit 1 began operation in 1962. In an effort to alleviate fish impingement, various behavior-influencing diversion devices and intake design modifications have been evaluated or implemented at Indian Point since 1963.

Behavioral systems include air bubble curtains, repellent sound, lights and reduced intake velocity. Design modifications include installation of fixed screens, extension of the warm-water discharge canal further downstream from the intakes to minimize recirculation, removal of the sheetpilings on the wharf of Unit 1 and movement of the hypochlorite discharge downstream of the traveling water screens. Evaluation of these systems showed them to be, at most, only partially effective in reducing impingement.

In June, 1972, Texas Instruments, Incorporated was contracted by Consolidated Edison to conduct an impingement monitoring program at Indian Point Units 1 and 2. The purpose of the study was to collect and analyze data on the seasonal occurrence, species composition and size distribution of fish impinged by Units 1 and 2 in order to relate this data to various physical-chemical parameters associated with the plant's operation and its location on the Hudson River. The effectiveness of various fish-handling and fish-protective devices was also evaluated. Results of the impingement-monitoring program and associated studies through December, 1973 have been published (Texas Instruments, 1974). These studies are continuing in 1975.

Units 1 and 2 have fixed, 3/8-inch mesh screens mounted at the entrance to each intake bay, flush with the shoreline. The intake bays are also equipped with bar racks and vertical traveling screens. Unit 3 intake bays have vertical traveling screens mounted flush with the entrance to the intake bay.

During the impingement-monitoring program, the fixed screens were raised and washed once per day at Unit 1 and between 1 and 3 times per day at Unit 2. The traveling screens were washed for 15 minutes following the fixed screen washings and during special tests on a regular schedule varying between 1 and 6 times per day. When the circulating water pumps in the Unit 3 intake bays were being operated, the traveling screens were operated and washed continuously.

Fish were collected from Units 1 and 2 by placing a wooden-framed, 3/8-inch mesh screen across the wash water sluice from the intake bay. The screens in each bay were washed separately and the sluice drained after each washing; thus, the fish collected in the wash sluice represented those impinged in an individual bay. After each wash period the fish collected were separated by species, enumerated, weighed and measured. If large numbers of fish of any species were caught, a random subsample was taken for length-weight determinations. Although Unit 3 was not completed, the circulating water pumps were operated periodically during 1974, and fish were collected from the screen wash trash baskets every four hours during pump operation. They were separated, weighed, measured and enumerated in the same manner as was used for fish collected at Units 1 and 2. Plant operational and water quality data pertinent to impingement were recorded during each collection period. The data recorded include: intake velocity, flow rate, intake (ambient) and discharge temperatures, dissolved oxygen (DO), pH, turbidity and conductivity (salinity). These physical data, when correlated with data on the fish impinged, provide a basis for determining the possible causes of impingement. The following discussion is a brief summary of the results and conclusions of the study being conducted by Texas Instruments.

During the course of the monitoring program (June, 1972 through December, 1973) 230,480 fish were collected from the Units 1 and 2 intake screens. Of the fish collected, six species made up over 90 percent of the fish impinged. These were white perch, tomcod, bay anchovy, striped bass, blueback herring and alewife. Two species, white perch and tomcod, were most abundant, comprising over 75 percent of all fish impinged. Striped bass, an important commercial and recreational species in New York State, made up 1.5 percent of the fish impinged. These three species, white perch, tomcod and striped bass, were selected for detailed study due to their numbers and/or their commercial and recreational value.

Impingement rates were found to be closely related to changes in salinity in the vicinity of Indian Point. Salinity changes are the result of the movement of a "salt wedge" up the Hudson River past Indian Point. Movement of the salt wedge results from an interaction between tidal mixing, freshwater flow and river morphometry. During low tidal mixing periods, a layer of dense saline water moves upriver along the bottom while a layer of less dense, fresh water flows downriver at the surface. There is little mixing between the two layers and the interface between the two layers is an area of rapidly changing osmotic pressure.

Increases in impingement associated with salinity intrusions into the Indian Point area are probably the result of an interaction of several factors. The interface between the fresh and saline waters is an area of high productivity. Fish densities are often noticeably high in this area due to the availability of plankton and forage organisms. Therefore, increased impingement may be a function of fish distribution associated with the salt wedge. It is also possible that some fish experience osmotic stress at the saline - fresh water interface and thus are potentially more susceptible to impingement.

Dissolved oxygen may also be an important factor in impingement. Generally, low DO concentrations (≤5 ppm) were associated with increased impingement and high DO concentrations were associated with reduced impingement (Texas Instruments, 1974). An inverse relationship between DO levels and tomcod impingement was particularly noticeable.

Seasonal temperature change and its effects on fish physiology and distribution can also affect the number of fish impinged. Impingement of white perch and tomcod showed a lagged relationship to temperature.

Impingement peaks for many species are also related to the species' life cycle. The three species being studied are anadromous and use the fresh water areas upstream of Indian Point as spawning grounds. The young later migrate downstream and eventually take up a marine existence before returning to the river to spawn. Fish migrations coincide with periods of high impingement at Indian Point. A discussion of the life history of the major species at Indian Point, and the relationship of life history phases to impingement is found in the following subsection.

3.2 LIFE HISTORIES OF THE TEST SPECIES

Much information is available on the habits, distribution and biology of the test species, tomcod, white perch and striped bass, as they occur in waters along the eastern coast of North America. The information presented in this section, however, is specific to those portions of each species' life cycle which are subject to impingement and entrainment by the Indian Point facility. Each discussion incorporates pertinent aspects of the species' life cycle with available data on impingement (Texas Instruments, December 1974) and a discussion of the swimming ability of the test fish with reference to avoiding impingement.

3.2.1 White Perch (Morone americana)

During the course of the TI study, 105,892 white perch were collected from Unit 1 and 2 intake screens. This is 45.9 percent of the total number of fish impinged during the 18-month study. These fish were mainly young-of-the-year white perch averaging 83.3 mm in length.

Adult white perch enter the Hudson River during the spring to spawn in fresh and brackish water. Spawning occurs from April through June at temperatures of 45 to 60°F. A female weighing 2 pounds will deposit an average of 20,000 demersal eggs over a 10 to 20 day period. These eggs are usually laid over a fine gravel bottom and adhere to each other in clumps on the bottom. Incubation requires from 3 to 6 days, depending upon the temperature.

Young-of-the-year spend the summer in shallow water areas, such as Haverstraw Bay. The juvenile white perch feed mainly on arthropods, insect larvae and crustaceans, and include small fish in their diet as they grow. During the fall, they migrate to deep water areas to overwinter. This fall migration may account for the increase in white perch impingement at this time of year. As temperatures drop during the winter the perch become lethargic and would thus be less likely to avoid impingement. This coincides with the period of peak impingement for this species which occurs from January through April.

Fish impingement is partly dependent upon the ability of a fish to sense and react to a current carrying it onto an intake screen and the ability of the fish to swim against that current, thus avoiding impingement. King (1970) conducted a series of experiments in order to determine the lowest velocity current to which white perch would react (threshold swimming speed) with a steady, active swimming motion. He also determined the critical swimming speed (C.S.S.) and endurance time at that speed for white perch acclimated to various temperatures. White perch acclimated to temperatures above 70°F had threshold swimming speeds ranging from 0.49 to 1.37 fps with most responding at 0.5 or 0.73 fps. These fish (88–160 mm in length) could sustain swimming speeds of 1.04 to 2.04 fps for 30 minutes. Fish condition, not size, seemed to be the major factor controlling sustained swimming ability in white perch at velocities of less than 1.7 fps.

In other tests, King showed that white perch swimming ability decreases at lowered temperatures. The mean critical swimming speed of white perch acclimated to 54°F was 1.29 fps (6 minutes endurance); those acclimated to 45°F had a mean C.S.S. of 1.05 fps (8.5 minutes), and those acclimated to 41°F had a mean C.S.S. of 0.81 fps (4 minutes). A summary of the data obtained is given in Table 3.1. These data may indicate that white perch may be too lethargic to avoid impingement at the existing intakes during the winter months.

3.2.2 Atlantic Tomcod (Microgadus tomcod)

Of the 230,480 fish impinged at Indian Point, 76,958 were tomcod (Texas Instruments, 1974). This represents 33.4 percent of the total impingement. The fish impinged averaged 91.3 mm in length.

Tomcod begin moving up the Hudson River to freshwater spawning grounds in December. The spawning migration continues through February and spawning occurs from January through April. The eggs are tolerant of saline waters and incubation takes 24 to 60 days at salinities ranging from 0–17 ppt. After spawning, the

TABLE 3.1

SUMMARY OF ENDURANCE TESTS ON WHITE PERCH
(KING, 1970)

Experiment Number	Test Temp. (°F)	Test Speed (ft/sec)	Endurance Time (min.)	Fork Length (mm)	Holding Time (days)	Salinity (ppt)
12-17-70-1	41	0.81	23	70	3	3.0
12-17-70-2	41	0.81	5	70	3	3.0
12-17-70-3	41	0.81	3	72	3	3.0
12-17-70-4	41	0.81	9	81	3	3.0
12-17-70-5	41	0.81	6	75	3	3.0
12-17-70-6	41	0.81	6	70	3	3.0
12-17-70-7	41	0.81	95+	72	3	3.0
mean	-	-	-	72.9	-	-
12-3-70-1	54	1.29	3	80	3	3.5
12-3-70-3	54	1.29	4	76	3	3.5
12-3-70-4	54	1.29	5	78	3	3.5
12-3-70-5	54	1.29	4	69	3	3.5
mean	-	-	-	75.8	-	-
12-10-70-1	48	1.05	3	88	3	3.0
12-10-70-2	46	1.05	4	79	3	3.0
12-10-70-3	45	1.05	13	88	3	3.0
12-10-70-4	45	1.05	90+	88	3	3.0
12-10-70-5	45	1.05	3	66	3	3.0
mean	-	-	-	81.8	-	-

adults move downstream, some remain in the lower Hudson and others leave the river completely. Larvae and juveniles tend to remain near their spawning grounds. Young tomcod feed on amphipods, crustaceans and fish fry. They are usually of impingeable size (50 to 60 mm) by the end of the summer and this is reflected in a rise in the impingement rate at this time. There is also a rise in the impingement rate during December-January. This coincides with the spawning run of adult tomcod as indicated by length-weight statistics of impinged fish.

3.2.3 Striped Bass (Morone saxatilis)

During 18 months of sampling, 3,368 striped bass were impinged on Units 1 and 2 intake screens. Although this represents only 1.5 percent of all the fish impinged, striped bass were chosen for study due to their importance to commercial and sport fisheries.

The majority of the impinged striped bass were young-of-the-year during the winter with some yearling bass being taken during the summer months. The average length of the fish impinged was 111.8 mm.

Adult striped bass enter the Hudson River during the spring and swim upstream to spawn in the fresh water areas of the river. The majority of the spawning, which begins in May (Raney, 1954), takes place at temperatures generally between 58 and 70°F. The eggs are slightly demersal and require a current of about 1 fps to keep them off the bottom (Albrecht, 1963). Hatching occurs after about 3 days (64°F).

Rathjen and Miller (1957) reported that major spawning of the bass probably takes place upstream of Indian Point. Young-of-the-year fish are, at times, common downstream of Poughkeepsie, in the general vicinity of Indian Point. In the fall, juvenile striped bass migrate downstream to the Haverstraw Bay area to overwinter.

Peak impingement occurs during the winter months but is noticeably dependent upon movement of the salt wedge past Indian Point. Trawling data obtained during the impingement monitoring program show markedly higher densities of striped bass in the immediate vicinity of the salt wedge interface than densities in areas upstream or downstream of the salt wedge. This indicates that high rates of impingement during the passage of the salt wedge past Indian Point are due to an increase in the density of fish associated with the salt wedge, and that they are not due to salinity changes and resultant stress.

Swimming speed experiments conducted by King (1970) at temperatures above 68°F were inconclusive due to an inadequate sample size but showed that relatively large bass (>170 mm) could successfully swim against currents greater than 1 fps.

Experiments conducted by Bibko, Wirtenan and Kueser (1972) showed that juvenile bass could swim at speeds exceeding 1.6 fps for 10 minutes at temperatures of 40 and 52°F (no size given) (Figure 3-1). At 63°F, small bass (88.5-137.5 mm) displayed 10-minute sustained swim speeds ranging from 0.9 to 2.0 fps (mean 1.6 fps). The velocities required to impinge bass at this temperature were somewhat higher. It is interesting to note that while striped bass avoided an air curtain at temperatures of 40°F, they were too lethargic to react at 33.5°F. This is again suggestive of potential impingement at low temperatures due to the inability of the fish to respond.

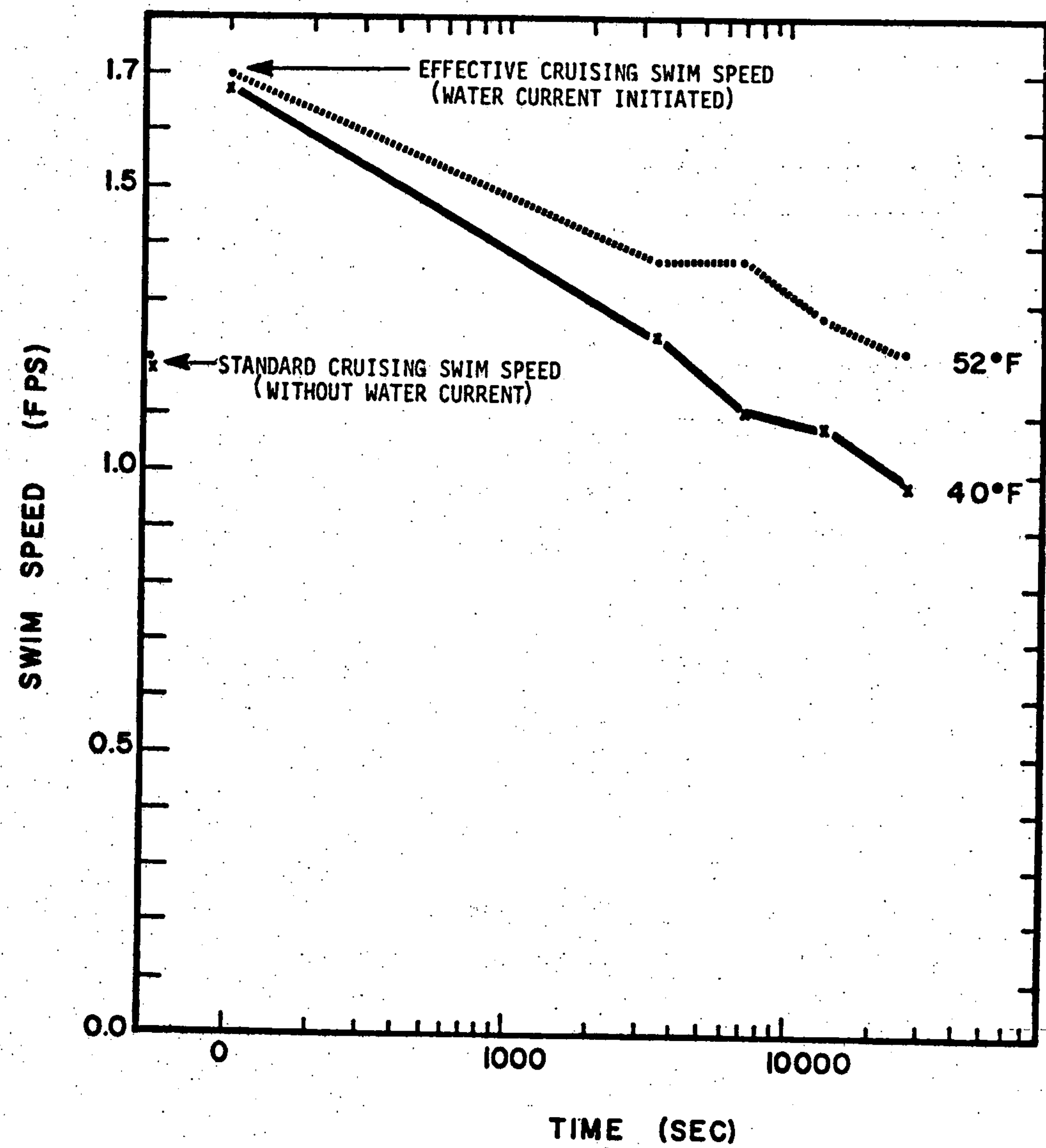

FIGURE 3-1.
STANDARDS AND EFFECTIVE CRUISING SWIM SPEEDS FOR YOUNG STRIPED BASS AT 40°F AND 52°F
(Bibko, Wirtenan and Kueser, 1972)

INDIAN POINT FLUME STUDY
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SECTION IV

FISH TRANSPORT AND HOLDING STUDIES

4.1 INTRODUCTION

In view of Con Edison's desire to transfer the site of the Indian Point Flume Study from the Hudson River to Alden Research Laboratories (ARL), it was necessary to investigate the feasibility of transporting and holding test specimens at ARL. Therefore, a series of studies were conducted to evaluate different holding techniques in order that optimum conditions could be established for maintaining the fish in good condition for flume testing. The following is a description of the procedures and results obtained from these studies.

4.2 STUDY 1

4.2.1 Procedure

Striped bass and white perch were collected by Texas Instruments, Inc. (TI) by beach seining in the area of Croton Point, New York, from August 26 to 29, 1974. When collected, they were transported to the TI Laboratories at Verplanck, New York, and held in a 400-gallon circular tank with a flow-through, unfiltered Hudson River water supply.

S&W personnel obtained the fish from TI on September 4, 1974. At the time of transfer from the 400-gallon holding tank to the transport tank, a number of fish of both species were removed because they were dead or badly fungused (particularly white perch). The remaining fish were in good condition, although a number of perch were scaled or bruised (presumably due to handling during collection).

A 200-gallon oval, galvanized steel tank (6x2x2 feet) was used to transport 50 white perch and 156 striped bass to ARL. The tank was lined with a net and fitted with a wooden lid containing plexiglass windows. Dissolved oxygen levels were maintained by supplying oxygen to the tank via four air stones. The trip to ARL lasted approximately 4 hours.

Careful records were made of temperature and salinity during transport and subsequent holding at ARL, as shown in Table 4.1.

In an effort to establish optimum holding conditions, fish were held at the laboratory in tanks filled with water from the city water supply and with water supplied directly from a nearby pond, as shown on Table 4.2.

The holding tanks were of the same dimensions as the transport tanks and were lined with fiberglass resin to prevent buildup of toxic elements contained in the galvanized steel. Each tank was equipped with a heater, a 150 gph carbon-floss recirculating filter, and an air distributor. A salinity of approximately 3.0 ppt was maintained by adding a synthetic sea salt, "Instant Ocean," to all the tanks.

4.2.2 Results

The striped bass and white perch were transported successfully to ARL and were held for two days without mortality. On the third day, striped bass in both city water and pond water began to die, and within two weeks all but four white perch had died.

Upon close examination of the tanks, it was apparent that the fiberglass resin used to coat the galvanized steel surface of the holding tanks dissolved and by the end of the two week holding period had gone completely into solution, resulting in toxic conditions.

As a result of this, the holding facilities were modified, a second fish collection was made and new facilities tested, as discussed below.

4.3 STUDY 2

4.3.1 Procedure

Sixteen 30-to-50-gallon aquariums and four 400-gallon circular holding tanks were obtained from Con Edison on September 10, 1974. Two of the 400-gallon tanks and seven of the 50-gallon tanks were set up at ARL and were filled with different types of water, as shown in Table 4.3. Each tank was supplied with a recirculating carbon-floss filter.

The different water conditions which were established were designed to simulate the range of possible conditions which might be used in proposed flume testing.

On September 13, 1974, 900 hatchery-reared, 50.0-to-76.0-mm striped bass were transported to ARL, using the same procedures outlined above. Seventy-five fish were placed in each of the 50-gallon aquaria (except Tank 4, which contained the white perch remaining from the first holding experiment) and the remainder were divided between the two 400-gallon tanks. All the holding tanks were set up with a charcoal-floss recirculating filter for the removal of dissolved organics and solid fish wastes from the water.

The behavior and condition of the fish were closely monitored during this holding study. They were eating vigorously (Tetramin dry flake food) and actively moving about the holding tanks for approximately three weeks. On October 2, 1974 fungus began to

TABLE 4.1

WATER QUALITY PARAMETERS (Study 1)

	Temp (°F)	Salinity (%)	Type of Water
400 gallon TI holding tank	76.8	2.5	Hudson River
Transport Tank (Departure)	77.3	2.5	Hudson River
Transport Tank (Arrival at ARL)	73.7	2.5	Hudson River
ARL Holding Tanks:			
Tank 1	77.0	3.2	City
Tank 2	77.0	3.2	City
Tank 3	77.0	3.0	ARL Pond
Tank 4	77.0	3,0	ARL Pond

DO of transport water = 6.95 ppm

TABLE 4.2

WATER SUPPLIES (Study 1)

Tank	Type of Water	Species	Number of Fish
1	Filtered City	Striped Bass	84
2	Filtered City	White Perch	38
3	Filtered ARL Pond	Striped Bass	72
4	Filtered ARL Pond	White Perch	12

TABLE 4.3

WATER SUPPLIES (Study 2)

Tank	Capacity (gal)	Type of Water
1-H	400	Unfiltered ARL Pond - Instant Ocean, 3 ppt
2-H	400	City - Instant Ocean, 3 ppt
1	50	Filtered ARL Pond - Instant Ocean, 3 ppt
2	50	Filtered ARL Pond - Instant Ocean-Ozone, 3 ppt
3	50	Unfiltered ARL Pond-Instant Ocean-Ozone, 3 ppt
4	50	City (Perch) - Instant Ocean, 3 ppt
5	50	City - Instant Ocean, 3 ppt
6	50	Filtered Hudson River - ambient salinity, 1 ppt
7	50	Unfiltered Hudson River - ambient salinity, 1 ppt

appear on some of the fish in the 400-gallon tanks, and within a week it was apparent in all of the tanks. In order to treat the fungus, treatment tanks were assembled and half of the fish were treated with malachite green for 1 hour at a concentration of 1 ppm, and the other half with a salt bath for 1 hour, at a salinity of 20 ppt. The fish treated with malachite green were cleansed of the fungus within 24 hours but the stress incurred from both the fungus and the treatment apparently caused a cessation of feeding and all fish died within 48 hours. The fish given the salt bath were also free of fungus within 24 hours but open lesions covering approximately 35 percent of their body surface upset their osmoregulation and caused them to die within 96 hours.

4.3.2 Results

Two factors were identified as probable causes for the problems encountered in holding the fish. First, the dry flake food that was not consumed by the fish dissolved and went into solution with the water, thereby forming a base for harmful bacteria buildup. The second factor that affected mortality was stress caused by ammonia-nitrogen levels as high as 4.5 ppm due to insufficient filtration to remove ammonia from the water.

A higher level of success was apparent during this study and the mortality factors were defined as controllable parameters. Therefore, additional study using advanced fish-holding techniques was initiated.

4.4 STUDY 3

4.4.1 Procedure

Two 2,550-gallon circular swimming pools with vinyl liners were assembled and filled with tap water. Each pool was outfitted with a biological sand filter for the removal of ammonia, a charcoal filter for the removal of dissolved organics, and a rapid speed sand filter for the removal of solid fish wastes (Figures 4-1 and 4-2). The rapid speed sand filter also provides sufficient flow to aid in the orientation of the fish. The system is operated entirely on a recirculatory basis.

Water flow through the biological and chemical filters is controlled by airlifts which also act as aerators and maintain the dissolved oxygen levels in the pools.

To aid in the nitrification of ammonia by the biological filter it is necessary to adjust the pH of the tap water to approximately 7.2 using sodium bicarbonate since it comes from the tap at a pH of approximately 5.5. This low pH is inhibutory to ammonia nitrification and therefore is constantly monitored and adjusted if needed.

On November 23, 1974 S&W personnel procured 1,035 fish from the TI Laboratory at Verplanck, N.Y. There were 98 white perch (50 to 100 mm), 410 hatchery-reared striped bass (50 to 150 mm), and 527 native striped bass (38 to 280 mm).

When the native fish were removed from the holding facilities at Verplanck many were dead and, of the living, 50 percent were fungused. Only those fish without visible fungus (925) were taken by S&W but these were still in relatively poor condition. The hatchery-reared striped bass were held in a separate holding pool and appeared to be in good condition.

The fish were transported to ARL in the aforementioned transport tanks with slight modifications. The inside net was removed to make room to carry more fish, and the tank cover was strengthened to stop leakage. In lieu of oxygen bottles and airstones, electric agitators, designed specifically for aeration of fish tanks, were used to maintain a sufficient level of dissolved oxygen in the transport tanks.

After 12 days of holding the fish at ARL, 75 percent of the native Hudson River striped bass and white perch died due to fungus or starvation. TI fishery personnel had made an attempt to feed the fish after they were captured; however, attempts at getting the fish to feed failed. Because of this many of the fish were emaciated, and stomach analysis at ARL indicated little or no food present. TI hatchery personnel fed the hatchery-reared striped bass brine shrimp, and they reported that the fish ate it eagerly. Only 2 percent of these fish died after the first 12 days.

On December 3, 1974, S&W personnel procured another 1,516 fish from the TI Laboratory. Of these, 1,432 were hatchery-reared striped bass, and 84 were striped bass from the Hudson River.

On December 10, 1974 EWOS automatic fish feeders were assembled on each holding pool at ARL, and preset to deliver salmon chow in pellet form to the fish.

4.4.2 Results

The remaining Hudson River striped bass and white perch continued to die from fungus despite intensive prophylactic treatments. The hatchery-reared striped bass appeared in good condition from November 23 to December 21, 1974 when fungus began to appear on them. From December 21, 1974 to January 3, 1975, 941 fish died from fungus. Laboratory examination of the striped bass at ARL showed a heavy infestation of a protozoan fish parasite from the Trichodina sp., which was characteristic of the Oklahoma hatchery-reared fish. This parasite infests the fish by burrowing into the ectoderm and causing an open lesion. The fungi Saprolegnia forms on the wound and because of this the fish continually debilitates until it dies. S&W personnel treated the

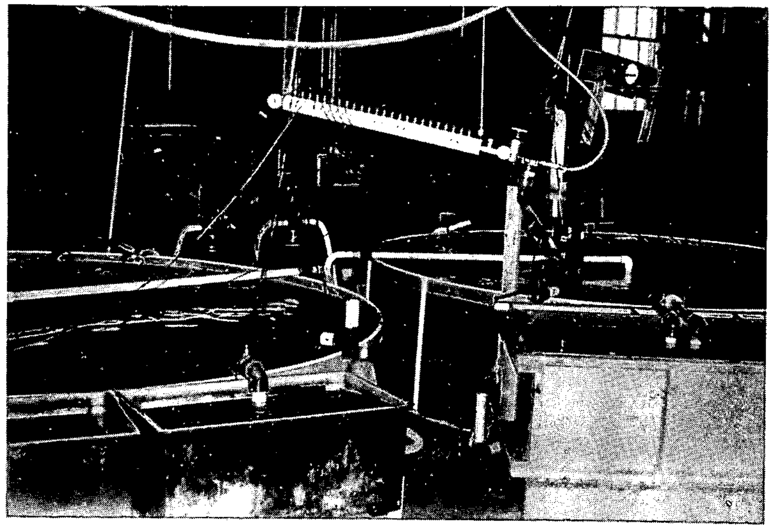


FIGURE 4-1.
FISH HOLDING FACILITY
SHOWING TWO 2,550-GAL POOLS, BIOLOGICAL FILTER (LOWER RIGHT), AND CHEMICAL FILTER (LOWER LEFT)

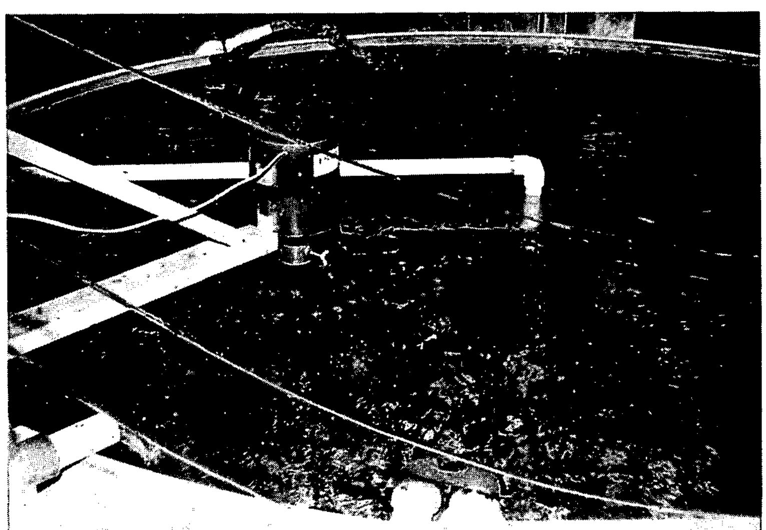


FIGURE 4-2.
FISH HOLDING FACILITY
SHOWING FILTER INTAKE (CENTER), DISCHARGE (UPPER LEFT), AND AUTOMATIC FILTER

fish in potassium permanganate ($KMnO_4$) at 3 ppm for 1 hour. The remaining 300 striped bass were cleansed to the parasite and were held in excellent condition. . To improve the condition of the fish, frozen brine shrimp and frozen squid have been supplemented to their diet.

