PAP-493

HYDRAULIC MODEL STUDY OF THE CHANDLER FISH SCREEN, WASHINGTON

BY

PERRY L. JOHNSON

PAP-493

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Memorandum

To: Regional Director, Boise, Idaho
Attention: PN-200, PN-700

From: FOR Chief, Division of Research and Laboratory Services

Subject: Model Study for Chandler Canal Fish Screen Structure - Yakima Project, Washington

A report describing the findings of the Chandler Canal Fish Screen Structure Hydraulic Model Study is enclosed. As a result of the model study, significant changes were made to the preliminary design of the structure. Approach channel modifications in conjunction with fish bypass intake modifications, bank realignment in the screen structure reach, and possible stoplogging at the trashrack structure will provide uniform flow distribution at the screens within the guidelines established by the fishery agencies. A summary video tape of the model study will be sent to your office under separate cover. This video tape has also been sent to the Project Superintendent. Ken Bates of the Washington Department of Fisheries and Steve Rainey of the National Marine Fisheries Service will be given a copy of the model study report and the summary video tape.

U.S. GPO: 1985-577-787

H. Walter Anderson

Enclosures

Copy to: Project Superintendent, Yakima, Washington
(with enclosure)

Blind to: D-241 (Green)
D-270
D-274
D-274 (Haider)
D-274 (Glickman)
D-1530
D-1531
D-1531 (PAP File)
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HYDRAULIC MODEL STUDY OF THE CHANDLER FISH SCREEN, WASHINGTON

by
P. L. Johnson

From 1900 through the 1950's, fairly extensive hydropower and irrigation development occurred at various sites on the Yakima River, Washington. Historically, prior to development, as many as 600,000 anadromous fish returned every year to the Yakima River system to spawn [1]. Fish runs are presently at 2,000 per year. Most of the damage to the fish runs has resulted due to the diversion structures and diversion practices used on the river. Diversion dams were constructed with inadequate fish passageways, both for upstream and downstream passage. In addition water was diverted to the point of drying up stretches of the river including spawning grounds [1].

An effort has been initiated to reestablish the anadromous fish runs on the river. Organizations involved include the Bonneville Power Administration, the Northwest Power Planning Council, the Yakima Indian Nation, the State of Washington, the Yakima River Association of Irrigation Districts, the National Marine Fisheries Service, and the Bureau of Reclamation. As part of the effort, new or modified fish passageways are being added to all the major diversion structures on the river. In addition, the Power Planning Council has developed plans for a $20 million fish hatchery on the Yakima Indian Reservation that would produce salmon and steelhead for other Yakima River tributaries.

One fishway that is being designed and constructed will intercept downstream migrating fish which have been diverted into the Chandler Canal and return the fish to the river. The facility includes a trashrack structure, an angled drum screen structure, a pumpback-bypass structure, a juvenile evaluation facility, and a river outlet structure (figure 1). The fish are directed by the drum screens into bypass intakes. The fish then pass through below grade 42-in-diameter pipe to the pumpback-bypass structure where the fish are concentrated and a portion of the bypass flow returned to the canal. The fish then pass through a pipe to the juvenile evaluation facility where, if desired, the fish can be sorted, sampled, and inspected. Finally the fish are returned to the river through an outlet structure that is aligned with the flow to minimize fish disorienting turbulence.

Water is diverted from the Yakima River into the Chandler Canal by Prosser Diversion Dam. Prosser Diversion Dam is located in south central Washington approximately 50 mi downstream of the city of Yakima. The maximum diversion discharge is 1,500 ft^3/s. The diverted flow is used to both generate power at Chandler Powerplant and irrigate downstream lands.

The fish screen structure would be located at station 43+00 on the canal or approximately 1 mi below the canal headworks. The screen would be located in a reach of canal that would supply approximately 500 ft of straight approach to the screen. This is sufficient length to establish

