STUDIES TO ALLEVIATE POTENTIAL FISH ENTRAPMENT AT UNIT NO. 6 - OSWEGO STEAM STATION

NIAGARA MOHAWK POWER CORPORATION

May 1977

Stone & Webster Engineering Corporation
Boston, Massachusetts

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SUMMARY AND CONCLUSIONS

In order to evaluate the potential for effective application of a fish diversion and transportation system at Niagara Mohawk Power Corporation's Unit No. 6, Oswego Steam Station a series of tests were conducted by Stone & Webster as a continuation of ongoing studies described in separate reports (Stone & Webster 1975, 1976a, 1976b, 1977). Previous studies by Stone & Webster have shown that an angled, flush-mounted traveling screen and pipe system, incorporating a jet pump, is highly efficient in diverting and transporting alewives with low resultant mortality. The Unit No. 6 cooling water system and fish diversion system will incorporate two jet pumps to return fish to Lake Ontario. The two-pump design is necessitated by expected high head losses in the cooling water system. The present study utilized an existing angled screen and fish transportation model at the Alden Research Laboratories with a second angled screen and jet pump added to test the feasibility of using such an expanded system.

Five tests were conducted in the Double Jet Pump model during the summer of 1976 over a range of hydraulic conditions. Statistical analyses of the results indicate that, under the conditions tested, no single variable accounted for a significant amount of the variation in test mortality. Further, a one-way analysis of variance showed that mortality among fish which passed through one jet pump did not differ significantly from that which occurred among fish which passed through two jet pumps; nor did either test mortality differ significantly from control mortality.

The mean mortalities and 95 percent confidence intervals for one-pump, two-pump, and control fish were 9.04 ±6.4, 17.28 ±9.07, and 8.04 ±16.14, respectively. Therefore, to obtain an estimate of the most probable increase in mortality which might be expected to occur in a prototype installation, the mean differential mortalities (test minus control) can be computed. These values are 1.0 percent for one pump and 9.2 percent for two pumps. Since these values are low, it appears that an angled screen and double jet pump transportation system offers an effective means for reducing impingement at Unit No. 6 - Oswego Steam Station.

SECTION 1

INTRODUCTION

Stone & Webster Engineering Corporation (S&W) has been conducting biological and hydraulic laboratory studies for Niagara Mohawk Power Corporation (NMPC) since May 1973. As a result of these studies, an effective fish diversion and transportation system has been developed which can be used to reduce fish losses commonly resulting from entrapment in power plant cooling water intakes on the Great Lakes. The system has three components: an angled, flush-mounted vertical traveling screen leading to a bypass; a transportation pipe; and a jet pump which supplies the energy for inducing bypass and pipe flows. The studies which led to the development of this system are described in separate reports (Stone & Webster 1975, 1976a, 1976b).

Due to the results obtained during earlier studies, NMPC requested S&W to design a prototype fish diversion and transportation system for Unit No. 6 - Oswego Steam Station (Oswego 6). Potential high head losses within the cooling water system require the fish transportation system to pump against a maximum total head of approximately 14 feet. S&W laboratory studies have shown that driving flow nozzle velocities within a jet pump should be within a range of 30 to 45 fps to minimize potential stress to the fish. Within this range, a jet pump is capable of overcoming 7 feet of total head (Stone & Webster 1975). Therefore, Oswego 6 will require two jet pumps to safely return bypassed fish to the lake.

Since the effects of a two-pump system on fish survival had not been evaluated experimentally, NMPC authorized S&W to conduct a series of tests within an existing model basin at the Alden Research Laboratories (ARL). These tests were conducted with alewives (<u>Alosa pseudoharengus</u>) in the summer of 1976. The model incorporated all of the components of the proposed Oswego 6 fish protective system, including a primary angled screen, bypass, pipe loop, and jet pump (previously evaluated individually as the System Demonstration Model, Stone & Webster 1977). A smaller, secondary angled screen, bypass, and jet pump were added to this model. A comparison of the components and parameters of the prototype and model is shown in Table 5-1. Studies conducted in this model facility are described in the following sections.

SECTION 2

MODEL DESCRIPTION

To evaluate the diversion and transport efficiency of the Double Jet Pump System, the large test basin incorporating the Angled Screen and System Demonstration Models was utilized, as illustrated in Figure 2-1.

To model a Double Jet Pump System, a second screenwell, bypass, and jet pump were installed in the model basin as an addition to the existing System Demonstration Model previously discussed. Consequently, the discharge from the first jet pump could be diverted into the second jet pump. A description of the model follows.

The angled screen test flume was 5 feet 9 inches wide, 6 feet deep, and 40 feet long. Flow was supplied to the model by six pumps with a total capacity of 130 cfs. To achieve a uniform distribution of flow in the flume, a series of turning vanes were located at the upstream end of the angled screen model. A 1/4-inch-mesh galvanized steel inflow screen kept fish within the test section of the flume.

A fish introduction box was installed on one wall of the flume just downstream of the inflow screen. In order to eliminate bias toward positive test results, the box was located on the screen side of the flume rather than on the bypass side. This placement increased the probability that fish would have to react to the screen should they have remained near the wall on the screen side.

The angled screen test device (3/8-inch mesh), located 14 feet downstream of the inflow screen, was identical to a prototype screen except that it could not be rotated. The screen measured 12 feet in length, was set at a 25-degree angle to the flow, and led to a 6-inch-wide bypass. Several feet downstream from the bypass entrance, an expanding, sloping plate directed the flow downward at a 45-degree angle to a connection with a short 12-inch-ID pipe, that was, in turn, connected to a 167-foot length of 10-inch-ID, PVC pipe incorporating five horizontal and vertical 90-degree bends leading into a 12-inch jet pump. This first jet pump, whose driving flow was supplied by two separate pumps, discharged into a 13-foot-long, 12-inch-ID steel mixing tube pipe and passed through a vertical 90-degree bend into a head tank, which, in turn, discharged into a secondary screenwell, containing a second angled screen. This screenwell was 3 feet wide, 3 feet deep, and the screen was 11 feet long. A 4-foot-long, removable section of the angled screen made it possible to divert fish away from the secondary bypass, after passing through one jet pump, into collection area No. 1 (Figure 2-1).

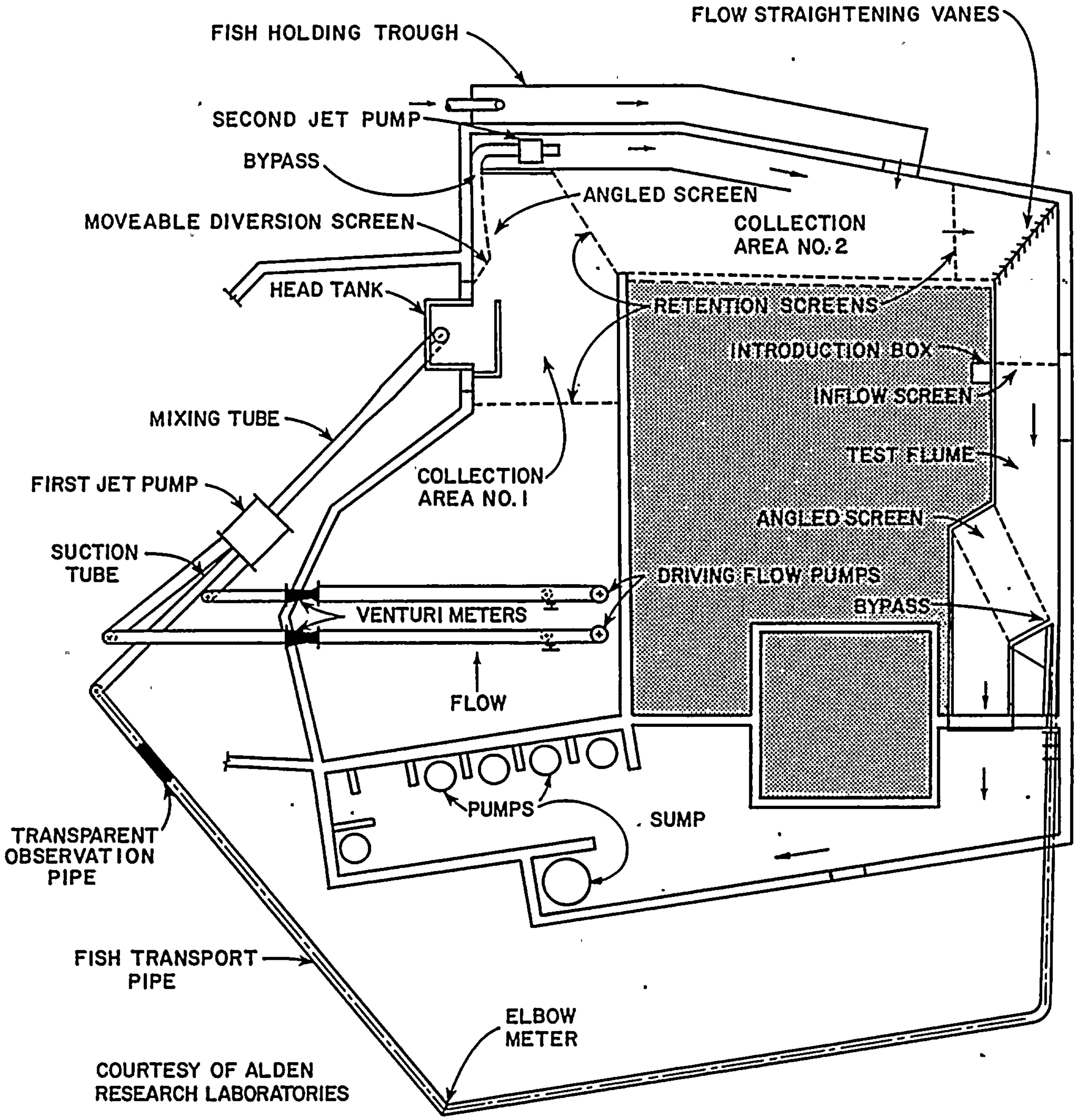


FIGURE 2-1
DOUBLE JET PUMP
SYSTEM DEMONSTRATION MODEL
UNIT NO. 6-OSWEGO STEAM STATION
NIAGARA MOHAWK POWER CORPORATION
STONE & WEBSTER ENGINEERING CORPORATION

A 6-inch-wide secondary bypass made a 90-degree bend leading to the second jet pump. This smaller 4-inch jet pump (previously evaluated individually for NMPC; Stone & Webster 1977) had a smooth bell-mouth transition where the fish were observed entering the suction pipe. The fish were also observed discharging from the mixing tube. The pump discharge entered into a large screened portion of the model designated as collection area No. 2 (Figure 2-1).

Adjacent to the model basin, an existing fish holding facility, containing two 2,500-gallon circular pools, was used to contain the fish for the study.

A new facility was constructed by ARL to hold control fish for mortality studies. It consisted of a rectangular trough measuring 2 feet in width, 2 feet in depth, and 40 feet in length.

All the water used to fill the model basin, the holding trough for control fish, and the pools to hold untested fish were supplied from the adjacent stream.

SECTION 3

TEST PROGRAM

The biological testing program extended from July 28 to August 12, 1976. Test support was supplied by ARL and involved establishing and documenting the hydraulic parameters specified for each test.

3.1 TEST PROCEDURE

A series of five tests were conducted for the double jet pump study. Water quality measurements were taken prior to the start of each test. The parameters observed were dissolved oxygen, phenolphthalein alkalinity, methyl orange alkalinity, hardness, ammonia nitrogen, and pH. Water temperature was monitored throughout the test. An additional intensive analysis was conducted once during the testing program to monitor TOC, fluoride, aluminum, arsenic, boron, cadmium, chromium, cobalt, copper, iron, lead, mercury, nickel, silver, and zinc.

Each test lasted from 3 to 6 hours and began approximately 2 hours before dusk and ended about 2 hours after dusk. Average velocities were determined for the primary approach channel and bypass prior to the beginning and at the end of each test using a propeller-type current meter.

Piezometer heads were measured at the jet pumps and screenwells to determine the pressure rise through the jet pumps. Driving and suction flow rates of the jet pumps were also measured using venturi meters, elbow meters, and velocity traverses. Velocity distributions at the primary bypass and along the screen were recorded. A detailed description of the hydraulic test procedures and data are presented in the ARL report in Appendix A.

To prevent mortality associated with the handling of fish during removal from the holding pools, the fish were not counted until the end of the mortality study; at this time, the exact number of fish was recorded for the controls, and for the fish in collection areas No. 1 and No. 2.