Since the source of the parasite has been defined, it is felt that successful holding of bass in 1975 will be possible provided that the fish are received in good condition. If necessary, a prophylactic treatment schedule will be established to prevent the mortalities associated with disease incidence experienced this year.

4.5 STUDY 4

4.5.1 Procedure

On January 28, 1975, S&W personnel procured 753 adult tomcod from the TI Laboratory, and another 46 tomcod on February 7, 1975. They were transported to ARL and were held in a rectangular sump with a capacity of approximately 2,000 gallons. The water used was filtered pond water supplied on a once-through basis at ambient temperature.

4.5.2 Results

Tomcod were transported to ARL without mortality. In the following weeks, certain individuals were observed to go into shock and die when handled. This mortality was probably due to the spawning condition of the fish and not to the holding facilities at ARL, since a similar shock response was noted among individuals during collections directly from the Hudson River.

It was found that mortality can be limited through careful handling of the fish. As discussed in Section V, a suitable number of tomcod were maintained at ARL to permit preliminary flume testing with an angled screen arrangement. Since adult tomcod can be collected from the river during the time of year when flume testing is required, availability of test specimens should not present a problem.

4.6 CONCLUSIONS

As a result of the studies above, it is believed that successful holding of test specimens at ARL will be possible. However, experience has shown that careful handling of the fish prior to transport to ARL is essential to the long-term survival of the fish at the laboratory.

During the study program, S&W personnel will conduct all fish collections from the Hudson River. Facilities have been set up for the holding of fish at the river until a suitable number have been collected.

Initially, beach-seining and box-trapping will be the methods employed for collecting river fish. However, other methods of obtaining fish, such as collecting them from the Indian Point intakes, are being investigated in an attempt to ensure the availability of fish for testing throughout the study program.

SECTION V

POSSIBLE INTAKE MODIFICATIONS

Two of the objectives of the study program are to review all literature pertaining to various fish diversion devices and to evaluate the prototype engineering feasibility of such devices in relation to potential application at Indian Point and Cornwall. The devices chosen for study include vertical, angled screens and louvers, an inclined plane screen, a lift basket collection system, an underwater wall, and an air bubble curtain. The following is a discussion of the findings and conclusions of our investigations.

5.1 VERTICAL FISH DIVERSION DEVICES

Two vertical diversion devices have been chosen for consideration; a louver system and an angled screen. Both could be stationary or traveling, depending on the extent of operational problems which might occur at a particular site. The majority of the research on vertical diversion devices has been concerned with developing louver systems for bypassing fish in river systems of the Pacific Northwest. More recently, however, encouraging results have been obtained with a traveling screen angled to the flow and leading to a bypass. The history of research with louvers and screens is discussed below.

5.1.1 Literature Review

5.1.1.1 Louvers

All louver systems developed and operating to date have been stationary. A louver system is simply a row of evenly spaced, vertical slats which are aligned across a channel at a specified angle and lead to a bypass. The system works on the principle that fish avoid areas of high velocity and will not cross through vertical streamlines having a wide differential in velocity between them (Cal. Dept. Nat. Res., 1967; Hallock, et al, 1968; Pavlov, 1969). Instead, they will seek out areas of relatively low velocity. The louvers act to establish a velocity barrier or vertical line of high velocity crossflow (Kerr, 1953).

It has been found that fish tend to orient themselves facing into a current, even if they are moving with it, in order to facilitate respiration and feeding (Kerr, 1953). This means that they cannot see obstructions or barriers downstream. Therefore, fish rely mainly on their other senses to guide them around obstacles. The louver systems take advantage of this behavior. As fish approach the louver system, which acts as a velocity barrier, they sense the increase in velocity and move laterally away from it (Hallock, et al, 1968). As they are carried downstream, their lateral movement and the current eventually direct them into a bypass and then to a collecting area where they can be removed by various methods.

Louver systems have proven to have many advantages over other systems which are presently in use or under study. Model and prototype studies, as summarizied in Table 5.1, have shown greater than 90 percent efficiency under many different experimental conditions with a large variety of fish species. Further, since the system relies on the natural ability of fish to sense velocity gradients, there is a minimum amount of handling involved, thus avoiding the injury and stress that can be caused by other systems (Riesbol and Gear, 1972). Finally, because there are no moving parts, the cost of construction is substantially less than mechanical systems such as horizontal traveling screens, and they are much easier to maintain.

Although louver systems have potential for screening large quantities of water, there are several features to evaluate. First, since the efficiency is dependent upon a rheotactile response, it is assumed the fish have the capacity of self-propulsion. The system is not, therefore, effective in screening eggs and larvae which are incapable of avoiding the flow through the louvers. Second, the velocity barrier design can result in a loss of head which might be important if head loss is a critical factor in intake design.

In order to design a louver system for a certain area, extensive model tests must be conducted so that the best design for the species present can be developed. Design criteria considered in this study are discussed below.

DESIGN CONSIDERATIONS

There is an almost unlimited number of design variations which can be implemented in a louver test flume. Naturally, all cannot be tested. Therefore, it is necessary to outline the basic design criteria of the flume and then draw from past experience gained from other studies as a starting point for the testing. Below is a list of the basic design criteria to be considered:

(a) Maximum and minimum flow velocity required approaching louvers,
(b) Flow patterns,
(c) Angle and length of the line of louvers,
(d) Angle and dimensions of individual slats, and spacing of the slats,
(e) Number and dimensions of bypasses, and
(f) Ratio of approach velocity to bypass velocity

These will be considered individually in the following discussion.

TABLE 5.1

SUMMARY OF PAST AND PRESENT LOUVER STUDIES

Study Site	Test Species	Test Facilities	References
Mayfield Dam, Washington for the City of Tacoma	Cuttroat and steelhead trout, chinook and coho salmon, whitefish	Prototype System	Thompson and Paulik, 1967.
Redondo Beach, Cal., for Southern California Edison	Northern anchovy, queenfish, white croaker, walleye sunperch, shiner perch	50x6x4 ft. redwood test flume	Schuler, 1973 Schuler and Larsen, 1974 Downs and Meddock, 1974
Robertson Creek, British Columbia Department of Fisheries of Canada	Juvenile chinook, Sockeye and coho salmon	80x10x6 ft. wooden test flume	Ruggles and Ryan, 1964
Tracy Fish Collection Facilities, California Dept. of Water Resources	Striped bass, King salmon, shad, catfish, smelt, Crappie, and others	36x5x2 ft. test flume, followed by a 60x6x2 ft. flume, then a prototype system	Bates and Vinsonhaler, 1956; Bates, Logan, and Personen, 1960; California Department of Water Resources, 1963, 1964
Delta Pumping Plant, California Department of Water Resources	Striped bass	Test flume and prototype system	California Dept. of Fish and Game and Dept. of Water Resources, Annual Reports 1962-1967
Ruth Falls, Nova Scotia for Nova Scotia Power Commission	Atlantic salmon	Prototype system	Ducharme, 1972
Nine Mile Point Nuclear Station, for Niagara Mohawk Power Corporation	Alewife, smelt and coho salmon	70x3x3 ft. test flume	Stone & Webster Engineering Corporation, 1975

Flow Velocity

The approach flow velocity in the test flume must be a function of the swimming speed and duration of the test fish. The velocity should be high enough to encourage the fish to move with the flow, but not so high that they become disoriented and cannot avoid the louvers. Studies in California have shown that velocities of 1 to 4 fps are most effective in guiding fish into bypasses (Hallock, Iselin and Fry, 1968). It is probable that most fish which are susceptible to guidance systems will be guided by velocities within this range.

Flow Patterns

In order to ensure maximum efficiency in a louver system, the flow of water should be as uniform as possible. Turbulence is an especially troublesome problem in louver systems where approach velocities are high. Turbulence in front of the louvers can cause the fish to lose their normal orientation to the flow, thus preventing a normal reaction to the velocity gradient. The problem can be compounded by the accumulation of trash and debris which disturbs the flow patterns through the system. Every effort should be made in a model study to minimize turbulence. Baffles and a long approach channel are possible solutions.

At the Tracy Pumping Plant test facilities, another problem arose which should be considered (Cal. Dept. Water Resources, 1967). It was found that the flow velocity increased two and one-half times from the upstream to the downstream end of the louver system, thus disturbing the pattern of the approach flow. The problem was largely alleviated by the installation of flow straightener vanes. The vanes, installed on the downstream side of the louvers, are essentially extensions of the louver slats, turned to redirect the flow parallel to the channel. Consideration should be given to this problem and its solution in testing a louver model.

Angle and Length of Line of Louvers

Louver angle is a critical parameter in designing an effective louver system. As louver angle decreases, louver length increases. Concurrently, as louver length increases, the flow velocity through the system decreases, and the swimming speed which a fish must maintain to avoid being carried through the louvers decreases proportionately. These relationships are shown on Figure 5-1. Utilizing the equation $V_s = V_a \sin \theta$, where Vs is the swimming speed of fish (fps), Va is the approach velocity, and θ is the louver line angle, it can be seen that decreasing the angle of the louvers permits the fish to guide along the louvers with decreased effort while the downstream guiding component (Va) is maintained. For example, at an approach velocity of 1.5 fps, decreasing the louver angle from 45° to 11.5° reduces the swimming speed (Vs) that a fish must maintain from approximately 1.0 fps to 0.4 fps. Such a vector analysis is theoretical and does not take into account the coefficient of contraction which will result in local areas of high velocity. However, the example is useful in exemplifying the relationship between swimming speed and louver angle.

At Indian Point, where fish entrapment occurs at low water temperatures, resulting in reduced swimming ability, a smaller angle and, therefore, a lower velocity through the louver system would be desirable.

In building a test flume, the line of louvers should be set on an adjustable frame so that various deflection angles can be tested. At the Tracy Plant, angles between 10° and 15° to the direction of flow were found to be the most efficient. However, angles up to 40° were found to direct fish into the bypass. In a particular test flume, the flexibility necessary to test a range of louver angles should be incorporated into the design.

The length of a louver system is related to the width of the flume and the angle at which it is set to the flow. The length is, therefore, determined by the design criteria of the test flume.

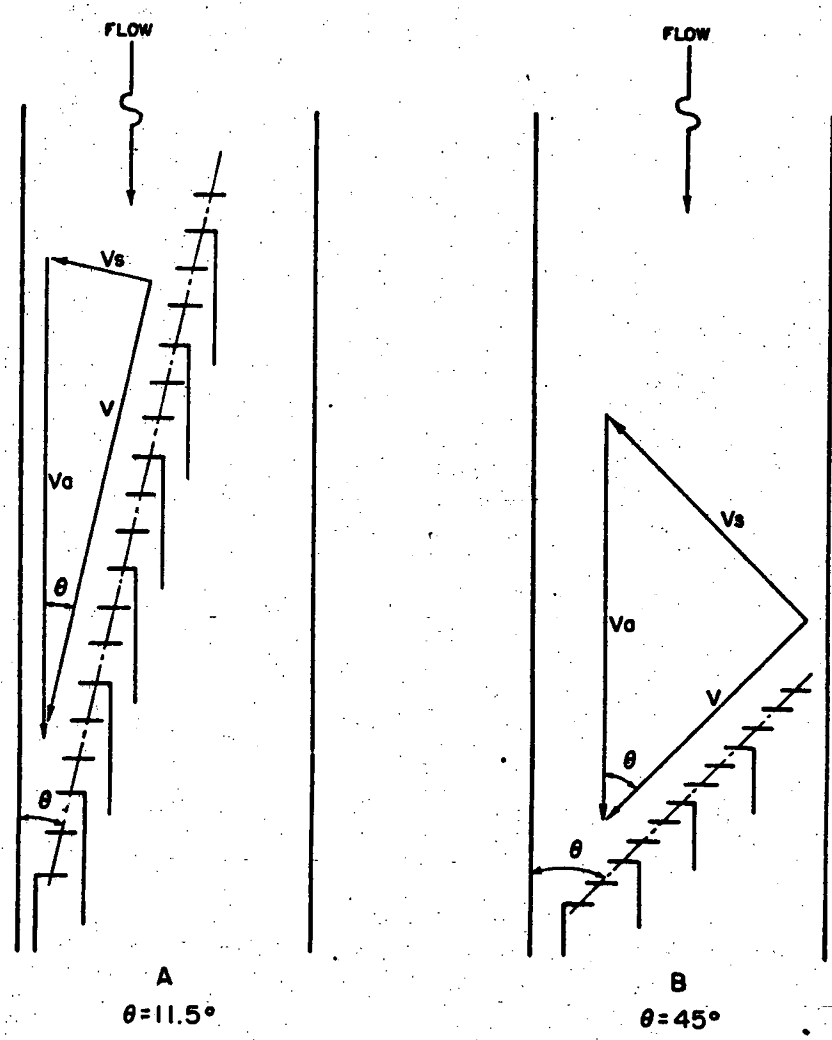
Angle and Dimensions of Individual Louver Slats, and Spacing of Slats

The louver system should be designed to allow testing of a variety of louver slat spacings and angle arrangements. Slats can be removable stuctures set on pivots so that the angle and number can be varied. At the Tracy Plant, slat angles of 90° to the direction of flow and spacings of 3.5-inch were found to be the most efficient. In this case, the spacing of the slats was equal to the width of each slat (i.e., 3.5 inch) However, the investigators found that the louver design allows for great variations of spacing without significantly altering the behavioral pattern of the fish.

The louver design in a test flume can be initially based on the size and swimming speed of the fish. In the case of the Tracy Plant, louver arrangement was chosen somewhat arbitrarily, i.e., because of the innumerable variations possible, if one particular arrangement was found highly effective, it was adopted without further testing.

Number and Dimensions of Bypasses

The width of the bypass must be large enough to allow free passage of fish and to avoid clogging with debris, but small enough to maintain the desired velocity and to minimize bypass flow requirements. Tests at the Tracy Plant showed a 6-inch opening to be the most effective. Larger openings might be studied if larger fish are present.



Va = Approach velocity of flow in feet per second
Vs = Swimming speed of fish in feet per second
V = Resultant movement of fish in feet per second
θ = Angle of the line of louvers

FIGURE 5-1.
DIAGRAM SHOWING RANGE OF ANGLES IN LINES OF LOUVERS TESTED AND VECTORS OF FORCE IN FLOW AND FISH MOVEMENT
(BATES, LOGAN & PESONEN, 1960)

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It is probable that in a small-scale test flume only one bypass is necessary. However, in developing a design for a full-scale louver system, where the length of the line of louvers can be greater than one hundred feet, consideration must be given to whether smaller fish can maintain their position away from the louvers long enough to travel the entire line and successfully enter the bypass. This is determined by the swimming speed and duration of the individual fish. As a result of prototype studies at the Tracy Plant, it has been recommended that bypasses 6-inches wide be installed at 75-foot intervals along the line of louvers. Of course, due to the small scale of louver test facilities, it would be impractical to study more than one bypass, but the recommendation should be kept in mind.

Ratio of Approach Velocity to Bypass Velocity

The flow velocity in the bypass should exceed the approach velocity at all times. A gradual increase in velocity along the line of louvers with a rapid acceleration in the bypass is desirable. If the velocity drops within the bypass, fish will remain stationary in the flow or even swim back upstream. However, care should be taken in designing the system so as to minimize turbulence. As mentioned before, flow straighteners can be useful in this respect and should be considered, if deemed necessary.

In the past, an approach to bypass velocity ratio of 1.0 : 1.5 has been found to be adequate. Larger ratios, such as 1:2, can be equally suitable, but efforts should be made to develop the smallest acceptable ratio in order to minimize the amount of flow which might be induced through the bypass.

Traveling Louvers

Recently, several screen manufacturers have developed a traveling louver system. The system consists of a conventional traveling screen frame with the screen panels replaced by louver slats. Other slight modifications to the conventional design permit mounting of the louver array in a manner which avoids projections or indentations which might adversely affect flow patterns.

To date, no prototype traveling louver system has been constructed and tested. However, recent studies have been conducted to determine the potential for traveling louvers, and two prototype designs, discussed below, have been developed.

Since 1956, Southern California Edison Company has sponsored studies to minimize fish entrapment at several coastal power plants in California (Downs and Meddock, 1974). As part of these studies, Ichthyological Associates was responsible for conducting flume studies to develop screenwell fish guidance structures for the San Onofre Nuclear Generating Station (Schuler, 1973 and Schuler & Larsen, 1974). Northern anchovy, queenfish, white croaker, walleye surfperch and shiner perch were selected as test species on the basis of abundance and frequency of occurrence.

During the flume studies, louvers and screens were evaluated at various angles to the flow and at different approach and bypass velocity ratios. Results of louver testing disclosed that the greatest guiding efficiencies (>95%) for all test species was obtained with 1.0-inch spaced louver slats set normal to the louver frame, a louver array angle of 20 to 30 degrees to the flow (20 degrees recommended), an approach velocity of 2.0 fps and a bypass velocity of 3.5 fps. It was also found that reducing the flow through the furthest downstream louver section resulted in reduced loss of fish in this area.

Although flume tests were conducted with a stationary louver array, results have been used to provide design criteria for a prototype traveling louver system for the San Onofre Station, as shown on Figure 5-2. This design has six screen bays with a traveling louver backed by a traveling screen in each bay for removal of debris which passes through the louvers. The six louver systems are aligned side by side at a 20 degree angle to the approach flow and lead to a common bypass and fish removal area. Guiding vanes were included in the design, on the basis of hydraulic model study results, to prevent the approach flow from turning into the louvers prematurely.

Fish collected in the removal area will be periodically raised to the surface and returned to the ocean through a 4-foot (I.D.) pipe extending 2,000 feet offshore.

It appears that a traveling louver design of the type proposed for the San Onofre Station could offer a practical method of diverting fish in an intake screenwell. This system could be particularly advantageous at a site where heavy trash loading could seriously effect the operational efficiency of a stationary louver system. However, several of the San Onofre design features may be undesirable, and consideration should be given to possible modifications for application at other sites. Of primary importance are the screenwell configuration and the length of the louver array.

At the San Onofre site, space considerations limited the dimensions of the screenwell and thereby necessitated an angled design. This design could be improved by utilizing a straight screenwell orientation with the louvers angled to the flow. This would eliminate the need for guiding vanes.

Another consideration is the length of the louver array. Flume studies were conducted with a louver length of less than ten feet, while in the prototype design, the length is almost 80 feet. Although fish guided well in the flume, they may not have the endurance to avoid the long line of louvers in the prototype. Therefore, if space is available, it would be

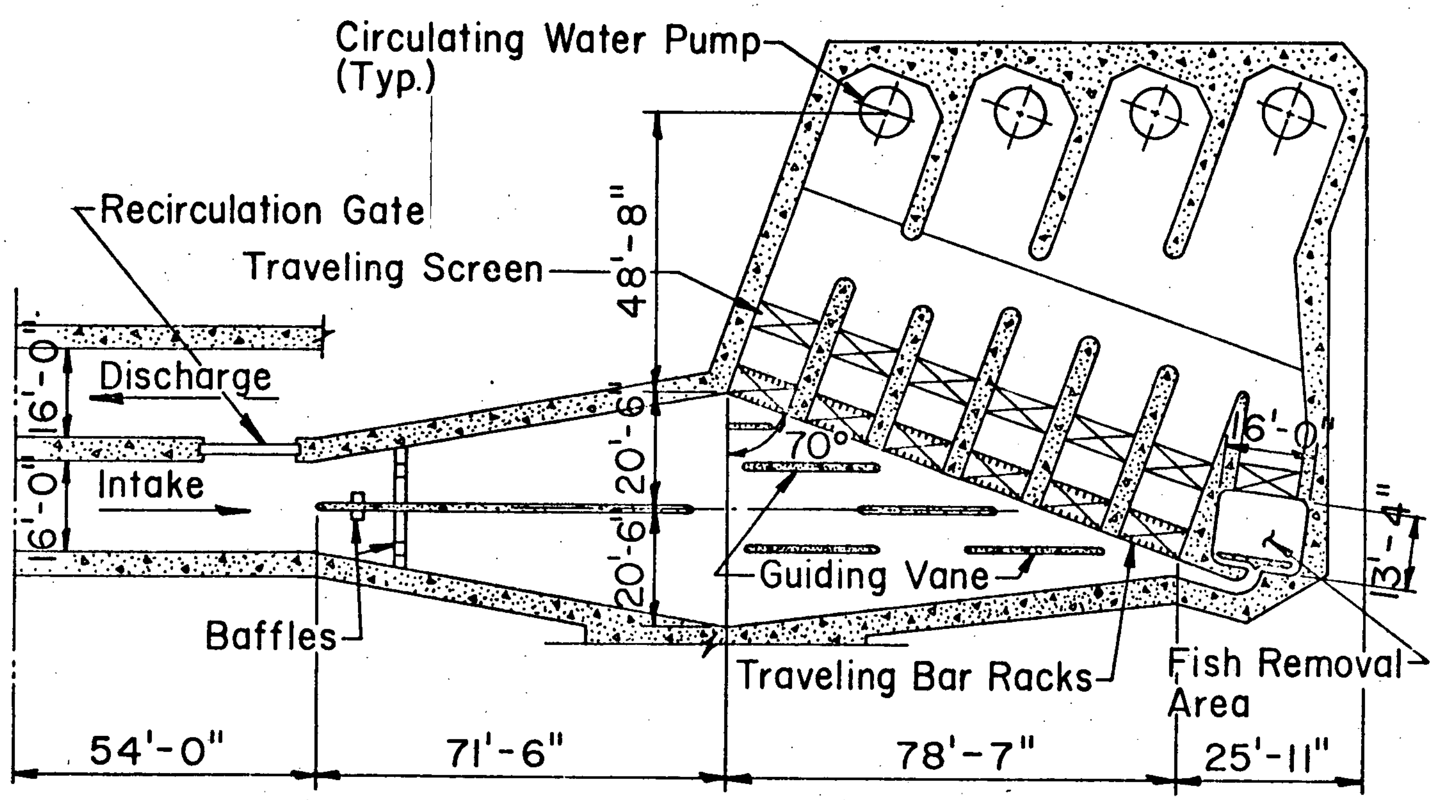

FIGURE 5-2.
SAN ONOFRE UNITS 2 & 3,
FINAL SCREENWELL DESIGN (DOWNS & MEDDOCK, 1974)
INDIAN POINT FLUME STUDY
CONSOLIDATED EDISON CO. OF NEW YORK, INC.
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preferable to have a V-shaped louver arrangement such that the distance that a fish must travel to the bypass is halved. Alternatively, additional bypasses could be supplied at intervals along the louver line.

Such a design is presently being developed for Niagara Mohawk Power Corporation by Stone & Webster Engineering Corporation, as shown in Figure 5-3. In this design, two straight screen bays contain two traveling louver systems which are angled symmetrically and lead to a common bypass. Guiding vanes are not necessary and the louver length (less than 24 feet) is short such that fish will not fatigue prior to entering the bypass. This system was developed on the basis of flume studies (3x3x70 feet) in which alewives, smelt and coho salmon were found to be guided to a bypass, by louvers, with consistently greater than 90 percent efficiency (Stone & Webster, 1975).

A number of the model and prototype louver studies listed in Table 5.1 have been concerned with protecting fish species found in the Hudson River. In particular, the Tracy and Delta louver facilities successfully divert striped bass, shad, catfish and smelt. At the Redondo Beach flume study, anchovies were diverted very effectively by louvers. Stone & Webster Engineering Corporation (1975) found that louvers are very effective in diverting land-locked alewives and smelt.

As a result of these studies, certain design criteria can be established. These criteria can be helpful in developing initial test parameters, as discussed in Section VI, for studies with Hudson River fish species, but cannot be used directly for identifying the parameters which will yield the greatest efficiencies with these fish. This is due to the fact that differences in environmental parameters, such as water quality, may have a pronounced effect on the efficiency of a certain louver arrangement. For example, at the Tracy and Delta facilities, louvers were found to be effective in diverting young striped bass. However, water temperatures at these facilities remain above 40°F throughout the year. At Indian Point, striped bass are susceptable to impingement in the colder months when temperatures drop below 40°F. As discussed in Section III, the swimming speed of striped bass decreases substantially at reduced temperatures. Therefore, while useful design criteria can be obtained from other facilities, careful consideration must be given to the possible effects of different water quality parameters on fish response to a given diversion device.

5.1.1.2 Screens

Fixed and traveling screens have been used extensively at electric generating facilities for many years. However, in the past, the primary function of such screens has been to block the passage of water-borne debris in order to protect condenser tubing from clogging. Only recently has attention been turned to protecting aquatic organisms which are also screened in cooling water systems. As a result, various screen designs and orientations have been researched in an attempt to establish conditions which prevent fish impingement.

Much of the research on screening techniques has been involved with designing screenwells to have screens mounted flush with the shoreline and to provide low intake velocities. While such an arrangement can act to reduce fish impingement, experience at Indian Point has pointed out the need for additional modification in order to reduce impingement to a more acceptable level. Recent studies by Stone & Webster Engineering Corporation, and discussions with other researchers, have led to the concept of utilizing traveling or fixed screens, angled to the flow and leading to a bypass.

The only other study which has been conducted with an angled screen for power plant application was conducted by Ichthyological Associates for Southern California Edison (Schuler, 1973). In this study, screens were not found acceptable due to poor to fair guidance of the northern anchovy, a primary test species. Moderate to good guidance (60 to 90 percent) of other test species was obtained with a screen set at 45 degrees to the flow, an approach velocity of 2.0 fps and a bypass velocity of 1.5 to 4.0 fps (higher efficiencies corresponded to higher bypass velocities). This was also the best setting for anchovies which guided with 30 to 70 percent efficiency.

The screen was dropped from consideration due to the large quantity of bypass flow required to yield good guidance efficiencies. However, because of space limitations at the San Onofre Station, for which the studies were conducted, only an approach velocity of 2 fps was tested, this velocity being the minimum possible. Therefore, to conclude that angled screens at other sites would not be feasible would be unreasonable. It is possible that other species may guide very well along screens, particularly at lower velocities.

It was this idea that led to the angled screen study by Stone & Webster. As shown in Table 5.2, results of angled screen testing with tomcod, striped bass, alewives and smelt have been very encouraging. In these tests, a 1/4-inch, No. 10 gage mesh screen was angled 25 degrees to the flow and led to a 6-inch bypass. The test flume was 3 by 3 by 70 feet. Approach and bypass velocities were set at 1.0 and 1.5 fps, respectively.

The only impingement noted occurred with tomcod within the first several seconds of each test. This was probably due to the weakened condition of the fish, associated with spawning, and a lack of ability to quickly orient to the flow in the short distance to the screen.