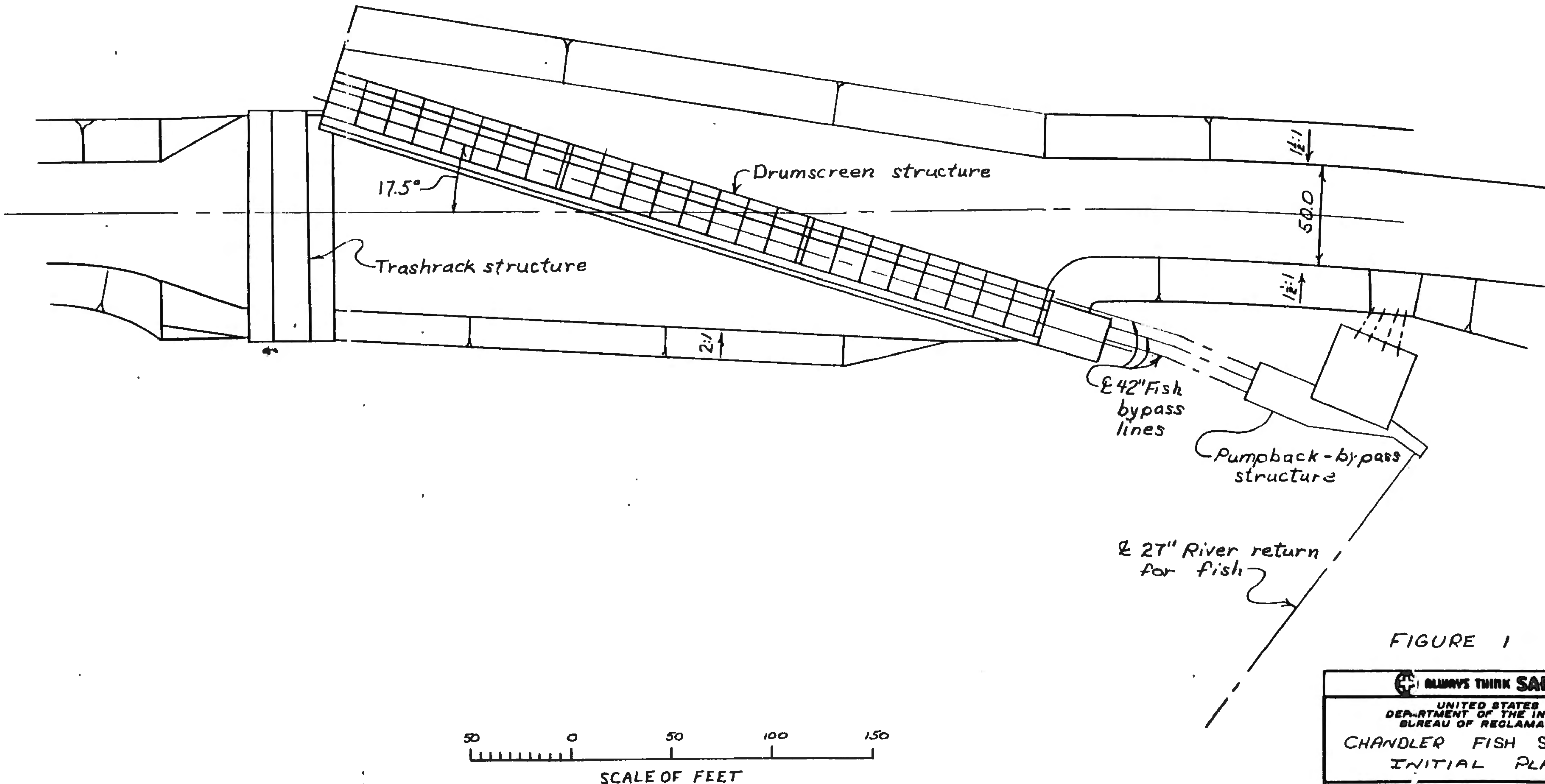

FIGURE 1

ALWAYS THINK SAFETY

UNITED STATES
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CHANDLER FISH SCREEN
INITIAL PLAN

DESIGNED ______ TECHNICAL APPROVAL ______
DRAWN ______ SUBMITTED ______
CHECKED ______ APPROVED ______

a fairly uniform approach flow distribution. A good approach flow distribution in turn is a good first step towards obtaining uniform flow distribution through the screens.

Flow patterns, velocity distribution, and velocity magnitude, both approaching and passing through the screens, were of primary interest in the model study. The objective of the study was to create a one-directional flow field with no back eddy or slack water zones. Such a flow field would assist the fish in moving directly to the drum screens and then assist in guiding the fish directly into the bypass intakes. There would be no back eddy or slack water zones in which the downstream migrating fish would hold or in which predator fish could hold and easily feed on the migrating fish. Also of concern was the magnitude and angle of the flow (relative to the screen face) near the screen. Design criteria require that to prevent fish impingement against the screens, the magnitude of the velocity component normal to the screen should be no greater than 0.5 ft/s [2]. Likewise, the criteria require that the magnitude of the velocity component parallel to the screens should be at least twice the magnitude of the normal component. This yields a sweeping flow that directs the fish across the screen face and into the bypass intakes.