Test fish were removed from the holding pool using a minnow seine and a shallow dip net. They were then transferred to the introduction box in 5-gallon buckets for a 15-minute acclimation period. During this period, an appropriate number of control fish were placed in a holding tank within the flow-through trough as part of mortality studies. A sliding gate on the flume side of the introduction box confined the test fish until the time of release. After the fish were released, the sliding gate was replaced and maintained a relatively flush surface and desirable flow characteristics along the wall.

The primary flume area was covered with a sheet of black plastic to reduce the presence of visual keys. As the fish moved through the transport system they were observed through a clear section of the 10-inch PVC pipe before entering the first jet pump. This made it possible to estimate the numbers of fish in transit through the system. As the fish entered the approach section of the secondary angled screen, they were diverted into collection area No. 1 by withdrawing the section of removable angled screen and placing a wall in front of the secondary bypass. Fish were also diverted into the second jet pump by removal of the wall and replacement of the removable section of angled screen. To avoid bias in the test results, the fish were randomly directed into each collection area in alternating cycles to avoid possible diversion of weaker or stronger fish into any one collection area. Control fish were handled in an identical fashion as the test fish except, that they were placed in a tank within the holding trough not subject to the model devices.

3.2 MORTALITY STUDIES

Studies were conducted for each test to evaluate the mortality associated with fish diversion and transport. The results were then analyzed to determine the total efficiency (E) of the system.

Mortality was monitored for the three separate groups of fish tested: (1) the control group; (2) the fish that traversed the primary diversion screen, pipe loop, and jet pump; and (3) those individuals that were diverted and passed through both jet pumps. The mortality was recorded every 24 hours following the end of a test for periods of 48 to 96 hours, depending on the time available for each test. A comparison of percentage mortality for each test group within each test was statistically analyzed, as discussed in Section 4.

SECTION 4

TEST RESULTS

The results of double jet pump testing are summarized in Table 4-1. The results of water quality analyses are presented in Tables 4-2 and 4-3.

The approach velocity was set at a constant value of 1.0 fps for the five tests, while the bypass velocity, as regulated by jet nozzle velocity, varied from 1.4 to 2.0 fps, with a mean of 1.7 fps. The jet nozzle velocity for the 12-inch jet pump ranged from 34.9 to 44.9 fps, with a mean velocity of 40.8. The jet nozzle velocity for the 4-inch jet pump varied from 35.0 to 43.9 fps, with a mean of 39.9 fps. The water temperature ranged from 66° to 74°F, with a mean of 70°F.

During the double jet pump tests, the fish were continually observed through a clear section of the transport pipe prior to entering the first jet pump, to determine approximately how many were in transit and at what time they were moving through the system. The greatest number of fish were observed to be bypassed and transported through the system at dusk and immediately thereafter. They were not observed to be bypassed before dusk. In observing the relationship between the percentage of fish bypassed and the total number of fish in the flume during a test, it was seen that a noticeable drop in the percentage bypassed occurred within 1 to 2 hours after dusk. This pattern was consistent in all tests.

The statistical analysis included the test results of the five double jet pump tests, and an additional six single jet pump tests from the System Demonstration Model Study (Stone & Webster 1977). The six tests were added to the five tests of this study to increase the number of observations from which conclusions could be drawn. The tests in the previous System Demonstration Model Study were sufficiently similar to consider the conclusions from that earlier study appropriate to this study. The results from testing for single jet pump mortality (11 tests) were used as a predictor of the second jet pump mortality (5 tests), since a portion of the second jet pump mortality is attributable to transport through the first jet pump.

The results of the five double jet pump tests were analyzed by an analysis of variance (ANOVA). Total mortality for each test was the dependent variable, and was defined as the number of fish transported by the second jet pump that died (during the mortality study), divided by the total number of fish transported through the second jet pump.

The mortality of fish that traversed the first jet pump was analyzed as an independent variable and was defined as the number of fish transported by the first jet pump that died (during the

TABLE 4-1

DOUBLE JET PUMP MODEL TEST PARAMETERS AND RESULTS

UNIT NO. 6 - OSWEGO STEAM STATION
NIAGARA MOHAWK POWER CORPORATION
STONE & WEBSTER ENGINEERING CORPORATION

A. TEST PARAMETERS[1]

Test number	1	2	3	4	5
Date	7/28/76	8/3/76	8/5/76	8/10/76	8/12/76
Approach velocity, fps	1.0	1.03	1.0	0.97	0.98
Bypass velocity, fps	1.4	1.52	2.02	1.82	1.95
12-inch jet pump velocity, fps					
Suction pipe	5.96	7.58	8.68	8.03	8.69
Jet nozzle	34.86	39.12	44.93	40.61	44.62
Mixing tube	10.20	12.50	14.40	13.10	14.33
Pressure rise, psi	4.30	5.30	6.90	5.70	6.80
4-inch jet pump velocity, fps					
Suction pipe	8.30	9.51	10.21	9.46	10.27
Jet nozzle	35.00	38.70	43.40	38.40	43.70
Mixing tube	12.53	14.07	14.90	13.98	14.98
Pressure rise, psi	3.55	4.53	4.98	4.48	5.00
Water temperature, °C	22.2	18.9	20.6	19.4	23.3

TABLE 4-1 (CONT'D)

B. TEST RESULTS

Test number	1	2	3	4	5
Date	7/28/76	8/3/76	8/5/76	8/10/76	8/12/76
Total No. of fish tested	1564	908	1498	1483	2467
No. fish tested through one jet pump (No. 1)(2)	1069	300	819	695	1774
Test mortality					
Number	98	28	147	38	58
Percent	9.2	9.3	17.9	5.5	3.3
No. fish tested through two jet pumps (Nos. 1 and 2)(3)	495	608	679	788	693
Test mortality					
Number	90	50	189	167	76
Percent	18.2	8.2	27.8	21.2	11.0
Control mortality					
Number	5	3	7	1	88
Percent	2.5	1.5	2.7	0.4	33.1(4)

Notes

(1) Refer to Appendix for actual hydraulic values

(2) No. of fish diverted and bypassed through 1st jet pump into collection area No. 1

(3) No. of fish diverted and bypassed through 1st and 2nd jet pumps into collection area No. 2

(4) High control mortality possibly due to rapid temperature rise in control holding tank during mortality study

TABLE 4-2

WATER QUALITY TESTS - MODEL

UNIT NO. 6 - OSWEGO STEAM STATION
NIAGARA MOHAWK POWER CORPORATION
STONE & WEBSTER ENGINEERING CORPORATION

	Maximum	Minimum	Mean
Water Temperature, °C	23.3	18.9	20.9
Dissolved Oxygen, ppm	9.2	8.6	9.1
Phenolphthalein Alkalinity, gr/gal	0	0	0
Methyl Orange Alkalinity, gr/gal	2.0	2.0	2.0
Hardness, gr/gal	4.0	2.0	3.0
Ammonia N, ppm	0.03	0.03	0.03
pH	6.8	6.6	6.6

TABLE 4-3

WATER QUALITY - INTENSIVE ANALYSIS

UNIT NO. 6 - OSWEGO STEAM STATION
NIAGARA MOHAWK POWER CORPORATION
STONE & WEBSTER ENGINEERING CORPORATION

Date of Analysis: July 29 to August 6, 1976

Parameter*	Stream	Model Basin
TOC	25.0	24.0
Fluoride	0.10	0.08
Aluminum	0.2	0.04
Arsenic	<0.005	<0.005
Boron	0.35	<0.01
Cadmium	<0.01	<0.01
Chromium	<0.01	<0.01
Cobalt	<0.03	<0.03
Copper	<0.01	<0.01
Iron	1.15	1.15
Lead	<0.01	<0.01
Mercury	<0.5	<0.05
Nickel	<0.01	<0.01
Silver	<0.01	<0.01
Zinc	<0.01	0.04

*Units measured in milligrams per liter

mortality study), divided by the total number of fish that passed through only the first jet pump. Since impingement on the angled screen never occurred (the screen was always 100 percent effective in diverting fish), impingement loss was not a variable during the study.

Another possible source of variation was the number of fish in the test facility. This number was indexed as the number of fish bypassed in the primary test flume (those which passed through the first jet pump), since this source of variability proved to be significant for the first jet pump in the previous System Demonstration Study (Stone & Webster 1977). This source of variation was analyzed in two ways. First, a predicted total mortality of the fish that traversed the second jet pump was calculated based on the regression determined from the results of the previous single jet pump study. This calculated mortality was used as an independent variable in the analysis of the double jet pump data.

The analysis of the mortality for the double jet pump was analyzed with three independent variables: jet nozzle velocity for both jet pumps, control mortality, and mortality predicted (predictor) from the previous System Demonstration Study. The equation for the predicted mortality (m) was:

$$\hat{m} = 0.1188 - 8.1 \times 10^{-4} (B - 717)$$

where:

B is the number bypassed through the first jet pump based on results of the System Demonstration Study.

Refer to Stone & Webster (1977) for the derivation of the constants in this equation.

The results of this analysis are summarized in Table 4-4. The independent variables did not explain a significant ($\alpha \leq 0.05$) amount of the variability in the mortality.

The second method of looking at this relationship was to apply the number of fish bypassed by the second jet pump. The jet nozzle velocity of the second jet pump was also included in this analysis.

These two independent variables, the number of fish bypassed and jet nozzle velocity, were analyzed singly and together. In all analyses, they did not account for a significant amount of the variation in test mortality (Tables 4-4 and 4-5).

Therefore, since none of the independent variables accounted for observed mortality, the performance of the double jet pump can be described as the average performance of all tests. For the five double jet pump tests, the mean test mortality and 95 percent

TABLE 4-4

DOUBLE JET PUMP ANALYSIS OF VARIANCE FOR TEST MORTALITY, MODEL 1

UNIT NO. 6 - OSWEGO STEAM STATION
NIAGARA MOHAWK POWER CORPORATION
STONE & WEBSTER ENGINEERING CORPORATION

Source	D.F.	Sums of Squares	Mean Squares	F-Ratio	Probability
Jet Velocity - Pump No. 2	1	0.0012	0.0012	0.109	0.7973
Predictor	1	0.0037	0.0037	0.338	0.6648
Control Mortality	1	0.0138	0.0138	1.266	0.4626
Residual	1	0.0109			
Total	4	0.0249			

TABLE 4-5

DOUBLE JET PUMP ANALYSIS OF VARIANCE FOR TEST MORTALITY, MODEL 2

UNIT NO. 6 - OSWEGO STEAM STATION
NIAGARA MOHAWK POWER CORPORATION
STONE & WEBSTER ENGINEERING CORPORATION

Source	D.F.	Sums of Squares	Mean Squares	F-Ratio	Probability
No. Bypassed	1	0.0036	0.0036	0.661	0.5017
Control Mortality	1	0.0126	0.0126	2.291	0.2693
Residual	2	0.0110	0.0055		
Total	4	0.0249			

confidence interval for fish that were diverted by the angled screen and traversed both jet pumps was 17.28 ±9.07 percent, while the mean test mortality for the fish diverted and transported through the first jet pump only was 9.04 ±6.40 percent. The mean test mortality and 95 percent confidence interval for the control group (the fish contained in the holding trough that were not exposed to the model devices) was 8.04 ±16.14 percent. A one-way ANOVA for the control, one-pump, and two-pump mortalities was conducted. The results of this analysis indicated that these three mortalities were not significantly different, as shown in Table 4-6. Therefore, under the conditions tested, the mortalities associated with passage through the single or double jet pump system were not greater than mortality of control fish.

The results of the statistical analyses conducted indicate that, under the conditions tested, variables which might be expected to influence test fish mortality (second jet pump nozzle velocity, predictor, control mortality, and number of fish tested) were not found to be significant ($\alpha \leq 0.05$) factors in mortality. Other variables which might contribute to mortality, namely, angled screen approach velocity, first jet pump nozzle velocity, water temperature, and dissolved oxygen, were not included in the double jet pump analysis since these factors were not found to be significant in System Demonstration Model studies (Stone & Webster 1977). In those studies, the only variable found to be significant was the number of fish bypassed ($\alpha = 0.025$). Accordingly, this variable was included in the double jet pump analysis in two ways: (1) as the actual number of fish which passed through the two jet pumps (5 tests), and (2) as a predictor of two-pump mortality based on one-pump mortality in the System Demonstration studies (11 tests). The fact that the number of fish bypassed was not found to be significant in either analysis may be a result of the reduced number of tests (5) available for analysis.

Finally, to determine whether a significant difference occurred between test mortalities (one-pump and two-pump) and control mortality, an ANOVA of the three mortalities (9.04, 17.28 and 8.04 percent, respectively) was conducted. As might be suspected by the confidence intervals given above, the means were not found to be significantly different. Therefore, under the conditions tested, there is no statistical difference ($p \geq 0.95$) in mortality due to passage through one or two jet pumps relative to control fish. However, it is possible to obtain an estimate of the most probable increase which might be expected to occur in a prototype installation by computing the differential mortalities (test mortality minus control mortality) of the means observed during the study program. These values are 1.0 percent for one pump and 9.2 percent for two pumps. It is expected that the potential for mortality associated with passage through two jet pumps in the prototype will be lower since the diameter of the pumps will be substantially larger than those tested during the study program.