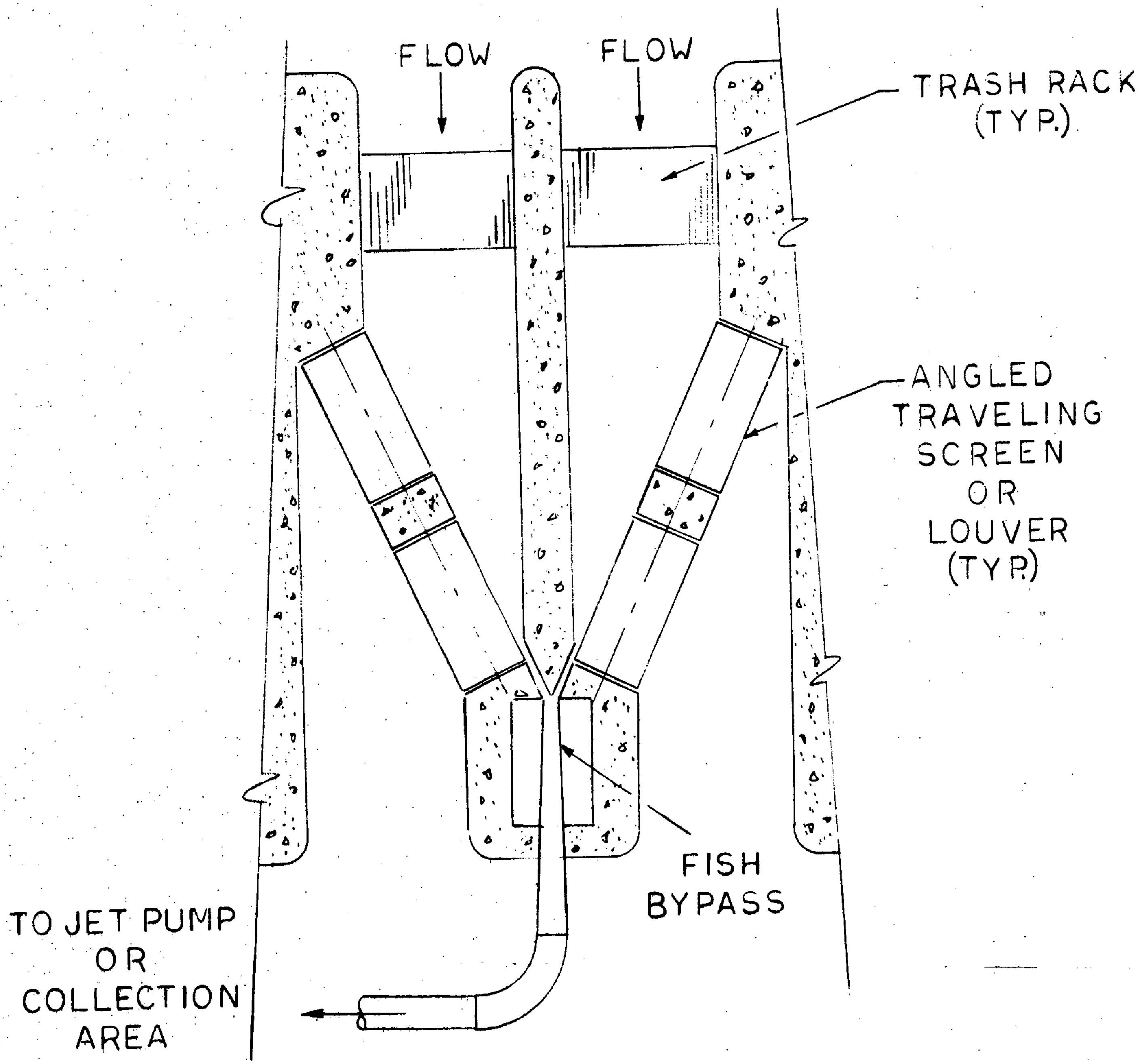

FIGURE 5-3.

CONCEPTUAL DESIGN OF V-SHAPED SCREENWELL ANGLED TRAVELING LOUVERS OR SCREENS

INDIAN POINT FLUME STUDY
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TABLE 5.2

RESULTS OF ANGLED SCREEN TESTING

Screen Angle: 25° off the flow
Approach Velocity: 1 fps
Bypass Velocity: 1.5 fps

Date	Species	Water Temperature (°F)	No. of Fish Bypassed	No. of Fish Impinged	Efficiency
7/10/74[1]	Alewife	78	42	0	100%
7/15/74	Alewife	75.6	33	0	100%
11/4/74	Alewife	50	1,080	0	100%
11/6/74	Alewife	49	446	0	100%
1/3/75	Striped Bass	36	33	2	94%
2/5/75	Tomcod	34	36	0	100%
2/10/75	Tomcod	34	120	1	99%
2/11/75	Tomcod	36	90	3	97%
2/13/75	Tomcod	34	139	1	99%
2/27/75[1]	Smelt	37	202	10	95%
2/28/75	Smelt	36	151	0	100%
3/3/75	Smelt	37	168	0	100%

[1] Refer to Stone & Webster, 1975 for details of alewife and smelt testing.

Another interesting study has been conducted at the Mayfield Dam on the Cowlitz River in Washington which further substantiates the effectiveness of angled screens in guiding fish (Thompson & Paulik, 1967). This dam is located 52 miles above the confluence with the Columbia River. Since the Cowlitz is a major salmonid producing tributary, louvers were installed to bypass chinook and coho salmon, steelhead and cutthroat trout and whitefish. Extensive studies were conducted in 1964 and 1965 to evaluate the effectiveness of the louver system. As a result, it was concluded that the louvers, spaced 2.25 inches apart and leading to an 8-inch-wide bypass, were not functioning satisfactorily. Therefore, a series of modifications were made and evaluated.

It was found that increasing the bypass width, screening one-third of the louvers nearest the bypass, and increasing the bypass velocity did not improve the efficiency of the system significantly. However, when the louvers were completely covered by woven-wire screen of 3/8-inch clear opening, 100 percent efficiencies were achieved.

Impingement of fish was noted only when the bypass was closed during the testing program. Otherwise, fish impingement was never observed when the screened louvers were lifted for examination. Tests were also conducted to determine whether fish which entered the screened louver system were injured during passage. It was found that some fish displayed signs of abrasion. However, the majority of the fish which suffered scale damage were only slightly abraded. It appears, therefore, that angled screens leading to a bypass may be more effective in guiding fish and should receive high priority in a test program.

5.1.2 Prototype Considerations

In selecting a test device, consideration must be given to the engineering design criteria which determine whether such a device is feasible for application at Indian Point and Cornwall. These criteria include the feasibility of construction, capability of creating the required hydraulic flow conditions, and the potential for minimizing clogging. These criteria are discussed individually below as they relate to the construction and operation of angled louvers and screens.

5.1.2.1 Feasibility of Construction

For the existing Indian Point intakes, the prototype design layout and the requirements for fish transportation are important considerations.

A design layout that can be constructed and backfitted with minimum interference with station operation and/or minimum shutdown results in a minimum loss of revenue due to decrease in power generation. A smaller-sized structure to accommodate the fish diversion device is more economical. Arrangements with louvers or screens placed at a larger angle to the direction of flow result in a shorter overall structure. Similarly, a V-arrangement (Figure 5-9) results in a shorter structure than an arrangement with a single array of louvers or screens (Figure 5-10). Another consideration is that the distance that the structure would protrude into the river is limited due to navigational requirements. The present permit limits the distance to about 75 feet which is the distance to which the present barge wharf in front of Unit 1 extends. An arrangement parallel to the river (Figures 5-4 and 5-5) would result in less protrusion into the river than an arrangement perpendicular to the river (Figures 5-6 and 5-7). The requirements for fish transportation would include a proper design of a bypass that fish would not avoid, a rate of flow to induce the fish into the bypass, a series of pipelines, a fish collection area, and a pumping unit to induce the bypass flow and/or to transport the fish back to the river without injury. The total flow rate required for the bypasses could be as much as 10 percent of the circulating water flow. If this amount of flow is judged excessive, a secondary fish screening arrangement could be utilized to concentrate the fish into a lesser amount of water for transport. A jet pump could be used if the number of fish to be bypassed is large and requires a continuous return to the river. However, if the number of fish is small, a lift basket could be incorporated.

For the proposed Cornwall intake, screens or louvers could be installed in the tailrace bay, since this space is available, thus resulting in no protrusion into the river. Other considerations of size, angle of the diversion device, and requirements for fish transportation are similar to those discussed above.

Protection from floating or frazil ice can be achieved by providing a curtain wall and warm water recirculation. Maintenance of the screens or louvers can be achieved by pulling out the screen or louver by a diver if the problem is minor, or by making provisions for stop gates upstream and downstream of the louver or screen for dewatering that section of the intake bay in order to do work in the dry.

5.1.2.2 Hydraulic Considerations

As previously discussed, uniform approach flow patterns to screens or louvers are required in order to maintain high fish guidance efficiencies. This requirement creates a problem due to tidal fluctuations in the river. However, uniform flow patterns could be achieved by providing a long approach channel or by providing guide vanes (Figures 5-4 and 5-5). A hydraulic model study may be required to determine the best scheme of obtaining flow patterns satisfactory for fish guidance. Also, the design approach velocities and the ratio of bypass to approach velocity required for fish guidance should be valid for the range of

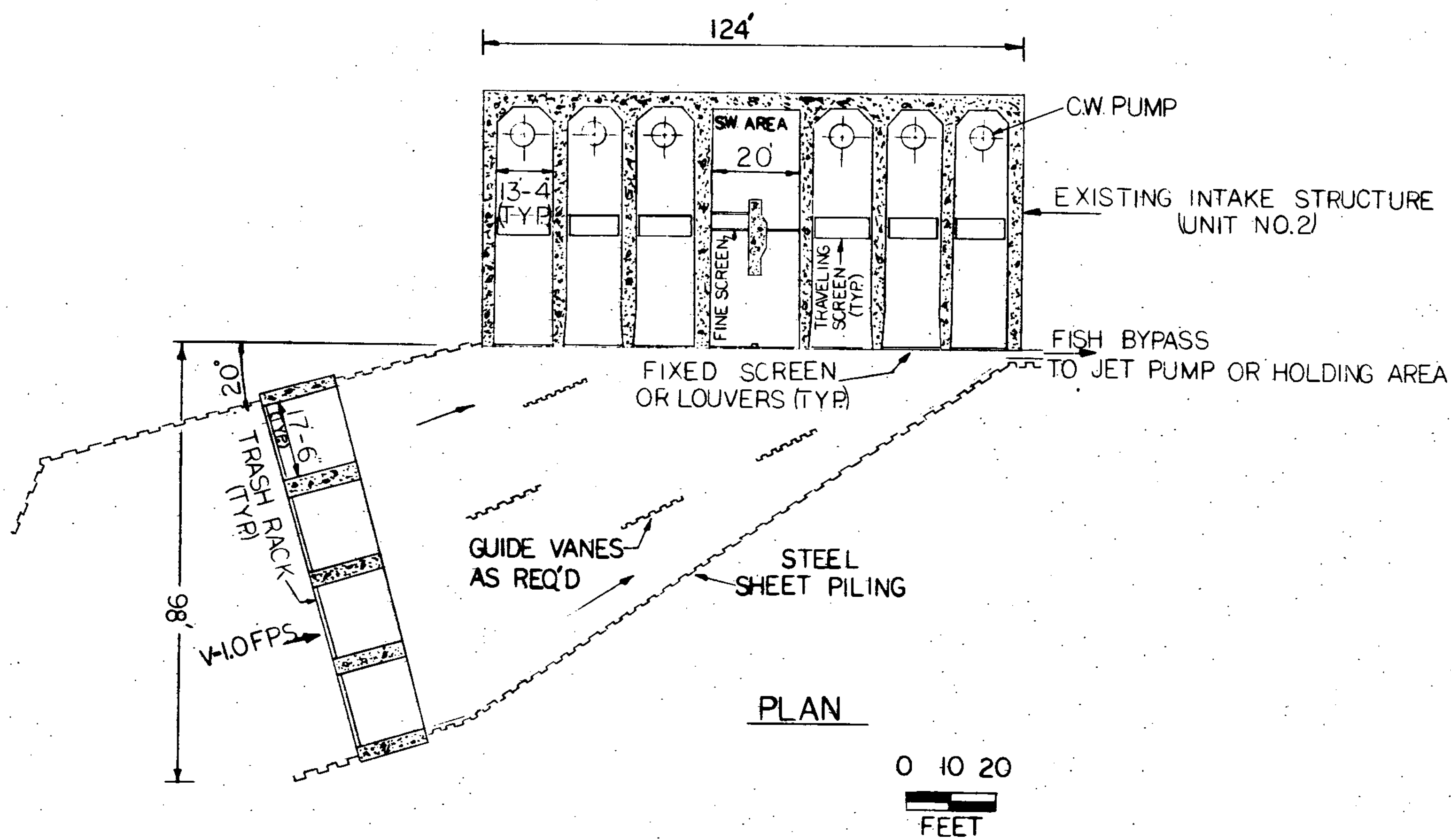


FIGURE 5-4.
CONCEPTUAL INTAKE MODIFICATION, LOUVERS OR SCREENS FLUSH WITH EXISTING INTAKE FACE, INDIAN POINT GENERATING STATION

INDIAN POINT FLUME STUDY
CONSOLIDATED EDISON CO. OF NEW YORK, INC.
STONE & WEBSTER ENGINEERING CORPORATION

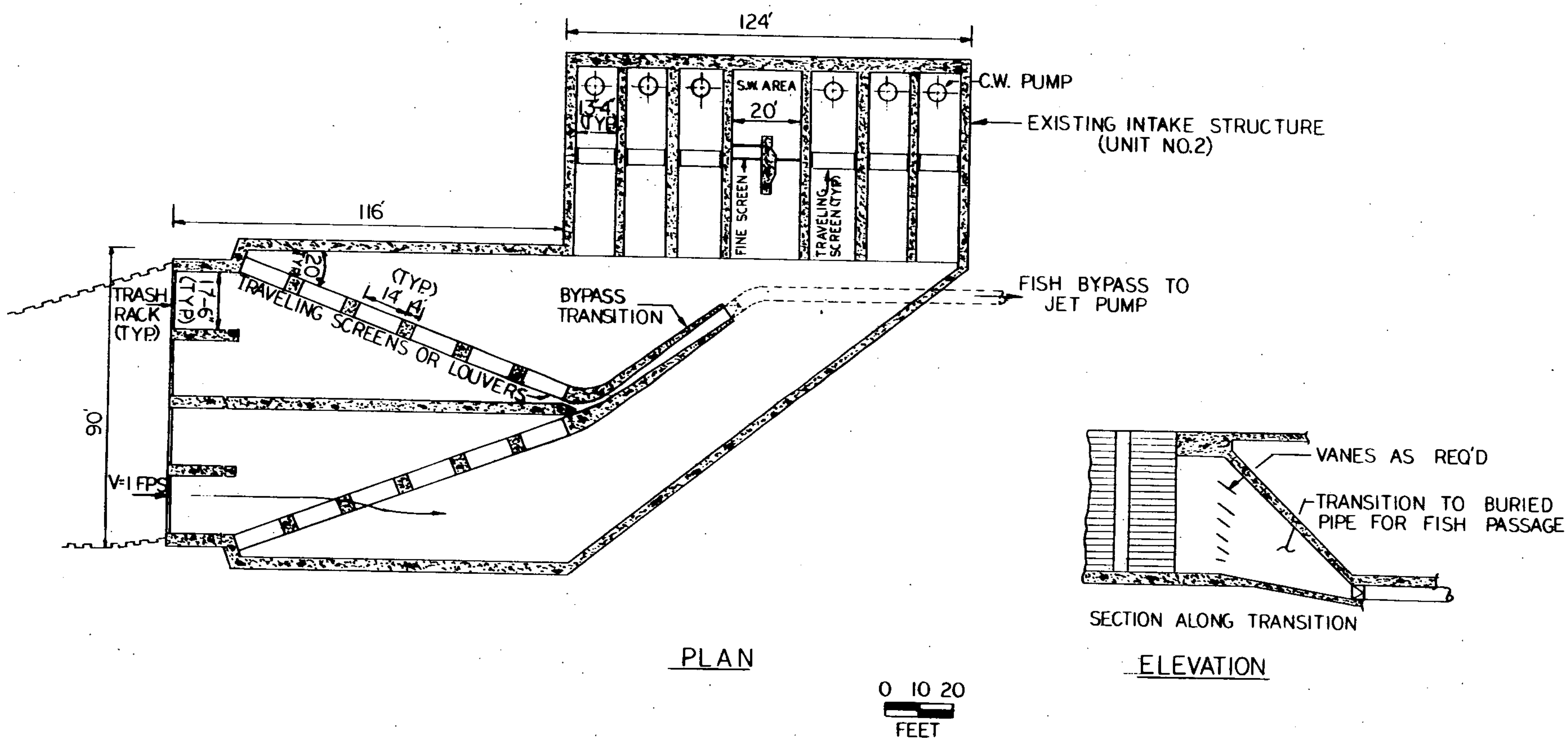
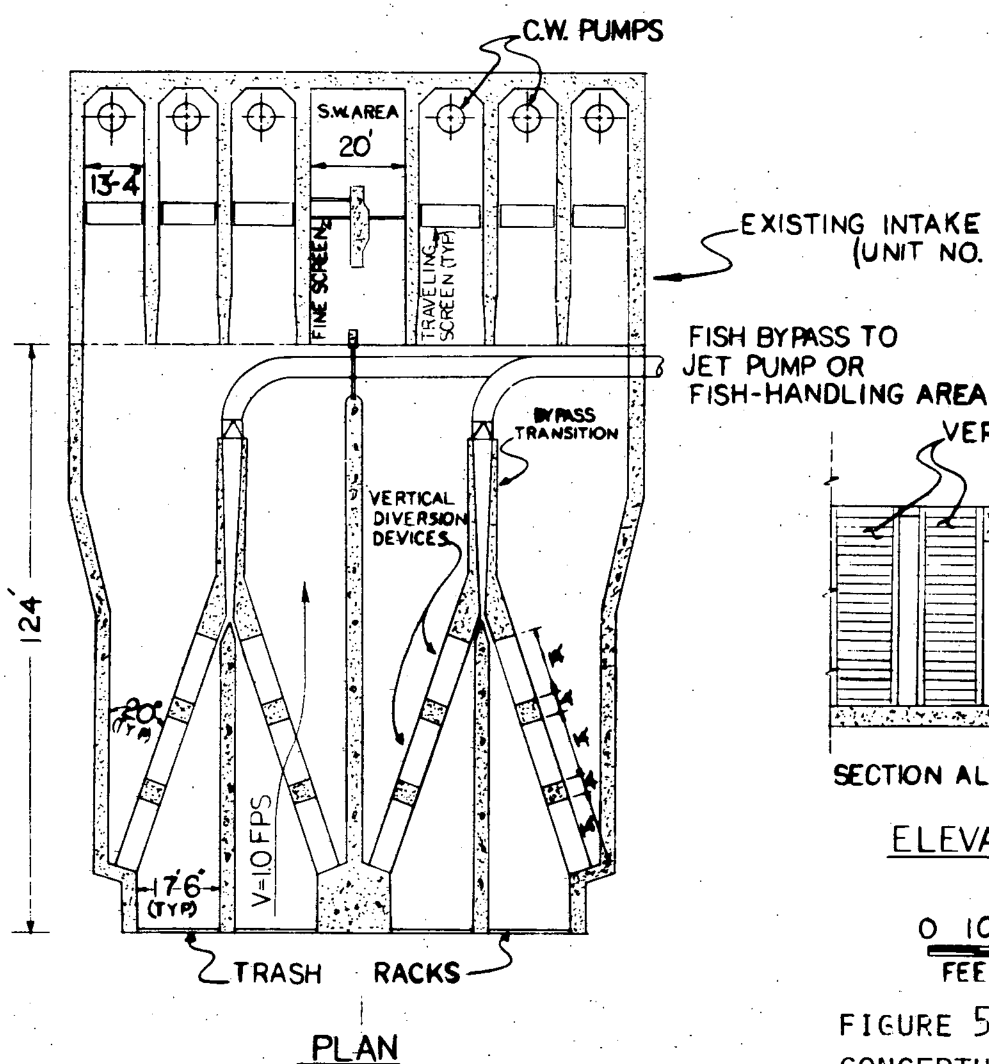


FIGURE 5-5.

CONCEPTUAL INTAKE MODIFICATION, LOUVERS OR SCREENS WITH A V-ARRANGEMENT, INDIAN POINT GENERATING STATION

INDIAN POINT FLUME STUDY
CONSOLIDATED EDISON CO. OF NEW YORK, INC.
STONE & WEBSTER ENGINEERING CORPORATION



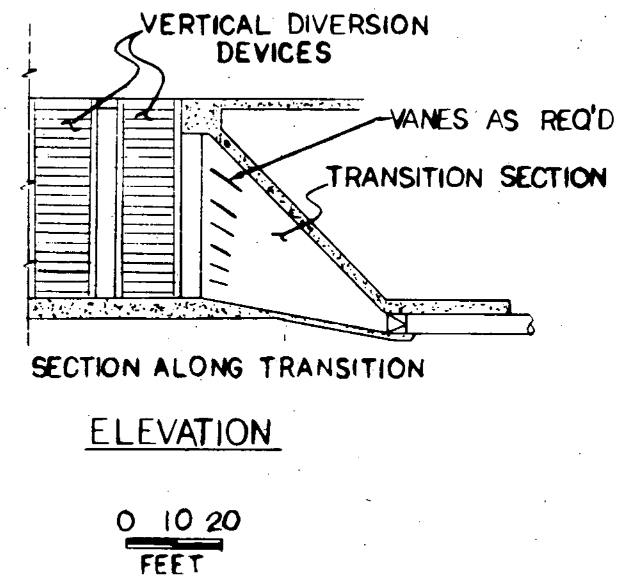


FIGURE 5-6.
CONCEPTUAL INTAKE MODIFICATION, LOUVERS OR SCREENS WITH A CHEVRON ARRANGEMENT, INDIAN POINT GENERATING STATION

INDIAN POINT FLUME STUDY
CONSOLIDATED EDISON CO. OF NEW YORK, INC.
STONE & WEBSTER ENGINEERING CORPORATION

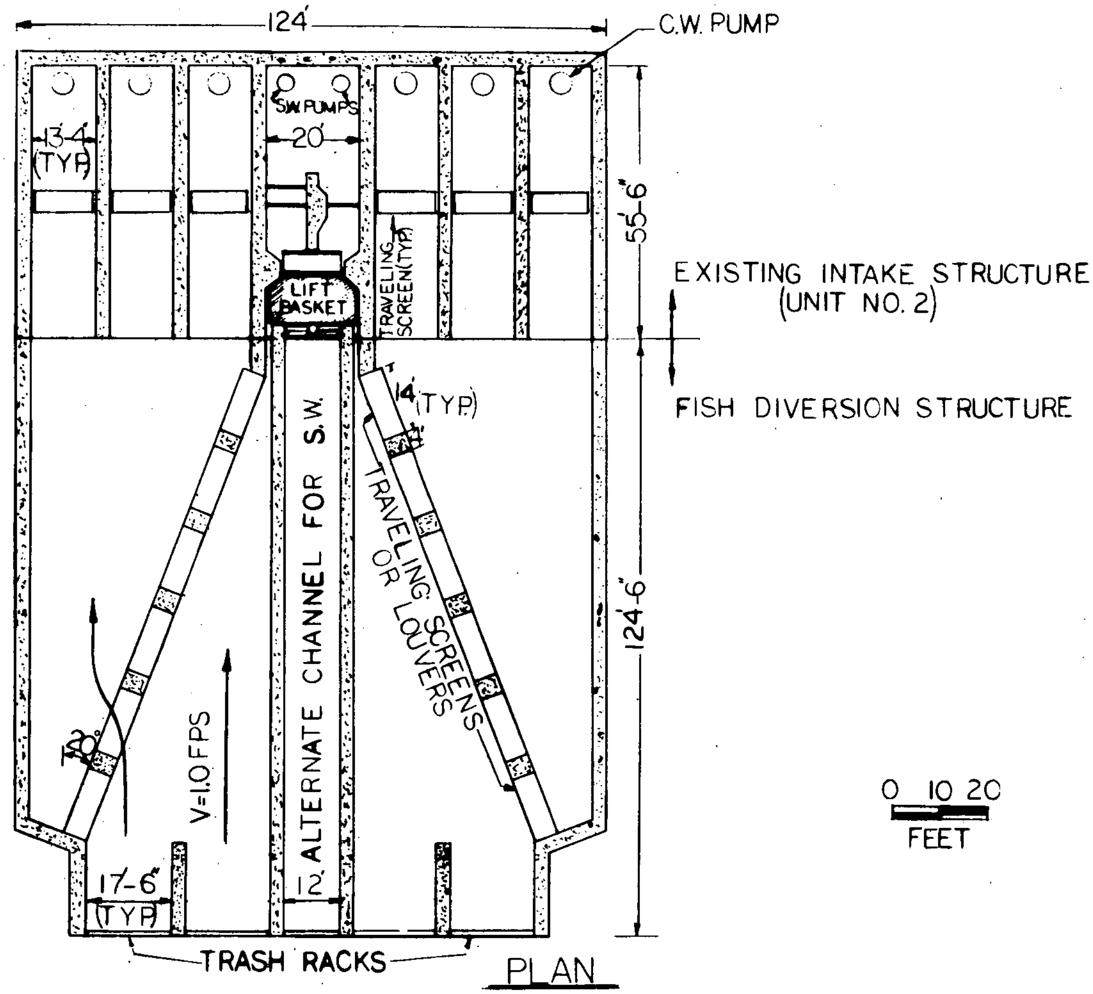
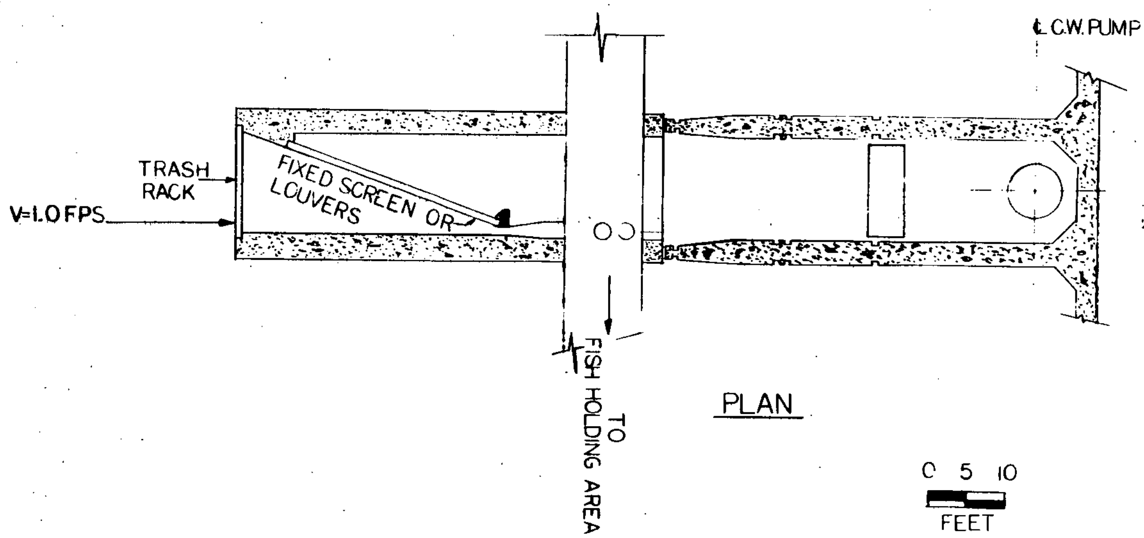


FIGURE 5-7.