The velocity field approaching, through, and downstream of the screen structure was also of interest in that it directly influences the sediment deposition. At times, substantial quantities of sediment are diverted into the canal. Historically, an expanded canal section at approximately station 53+00 which contains drum screens has experienced substantial deposition. Velocities though this section are higher than those that will occur at the new structure. Thus, substantial deposition at the new structure can be expected. Deposition is of concern in that in sufficient quantities it will modify the flow characteristics of the screen structure and could yield increased maintenance due to abrasive wear of screens and seals. It is expected that an annual sediment removal program will be required. In the model, efforts were directed at creating flow patterns that would minimize deposition at and near the screen structure. This would allow for easier cleaning and hopefully will result in reduced sediment influence on the structure.

To evaluate and refine the flow patterns approaching, through, and exiting the structure a 1 to 12 scale physical hydraulic model was built (figure 2). The model included a 700-ft-long reach of canal which contained the new drum screen, trashrack, and fish bypass structures. The model included approximately 350 ft of approach canal to the trashracks and 100 ft of exit canal downstream of the end of the structure. Flow was supplied to the model using the laboratory pump and piping system. Discharges were measured using Venturi meters. Velocities were measured using electromagnetic and propeller type current meters. Both documentation photographs and video tape were taken.

As a first step, the approach flow distribution in the model was adjusted and confirmed by comparison to field velocity data collected at station 41+70 for a discharge of 1,244 ft^3/s. The field data were collected by the Yakima Project Office specifically for this study. Expanded metal lath