Since the sizes of the fish tested were the same as those commonly impinged in Lake Ontario power plants, the larger diameter of the prototype pumps will reduce the probability that fish will enter the areas of high shear forces at the jet nozzle exit, thereby reducing the potential for injury or stress.

On the basis of the test results and the low mortalities observed, it appears that an angled screen and double jet pump transportation system offers an effective means for reducing impingement at the Unit No. 6 - Oswego Steam Station. The proposed prototype system is described in Section 5.

SECTION 5

DESCRIPTION OF PROTOTYPE

The Unit No. 6 screenwell and associated fish guidance and transportation systems are shown in Figures 5-1, 5-2, and 5-3. It will consist of a primary and secondary screenwell and two jet pumps. There will be two screenbays in the primary screenwell, each 17 feet wide with a water column depth that varies from 24 to 33 feet. Fish entering the screenwell will pass through trash racks with 3-inch clear spacings, and be guided by angled flush-mounted, traveling water screens into a 6-inch-wide bypass. Each bay will be sized to accept three 10-foot-wide traveling screens separated by 3-foot 3-inch-wide, concrete piers. Initially, each bay will be equipped with two screens and the third opening will be blocked off with stop gates for a possible future screen. The screens will be angled 25 degrees to the direction of flow with their downstream ends converging but separated by a 5-foot-wide pier.

Two dry-pit circulating water pumps will draw the flow through the screenwell. Each pump will take its suction from a 10.5-foot-by-10.5-foot opening located in the south wall of the screenwell approximately 20 feet downstream from the bypass. Each pump suction opening will be on the centerline of a screenbay and level with the screenwell floor. The location and proximity of these pump suctions will cause a skewed vertical velocity distribution at the traveling water screens with a higher velocity at the lower section of the screens. Also, due to the blockage of the third screen opening and the location of the pump, a non-uniform velocity distribution would exist along the face of the screens. The bypass suction flow is designed such that the ratio of the average screenwell approach velocity to the average bypass entrance velocity is 1:1. Each 6-inch-wide bypass slot extends the full depth of the water column. The two slots converge in the horizontal plane while at the same time converging in the vertical plane at a 45-degree angle to two 24-inch-diameter pipes. The two pipes manifold into a single 32-inch-diameter pipe which becomes the suction pipe of the primary peripheral jet pump. The mixing tube of the primary jet pump is 36 inches in diameter, resulting in an area ratio of driving nozzle to mixing tube of 0.18. The primary jet pump discharges to a 5-foot 5-inch-wide, secondary fish diversion bay within the screenwell. The secondary bay contains one angled traveling water screen identical in design to the main screens except for the depth of the bay. The water column depth in the secondary bay varies from 8 feet to 15 feet. The majority of the water discharged from the primary pump flows through the secondary screen and is returned to the screenwell through a 42-inch-diameter pipe. The fish are guided by the secondary screen into another 6-inch-wide bypass slot. The secondary bypass slot converges in the vertical plane to an

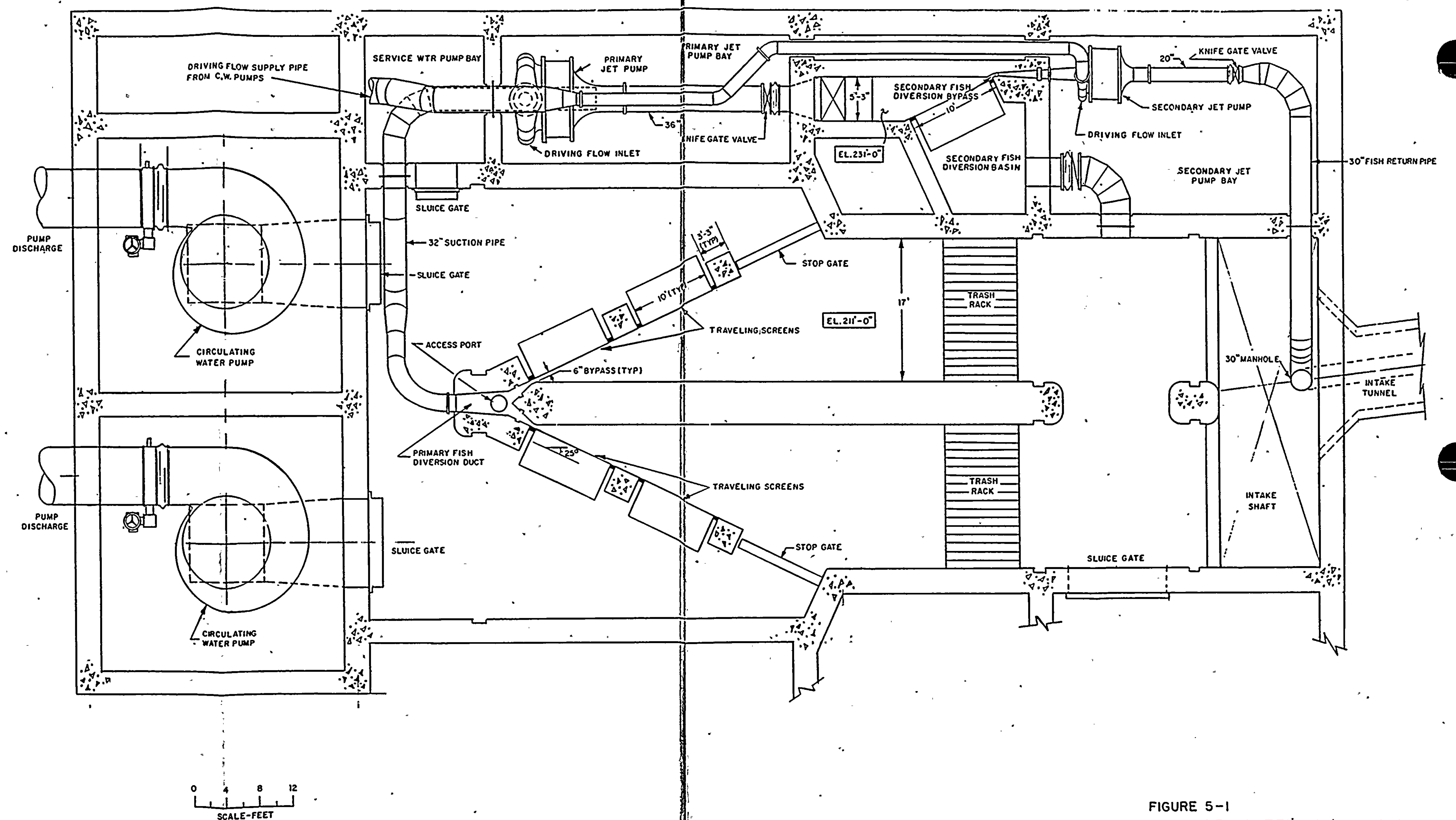
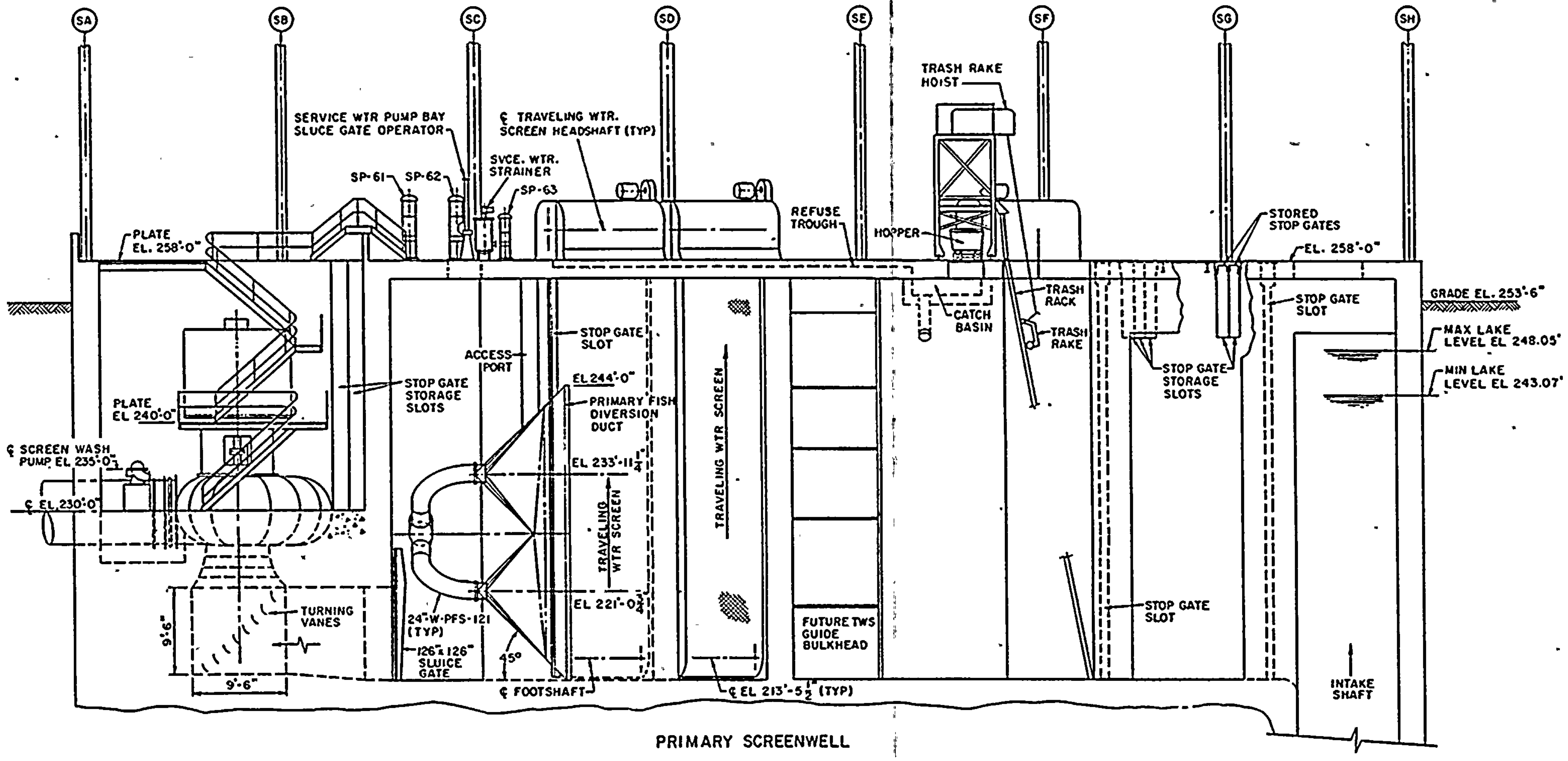
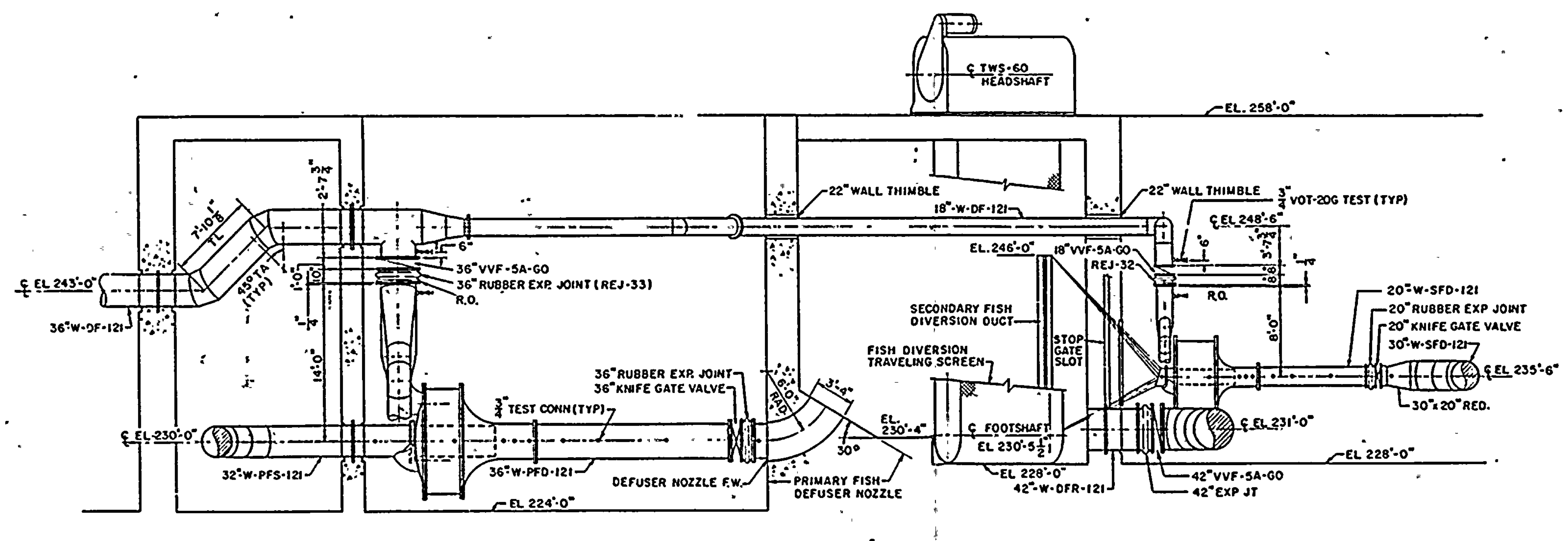