CONCEPTUAL INTAKE MODIFICATION, LOUVERS OR SCREENS WITH A V-ARRANGEMENT, INDIAN POINT GENERATING STATION

INDIAN POINT FLUME STUDY
CONSOLIDATED EDISON CO. OF NEW YORK, INC.
STONE & WEBSTER ENGINEERING CORPORATION



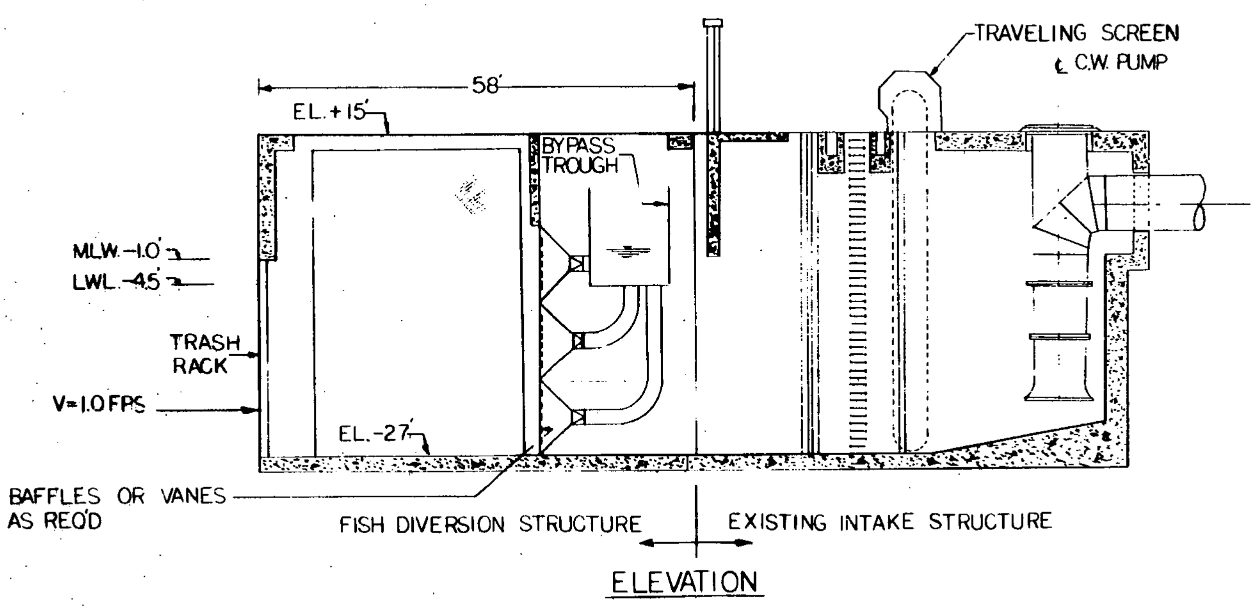


FIGURE 5-8.

CONCEPTUAL INTAKE MODIFICATION, FIXED LOUVER OR SCREEN IN EACH BAY

INDIAN POINT FLUME STUDY
CONSOLIDATED EDISON CO. OF NEW YORK, INC.
STONE & WEBSTER ENGINEERING CORPORATION

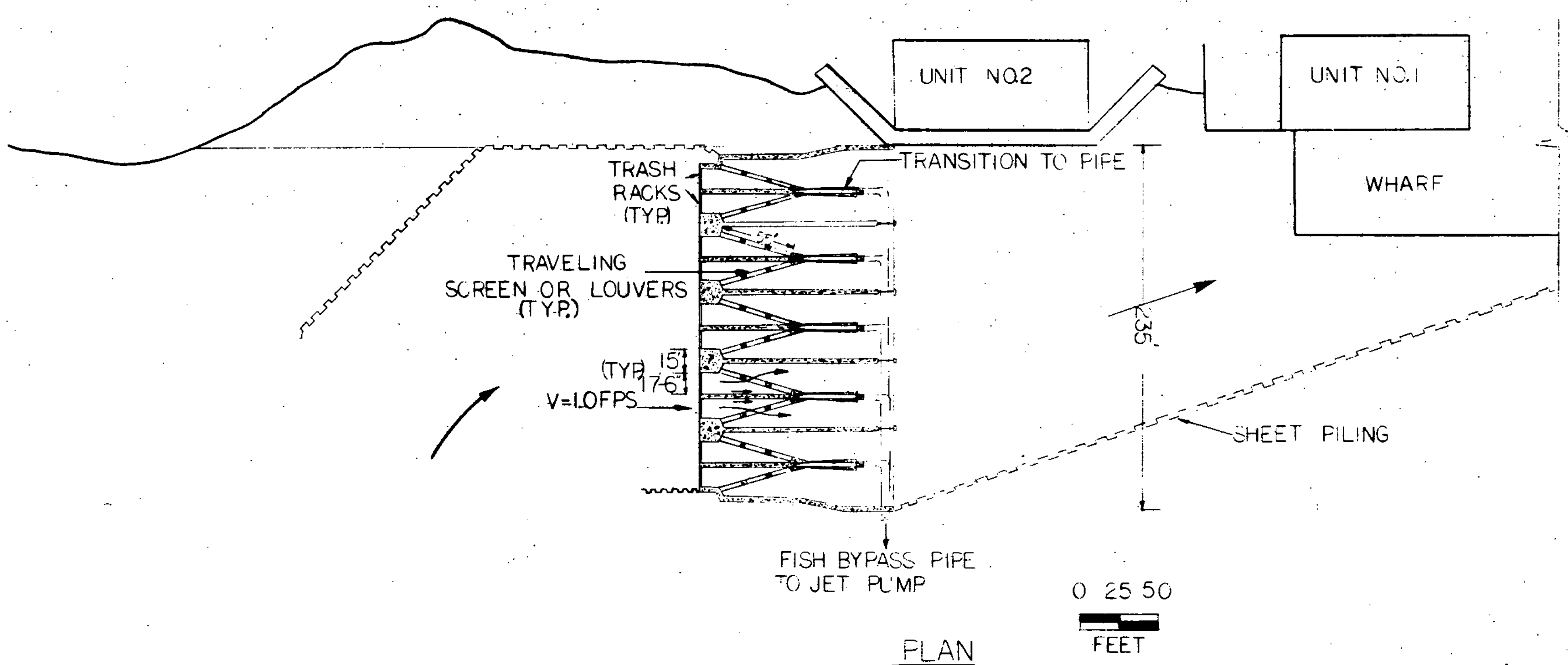


FIGURE 5-9.

CONCEPTUAL INTAKE MODIFICATION
WITH CHEVRON ARRANGEMENT OF LOUVERS OR SCREENS

INDIAN POINT FLUME STUDY
CONSOLIDATED EDISON CO. OF NEW YORK, INC.
STONE & WEBSTER ENGINEERING CORPORATION

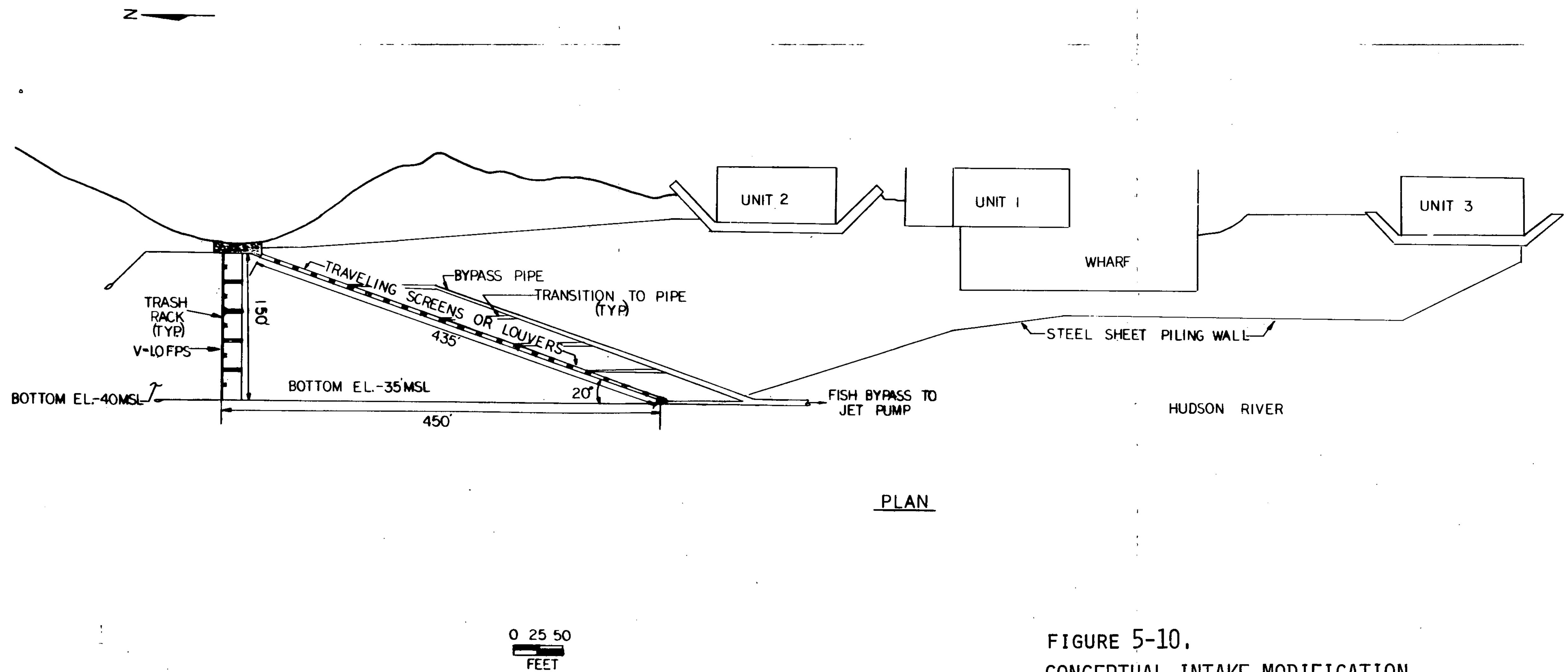


FIGURE 5-10.

CONCEPTUAL INTAKE MODIFICATION
LOUVER OR SCREEN ARRAY

INDIAN POINT FLUME STUDY
CONSOLIDATED EDISON CO. OF NEW YORK, INC.
STONE & WEBSTER ENGINEERING CORPORATION

velocities resulting from tidal fluctuations. Another consideration is that the flow patterns along the face of the screens or louvers and into the bypass should be smooth and uninterrupted since it has been demonstrated through model and prototype studies that turbulence causes disorientation of the fish and leads to lower efficiencies. This condition could be accomplished by using guide vanes behind louvers to decrease losses and to distribute the flow more evenly through the louvers. Guide vanes could be utilized in the approach channel to create the proper flow patterns along the face of the louvers or screens. Also, the possible effect of the louvers and screens on the performance of the circulating and service pumps should be investigated, since zones of separation would result behind these devices that could create vortices at the pumps.

5.1.2.3 Clogging

The intakes on the Hudson River are subjected to medium-to-heavy loading of debris which can cause potential clogging to the louvers, screens, bypass, and fish transport pipes. The existing fixed screens at the face of Units 1 and 2 Indian Point intakes are cleaned manually almost every day. Clogging could result in lower fish diversion efficiencies since, as parts of the screen or louver clog, the velocities across the remaining open area would increase. Consequently, the velocity distribution and flow patterns along the face of the screen or louver would change, resulting in unfavorable hydraulic conditions. Clogging would also result in higher differential head loading on the screen or louver structure. Therefore, mechanical cleaning is recommended.

For the louver application, guided rakes could not be used because the walls supporting the guides would protrude into the flow, thereby disturbing the uniform flow patterns necessary for successful fish guidance. Vertical unguided rakes (such as the clam shell type manufactured by Allis Chalmers) could be used to clean the major length of the louver, except in the vicinity of the bypass because the rake would protrude about 2 feet into the flow, a width which is larger than the clear spacing available in this area. Traveling louvers, similar to those proposed for the San Onofre Nuclear Generating Station Units 2 and 3, are recommended in this section. The traveling louver assembly is a modification of the conventional traveling screen assembly which provides a flush face along the louvers. The louver bars, which can be fabricated of steel, aluminum, or plastic, are mounted on the panel frames, and can be cleaned by water sprays similar to those used on conventional screens. For screen application, traveling flush mounted fish screens are recommended. These screens have not been used in any power plant to date. They are a modification of the conventional traveling screens. At present, Stone and Webster is testing this screen to determine its fish guiding potential. The screen is being considered for use at intakes of power plants on Lake Ontario.

For the Cornwall intake, cleaning of the louvers or screens might not be required because of the flushing action during the generating mode. If cleaning were judged necessary, mechanical methods are recommended, as discussed above.

Clogging of the bypass and fish transport pipes can be cleared by backflushing the track so that it can be lifted by the traveling screen or louver. Also, the bypass entrance will be constructed of removable steel sections so that sticks or other debris can be cleaned manually when necessary.

To demonstrate the feasibility of installing louvers or screens at the Indian Point Units, several conceptual arrangements are presented and briefly discussed below. All of these arrangements are designed with an assumed approach velocity of 1 fps, a 20 degree angle between the screens or louvers and the direction of flow, a bypass width of 1 ft., and a bypass velocity of 1.5 fps. All are equipped with a trash rack upstream for the removal of large debris. The arrangements are discussed in the order of the most desirable first.

Figure 5-4 shows an arrangement utilizing the existing fixed screens or a replacement traveling louver or screen at the face of the Unit 2 intake. Guide vanes would be required to prevent the approach flow from turning into the louvers or screens prematurely. The advantage of this arrangement is that it could be constructed with minimum interference with station operation. The trash rack piers could be constructed separately, while the station is in operation, by installing a cofferdam around that area. At the completion of this construction, the approach channel sheet piling could be driven in place while the cooling water is supplied through the completed trash racks section. Another advantage is that the structure would protrude only about 100 feet into the river. This distance could be decreased easily by decreasing the angle to the approach flow or by proper placement of the guiding vanes.

Figure 5-5 shows a V-arrangement for the Unit 2 intake, set parallel to the river bank. The advantages of this arrangement are that no guide vanes would be required, it could be constructed with minimum interference with the station operation, and it would only protrude 90 feet into the river. Fish entering the bypass could be pumped back to the river with a jet pump or diverted to a collection area.

Figure 5-6 shows a chevron arrangement at the front of the Unit 2 intake with the bypasses leading to a jet pump or a collection area. The disadvantages of this arrangement are that at least half the cooling water pumping capacity would be interrupted during construction of the louvers and screens and that the structure could protrude as much as 124 feet into the river.

Figure 5–7 shows a V–arrangement in front of the Unit 2 intake with the bypass leading to a lift basket placed in the service water bay. The service water pumps would provide the required inducing flow into the bypasses. This arrangement, however, would protrude about 124 feet into the river, and construction would interrupt at least one–half the cooling water flow.

Figure 5–8 shows fixed screens or louvers installed in each of the intake bays with the bypasses leading to a trough. The disadvantage of this arrangement is the clogging potential of the screen or louver. A traveling louver or screen could be utilized instead if the approach velocity is higher than 1.5 fps. The advantage of this arrangement would then be the short distance that the structure would protrude into the river.

Figure 5–9 shows a chevron arrangement parallel to the river bank and serving all three units. The disadvantage of this arrangement is that the structure would protrude about 235 feet into the river.

Finally, Figure 5–10 shows a traveling louver or screen array set parallel to the river bank and serving all three units. The disadvantage of this arrangement is that the louvers or screens would extend about 435 feet and would protrude about 150 feet into the river.

For the Cornwall intake, a chevron arrangement placed in the tailrace bay, as shown in Figure 5–11, with the bypasses leading to either a lift basket or to a jet pump would be possible. Since clogging might not be a potential problem due to the flushing action during the generating mode, stationary louvers could be utilized for most of the screening area with a traveling louver or screen installed in the vicinity of the bypass to insure proper cleaning and the required hydraulic conditions.

5.2 INCLINED PLANE DIVERSION DEVICES

Two types of inclined plane diversion devices have been proposed for study - a louver system and an inclined screen. Although very limited research has been conducted on such systems in the past, it is possible that an inclined plane system could offer a solution to the problem of fish impingement at Indian Point. A review of the available literature and a description of prototype design considerations are given below.

5.2.1 Literature Review

5.2.1.1 Inclined Plane Screens

Several types of inclined plane screens have been developed to date. The first is simply a conventional traveling screen inclined downstream at a small angle. This design is used in areas of very heavy debris loading where the conventional vertical screen allows collected debris to fall back to the water during the wash cycle. By inclining the screen up to 12 degrees, debris is held down by the force of gravity until it can be removed into a collection trough. Larger angles have been used at some installations. Figure 5-12 shows a 45-degree inclined plane screen used at the intake of a lumber operation in Oregon for the removal of heavy debris. Because this type of inclined screen is essentially the same as the conventional type, it has the same environmental drawbacks. Fish must be impinged and carried out of water in order to collect them.

Another type of inclined screen is shown on Figure 5-13. In this case, the screen is fixed and is placed nearly horizontal to the flow. An endless band of rotating brushes sweeps debris and fish across the screen face to a surface collecting area. Such a screen has been used in Canada to divert migratory salmon from a spawning channel with good results (Kupka, 1966). However, there are two problems with this screen which limit its application. First it is necessary to maintain a constant water level in the screen area in order that water always flows to the surface bypass. Second, in regions of high debris loading, such a screen could clog quickly.

Two other applications of an inclined plane screen have been tested in the Pacific Northwest. The first is a self-cleaning design called a "Model T," and is installed in an irrigation channel in British Columbia (Clay, 1961). The design consists of a perforated plate inclined at 33 degrees to the flow with a bypass supplied on one side (Figure 5-14). A T-shaped wiper blade, driven by a paddle, sweeps up and down the screen removing debris on the upstroke. The plate has 5/32-inch holes spaced on 7/32-inch centers.

Operation of the "Model T" has shown the design to be ineffective in diverting salmon fry at velocities above 0.4 fps. Under these conditions, the fish were held on the screen and were subsequently injured or killed by the wiper blade. At velocities less than 0.4 fps, injuries were eliminated. With larger fish, the screen was an effective diversion device at higher velocities.

The second inclined screen is known as a "skimmer" (Figure 5-15). Such a device is installed at the Pelton Dam on the Deschutes River in Oregon to divert downstream migrants to a fishway (Eicher, 1960). A flow of 200 cfs is drawn from the upstream reservoir. The majority of the flow passed through an inclined screen while a small quantity of flow carrying the fish drops over the end of the screen. The fish are then transported to the fishway. Two problems have arisen which make conclusions on the general applicability of a skimmer device impossible. First, changing water elevation in the forebay makes reliable operation difficult. Second, an evaluation of whether downstream migrants

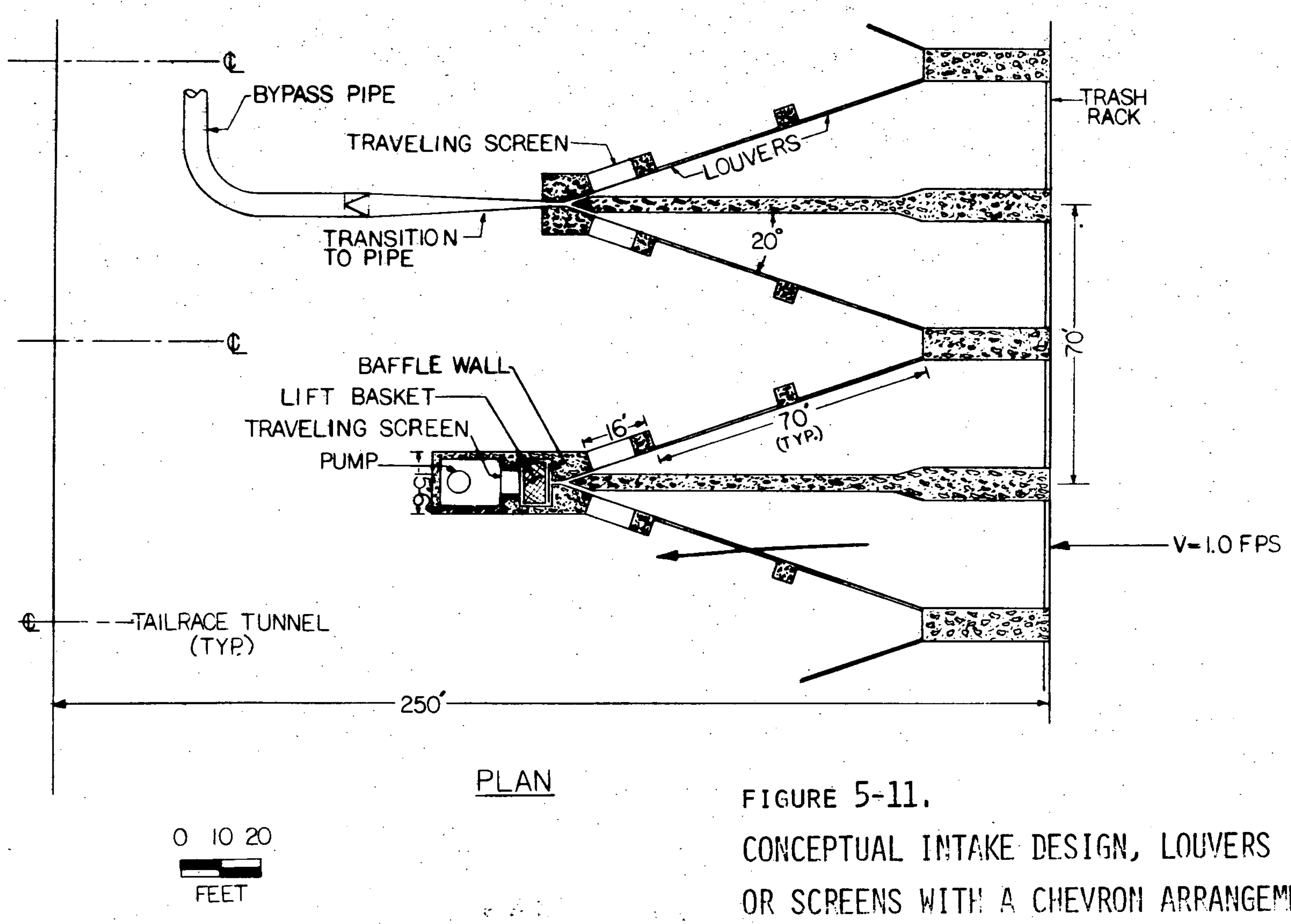


FIGURE 5-11.

CONCEPTUAL INTAKE DESIGN, LOUVERS OR SCREENS WITH A CHEVRON ARRANGEMENT

CORNWALL PUMPED STORAGE PROJECT
INDIAN POINT FLUME STUDY
CONSOLIDATED EDISON CO. OF NEW YORK, INC.
STONE & WEBSTER ENGINEERING CORPORATION

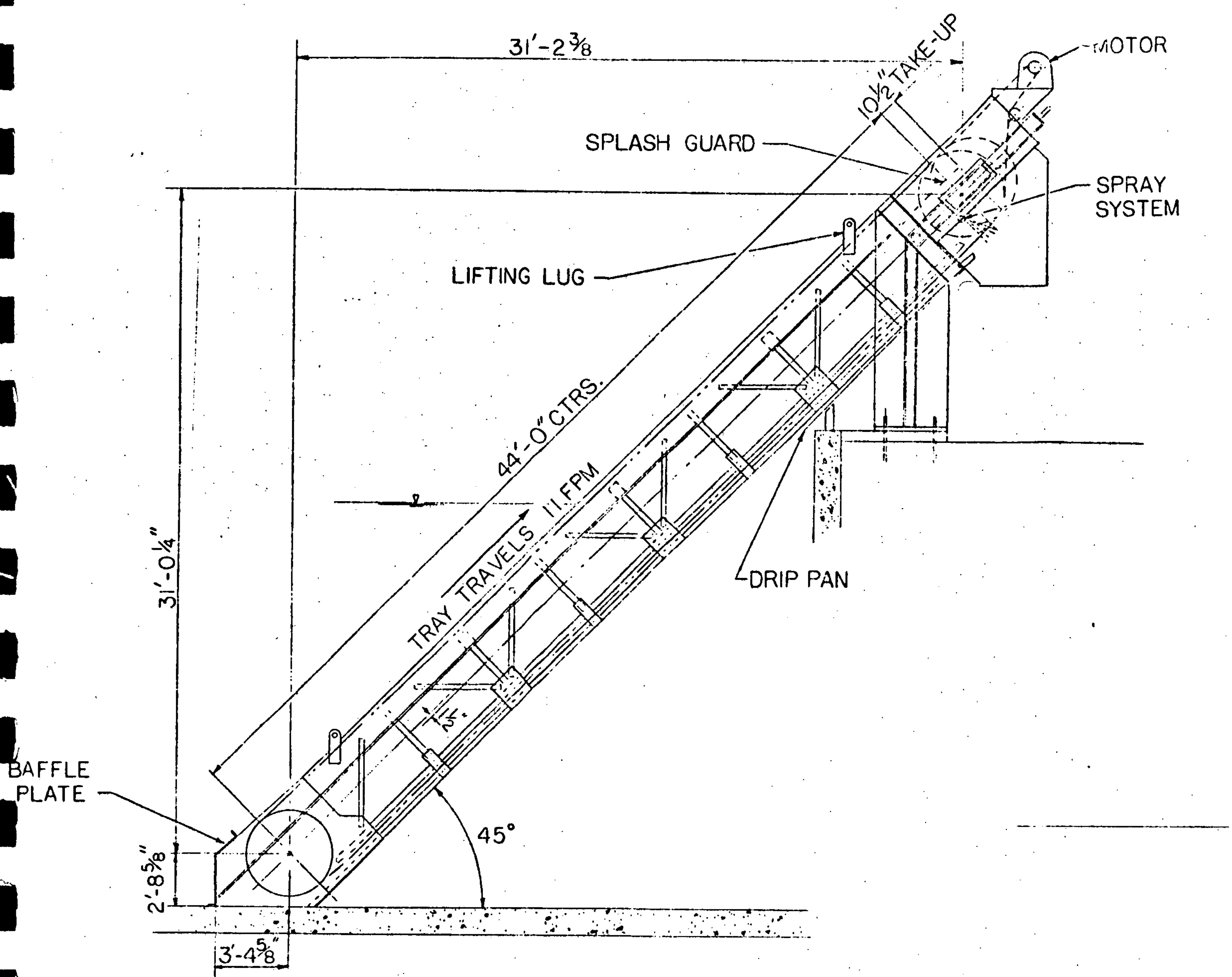


FIGURE 5-12.

45-DEGREE INCLINED PLANE SCREEN

INDIAN POINT FLUME STUDY
CONCOLIDATED EDISON CO. OF NEW YORK, INC.