FIGURE 5-1
PLAN OF SCREENWELL LAYOUT
UNIT NO.6 – OSWEGO STEAM STATION
NIAGARA MOHAWK POWER CORPORATION
STONE & WEBSTER ENGINEERING CORPORATION

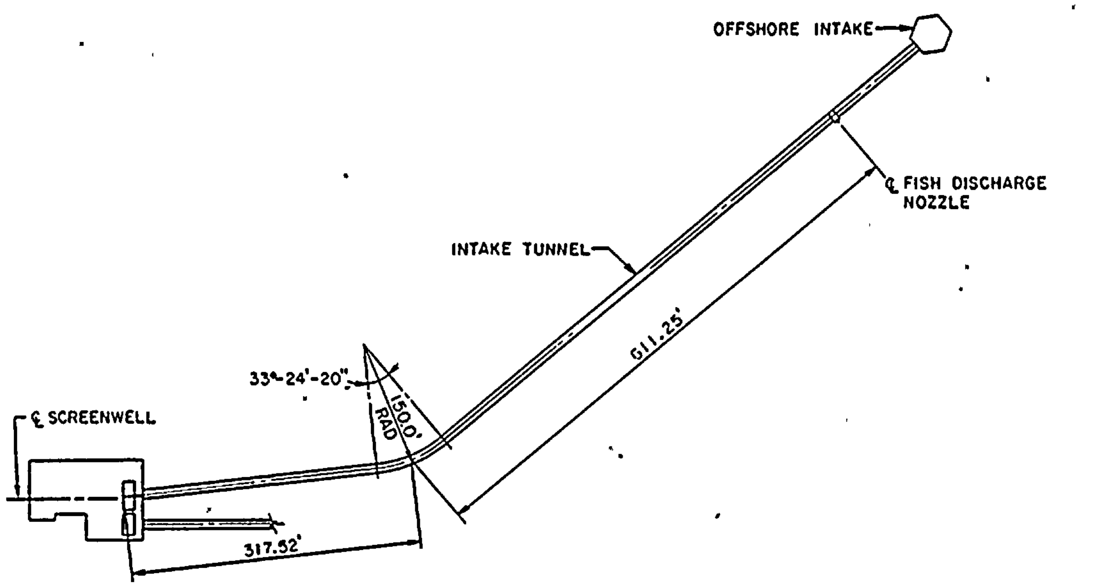


PRIMARY SCREENWELL



SECONDARY SCREENWELL

FIGURE 5-2
PROFILE OF PRIMARY AND SECONDARY SCREENWELLS
UNIT NO 6.- OSWEGO STEAM STATION
NIAGARA MOHAWK POWER CORPORATION
STONE & WEBSTER ENGINEERING CORPORATION



KEY PLAN
CIRC WATER INTAKE TUNNEL
NO SCALE

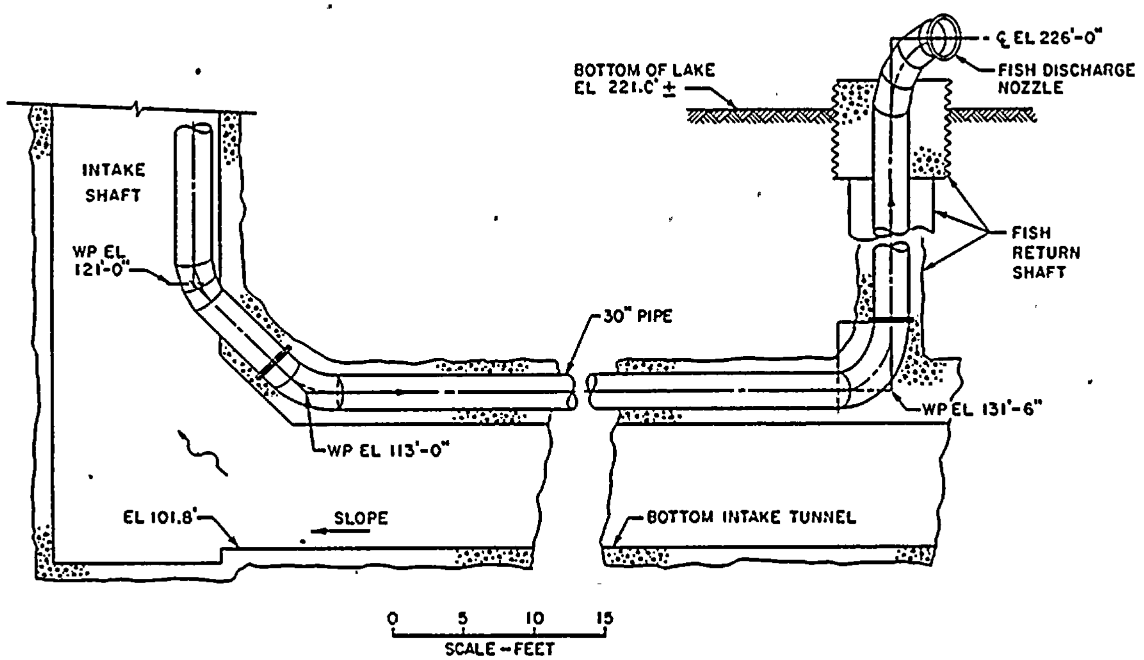


FIGURE 5-3
FISH RETURN PIPE
UNIT NO. 6 – OSWEGO STEAM STATION
NIAGARA MOHAWK POWER CORPORATION
STONE & WEBSTER ENGINEERING CORPORATION

18-inch-diameter pipe. At the secondary jet pump, this 18-inch-diameter pipe reduces to a 17-inch-diameter suction pipe. The mixing tube of the secondary pump is 20 inches in diameter, yielding an area ratio of driving nozzle to mixing tube of 0.22. The ratio of the average secondary bay approach velocity to the average secondary bypass velocity varies from 1:1 to 1:1.3. The secondary jet pump discharges into a 30-inch-diameter discharge pipe embedded in the roof of the intake tunnel for a distance of approximately 1,000 feet where it rises vertically and terminates as a horizontal discharge at the lake bottom, as shown in Figure 5-3.

Both jet pumps are designed to operate with a nozzle velocity between 30 and 40 fps and take their driving flow from the circulating water pumps. The primary pump discharges from 60 to 70 cfs to the secondary bay. The secondary pump discharges from 20 to 25 cfs to the lake at a transport velocity of 4.6 to 5.2 fps.

A comparison of the geometric and hydraulic parameters between the model and the prototype for normal and future modes of operation is given in Table 5-1.

Utilizing the model test parameters in comparison to the prototype parameters of Unit No. 6 - Oswego Steam Station fish diversion system, it appears that an angled screen and a double jet pump transportation system offers an effective means for reducing fish impingement.

TABLE 5-1

COMPARISON OF PROTOTYPE AND MODEL PARAMETERS

UNIT NO. 6 - OSWEGO STEAM STATION
NIAGARA MOHAWK POWER CORPORATION
STONE & WEBSTER ENGINEERING CORPORATION

Parameter	Prototype	Model
Fish species	Smelt, alewife (key species)	Alewife
Water temperature, °F	35-75	60-75
Water quality	as naturally occurring in Lake Ontario	as naturally occurring at ARL
Fish transport from lake to screenwell	Yes	No
Tempering in screenwell during winter	Yes	No
Screenwell		
Approach velocity, fps	0.8 to 1.5	1.0
Bypass width, ft	0.5	0.5
Bypass velocity, fps	0.8 to 1.5	1.4 to 2.0
Depth, ft	23 to 30	6
Number of screens per bay	2 or 3	1
Screen length, ft	10	12
Screen angle	25 deg	25 deg
Trash	Yes	No
First Jet Pump		
Suction velocity, Vs, fps	4.6 to 4.8	6.0 to 8.7
Mixing tube velocity, Vd, fps	9 to 10	10.2 to 14.4

TABLE 5-1 (CONT'D)

Parameter	Prototype	Model
Nozzle velocity, Vn, fps	30 to 40	35 to 45
Pressure rise, Pd-Ps, ft	3.5 to 5.5	4 to 7
Mixing tube diameter, in.	36	12
Area ratio, R	0.2	0.2
Secondary Bay		
Entrance	5-ft-wide bay	Tank
Approach velocity, fps	0.8 to 1.6	1.4 to 2.0
Bypass width, ft	0.5	0.5
Bypass velocity, fps	0.8 to 1.7	0.6 to 0.7
Depth, ft	8 to 15	2
Number of screens	1	1
Screen length, ft	10	12
Screen angle	25 deg	10 deg
Second Jet Pump		
Suction velocity, Vs, fps	4.8 to 5.3	8.3 to 10.3
Mixing tube velocity, Vd, fps	10.6 to 12	12.5 to 15.0
Nozzle velocity, Vn, fps	30 to 40	35 to 44
Pressure rise, Pd-Ps, ft	4.5 to 7.5	3.5 to 5
Mixing tube diameter, in.	20	4
Area ratio, R	0.2	0.2

TABLE 5-1 (CONT'D)

Parameter	Prototype	Model
Transport Pipe		
Velocity, fps	4.6 to 5.2	7.0
Length, ft	1,300	180
Diameter, in.	30	10
Material	Steel & fiber glass	PVC
Pressure changes, psi	8 to 33	1 to 3
Number of bends	8	4
Exit of Fish		
Location	Open body	Collection area
Velocity, fps	4.6 to 5.2	12.5 to 15

REFERENCES CITED

Stone & Webster Engineering Corp. 1975. Summary report of studies to alleviate potential fish entrapment problems at Lake Ontario power plant intakes, May 1973 – December 1974. Prepared for Niagara Mohawk Power Corporation (February 1975).

__________. 1976a. First interim progress report, studies to alleviate potential fish entrapment problems at Lake Ontario power plant intakes. Prepared for Niagara Mohawk Power Corporation and Rochester Gas & Electric Corporation (April 1976).

__________. 1976b. Final report, studies to alleviate fish entrapment problems at power plant cooling water intakes. Prepared for Niagara Mohawk Power Corporation and Rochester Gas & Electric Corporation (November 1976).

__________. 1977. Final report, Nine Mile Point Nuclear Sta.–Unit 2, studies to alleviate potential fish entrapment problems. Prepared for Niagara Mohawk Power Corporation (May 1977).

APPENDIX

DOUBLE JET PUMP FISH

TRANSPORT SYSTEM

DOUBLE JET PUMP FISH
TRANSPORT SYSTEM

NIAGARA MOHAWK POWER CORPORATION

STONE & WEBSTER ENGINEERING CORPORATION

Dean K. White
Johannes Larsen

George E. Hecker, Director

ALDEN RESEARCH LABORATORIES
WORCESTER POLYTECHNIC INSTITUTE
HOLDEN, MASSACHUSETTS 01520

May, 1977

ABSTRACT

A fish diversion and transportation system has been incorporated in the design of the Unit 6 screenwell at the Oswego Steam Station. To evaluate the efficiency of the system, Niagara Mohawk Power Corporation contracted Stone & Webster Engineering Corporation and the Alden Research Laboratories to model study the system.

The existing system demonstration model, incorporating an angled fish diversion screen, a transport pipe, and a 12 inch jet pump, was expanded to include a secondary angled screen and bypass leading to a 4 inch jet pump.

The double jet pump transport system was tested with alewives to evaluate screen efficiency and subsequent fish survival. Biological testing results are discussed in the main portion of this report. This appendix describes the system model, and contains hydraulic data obtained during biological testing.

TABLE OF CONTENTS

INTRODUCTION

The removal of fish from cooling water flow, and the return of these fish to their natural environment, has been investigated in previous model studies at ARL. Each model study has yielded specific information related to possible stress upon the fish induced by the particular device tested. In this study, devices were combined to form a complete fish diversion, bypass and return system as required for a specific application.

The results of this test program, and previous studies, will form the basis for evaluation of the fish transport capabilities of a double jet pump system as it would be applied to the Oswego Steam Station, Unit 6 screenwell structure. Results from biological testing of this model are presented in the main body of this report. This appendix includes a description of the model and the associated instrumentation and presents hydraulic data obtained during testing.

DESCRIPTION OF TEST FACILITY

To simulate the diversion and transport system proposed for the Oswego Steam Station, Unit 6 screenwell structure, the existing System Demonstration model (Reference 1) was modified by the addition of a 4 inch peripheral jet pump. The two jet pumps, operating in series, simulated the proposed fish transport system. Table 1 shows the prototype design parameters, and the corresponding model parameters tested. Figure 1 shows the model arrangement with the primary angled screen and bypass, transport pipe, first stage jet pump, and the secondary angled screen and bypass, and second stage jet pump. Two large fish collection areas contained the discharge from each jet pump. The individual parts of the system have been described in detail in previous reports: the primary screenwell and fish bypass, Figure 2 and Photograph 1, were described in Reference 2, the transport system, with the secondary screen and the second stage jet pump were discussed in References 1 and 3, respectively. Changes which were made to the system for this study are given below:

Primary Bypass

The bypass roof angle was changed from 28° to 45° for this study in an attempt to simulate the prototype bypass section. The resulting bypass geometry is shown in Figure 3. The model bypass roof geometry differed from the prototype in that the inclination of the roof started further downstream from the beginning of the bypass than in the prototype. This was done for ease of model modification.

Transport Pipe

The transport pipe was modified by lowering the elevated section of the pipe four feet to reduce the tendancy for air leakage at the joints.

First Stage Jet Pump

The first stage jet pump as described in Reference 1, was not altered. The pump is shown in Photograph 2. The driving flow was provided by two twelve inch supply pumps.

Secondary Bypass

The secondary bypass was fitted with a 90° curved transition leading from the secondary angled screen to the second stage jet pump.

Second Stage Jet Pump

The second stage jet pump, Photograph 3, as described in Reference 3, was located immediately downstream of the transition from the secondary bypass. The pump discharged into fish collection area number 2, as shown in Figure 1.

INSTRUMENTATION AND TEST PROCEDURE

General

Instrumentation was provided to monitor the operation of the transport system. Data obtained were used to check the operation of the two jet pumps against their operating curves.

Pressure Measurements

The piezometric heads were measured on manometers using the jet pump centerlines as datum. Figure 4 shows the location of the various piezometer taps.

Velocity and Flow Measurements

Velocities were measured across the approach channel ten feet upstream of the primary angled screen and in the bypass entrance with a propeller type current meter.

Flow rates in the two supply lines for the 12" jet pump were measured by 12" x 8" Venturi meters. The flow rate to the 4" jet pump was metered by an orifice plate installed in the pipe supplying the driving flow. Both venturi meters and the orifice section were calibrated before being installed in the model.

Suction flow for the 12" jet pump was metered by use of an elbow meter which was calibrated in place. The mixing tube flow in the 4" jet pump was calculated from a velocity profile obtained by a pitot meter. The suction flow was calculated as the difference between the mixing tube flow and the driving flow.

Test Procedure

Fish test procedure is discussed in the main portion of this report.

The hydraulic test procedure was governed by the Quality Assurance Program to assure consistency and accuracy of the acquired data. This program specified meter calibration procedures, dimensional checks of the model, data retrieval procedures and evaluation of the acquired data.

The test basin was filled and the approach flow started. The driving flows to the two jet pumps were set to establish predetermined jet nozzle velocities. When the system was stabilized, pressure data were obtained at the locations shown on Figure 4. The measurements of approach and bypass velocities of the primary angled screen were obtained before and after each test. Driving flows were monitored hourly during the entire test.

TEST DATA

Table 1 presents operating conditions for the 10 tests performed. Tests 1 through 5 were biological tests with alewives, and tests 1H through 5H were hydraulic tests to verify the velocity in the system.

A comparison of pressure and flow data for each pump to previously obtained data are shown in Figure 5. The data indicated that both pumps were seemingly less efficient than during previous testing. Since the primary purpose of this testing was biological, elbow meters and pitometer traverse were used to obtain suction and discharge flow rates. These measurement procedures were less accurate than previous flow measurement procedures used during hydraulic performance testing.

Velocity distribution in the screenwell is shown in Figure 6. The isovels shown are based on the average of the normalized point velocities in tests 1 through 5. The distribution shows good agreement with previously obtained data (Reference 2). The absolute approach velocity at the traverse location was maintained at approximately one foot per second for all biological tests. A velocity traverse was taken along the upstream face of the screen. The traverse shown in Figure 7 was obtained with an approach velocity of 0.73 feet per second and a bypass velocity of 1.08 feet per second. The isovels indicate a uniform velocity distribution slightly higher at the bypass end of the screen.

The bypass velocities varied according to the transport pipe flows as governed by the nozzle velocities in the primary jet pump. Bypass velocities were obtained in two traverse locations as shown in Figure 3. The normalized velocity distribution at the bypass entrance is shown in Figure 8. The flat profile is due to the contracting flow as it enters the bypass channel. The normalized velocity distribution at the 45° bypass roof shown in Figure 9 is a more fully developed profile of the flow moving toward the pipe inlet.

REFERENCES

1. Screenwell Fish Guidance and Transport Systems Demonstration, ARL Report, April, 1977.

2. Fish Diversion Studies for Screenwell Structures, Angled Screen, ARL Report December 1975.

3. Peripheral Jet Pump Study, ARL Report, December 1975.

TABLE 1

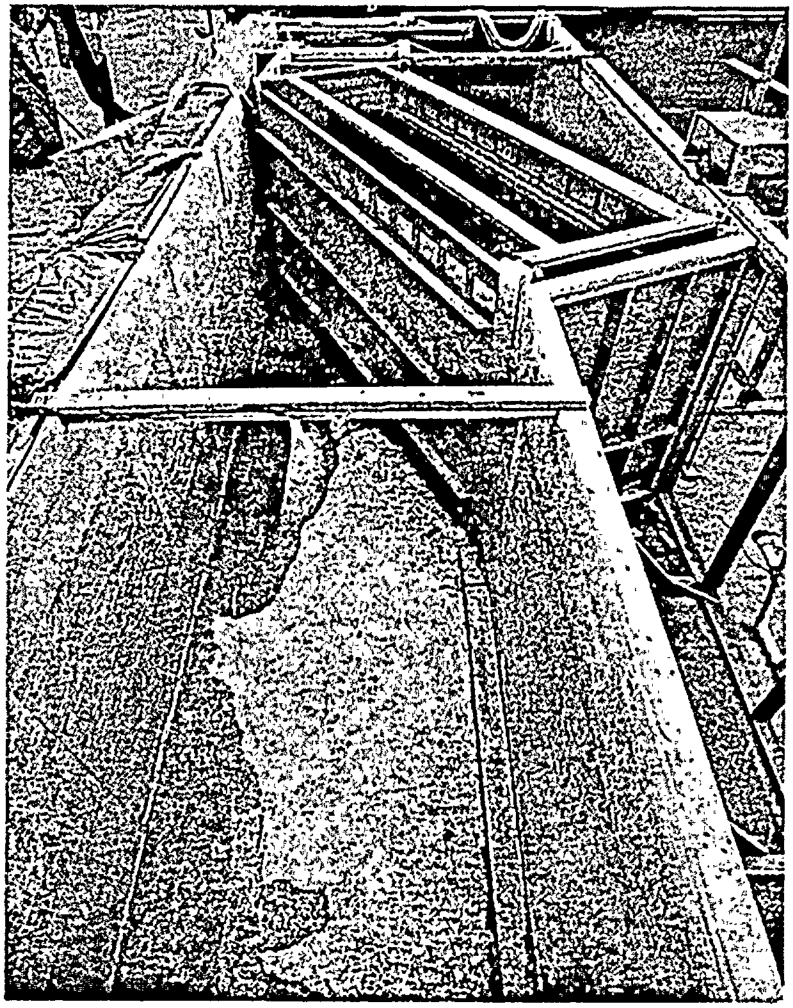
TEST NUMBER	Prototype	1	2	3	4	5	1H	2H	3H	4H	5H
Screenwell											
Approach Velocity	0.8 - 1.5	---	1.03	---	0.97	0.98	---	---	---	---	---
Bypass Velocity	0.8 - 1.5	---	1.52	2.02*	1.82	1.95	2.0*	1.63*	1.62*	1.34*	1.04*
Depth	23 - 30	---	5.58	5.56	5.45	5.42	5.43	5.53	5.85	5.55	5.50
First Jet Pump											
Suction Velocity, V_s	4.5	6.17**	7.52	8.61	7.97	8.62	8.79	6.91	6.97	5.66	4.40
Mixing Tube Vel., V_d	11	10.20**	12.50	14.40	13.10	14.33	14.47	12.26	11.42	9.54	7.71
Nozzle Vel., V_n	40	34.86	39.12	44.93	40.61	44.62	45.00	40.00	35.00	30.00	25.00
Pressure Rise, $P_d - P_s$	7	4.30	5.30	6.90	5.70	6.80	7.01	5.38	4.15	4.15	2.15
Second Jet Pump											
Suction Velocity, V_s	11	8.30**	9.51**	10.21**	9.46**	10.27**	11.20	9.80	8.30	7.18	6.86
Mixing Tube Vel., V_d	15.3	12.53**	14.07**	14.90**	13.98**	14.98**	16.07	14.41	12.53	10.78	9.61
Nozzle Vel., V_n	40	35.00	38.70	43.40	38.40	43.70	45.00	40.00	35.00	30.00	25.00
Pressure Rise $P_d - P_s$	5	3.55**	4.53**	4.98**	4.48**	5.00**	5.39	4.88	3.55	2.71	1.87
Transport Pipe											
Velocity	4.6	5.96	7.58	8.68	8.03	8.69	8.86	6.96	7.03	5.70	4.43
Water Temperature	32 - 75	72.00	66.00	69.00	67.00	74.00	73.00	73.00	73.50	72.50	72.50
Test Date		7/28	8/3	8/5	8/10	8/12					