STONE & WEBSTER ENGINEERING CORPORATION

[COURTESY OF FMC CORPORATION (LINK-BELT)]

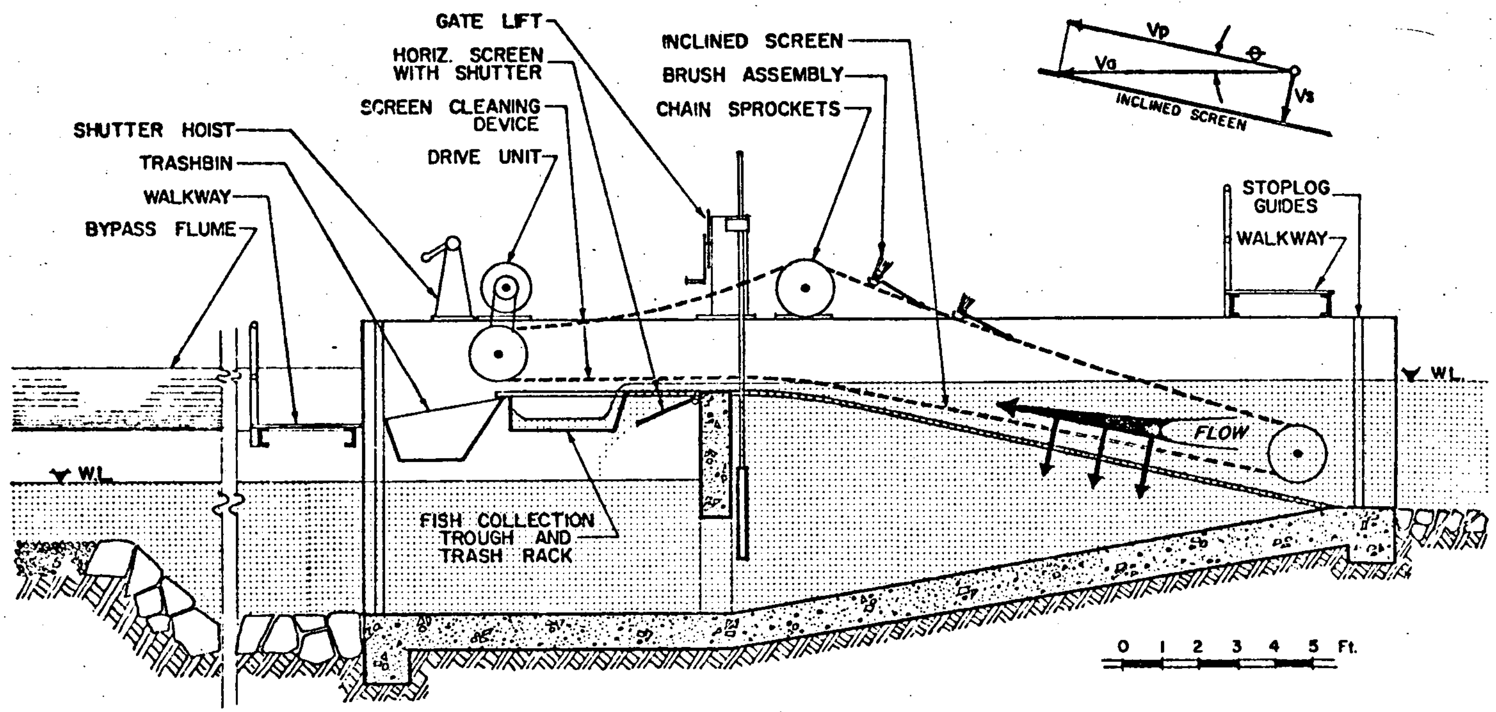


FIGURE 5-13.
SECTION OF THE DOWNSTREAM MIGRANT
DIVERSION STRUCTURE (KUPKA, 1966)
INDIAN POINT FLUME STUDY
CONSOLIDATED EDISON CO. OF NEW YORK, INC.
STONE & WEBSTER ENGINEERING CORPORATION

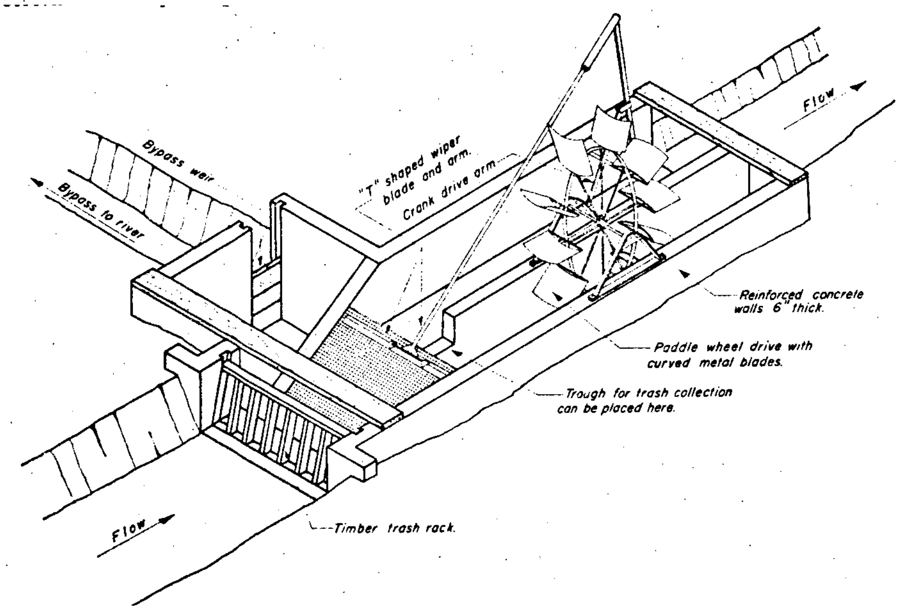


FIGURE 5-14.
MODEL-T DESIGN (CLAY, 1961)
INDIAN POINT FLUME STUDY
CONSOLIDATED EDISON CO. OF NEW YORK, INC.
STONE & WEBSTER ENGINEERING CORPORATION

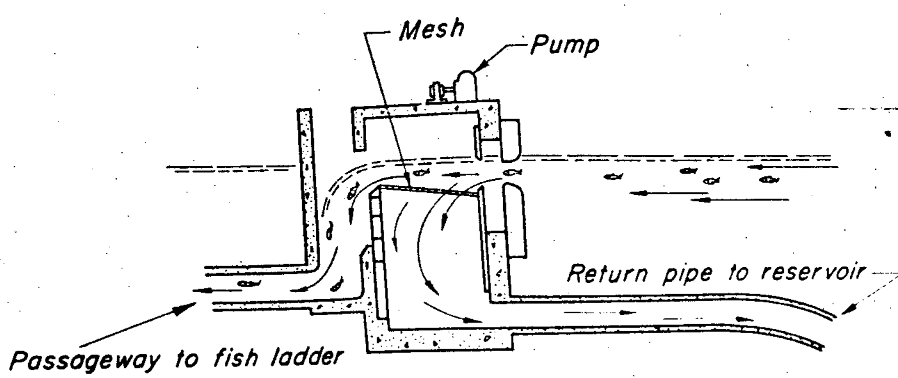


FIGURE 5-15.
PELTON "SKIMMER" (CLAY, 1961)
INDIAN POINT FLUME STUDY
CONSOLIDATED EDISON CO. OF NEW YORK, INC.
STONE & WEBSTER ENGINEERING CORPORATION

are successfully bypassed by the inclined screen has not been made.

None of the inclined plane screening devices described thus far appear to have potential for application at power plants without extensive additional research and design development.

5.2.1.2 Inclined Plane Louvers

Only two studies have been conducted utilizing inclined plane louvers. The first study was done by the U.S. Fish and Wildlife Service and the Bureau of Reclamation in 1953 (Bates, Logan and Pesonen, 1960). The study lasted several months and although it was found that fish could be diverted efficiently, several operational problems arose which could not be rectified. The primary problem was fluctuating water level. Since the louvers divert fish to a surface bypass, it is necessary to maintain a constant rate of overflow, a condition which is not possible when water level changes several feet with the tide. A second problem was cleaning. Because the louvers were arranged horizontally, the removal operation involved in cleaning was very difficult. For these reasons, the inclined louver was dropped from the study.

The only other inclined plane louver study led to a prototype installation at two dams on the Baker River in Washington (Clay, 1961). These louver systems have been designated as "gulpers" and are similar to the skimmers discussed earlier. The major difference, besides the fact that louvers are utilized in place of screens, is that the gulpers are mounted on floating platforms. In this way, a constant overflow height can be maintained since the gulper adjusts to fluctuating reservoir water levels. Fish are guided up the louver slats, which gradually narrow as they approach the surface overflow, and pass into a bypass collection area.

Unfortunately, as with the skimmer, the gulper inclined plane louver system has not been fully evaluated and is still in the experimental stage of development.

5.2.2 Prototype Considerations

As with angled screens and louvers, the feasibility of construction, hydraulics, and clogging potential are important considerations in designing an inclined plane diversion system.

A desirable layout arrangement is one in which the inclined screens would be installed in bays upstream of the existing bays with the screens inclined to the horizontal at the largest angle feasible for fish guidance. This would result in the smallest screen and associated structures.

Uniform approach flow patterns should be maintained together with an uninterrupted velocity distribution along the face of the screen. The effect of the inclined screens on the performance of the pumps downstream should also be considered.

Clogging of the screens could result in lower fish diversion efficiencies and higher differential loading on the frame structure. Mechanical cleaning is therefore recommended. A submerged inclined traveling screen offers the best solution. Two leading screen manufacturers were contacted to investigate the feasibility of a submerged screen. Such a screen has not been developed. However, a design could be developed if such a system were found effective in diverting fish. The screen would be driven by a drive unit located on the deck or above high water. The screen should be operated continuously with an internal spray system utilized to remove debris. A conventional backup screen would be required to intercept debris that is carried over the inclined screen. The fish bypass and collection system would also have to be designed to handle debris. Some investment would be necessary to carry out the design work. A good maintenance program would be required and large quantities of spare parts would have to be stocked. The submerged inclined screen would have a shorter life expectancy, due to the wearing of matting surface, than the conventional vertical screen.

To demonstrate the feasibility of inclined screens at the Indian Point intakes, several conceptual arrangements are presented and briefly discussed below in the order of most-desirable first. All these concepts show a screen in a bay upstream of the existing bays and inclined 30 degrees to the horizontal. Figure 5-16 shows an inclined submerged screen with a fish bypass leading to a transport pipe at the top of the screen. The backfit structure would protrude about 70 feet into the river, which is within the limit of the present permit. The disadvantages of this concept are that a backup screen would be required, there is no operational experience with such a screen, and the screen would be costly.

Figure 5-17 shows an inclined submerged fixed screen. The screens would require removal for manual cleaning, which is the major disadvantage of this concept.

An alternative arrangement is to incline the screen or louver horizontally downward with a fish bypass at the bottom. The disadvantages of this scheme are that the bypass will become more susceptible to clogging by sedimentation. If the screen is to travel with the upstream screen descending to create a downward velocity component toward the bypass, then debris would collect in the boot section and block the screen; on the other hand, if the screen is to travel with the upstream screen ascending, then a velocity component in the opposite direction of the bypass would be created, which would counter the objective of fish guidance to a bypass.

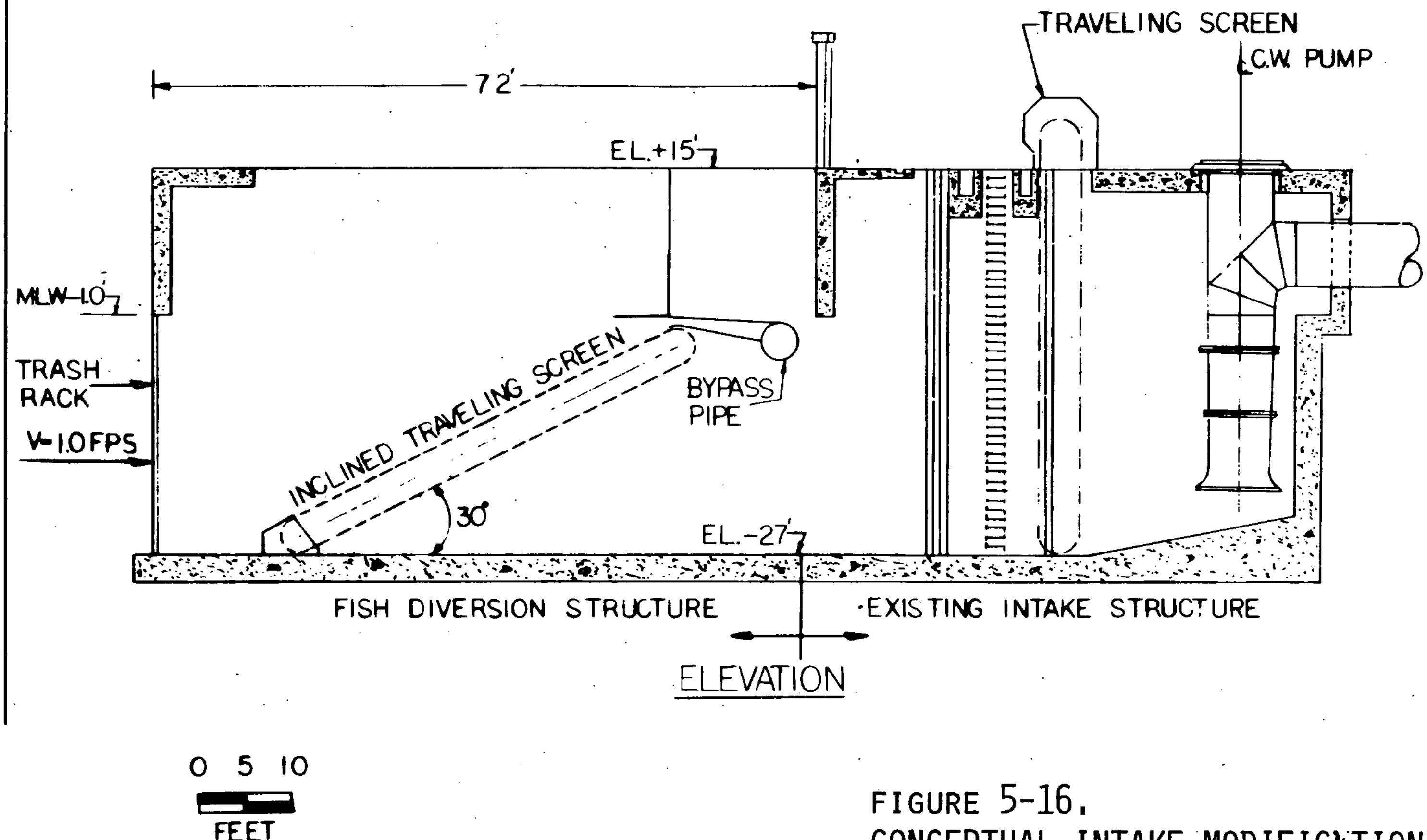
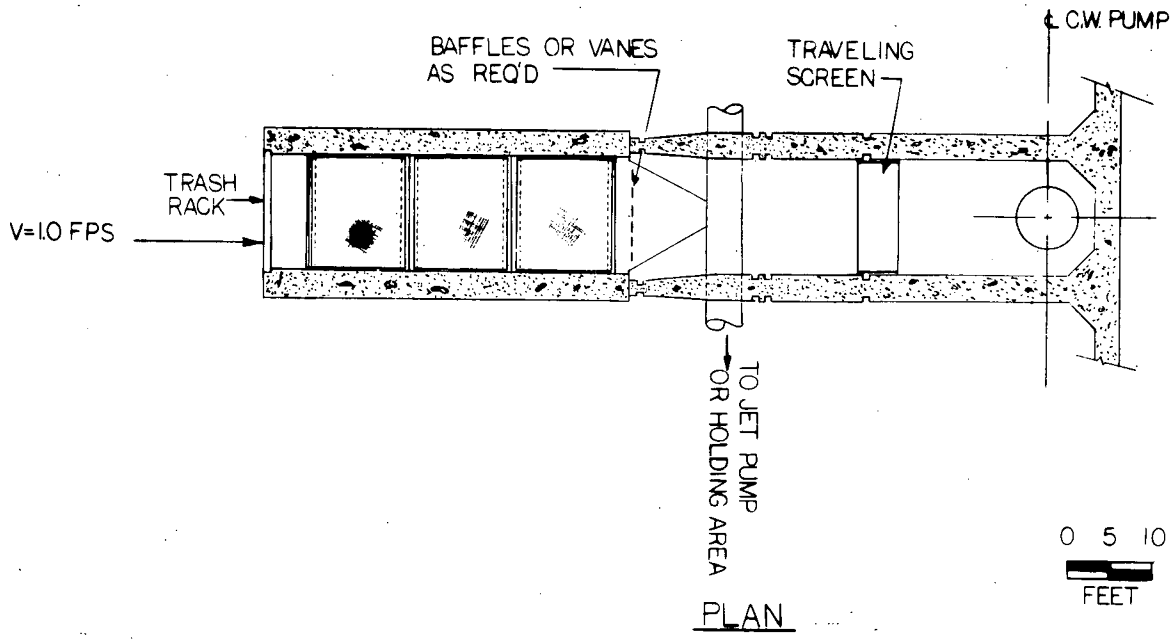


FIGURE 5-16.
CONCEPTUAL INTAKE MODIFICATION,
INCLINED SUBMERGED TRAVELING SCREEN,
INDIAN POINT GENERATING STATION

INDIAN POINT FLUME STUDY
CONSOLIDATED EDISON CO. OF NEW YORK, INC.
STONE & WEBSTER ENGINEERING CORPORATION



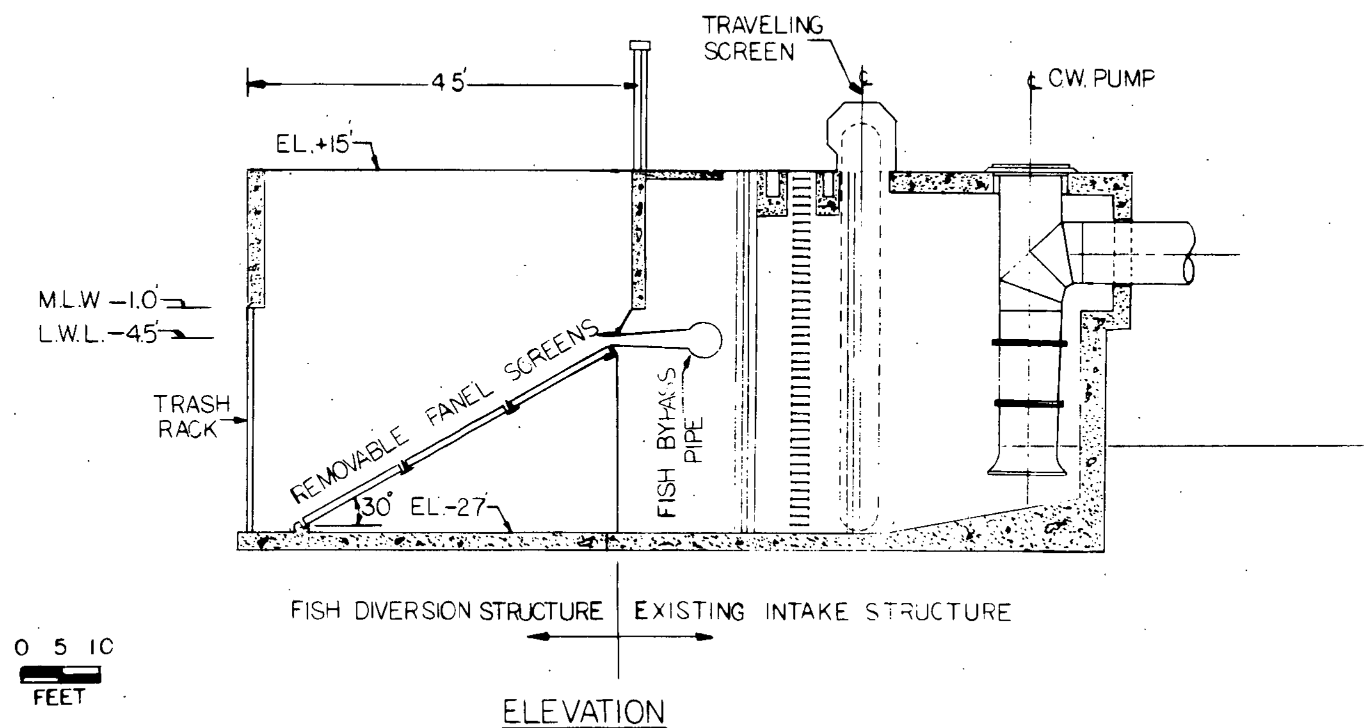


FIGURE 5-17.
CONCEPTUAL INTAKE MODIFICATION,
INCLINED SUBMERGED FIXED SCREEN,
INDIAN POINT GENERATING STATION

INDIAN POINT FLUME STUDY
CONSOLIDATED EDISON CO. OF NEW YORK, INC.
STONE & WEBSTER ENGINEERING CORPORATION

Figure 5-18 shows an inclined submerged fixed screen which could be cleaned by mechanically operated brushes. The brushes would move up the screen on a belt or chain assembly. Fish would be guided to a trough at the top of the screen. This concept requires a constant water level over the screen which could be maintained by a sluice gate at the entrance of the bay. Controlling the water surface at a constant level is difficult, since the gate opening should be changed with the river water levels. At the high water elevation of 7.4 feet MSL, it would be necessary to dissipate about 12 feet of head. This would result in a gate opening of about 1.5 feet and a velocity under the gate of 17 fps. This concept is not, therefore, considered practical.

5.3 LIFT BASKET COLLECTION SYSTEM

A lift basket collection system, similar to the type used to remove fish from bypass collecting areas at several West Coast installations, has been suggested for use within the intake bays at Indian Point. Such an application has never been investigated in the past, but is incorporated in the present study program. The following is a review of the literature pertaining to the conventional bypass lift basket application and prototype considerations of screen bay application.

5.3.1 Literature Review

The Tracy and Delta Fish Protection Facilities and the proposed San Onofre Station fish retrieval system have been discussed earlier in this section. All three installations have, or plan to utilize, lift basket systems for removing fish which have been diverted to collecting areas by louvers. Two designs are shown on Figures 5-19 and 5-20. For application in a screenwell bay, the design would have to be similar to that studied by Schuler (1973; see also Downs and Meddock, 1974), and proposed for the San Onofre Station (Figures 5-20 and 5-21). With this lift basket design, bypass water flows in a channel to a collecting and holding chamber. Upon entering the chamber, the flow separates around a baffle wall with equal clearing on each side. The flow then passes through the chamber and exits through a screen. Fish collect in the quiescent area behind the baffle wall. When a specified number of fish have accumulated, the lift basket, normally located at the bottom of the chamber, is lifted to the surface and the fish are released to a sluice or trough.

This design proved successful in model tests and is considered a safe and effective method of removing fish from a collecting area. Possible application to a screenwell bay in relation to engineering feasibility is discussed in the following section.

5.3.2 Prototype Considerations

The most important consideration would be the effect of the lift basket on the pumps downstream. The baffle wall would cause high velocities near the side walls of the intake bay and result in non-uniform flow patterns approaching the pumps. This could be remedied by placing the lift basket at a further distance upstream or by using baffles or guide vanes downstream to achieve uniform approach velocities to the pumps.

Figure 5-22 shows a conceptual arrangement of a lift basket installed in the bays upstream of the existing intake bays. The backlift structure would protrude only about 30 feet into the river. However, during construction, pumping through the bay under construction would be interrupted.

5.4 UNDERWATER WALL

Due to an abundance of Atlantic tomcod in the impingement samples taken at Indian Point, it has been suggested that an underwater wall, or bottom sill, be utilized to prevent the passage of this benthic dwelling species into the intake structures. Although very little has been published on the effectiveness of such a structure, it is possible that the concept warrants further investigation. The following is a review of the available literature pertaining to bottom sills.

5.4.1 Literature Review

Various authors have suggested that at least a partial solution to the problem of excluding fish from power plant intakes may lie in the withdrawal of water from selective depths of the water column. To date, the selection of the proper location for water intakes has been based upon engineering requirements (EPA, 1973). For example, surface skimmer walls extending several feet into the water are often incorporated into shoreline intakes to prevent the passage of ice and debris into the intake screenwell and to seal that structure from cold air intrusion. Skimmer walls are also used to draw cooler water from lower depths, particularly where the potential for warm discharge water recirculation exists.

At offshore intakes, the submerged structure is often elevated several feet off of the bottom, effectively creating a bottom sill. Such a design is generally a product of construction and operational requirements. The primary reason for providing a sill at offshore intakes, particularly at coastal sites, is to prevent the entrance of sand and other fine material which pass the structure as a result of littoral drift. Although there is no published information on the possible effect of a raised intake on the entrapment of bottom dwelling fish, primary information from power plants operating with this type of intake structure do not suggest that the bottom sill is highly

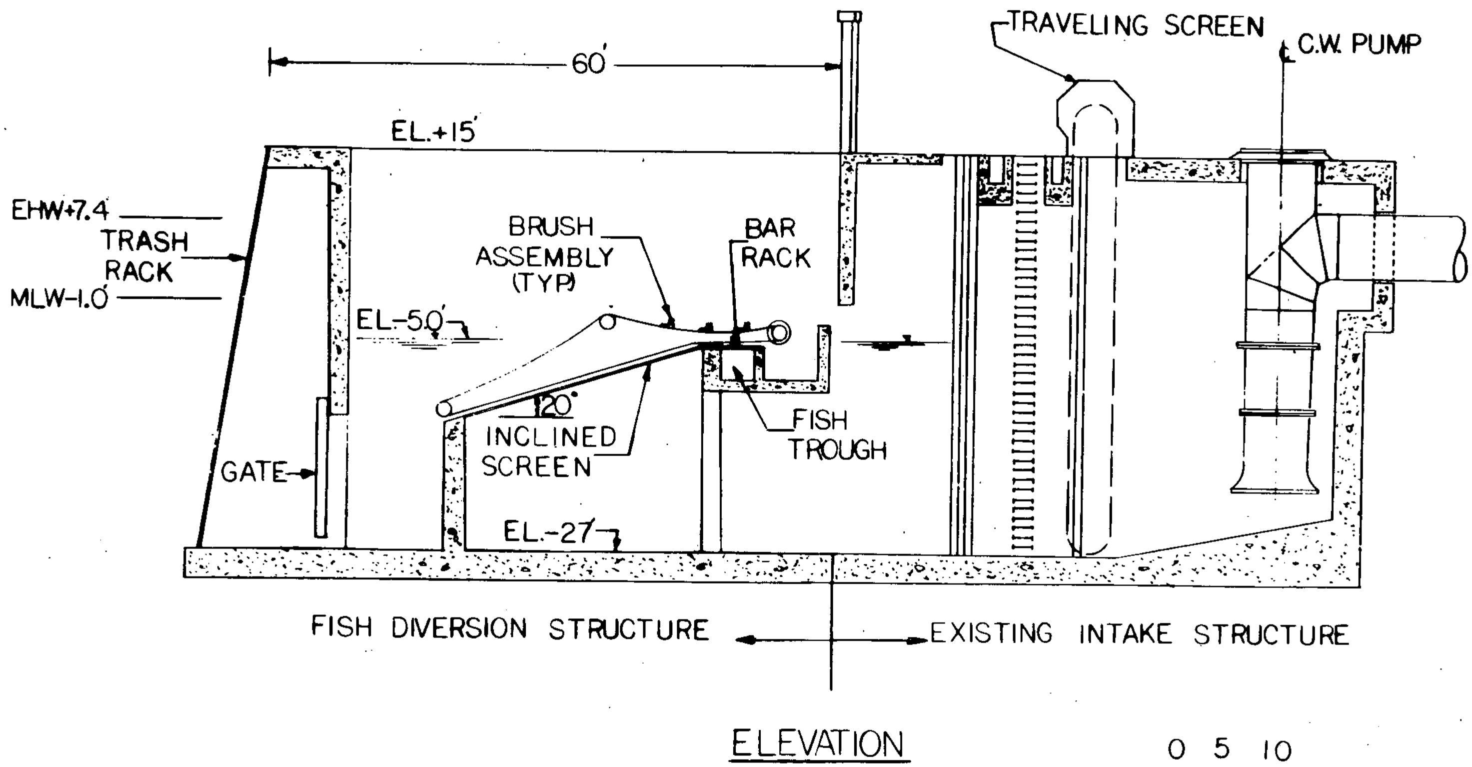


FIGURE 5-18.
CONCEPTUAL INTAKE MODIFICATION,
INCLINE SUBMERGED SCREEN WITH BRUSH ASSEMBLY,
INDIAN POINT GENERATING STATION