*Calculated as Average Velocity using V_s

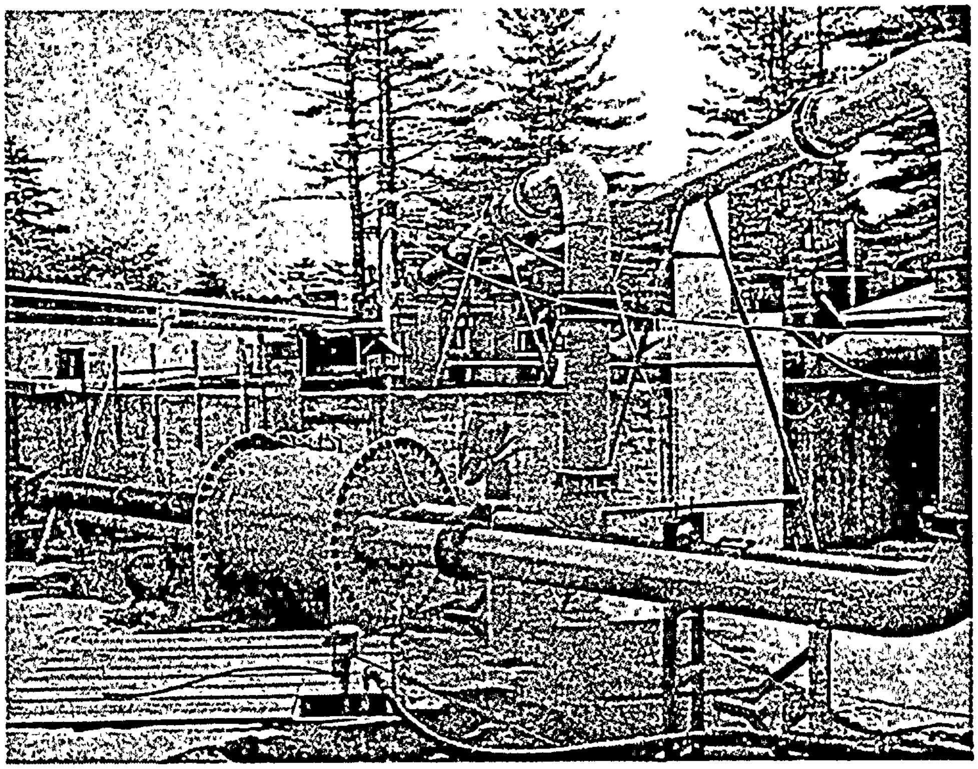
**Computed from Pump Performance

---Not measured

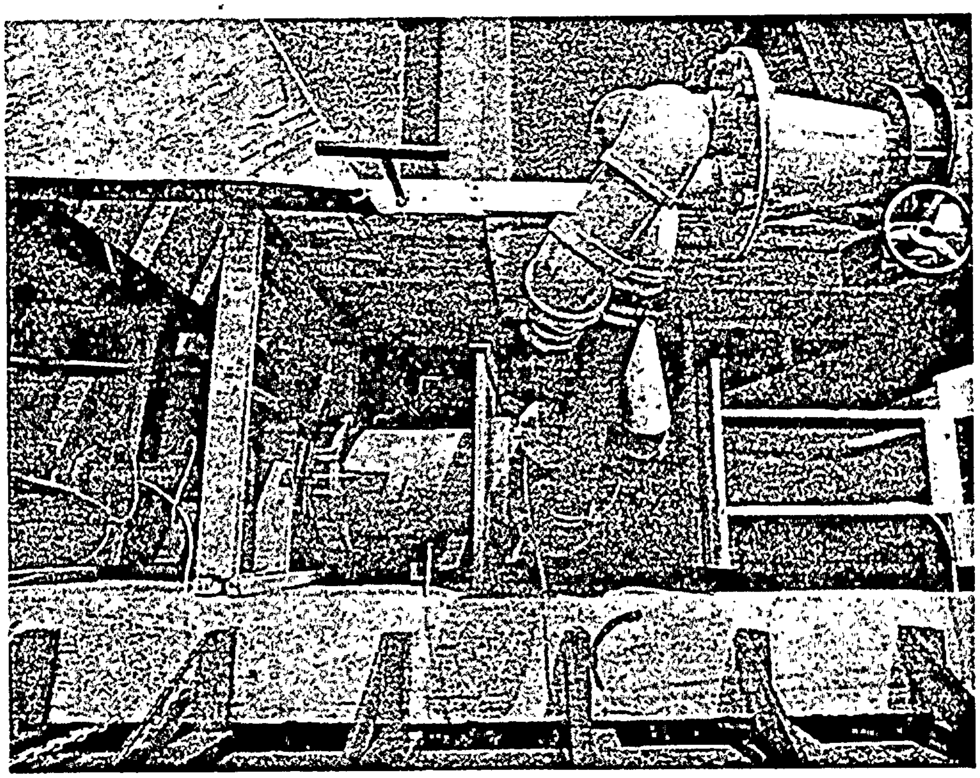
PHOTOGRAPHS



Photograph 1   Approach Channel to Primary Angled Screen



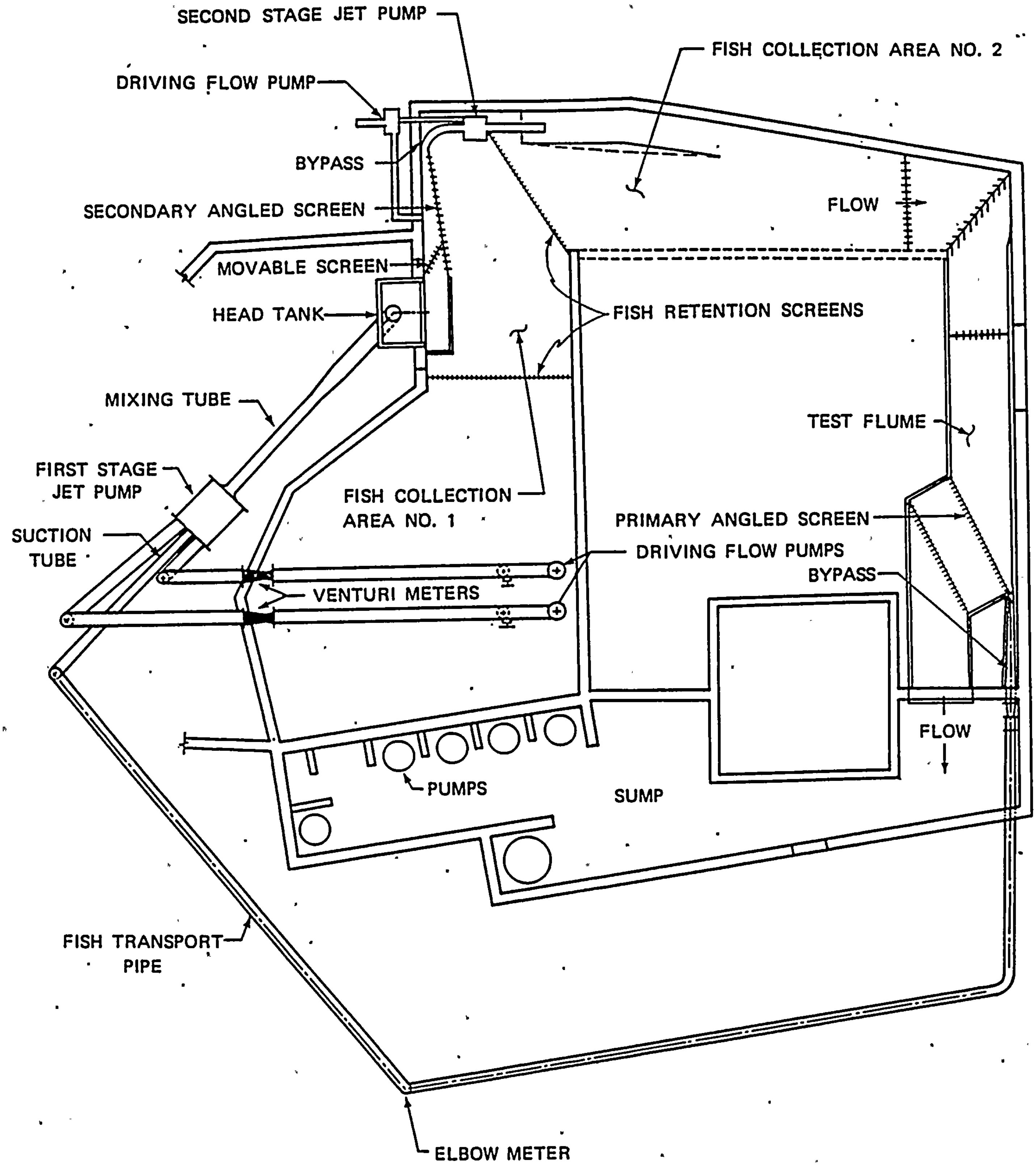
Photograph 2 Twelve Inch Jet Pump



Photograph 3 Four Inch Jet Pump

FIGURES

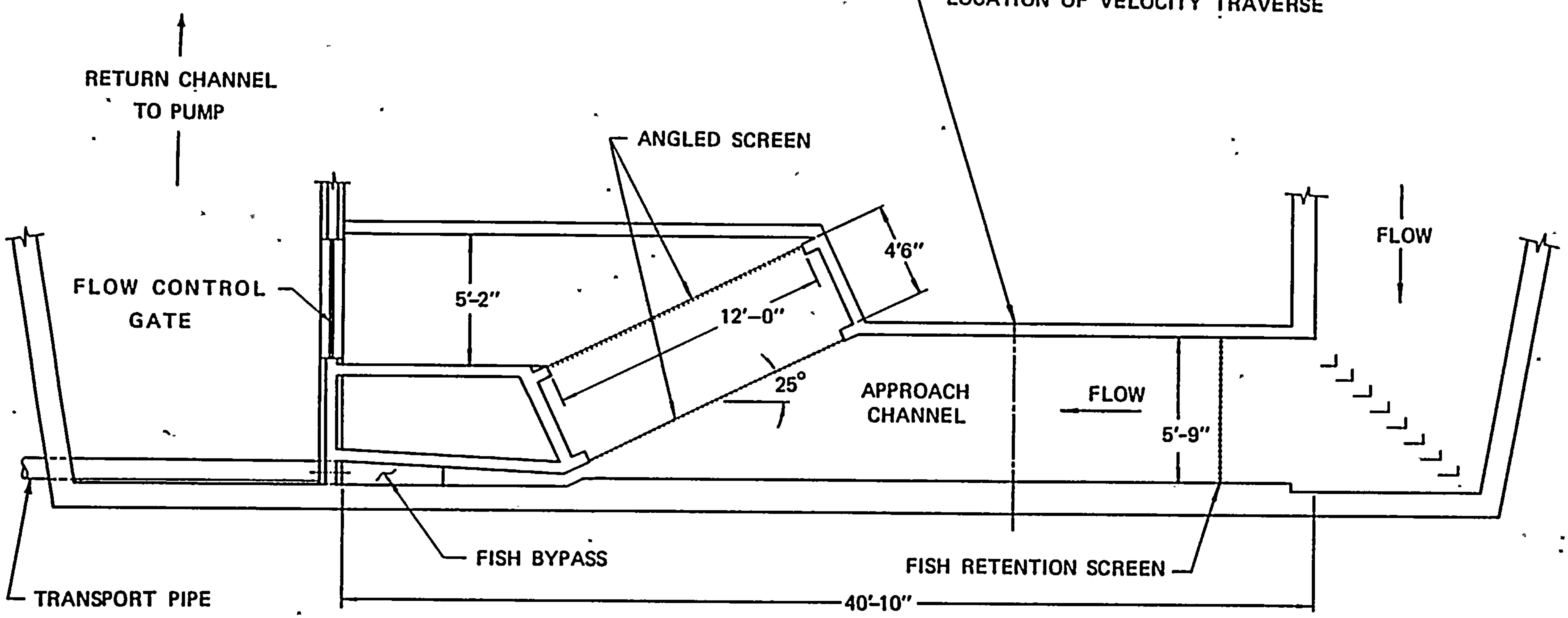
FIGURE



MODEL ARRANGEMENT

FIGURE 2

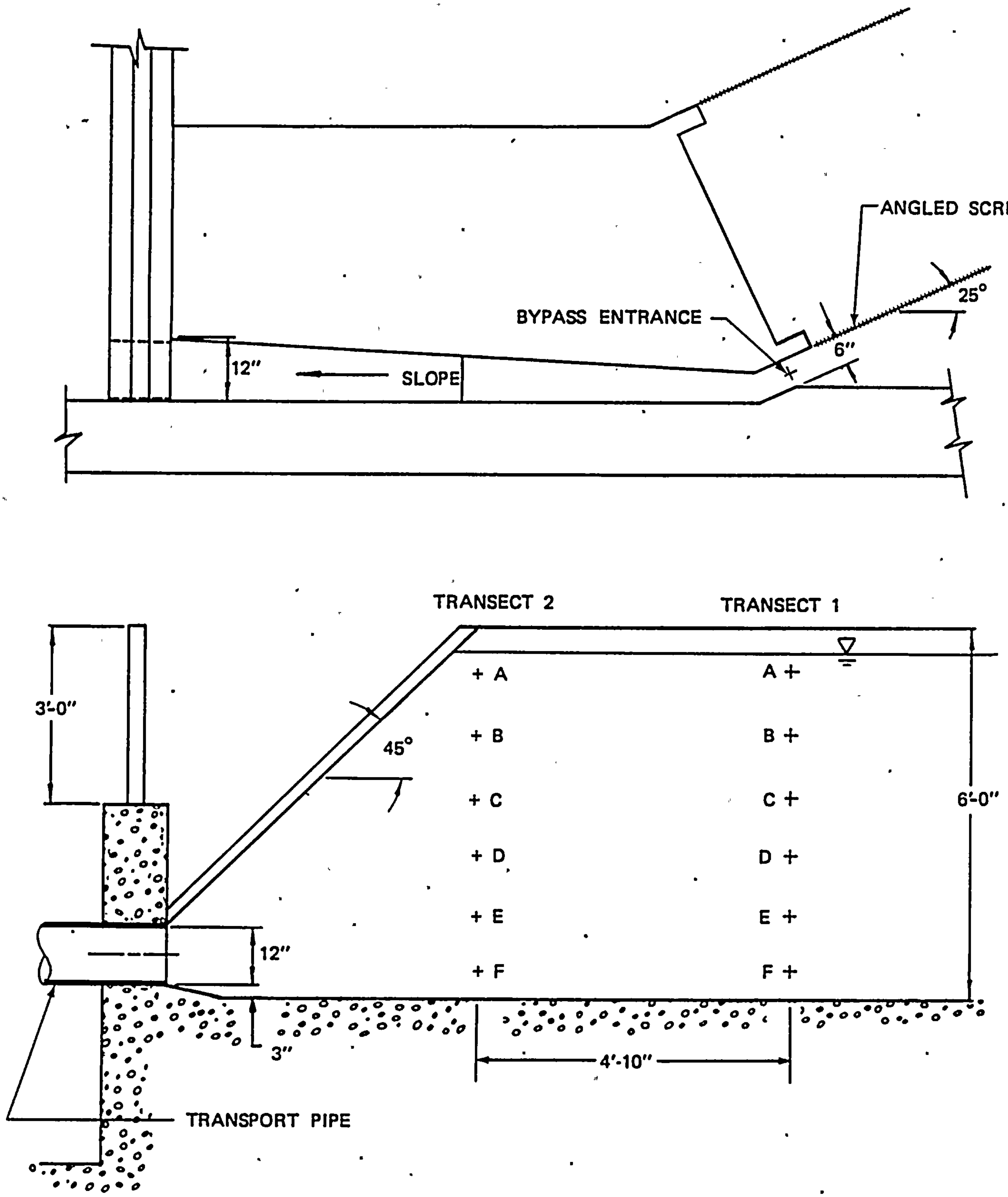