INDIAN POINT FLUME STUDY
CONSOLIDATED EDISON OF NEW YORK, INC.
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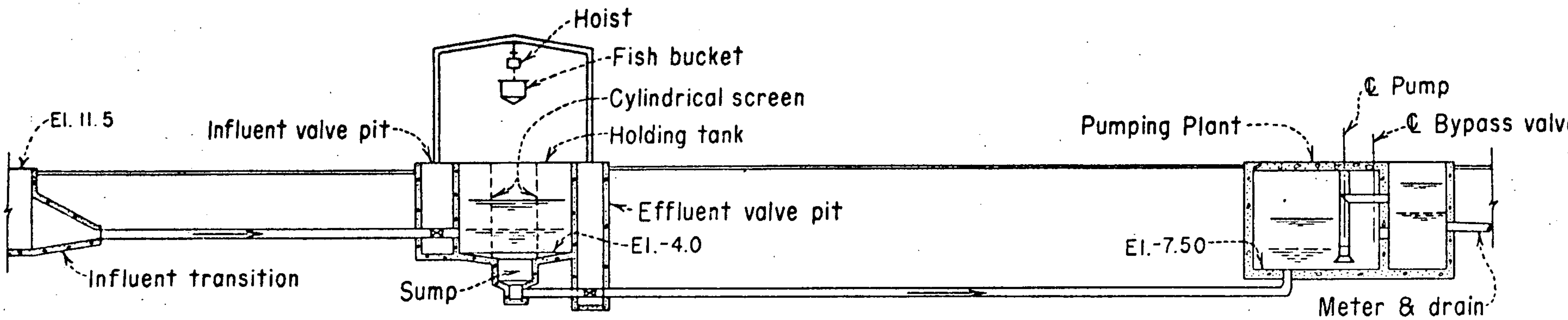

FIGURE 5-19.
SECTION THROUGH THE TRACEY PUMPING PLANT
BYPASS LIFT BASKET COLLECTION SYSTEM
(BATES, LOGAN & PERSONEN, 1960)

INDIAN POINT FLUME STUDY
CONSOLIDATED EDISON CO. OF NEW YORK, INC.
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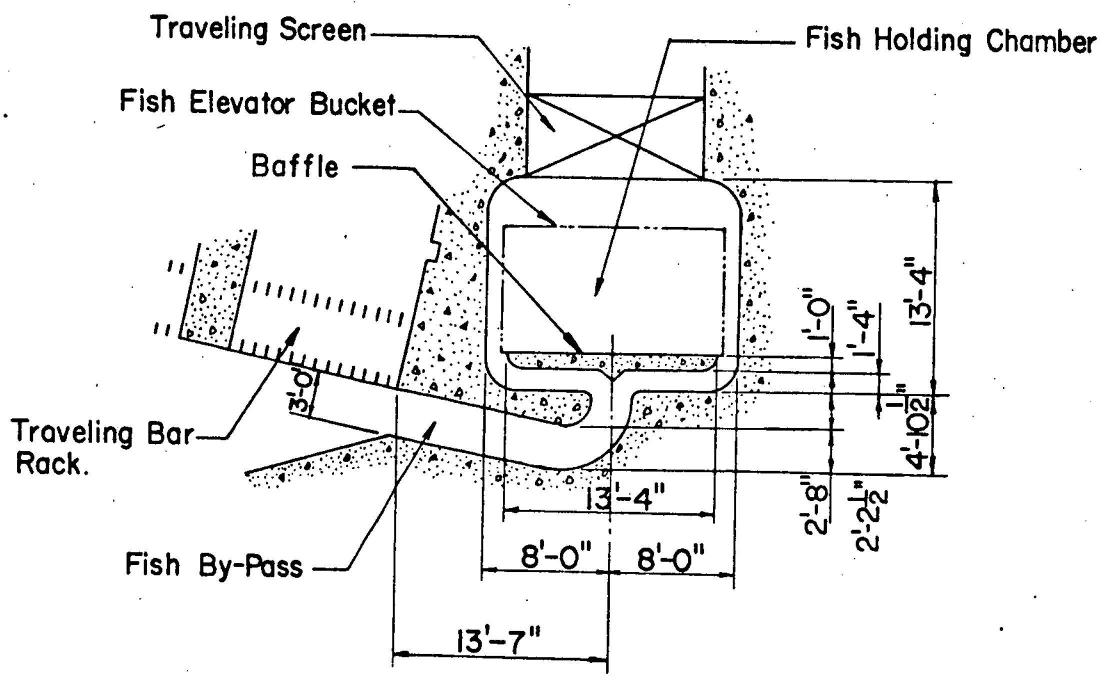

FIGURE 5-20
FISH BYPASS AND HOLDING CHAMBER
(DOWNS & MEDDOCK, 1974)

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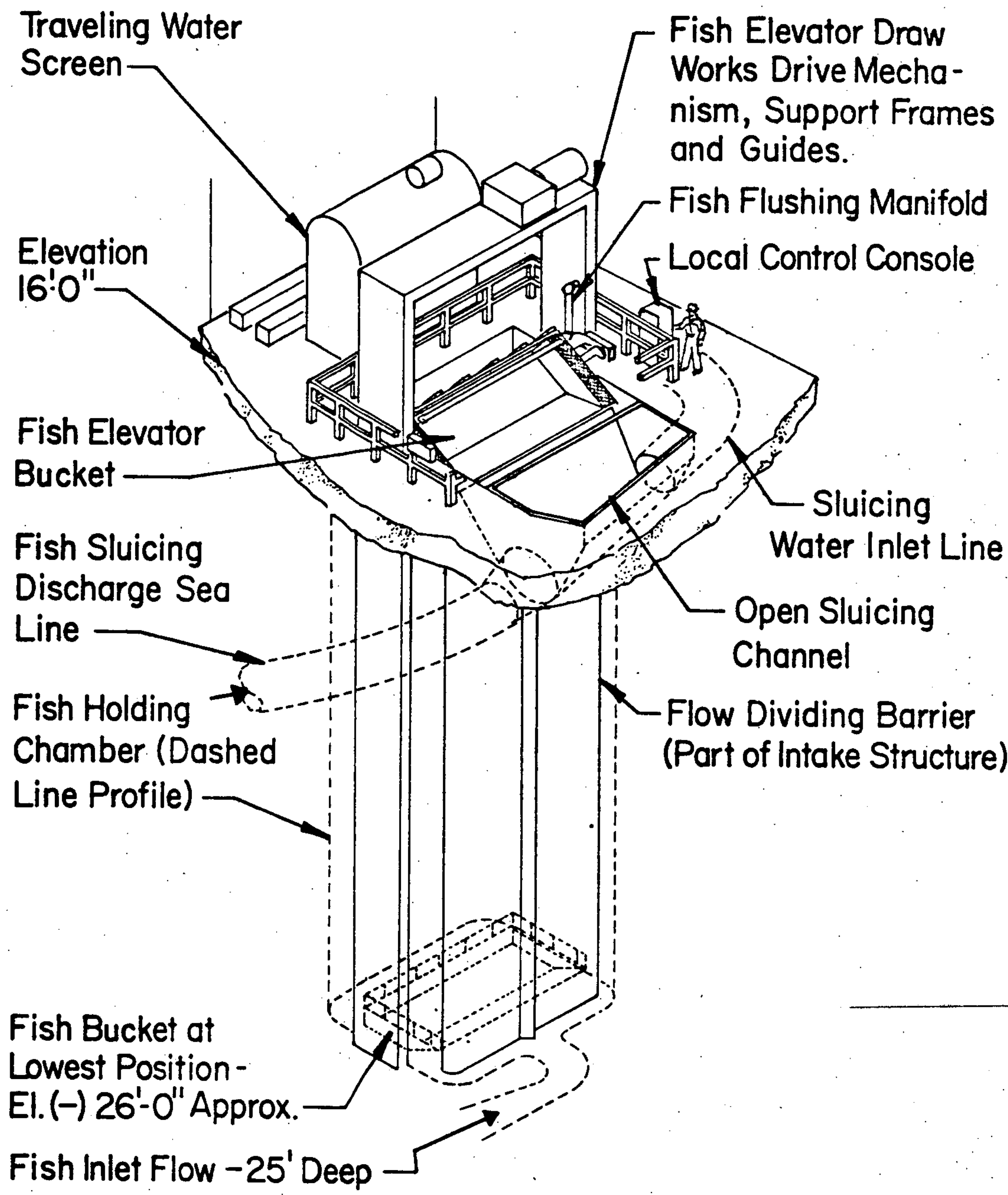

FIGURE 5-21
FISH REMOVAL ELEVATOR
AND SLUICING CHANNEL
(DOWNS & MEDDOCK, 1974)

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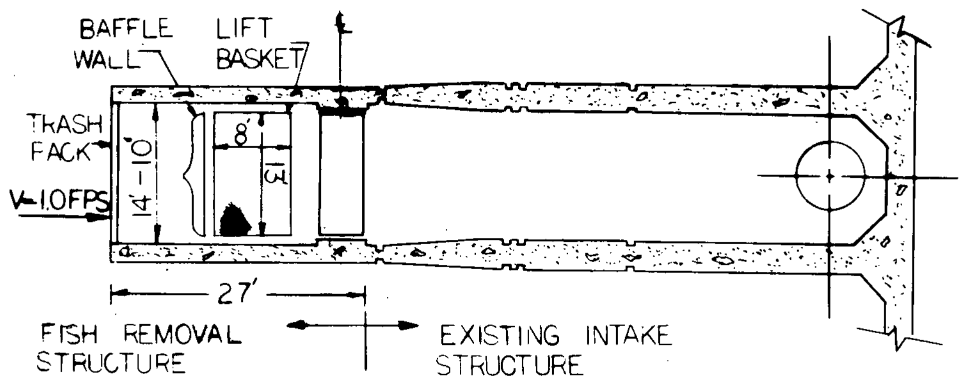
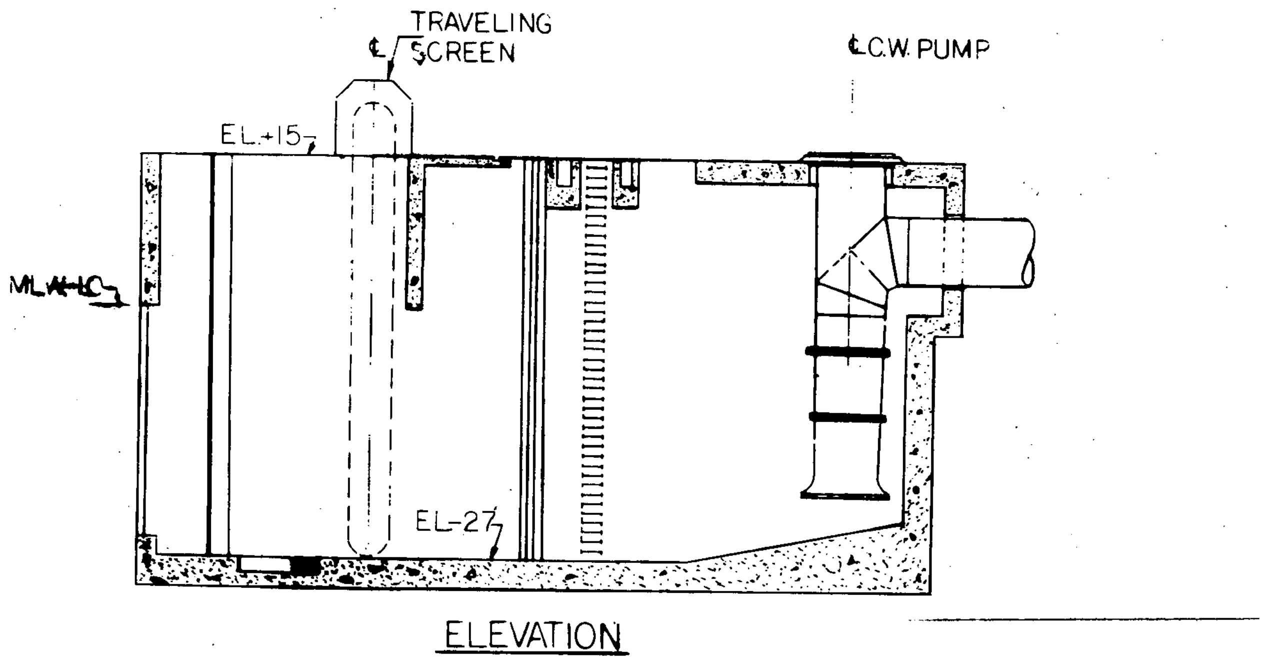


PLAN



ELEVATION

FIGURE 5-22.
CONCEPTUAL INTAKE MODIFICATION,
SCREENWELL BAY LIFT BASKET,
INDIAN POINT GENERATING STATION
INDIAN POINT FLUME STUDY
CONSOLIDATED EDISON CO. OF NEW YORK, INC.
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effective. It is possible, however, that increasing the height of the sill could reduce the entrapment of these fish.

There is also no information published on the design or effectiveness of an underwater wall of the type proposed for Indian Point. Such walls have been suggested for utilization at several power plants on the East Coast to block the passage of bottom dwelling fish, such as flounder. However, studies have not been conducted to evaluate their effectiveness.

As a result of studies conducted by the Massachusetts Division of Marine Fisheries (Fairbanks, et al, 1971), a 9-foot sill has been recommended for installation at a power plant on the Cape Cod Canal. The sill is designed mainly to prevent the entrance of winter flounder into the intake screenwell. An evaluation of the sill is planned, but data are not available to date.

Due to the lack of information on the design and potential effectiveness of an underwater wall in alleviating the entrapment of bottom dwelling fish, an evaluation of this device will not be conducted during the present flume study. It is not believed that the depth of the test flume would allow an adequate evaluation of an underwater wall. Such an evaluation should be, and is presently being conducted on a prototype scale at the Indian Point – Unit 1 intake (J. Cianci, Con Edison, personal communication).

5.5 AIR BUBBLE CURTAIN

An air bubble curtain has been suggested for study during the present program. The following is a discussion of past experience with air bubbles used to minimize fish entrapment and impingement, and the potential for application at Indian Point.

5.5.1 Literature Review

Based upon the literature, it is evident that the effectiveness of an air bubble curtain in diverting fish from water intakes is highly variable. Positive response to an air bubble curtain is species specific and is greatly effected by water temperature, turbidity, flow velocity, ambient light level, and the type of bubble array produced.

The Lake Michigan Intake Committee (1973) reports that an air bubble curtain has been used to divert large schools of alewives away from the intake structure of a Lake Michigan power plant.

Smith (1961) obtained good results when using air bubbles to direct sardines to a seineable location in Maine.

Kupfer and Gordon (1966) reported that an air bubble curtain impeded the movement of alewives in their spawning migration up the Milwaukee River. However, the effectiveness of this particular system was biased due to the river width, strong currents, and the fact that no alternative passage for the alewives was present.

Bibko et al. (1972) found an air bubble screen to be equally effective in preventing fish passage in a flume under light and dark conditions. Prior to this work, it had been believed that the effectiveness of bubbles was dependent on visual perception, and that curtains would block fish passage only in daylight or when artificially lighted. The researchers also found that bubble curtain effectiveness is effected by water temperature. At 52°F, passage of young striped bass (80 to 250 mm) was blocked by the air curtain. However, at 33.5°F, the bass became lethargic and moved passively through the bubbles. Similar results were noted for gizzard shad (300-to-400 mm), except that the critical lower temperature was 40°F.

In addition, the researchers found that the spacing of the air holes has an important influence on curtain effectiveness. In all cases, air was supplied to a 0.75-inch PVC pipe with 1/32-inch holes drilled at 1-inch intervals. When a 2-inch opening was left in the curtain, fish were observed to move along the bubbles to the opening which they then passed through. Therefore, it appears that a 1-inch spacing is the maximum for curtain effectiveness.

The most meaningful studies conducted which are applicable to Indian Point are those which have been conducted at that site since the summer of 1972. At that time, two arrays of seven horizontal headers placed at seven different depths were installed in front of one bay of Unit 1. A maximum air flow of 400 cfm was supplied to the headers and exited through 0.03-inch holes spaced 0.5-inch apart.

A similar arrangement was later installed at Unit 2 and was tested in the winter of 1973. In this case, the 0.03 inch vent holes were located 1-inch apart.

Results of sampling at Unit 1 indicated that the air bubble curtain had little effect during the daytime and may have caused an increase in impingement at night. At Unit 2, it was found that impingement varied relative to the length of time that the air curtain was in operation. This may have been due to the fact that impinged fish were removed from the screens by the bubbles and carried back to the river, and were not, therefore, counted.

In conclusion, results at Indian Point indicate that an air bubble curtain placed directly in front of screens is not significantly effective in reducing fish impingment. It is possible, however, that angling the bubble curtain to the flow such that it leads fish to a bypass or refuge area could increase the effectiveness of this system, as discussed later.

5.6 CONCLUSIONS

On the basis of the literature review and an evaluation of prototype design considerations, the proposed test devices have been ranked according to their potential for application at Indian Point and Cornwall.

Angled screens and louvers have been given top ranking and will receive primary attention. As discussed in the following section, these devices will be tested simultaneously during the study program.

Angled screens are believed to offer a better solution to the problem of fish impingement than louvers at Indian Point, or other power plant sites, for the following reasons:

(1) In recent studies, screens have been found more effective in diverting fish than louvers.

(2) Where fine-screening is required for the protection of condenser tubing, louvers would require backup screens to remove fish and debris, which pass through the louver slats, thus increasing the cost of the installation. Since screens act as both a screening medium and a guidance device, only one structure is required.

(3) In a louver or screen system, there is the possibility that fish traversing the structure may momentarily lose their orientation to the flow due to turbulence. This disorientation would be likely to cause a fish to be swept through a louver system. However, since the fish cannot pass through a screen, temporary impingement may result, but if low velocities are provided, the individual can swim off the screen and continue its traverse to the bypass. This reaction has been observed repeatedly during tests at ARL where the test fish were forced against the screen by a net (Stone & Webster, 1975). In every case, when the net was removed, all fish swam off the screen and resumed their normal swimming behavior.

(4) Finally, with any diversion device, there is the possibility that its effectiveness will be species specific and cannot be designed to guide all species of concern. With a louver system, species which are not guided effectively will pass through the louver and become impinged on the backup screens. With an angled screen system, fish which are impinged could be washed off the screens gently and sluiced to the bypass.

Although angled screens offer the above advantages over louvers for application at power plant sites, louvers have also been assigned top ranking for possible application at Cornwall. At a pumped storage facility, fine screening may be unneccessary and the cost of screens at such a large facility would make louvers a more economical solution to fish entrapment problems.

Should angled screens and louvers prove less effective in diverting fish than desired, a screenwell lift basket system will be evaluated. As discussed in the following section, a preliminary evaluation of the effectiveness of a lift basket will be conducted in the flume bypass collecting area in conjunction with louvers and screen testing.

The lowest ranked device is an inclined plane louver or screen leading to a surface bypass. Since such devices have not been developed for application at power plant intakes, they will be tested only in the event that all other devices proved to be ineffective.

As previously discussed, an evaluation of an underwater wall in the test flume would not provide an adequate assessment for applicability at Indian Point, and will not, therefore, be tested during the study program.

Finally, it is evident that an air bubble curtain should not be tested as an individual diversion device. However, this device can be evaluated in conjunction with the most effective device to improve overall system efficiency, if deemed necessary.

SECTION VI

PROPOSED STUDY PROGRAM

6.1 INTRODUCTION

The flume testing will proceed according to the ranking of the test devices discussed in Section V. The statistical methods which will be applied in data analysis and the details of the test devices and procedures, to be employed during the study program, are discussed below.

6.2 TEST FLUME DESIGN

The test flume layout was developed by Con Edison, ARL and S&W and is designed to allow the flexibility necessary to incorporate any or all of the devices proposed for the study. ARL designed and constructed the flume. A detailed description of the flume and its hydraulic characteristics will be discussed in a separate report by ARL. The following is a brief description of the flume as it relates to the fish testing program.

Figure 6-1 shows a plan view of the flume. The overall length is 80 feet and the depth is 7 feet. Three sections are designated: a 39-foot-long by 6-foot-wide approach section in which the flow will be straightened to achieve a uniform flow distribution and to introduce the fish; a 24-foot-long by 12-foot-wide test section to install the fish diversion test devices and bypass, and an 8-foot-long by 7-foot-wide fish collection area to test a lift basket system. The flow through the flume is a closed-loop system. A 42-inch bow thruster powered by a 300-hp marine engine drives the flow. Velocities up to 3 fps in the approach section and a 1:2 approach to bypass velocity ratio can be attained. The flow through the test device and the bypass will be controlled by adjustable gates.

6.3 DATA ANALYSIS

The first phase of the study program involved a ranking of the potential effectiveness and feasibility of the various fish diverting devices for the Indian Point site (Figure 6-2). The ranking is based on the potential efficiency of each device from a biological perspective and the engineering problems associated with prototype design. The information necessary for this initial evaluation was obtained from a survey of previous studies, experience gained by S&W from other biological studies and engineering studies of fish diversion devices, as discussed in Section V. The result of the initial analysis is the ranking of the diverting devices for their potential effectiveness.

The devices which have been ranked most feasible (louvers and screens) will be tested in the second phase of the program. The test efficiencies will constantly be evaluated relative to efficiencies predicted from previous experience or testing.

The testing plan will maximize the necessary flexibility in engineering design, but maintain the rigor necessary for statistical analysis of the data. The species of fish to be tested are sequentially available, one after the other. Therefore, simultaneous testing of all species for each engineering design is not an efficient strategy. Since time is the most limiting aspect of the program, another testing strategy has been chosen to allow more flexibility in the available time (Figure 6-3).

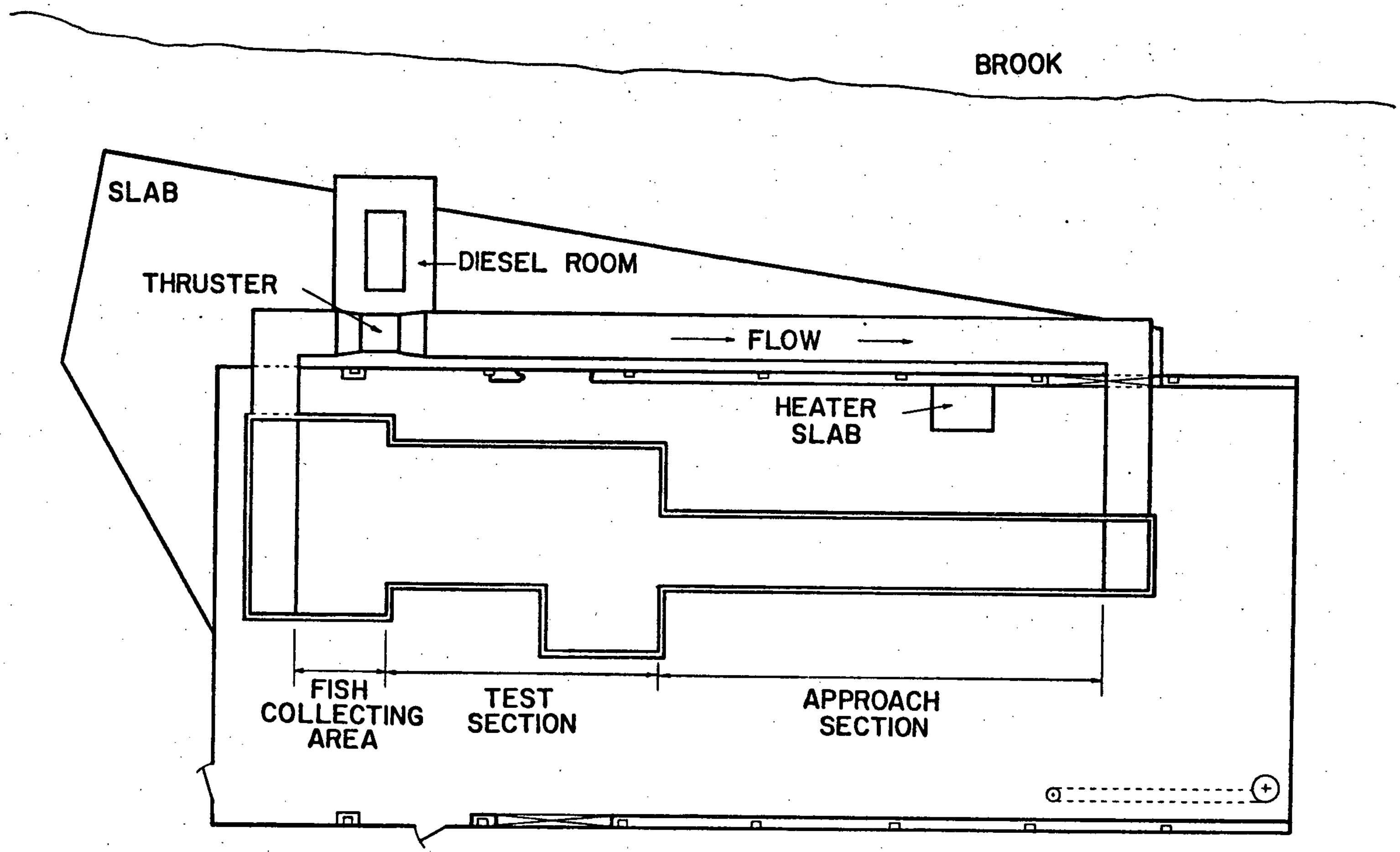
The basic strategy will be to predict the efficiency of each test based on previous tests and to investigate the statistical significance of the prediction. The hypothesis will generally be, "the new test is expected to give a greater efficiency than the previous test." This hypothesis may be tested by a contingency table analysis. The progression of engineering designs will then be based on the most recent information rather than a fixed plan established at the begining of the program.

Due to the variable nature of the physical environment in which the fish live it will be necessary to establish the effect of changing environments on the test results. Therefore, during the testing for each species several controlled factorial experiments for one engineering design will be conducted. The experimental design for this factorial testing will be fixed before any testing begins. The design will consist of fixed effects which can be controlled, such as light or darkness, and continuous effects which can not be controlled, such as water temperature. These factorial experiments can be analyzed by an analysis of covariance where test efficiency is the dependent variable. A transformation of the data may be necessary due to the non-normal distribution of percent data.

These factorial experiments for the effect of the physical environment on test results will be conducted when each species becomes available and near the end of the availability of each test species. Additional factorial experiments will be conducted as necessary.

This testing strategy will allow a comparision of the first and last factorial experiment for each species to further evaluate the effect of changes in engineering design on the efficiency. The factorial experiment conducted with the same engineering design at the end of the availability of one species and the begining of the availability of the next species will test for between species variability in the response to the diverting device.