PLAN VIEW



ANGLED SCREEN

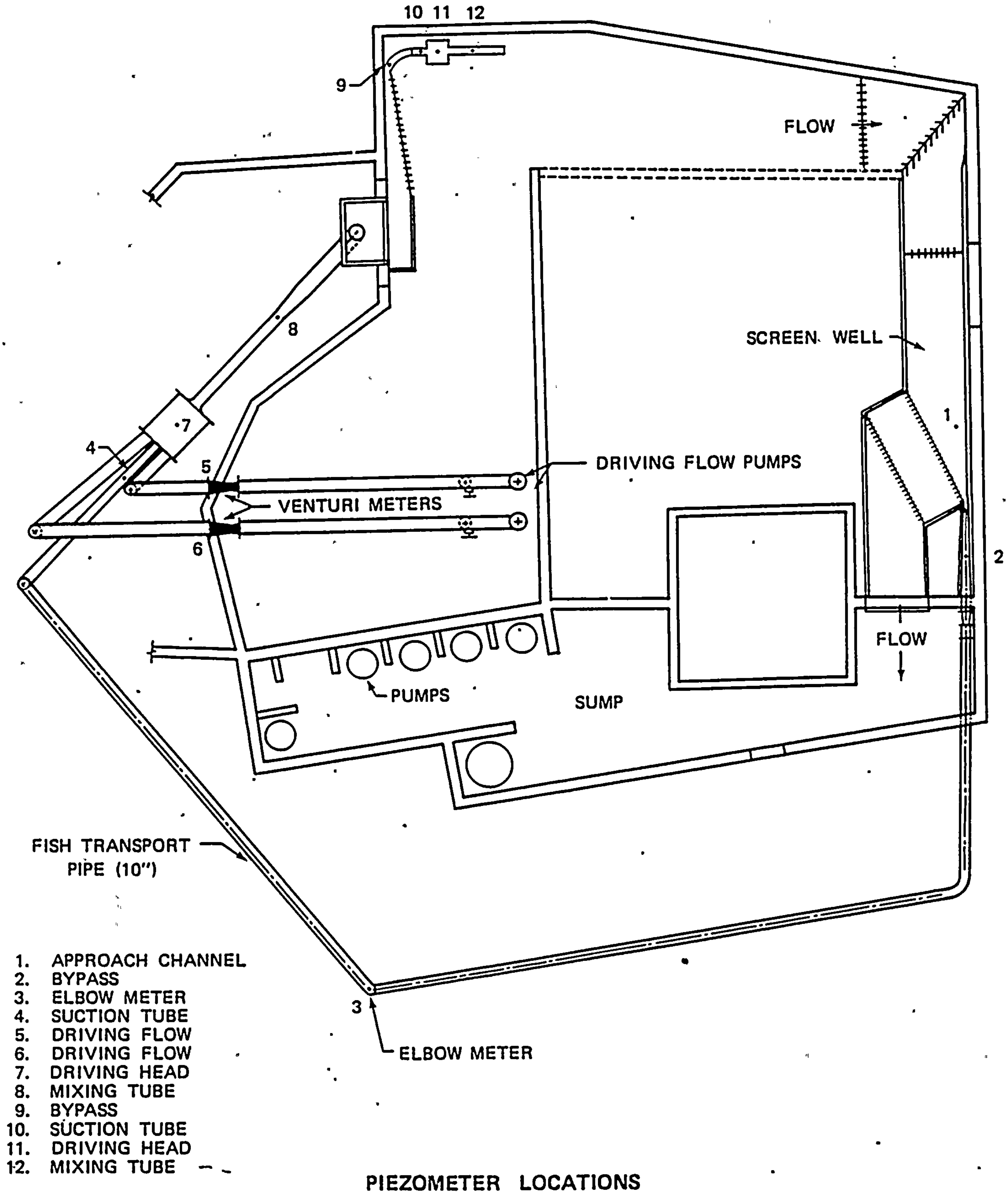
ARL

FIGURE 3



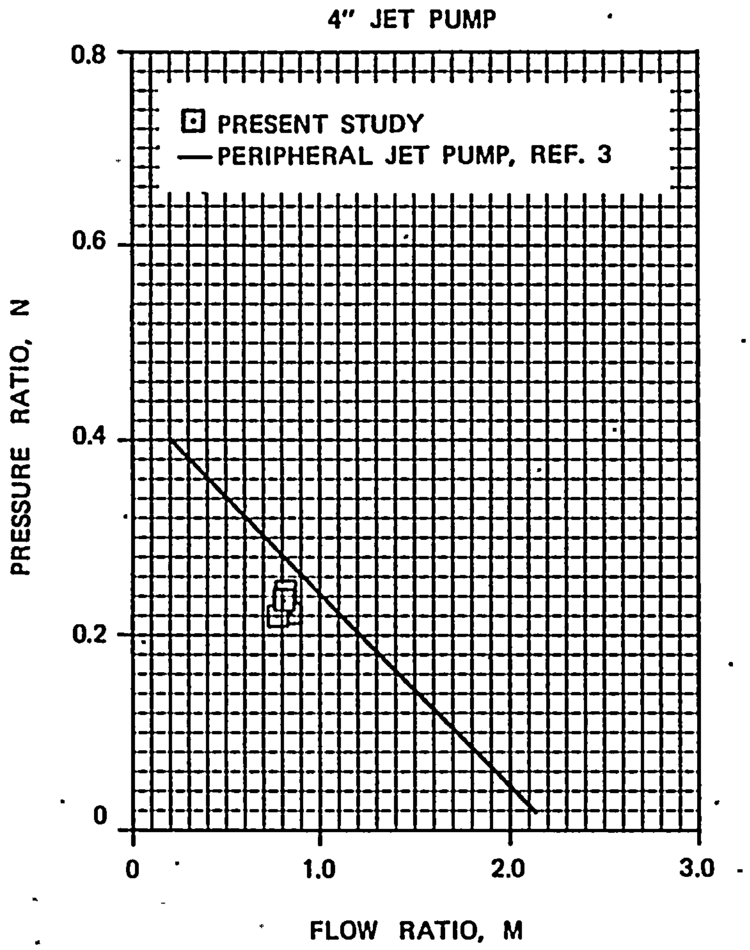
FISH BYPASS AND CONVERGING SECTION

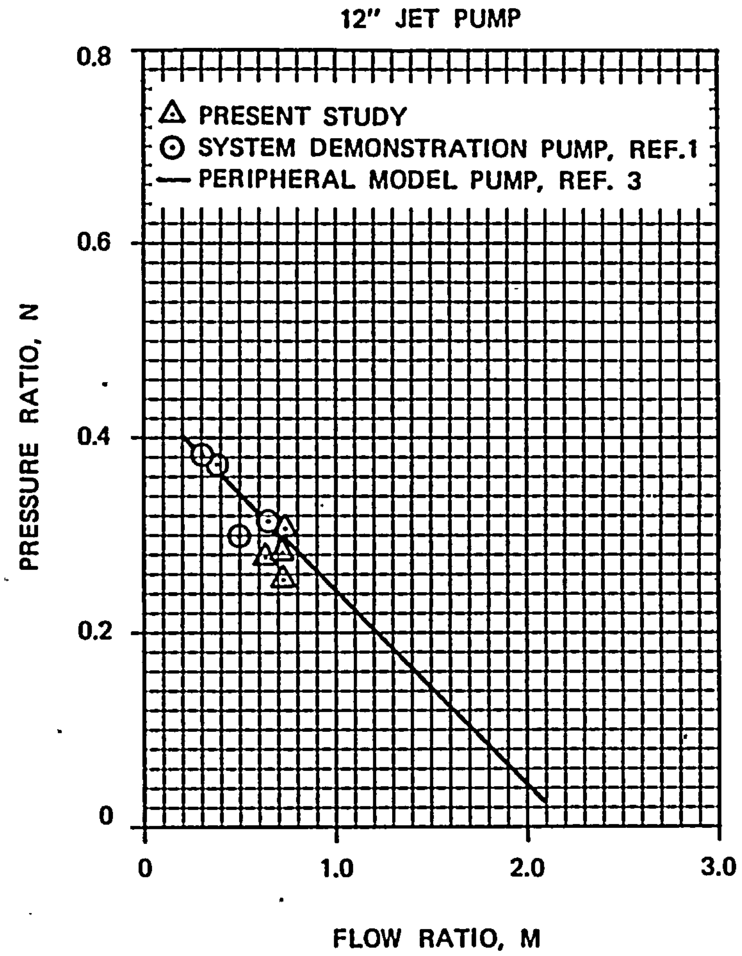
FIGURE 4



PIEZOMETER LOCATIONS

ARL





Q_s = SUCTION FLOW, CFS
Q_n = DRIVING FLOW, CFS
P_d = TOTAL DISCHARGE FLOW HEAD MEASURED 9D DOWNSTREAM OF NOZZLE – FEET
P_s = TOTAL SUCTION FLOW HEAD MEASURED 4D UPSTREAM OF NOZZLE – FEET
P_n = TOTAL NOZZLE FLOW HEAD – FEET