The factorial experiments will provide the most powerful test of the efficiency of the diverting device as it enables the



FISH FLUME TEST FACILITY

[COURTESY OF ALDEN RESEARCH LABORATORIES]

FIGURE 6-1.
PLAN VIEW OF TEST FLUME
INDIAN POINT FLUME STUDY
CONSOLIDATED EDISON CO. OF NEW YORK, INC.
STONE & WEBSTER ENGINEERING CORPORATION

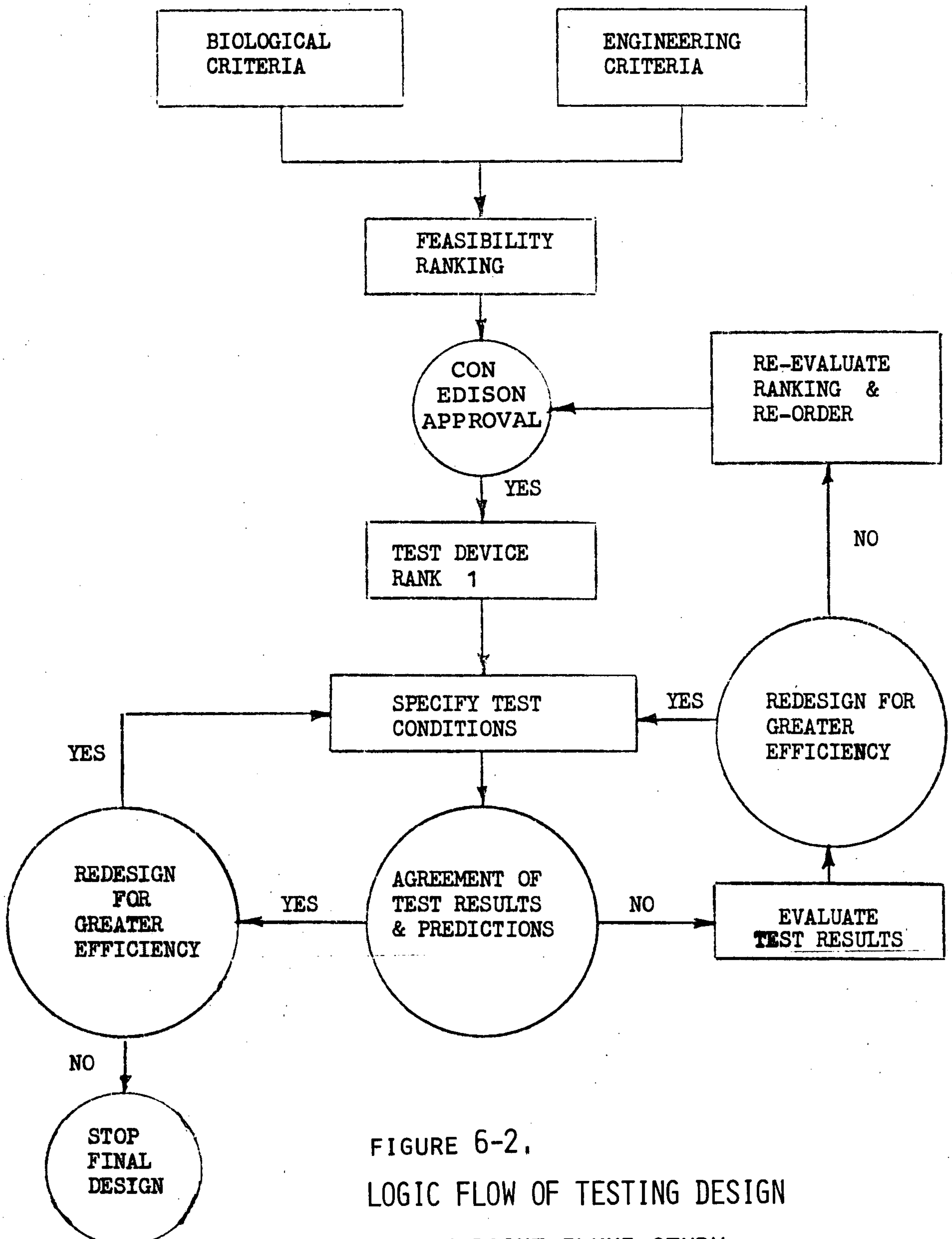


FIGURE 6-2.

LOGIC FLOW OF TESTING DESIGN

INDIAN POINT FLUME STUDY
CONSOLIDATED EDISON CO. OF NEW YORK, INC.

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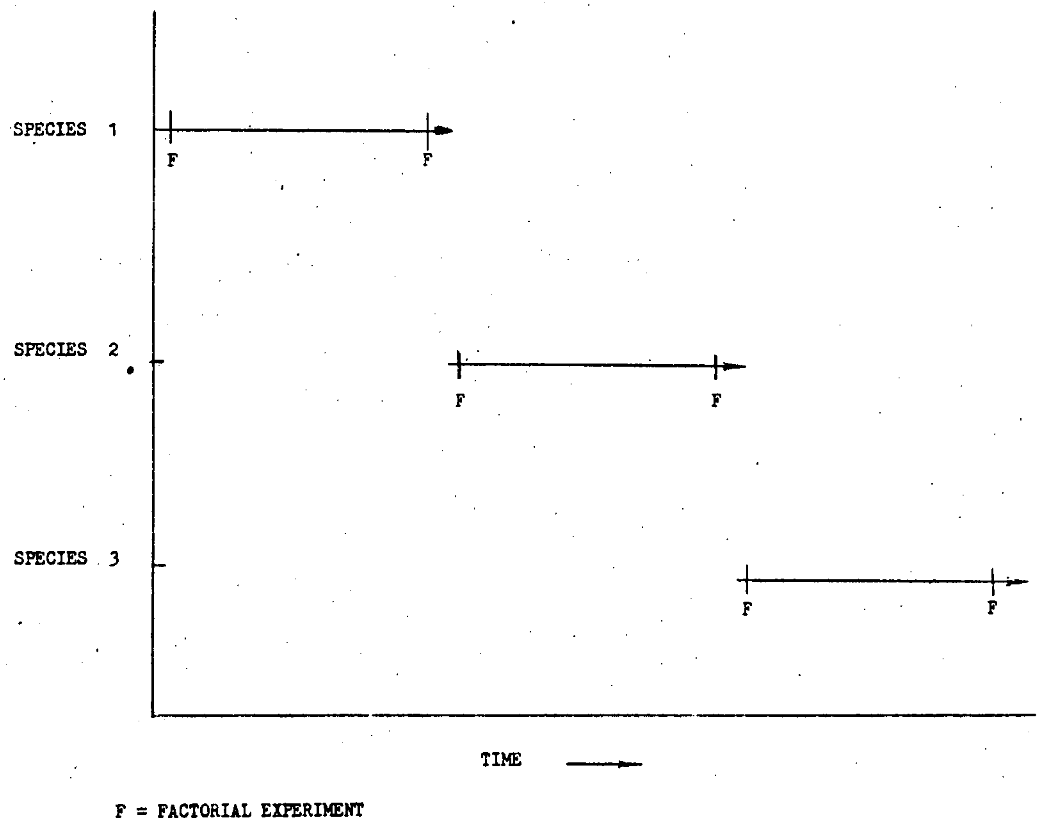

FIGURE 6-3.

SCHEDULE OF FACTORIAL EXPERIMENTS

INDIAN POINT FLUME STUDY
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experimental variability to be partitioned into environmental effects, species effects and diverting device effects. The contingency table analysis however, provides the flexibility necessary to test many engineering designs in the limited time available but maintains statistical rigor in the experimentation. The factorial experiments provide additional statistical rigor by investigating environmental and biological factors affecting the efficiency of each device.

Figure 6-2 contains the basic logic for the testing outlined above. The data resulting from the testing will be computerized in specified format. The contingency table analysis will be completed following each test. The factorial experiments will be analyzed after their completion.

6.4 TEST DEVICES

As previously discussed, the test devices proposed for study have been ranked for potential effectiveness at Indian Point on the basis of a literature review and prototype considerations. Although all devices may not be tested, each is discussed below and the testing will proceed according to the logic flow diagram shown in Section 6.3. The test schedule is discussed in Section 6.7.

6.4.1 Angled Vertical Screens or Louvers

Vertical traveling screens angled to the flow have been assigned top ranking for this study. As discussed in Section V, such a device has proven very effective in guiding fish to a bypass, and offers several engineering design advantages over other structures.

The proposed initial test structure and parameters are shown in Figure 6-4. Although past studies with louvers have shown that an angle of about 10 degrees to the flow is most efficient in guiding fish, an initial test angle of 25 degrees has been chosen for the present study for two reasons: first, a larger angle is more desirable from a prototype design viewpoint since the length, and, hence, the cost, of an angled device decreases as the angle is increased. Second, in studies presently being conducted by Stone & Webster Engineering Corporation, an angle of 25 degrees in a small-scale model has proven highly effective in diverting alewives, smelt, striped bass and tomcod. Therefore, screen testing will begin at a 25 degree angle with an equal approach and bypass velocity of 1 fps and a bypass width of 6 inches.

The angled screen frame assembly will include all of the pertinent prototype details, such as horizontal and vertical support plates, bars and braces, and the trash-lifting lip as designed by a leading screen manufacturer (Envirex, Figure 6-5). The effect of these structural members is to decrease the gross open area by 20 to 25 percent. Therefore, these details will be included to ensure the proper simulation of flow patterns along the face of the screen, as well as losses through the screen.

Angled traveling louvers have also been assigned top ranking for this study. The test flume has been designed such that both screens and louvers can be tested interchangeably under similar conditions. This will allow a comparative evaluation of the effectiveness of the two structures.

The proposed initial louver test arrangement is also shown on Figure 6-4. On the basis of past studies, an initial louver angle of 25 degrees and louver slat spacing of 1 inch have been chosen. The louver array will be constructed in three two-foot-high sections which can be installed in the flume, one on top of the other, to give a total height of six feet. Louver slat spacing will be varied by installing in prefabricated frames, the number of slats necessary to obtain the required spacing.

The louver slats will always be orientated normal to the angle of the louver line, as recommended by screen manufacturers to permit effective cleaning. Initially, each slat will be 1/4-inch thick by 2-inches deep, and will be constructed of wood (Figure 6-6).

6.4.2 Lift Basket Collection System

As discussed in Section V, a lift basket collection system has proved effective in removing fish from a bypass collecting area. The concept of utilizing such a device in a screenwell bay has never been investigated. Therefore, a twofold approach will be taken in evaluating the lift basket for application to both situations.

Initially, the lift basket will be tested in the flume bypass collecting area, as shown in Figure 6-7. Early in the test program, a baffle wall will be installed in this area to determine whether the test fish will collect behind it. If this is found to be the case, then a lift basket will be placed at the bottom of the collection area and its effectiveness in removing fish will be determined. Should the basket prove to be effective, it will be used to remove bypassed fish throughout the study program. Further, successful operation in the bypass will indicate that the lift basket could provide a potentially effective means of collecting, and removing fish from a screenwell bay. In this case, the lift basket will retain its secondary ranking and will be considered for study in the event that louvers and screens do not achieve the level of effectiveness anticipated. While a final lift basket test design will depend upon results of the bypass evaluation, a conceptual design for flume testing is shown on Figure 6-8.

If the bypass lift basket design proves unsuccessful, then an alternative method of collecting bypassed fish in the test flume

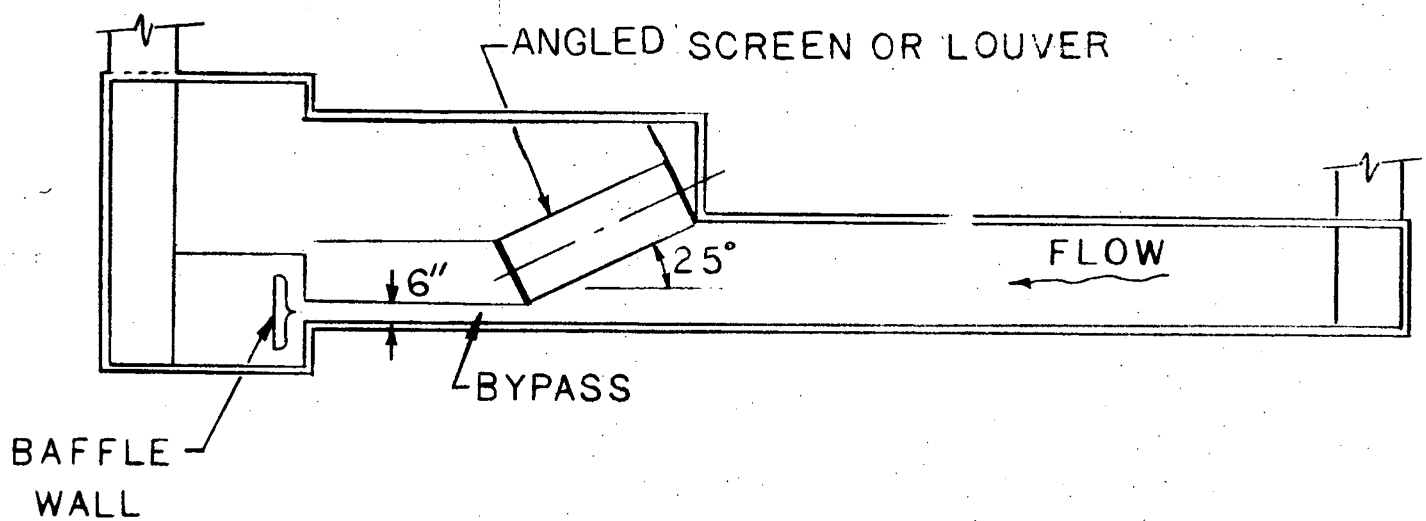

FIGURE 6-4.

INITIAL ANGLED SCREEN OR LOUVER
TEST ARRANGEMENT

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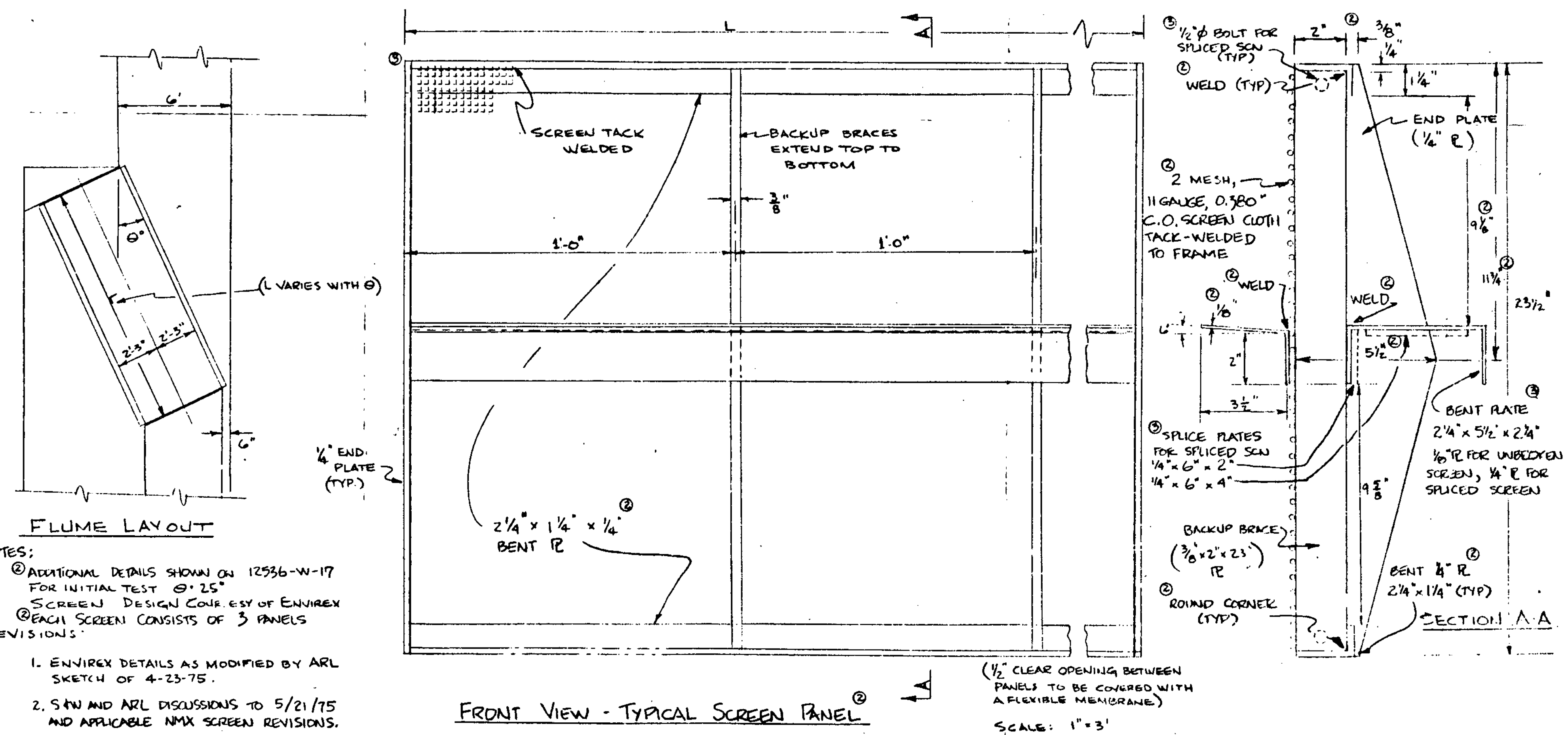

Notes:
② Additional details shown on 12536-W-17 for initial test θ = 25°
Screen design courtesy of Envirex
③ Each screen consists of 3 panels

Revisions:

1. Envirex details as modified by ARL sketch of 4-23-75.
2. S&W and ARL discussions to 5/21/75 and applicable NMX screen revisions.
3. Spliced screen concept for 3 θ values.

FIGURE 6-5.

DETAILS OF ANGLED SCREEN

INDIAN POINT FLUME STUDY
CONSOLIDATED EDISON CO. OF NEW YORK, INC.

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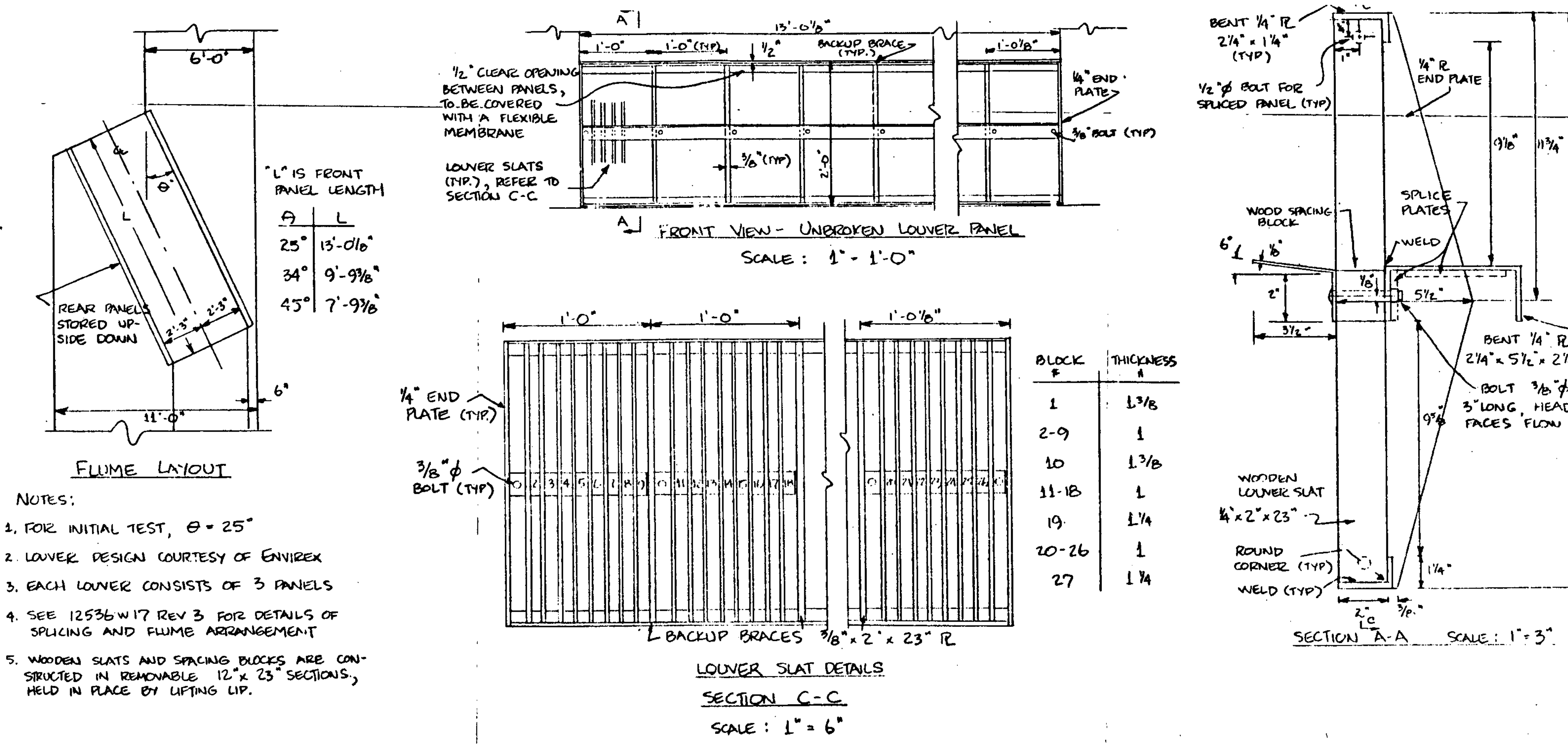

FIGURE 6-6.

DETAILS OF ANGLED LOUVER

INDIAN POINT FLUME STUDY
CONSOLIDATED EDISON CO. OF NEW YORK, INC.

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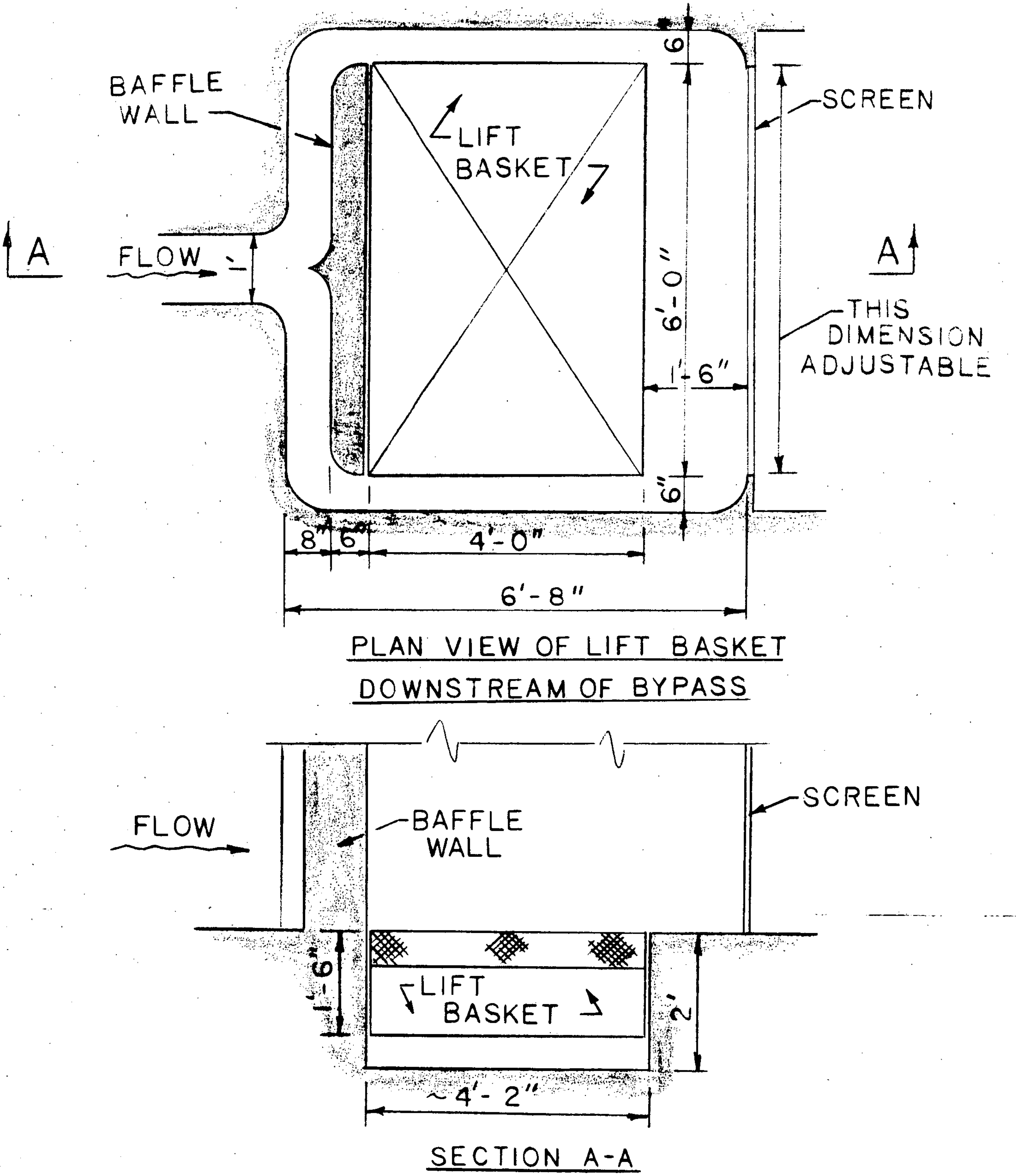

FIGURE 6-7.
BYPASS LIFT BASKET SYSTEM
INDIAN POINT FLUME STUDY
CONSOLIDATED EDISON CO. OF NEW YORK, INC.
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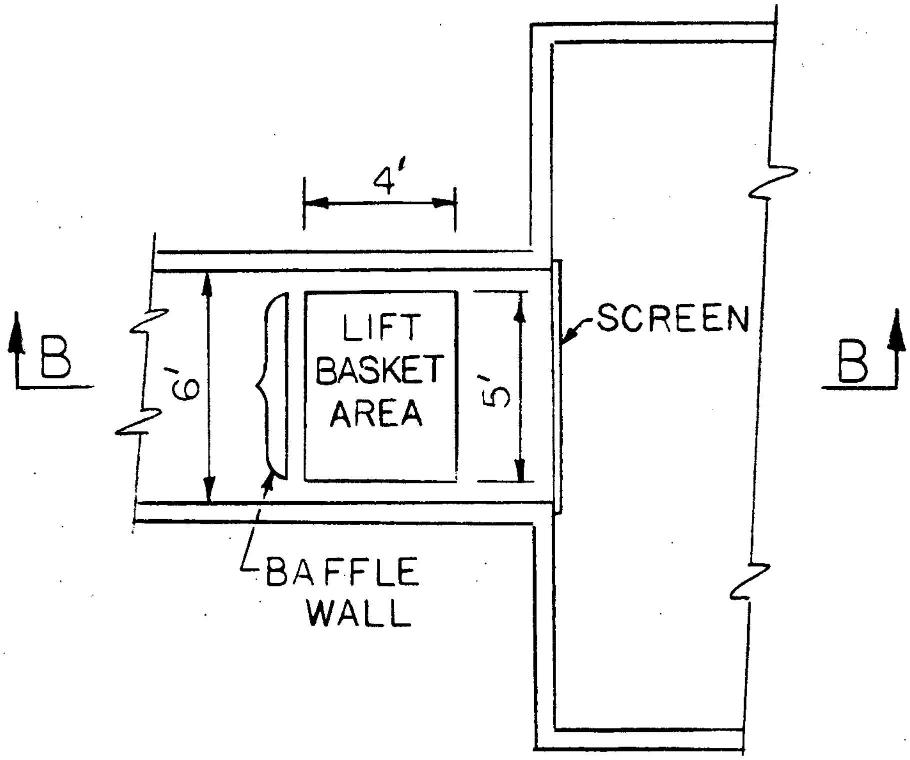
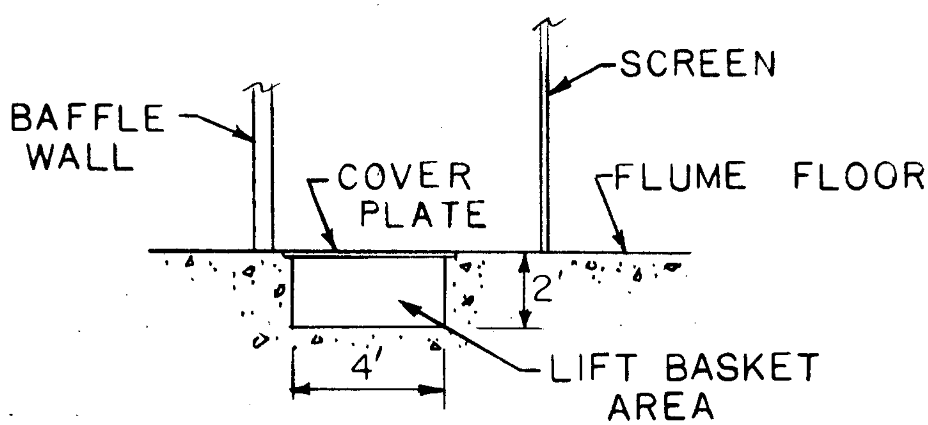


PLAN VIEW OF LIFT BASKET
IN MAIN FLUME



SECTION B-B

FIGURE 6-8.

SCREENWELL BAY LIFT
BASKET TEST DEVICE

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will be developed and the potential effectiveness of a screenwell bay lift basket collection system will be reevaluated, and the basket may be dropped from consideration.