$$N = \frac{P_d - P_s}{P_n - P_d}$$

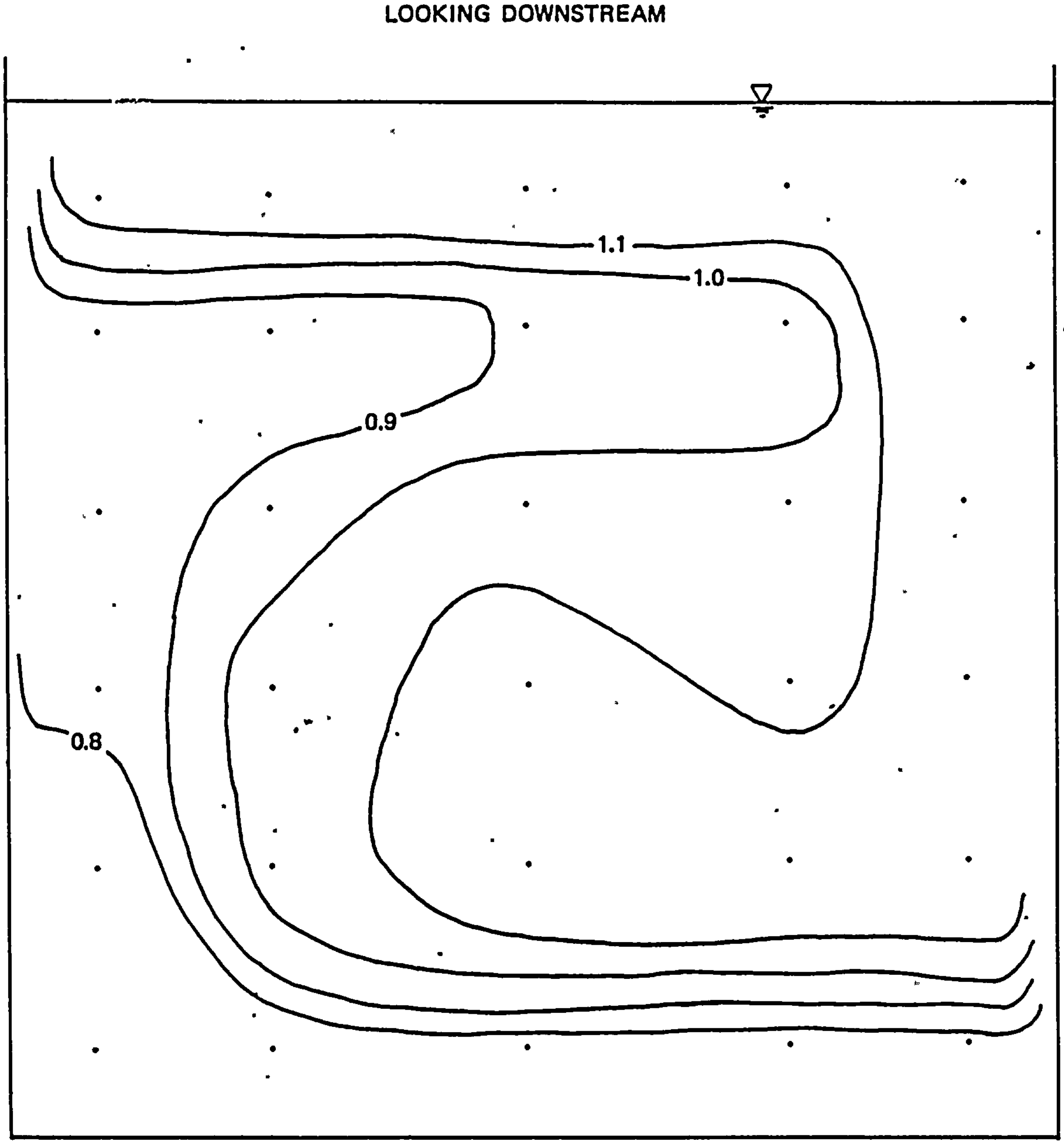
$$M = \frac{Q_s}{Q_n}$$

PERFORMANCE CURVES

ARL

FIGURE 5

FIGURE 6



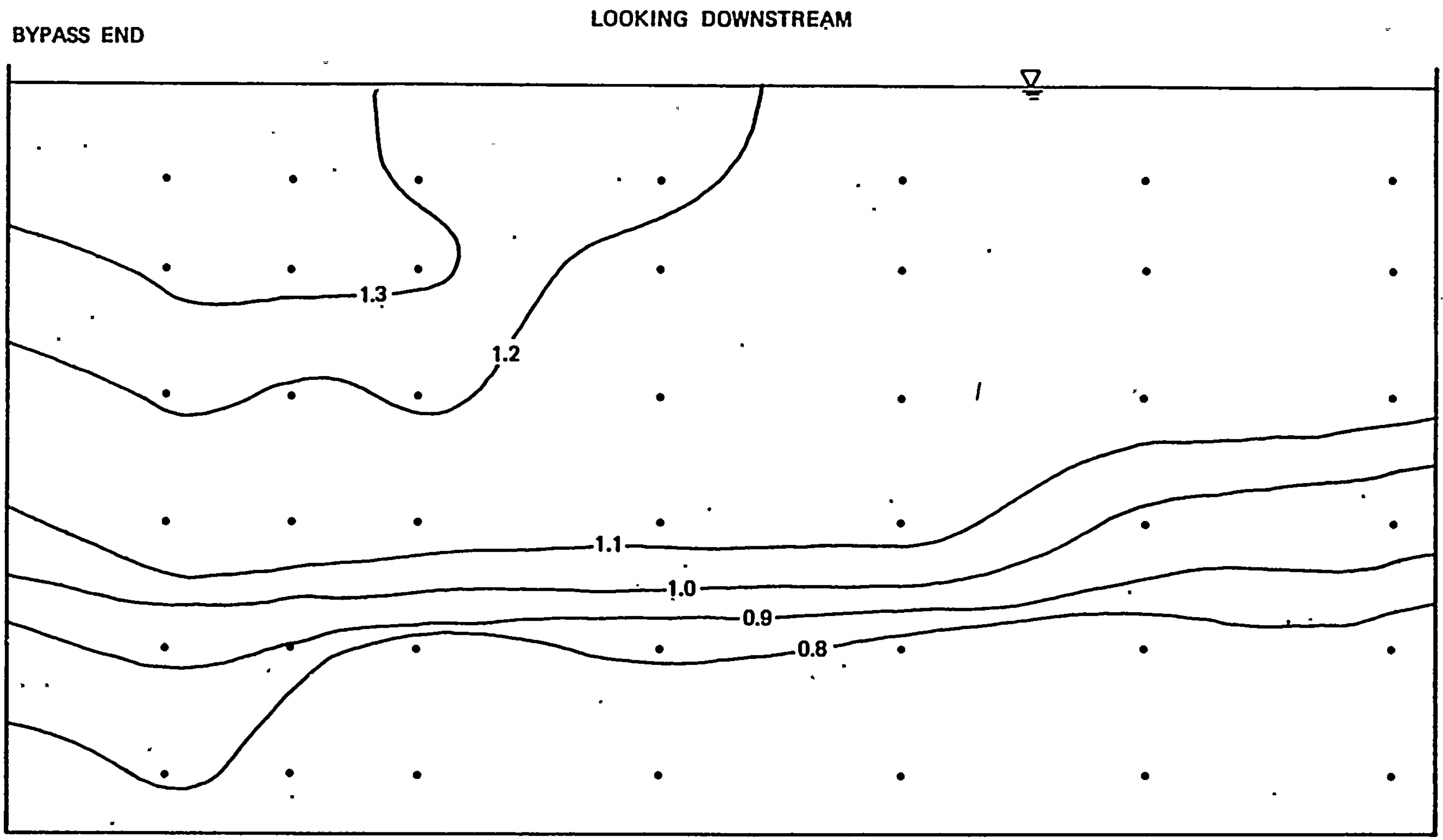
NOTES:

1. TRAVERSE LOCATION SHOWN IN FIGURE 2
2. ISOVELS BASED ON NORMALIZED VELOCITY V/V̄ AVERAGED FOR TESTS 1 THROUGH 5

NORMALIZED ISOVEL PLOT FOR APPROACH CHANNEL

(AVERAGE OF TESTS 1-5)

ARL



V APPROACH = 0.73 FPS

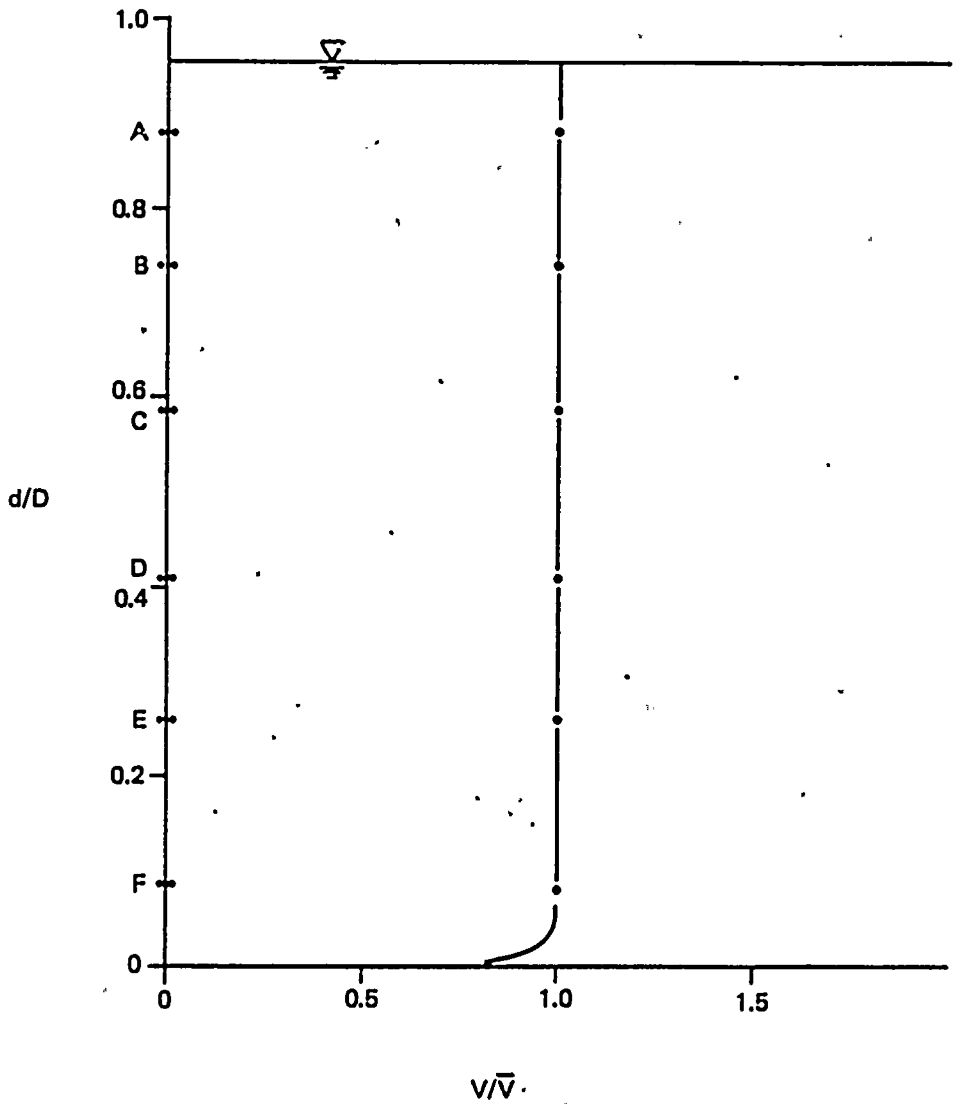
V BYPASS = 1.08 FPS

NORMALIZED VELOCITY DISTRIBUTION
ALONG FACE OF ANGLE SCREEN

FIGURE 7

ARL

FIGURE 8



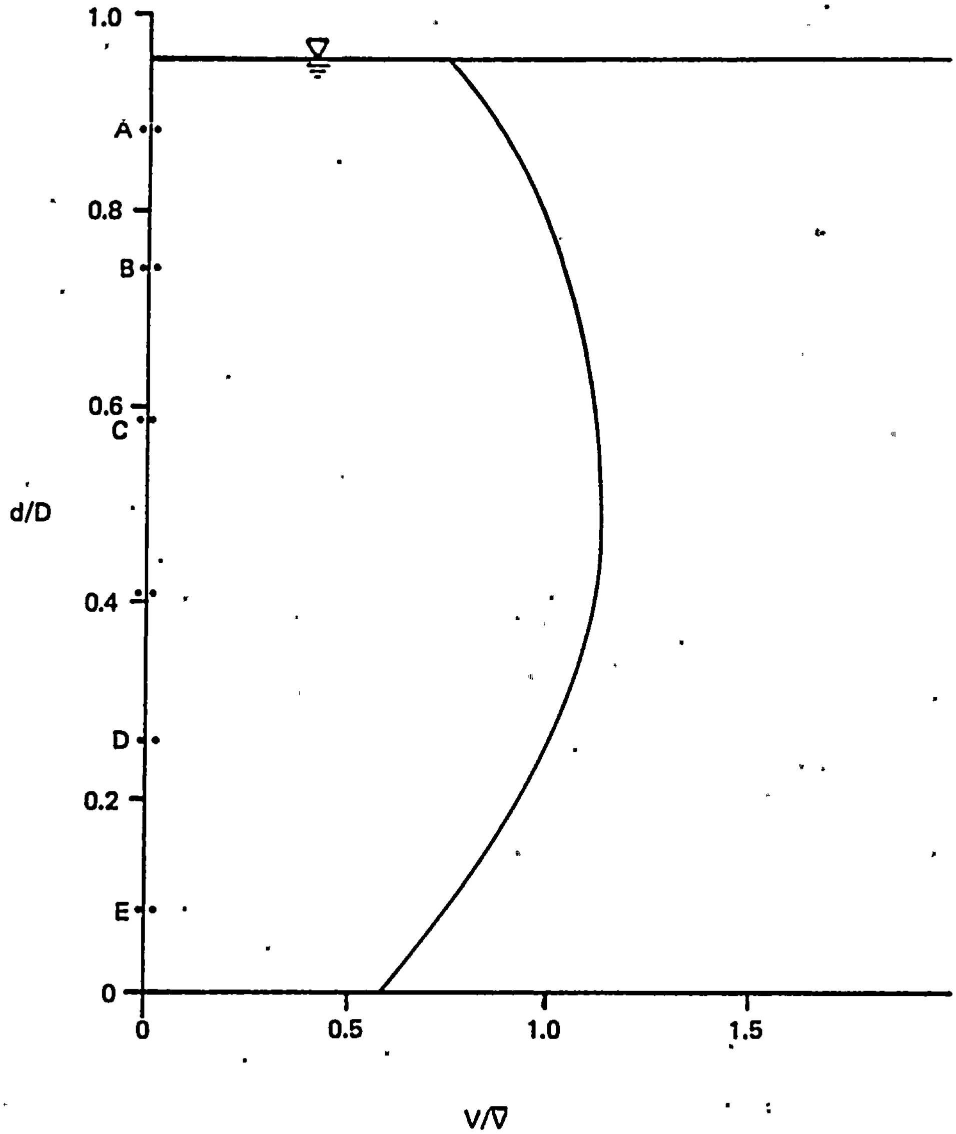
NOTE: TRANSECT LOCATION SHOWN IN FIGURE 3

BYPASS VELOCITY DISTRIBUTION

TRANSECT 1

ARL

FIGURE 9



BYPASS VELOCITY DISTRIBUTION
TRANSECT 2

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