6.4.3 Inclined Plane Louvers and Screens

A possible arrangement of an inclined plane diversion test device is shown on Figure 6-9. Since such structures have not been developed for use at power plants, it is not possible to show a detailed design at this time. Should other higher ranked devices prove less effective than desired, thereby necessitating testing of an inclined plane screening device, screen manufacturers will have to be consulted for the details of feasible prototype arrangements.

6.4.4 Air Bubble Curtain

On the basis of the literature and on results of an evaluation at Indian Point, it has been agreed that an air bubble curtain will not be tested as an individual diversion device during the present study. However, air bubbles might be tested in conjunction with the most effective device to improve overall system efficiency. For example, as shown on Figure 6-10, an air bubble curtain could be placed upstream of a vertical louver or screen system in order to evaluate its effect on the distribution of fish in the approach channel.

The probability that a fish will enter the bypass is directly related to its horizontal position in the water column; that is, fish moving downstream on the bypass side of the approach channel have a better chance of being guided into the bypass than those on the opposite side. Therefore, if an air bubble curtain, angled toward the bypass, proved partially effective in concentrating fish on the bypass side of the approach channel, the overall efficiency of a screen or louver system downstream could be increased.

The configuration and design of an air bubble curtain is dependent upon the design of the device with which it is being tested. Therefore, specifications for the curtain will be determined at a later date. A compressor is available to supply the volume of air necessary for any configuration.

6.5 TEST PARAMETERS

The relationship between impingement and environmental parameters has been previously discussed in Section III. One of the limitations of conducting a model study at a location remote from the Hudson River is that it is difficult to establish and control water quality parameters similar to those in the river. It is not possible, therefore, to simulate all of the parameters which might exist at a prototype fish diversion facility. In addition, conducting studies in a recirculating flume does not allow an evaluation of the effect of short-term fluctuations in the environmental parameters, such as temperature, salinity and turbidity, on fish behavior. Therefore, it is necessary to limit the parameters to be studied in the interest of developing an expeditious, yet meaningful, flume study program.

As discussed in Section 6.3, it will be possible to determine the effect of certain changing environmental parameters by conducting factorial experiments for one engineering design. For example, the effect of controllable factors (such as light and dark) on the efficiency of a particular device can be determined for each species early in the program by conducting tests where all parameters are held constant except for the lighting conditions of the flume. After replicate testing, the data can be analyzed by an analysis of covariance where test efficiency is the dependent variable. Should the analysis not detect a difference in efficiency under light or dark conditions, then future tests can be conducted under either condition with the assumption that lighting does not influence test results.

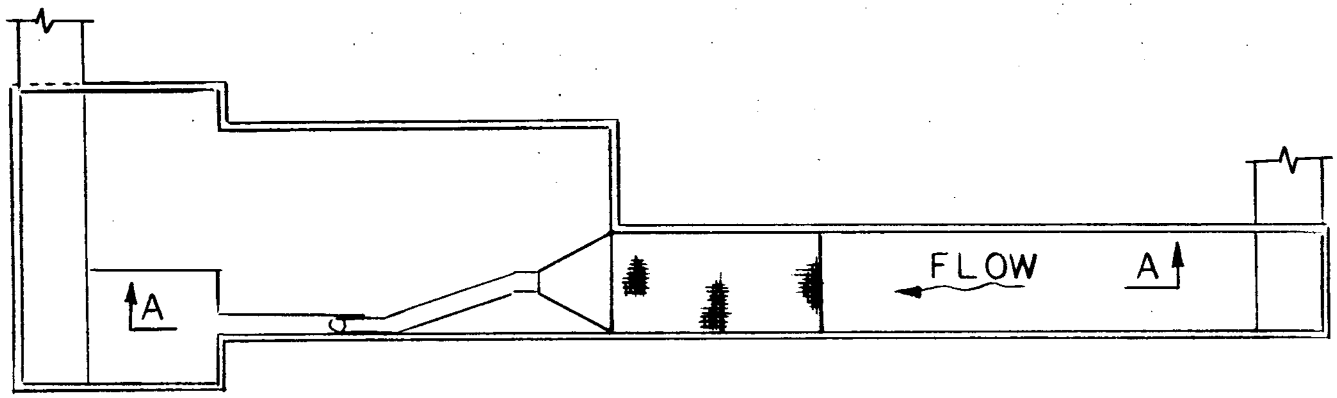
Other environmental parameters which might effect fish impingement include salinity, turbidity, dissolved oxygen (DO) and temperature. Again, the effects of short-term fluctuations in these parameters cannot be simulated in the recirculating flume.

The effect of salinity on diversion device effectiveness can be roughly determined through factorial experiments similar to the one discussed above. However, within the time allowed for the study program, it will not be possible to test the effect of short-term fluctuations in salinity. Instead, factorial experiments will be conducted at the lowest and highest salinities (approximately 0 and 3 ppt, respectively) that occur in the Hudson River. It will further be assumed that the relationship between salinity and test efficiency determined from this analysis is consistent for all species and engineering designs.

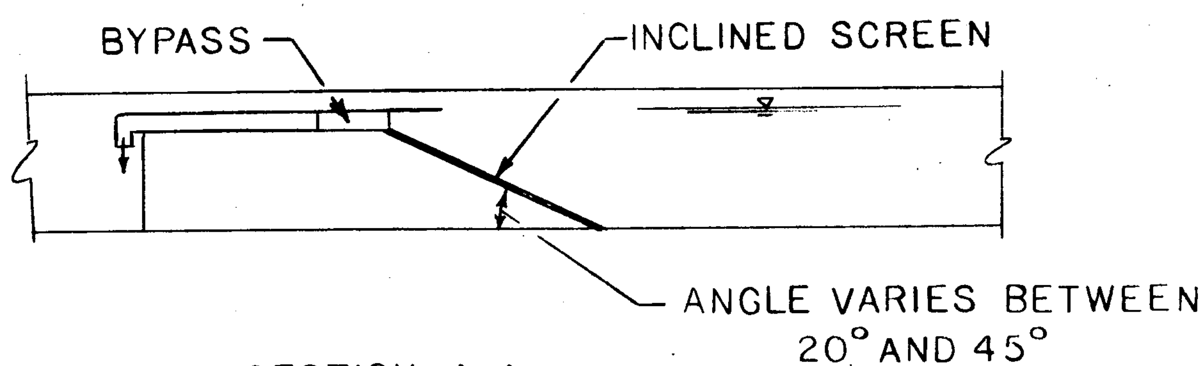
The water used for flume testing will be supplied from a pond at ARL. Some control over tubidity will be possible through the use of filtration. Turbidity will be recorded at the time of each test and its effect on fish guidance will be determined in the statistical analysis of the data.

Because the flume is recirculating, it will not be possible to control DO levels to any extent. Flow straightening devices, diversion devices, and surface turbulence will all result in air entrainment which will most likely create high DO concentrations.

The range of DO values which occur at Indian Point Units 1 and 2 is approximately 4.6 to 16.2 ppm. It is not known what the DO concentrations in the flume will be during testing. However, since little, if any, control over DO concentrations will be



PLAN



SECTION A-A

FIGURE 6-9.

POSSIBLE ARRANGEMENT OF AN INCLUDED PLANE DIVERSION TEST DEVICE

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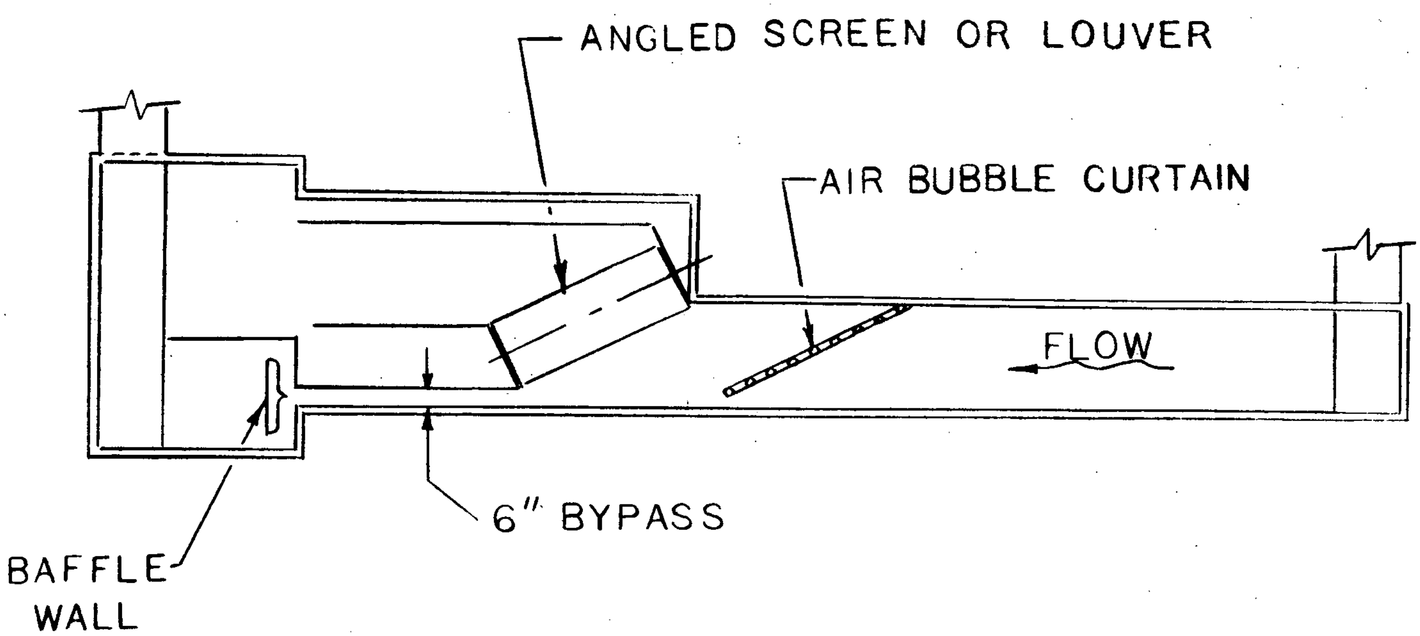

FIGURE 6-10.
AIR BUBBLE CURTAIN IN CONJUNCTION
WITH VERTICAL LOUVER OR SCREEN SYSTEM
INDIAN POINT FLUME STUDY
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possible, DO values will simply be recorded during each test, and the effects of variations, if any, will be determined through statistical analysis, if sufficient variability in DO is present. This analysis will be very limited.

Water temperatures at ARL cover the range of temperatures which occur naturally in the Hudson River. Therefore, tests will be conducted with each species at the temperatures at which they occur in impingement samples at Indian Point. This will permit an evaluation of the effects that temperature may have on prototype diversion device effectiveness.

Despite the limitations of conducting the study program at a fresh water site, it is felt that data can be obtained which will supply preliminary prototype design criteria for Indian Point and Cornwall. Texas Instruments (1974) concluded that impingement variability appears to be more directly related to relative species abundance than to physical/chemical variables. That is, physical/chemical variables affect the distribution of fish in the river, as related to the life history of each species, but may not have a strong influence on the susceptibility of fish to impingement. Therefore, although close simulation of the environmental parameters occurring at Indian Point will not be possible in the flume, the design criteria required for developing conceptual prototype designs can be obtained.

6.6 TEST PROCEDURE

All of the test devices proposed for study are similar in that their efficiency depends upon the ability of fish to guide along or around a structure and collect in a small percentage of the total flow. For this reason, it will be possible to utilize essentially the same test procedure for each device.

As already discussed, test parameters will be determined and established at the time of each test. A record will be made of temperature, dissolved oxygen concentration, pH, turbidity, salinity, approach velocity, bypass velocity, time of day, and lighting conditions. During each test, those parameters which might change will be checked periodically.

When the desired conditions have been established, fish will be carefully removed from the holding tanks (described in Section V) and placed in a fish introduction box, shown on Figure 6-11. At the time of introduction, the box will be closed to the flow such that the fish can adjust to the flume water quality conditions. After a suitable period of time, stoplogs on the upstream and downstream ends of the box will be slowly raised allowing a flow to pass through. When the fish have orientated to the current and are swimming normally, the screen on the upstream end of the box will be removed and the fish permitted to swim out naturally into the flume.

In all cases, the box will be located on the side of the flume opposite the bypass such that the greatest number of fish moving downstream will be forced to react to the test device. In this way, results will not be biased toward higher efficiencies.

Once the fish have been released, the box will be removed from the flume so that flow characteristics will not be disrupted. At this point, the test will proceed naturally.

During tests conducted under light conditions, visual observations will be made to determine the behavioral characteristics of the test fish. Records will be made of the following observations:

(1) How the fish orient to the flow,
(2) Where in the flume they prefer to reside,
(3) The vertical and horizontal distribution of fish,
(4) The length of time that fish swim against the flow, prior to guiding along, passing through or impinging on a particular test device,
(5) How strong an avoidance reaction the fish display to a device,
(6) At what location fish pass through or impinge on a particular device,
(7) How individual fish react versus groups of fish, and
(8) Any other responses which might aid in the final evaluation of a diversion device.

At the end of a test, the number of fish which enter the bypass will be compared to the number which pass through or impinge on a device, and the efficiency of that structure will be calculated. This efficiency, together with a subjective evaluation of the observed responses listed above, will then be used to determine the overall effectiveness of a device in guiding fish. All test fish will be removed from the flume following each test and held in separate holding tanks for observation of long-term survival. It is believed that a 48-hour holding period will be suitable to establish meaningful survival data. However, during the first few tests, fish will be held for one week in order to verify that delayed mortality will occur within the shorter period of time.

In all tests, an equal number of control fish will be held in a separate tank for comparison.

In addition, if the number of fish available for testing is large enough to permit sacrifice of a random subsample, such a subsample will be used to establish length/weight data. These data can then be used to determine the effect of size and condition of test fish on the efficiency of a device.

On the basis of the results obtained and an analysis of the data, the decision to continue testing with a particular test device will be made, as discussed in Section 6.3.

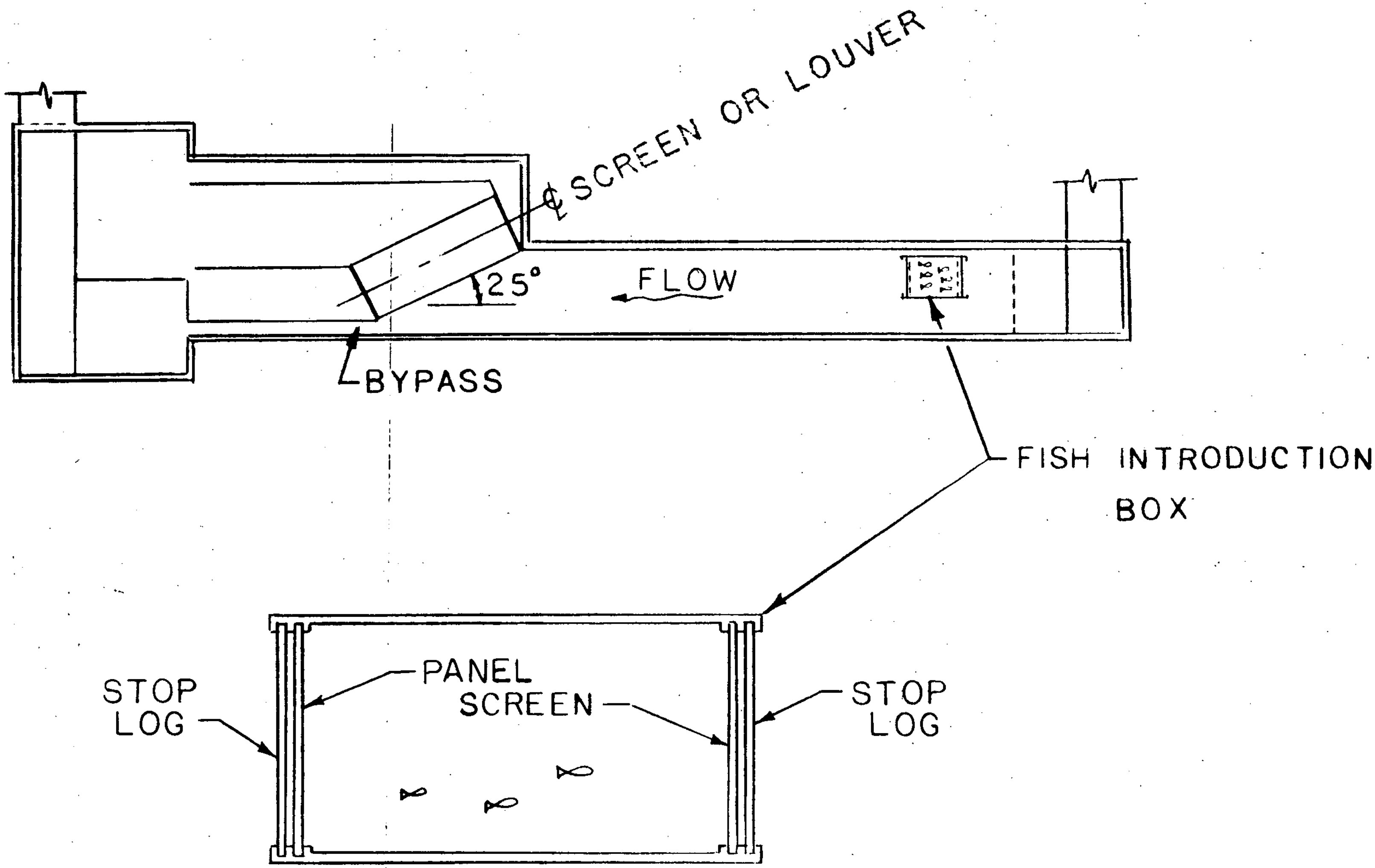

FIGURE 6-11.

METHOD OF FISH INTRODUCTION
TO THE TEST FLUME

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On the basis of test fish holding studies to date (Section IV), it is possible that the number of fish necessary to conduct all the tests required to establish meaningful data may not be available if each fish is tested only once. It may be desirable, therefore, to retest fish at certain times. Based on studies conducted by Stone & Webster Engineering Corporation (1975), it is not felt that such a procedure would bias the test results. However, if retesting of fish is necessary, a careful evaluation and analysis of the results obtained will be conducted in order to verify that a conditioned reflex is not biasing the efficiency of a device.

6.7 TEST PROGRAM SCHEDULE

The schedule for the Indian Point Flume Study is shown in Figure 6-12. The schedule reflects the ranking of the test devices such that a particular device will be tested only if the next highest ranking device proves ineffective. As shown, it will be possible to evaluate each device with at least two species. Further, if all devices prove less effective than desired, it would be possible to resume testing with the most effective device at the beginning of January, 1976. This would permit an extensive reevaluation of that device with all three test species during the critical months of the year when water temperature is low and impingement is high.

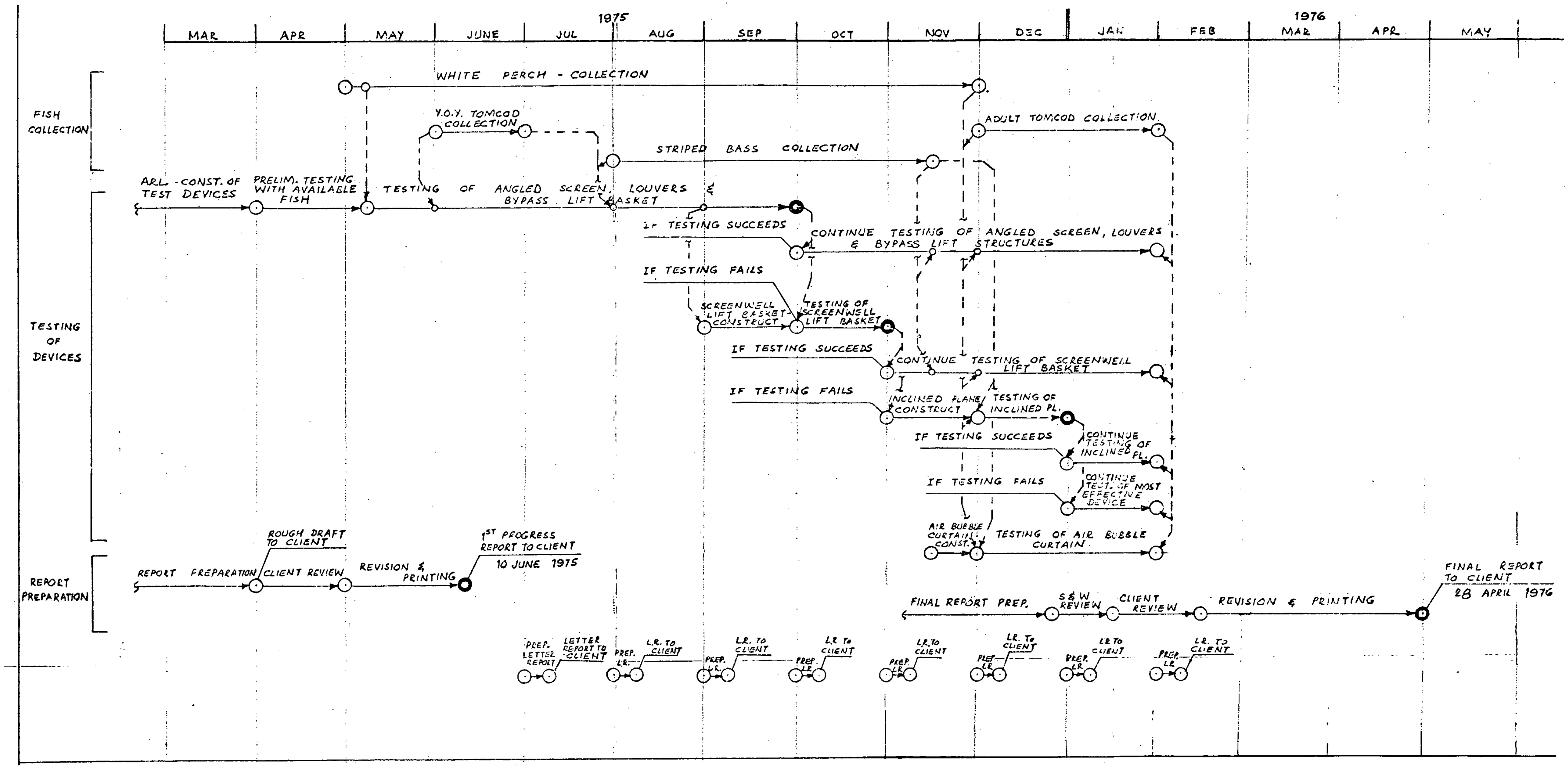

FIGURE 6-12.

SCHEDULE OF INDIAN POINT FLUME STUDY

INDIAN POINT FLUME STUDY
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REFERENCES

Albrecht, Arnold B. "Some Observations on Factors Associated with Survival of Striped Bass Eggs and Larvae." Calif Fish and Game 50(2): 100-113, 1964.

Bates, D.W., Logan, O. and Pesonen, E. Efficiency Evaluation, Tracy Fish Collecting Facility, Central Valley Project, 1960.

Bates, D.W., and Vinsonhaler, R. "Use of Louvers for Guiding Fish," Trans. of Am. Fish Soc., 86, 1956.

Bibko, P.N., Wirtenan, L. and Kueser, P.E. "Preliminary Studies on the Effects of Air Bubbles and Intense Illimination on the Swimming Behavior of the Striped Bass (Morone saxitilis) and the Gizzard Shad (Derosoma cepedianum), Presented to the Third Annual Symposium on Entrainment and Entrapment Effects., Johns Hopkins University, Baltimore, Md. March 1972.

California Department of Fish and Game, Department of Water Resources. Delta Fish and Wildlife Protection Study. Annual Reports Nos. 1-6. The Resources Agency of California, 1962-1967.

California Department of Water Resources. Fish Collection Facilities Bypass Intake Passage Spacing Tests at Tracy Fish Collecting Facility 1963, 1964. The Resources Agency of California, 1967.

Clay, C.H. Design of Fishways, Dept. of Fisheries, Ottawa, Canada, 1961.

Downs, D.I. and Meddock, K.R. "Design of Fish Conserving Intake System," Jour. Power Div. ASCE, Vol. 100, No. P02, Dec. 1974.

Ducharme, L.J.A. "An Application of Louver Deflectors for Guiding Atlantic Salmon (Salmo salar) Smolts from Power Turbines," J. Fish Res. Bd. of Can., 29: 1397-1404, 1972.

Eicher, G.J. "Studies of Louver Guidance and Traveling Screens at Pacific Northwest Power Plant Intake Systems," Paper presented at Johns Hopkins University, February 5-8, 1973.

Fairbanks, R.B., Collings, W.S. and Sides, W.T. "An Assessment of the Effects of Electrical Power Generation on Marine Resources In the Cape Cod Canal." Massachusetts Department of Natural Resources, March 13, 1971.

Hallock, R.J., Iselin, R.A. and Fry, Jr., D.H. "Efficiency Tests of the Primary Louver System." Tracy Fish Screen, 1966-67, Marine Resources Branch, California Department of Fish and Game, 1968.

Kerr, J.E. "Studies on Fish Preservation at the Contra Costa Steam Plant of the Pacific Gas and Electric Co." California Fish and Game, Bulletin, No. 92, 1953.

King, Lawrence R. "Supplementary Results of Swimming Speed and Endurance Studies on White Perch as Determined by the Beamish Respirometer." Ichthyological Associates, Ithaca, N.Y. for Consolidated Edison Co. of N.Y., Inc., December 1970.

Kupfer, G.A., and Gordon, W.G. "An Evaluation of 1966: The Air Bubble Curtain as a Barrier to Alewives," Comm. Fish Review Vol. 28(9), 1966.

Kupka, K.H. "A Downstream Migrant Diversion Screen." The Canadian Fish Culturalist, No. 37, Sept. 1966.

Lake Michigan Intakes: Report on the Best Technology Available by Lake Michigan Cooling Water Intake Technical Committee, 1973.

Pavlov, D.S., "Entrapment of Fish Fingerlings in Pumping Installations as Related to Features of Their Behavior and Orientation to the Stream of Water," Problems in Ichthyology, American Fisheries Society, 9(2): 237–243, 1969.

Raney, Edward C. "The Striped Bass in New York Waters." N.Y. State Conservationist 8(4): 14–16, 1954.

Rathjen, W.F. and Miller, L.C. "Aspects of the Early Life History of the Striped Bass (Roccus saxatilis) in the Hudson River. N.Y. Fish and Game Jour. 4(1): 43–60, 1957.

Riesbol, H.S., and Gear, P.J.L. "Application of Mechanical Systems to Alleviation of Intake Entrapment Problems," Presented at Atomic Industrial Forum Conference on Water Quality Considerations, Washington, D.C., 1972.

Ruggles, C.P., and Ryan, P. "Louvers for Guiding Pacific Salmon," Can. Fish. Cult., 33: 1–68, 1964.

Schuler, V., "Experimental Studies in Guiding Marine Fishes of Southern California with Screens and Louvers," Ichthyol. Assoc., Bulletin 8, February 1973.

Schuler, V., and Larson, W.E. "Experimental Studies Evaluating Aspects of Fish Behavior as Parameters in the Design of Generating Station Intake Systems," 1974.

Smith, K.A. "Air Curtain Fishing for Maine Sardines," Commercial Fisheries Review, U.S. Department of the Interior, No. 614, 1961.

Stone & Webster Engineering Corporation. "Studies To Alleviate Potential Fish Entrapment Problems – Summary Report, 1973–1974 Efforts," for Niagara–Mohawk Power Corporation, February, 1975.

Texas Instruments, Inc. "Hudson River Ecological Study in the Area of Indian Point." 1973 Annual Report. Prepared for Consolidated Edison Co. of N.Y. Inc. July 1974.

Thompson, J.S., and Paulik, G.J. "An Evaluation of Louvers and Bypass Facilities for Guiding Seaward Migrant Salmonid Past Mayfield Dam in West Washington," Washington Department of Fisheries, Olympia, Washington, 1967.

U.S. Environmental Protection Agency. "Development Document for Proposed Best Technology Available For Minimizing Adverse Environmental Impact of Cooling Water Intake Structures," December 1973.