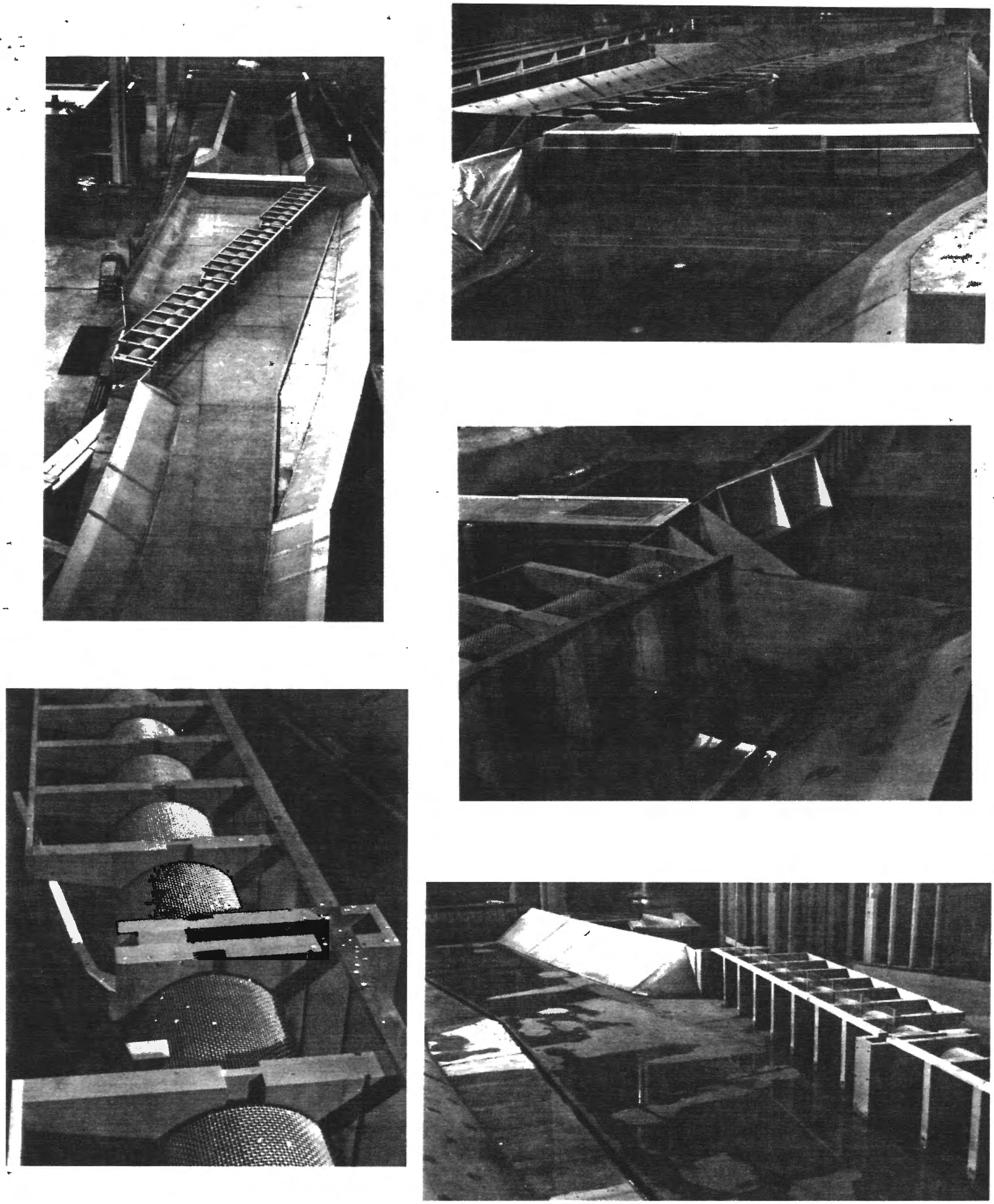


Figure 2. - The 1:12 scale model.

(figure 3) was used in the model to create selective resistance which modified the model flow distribution. By forcing the model distribution to match the field it was assured that the model was a true representation.

The flow patterns and flow distribution for the initial design were then observed. Because the maximum discharge of 1,500 ft^3/s was recognized to be critical with respect to eddy formation, flow distribution, and velocity magnitudes, all observations and data were taken at that discharge. Separation or eddy zones were observed on both sides of the channel at the expansion transitions upstream of the trashrack structure (figure 4). On the left side (looking downstream) the flow re-attaches prior to the drum screen structure. Thus no reverse flow through the drum screens resulted. The right bank eddy did not significantly effect the flow through the drum screens but it did represent a generally undesirable flow condition.

Separation or eddy zones were also observed in front of the drum screens immediately downstream of the two intermediate bypass intakes (figure 5). The original bypass intake design included a mitered transition between the guide wall and the main screen structure which yielded a trailing separation. The influence of this separation, either in the form of reverse flow through or increased angle of flow impingement on the following drum, extended about half way down the drum (figure 5).

Velocity distribution data were collected along the screen structure face. Velocities were measured in a vertical plane located approximately 2 ft in front of the leading edge of the drums. Velocities were measured at the drum centerlines for 0.2, 0.5, and 0.8 depths. The observed distribution for the initial design concept is shown in figure 6. Note that vertical variations in velocity magnitude are relatively small but that variation in velocity magnitude along the structures length was substantial. Average velocities ranged from 1.1 to 1.2 ft/s over the first three screens to 1.7 to 1.8 ft/s over the last three screens. Imposed on this pattern of generally increasing velocities were the localized influences of the bypass intakes. These influences consisted of slightly decreasing velocities across the two screens prior to the intake and a separation zone with a following flow concentration across the screen immediately behind the intake (figure 6). The decreasing velocities resulted because the guidewalls were not aligned exactly with the flow. Typically at these sites the flow is approaching the screen at an angle of approximately 12°. However, the initial design had the walls set parallel to the approach canal centerline and at an angle of 17.5° with the structure (figure 4). This 17.5° angle yielded an excessive cross-sectional area between the wall and the screens which resulted in the reduced velocities. At 17.5° the guidewalls also constrict the channel which yields a localized acceleration of the flow on the outside of the walls. This resulted in the flow concentrations following the separation zones.

In an effort to improve the general flow distribution over the screen structure length, the influence of various stoplogging patterns at the

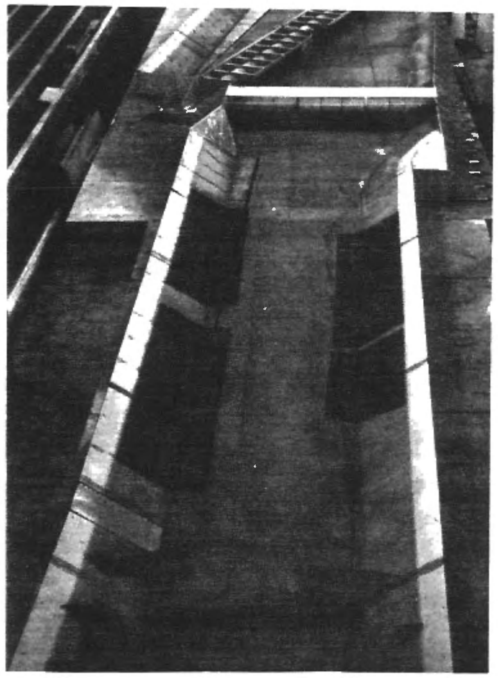


Figure 3. - Expanded metal lath flow resistance.

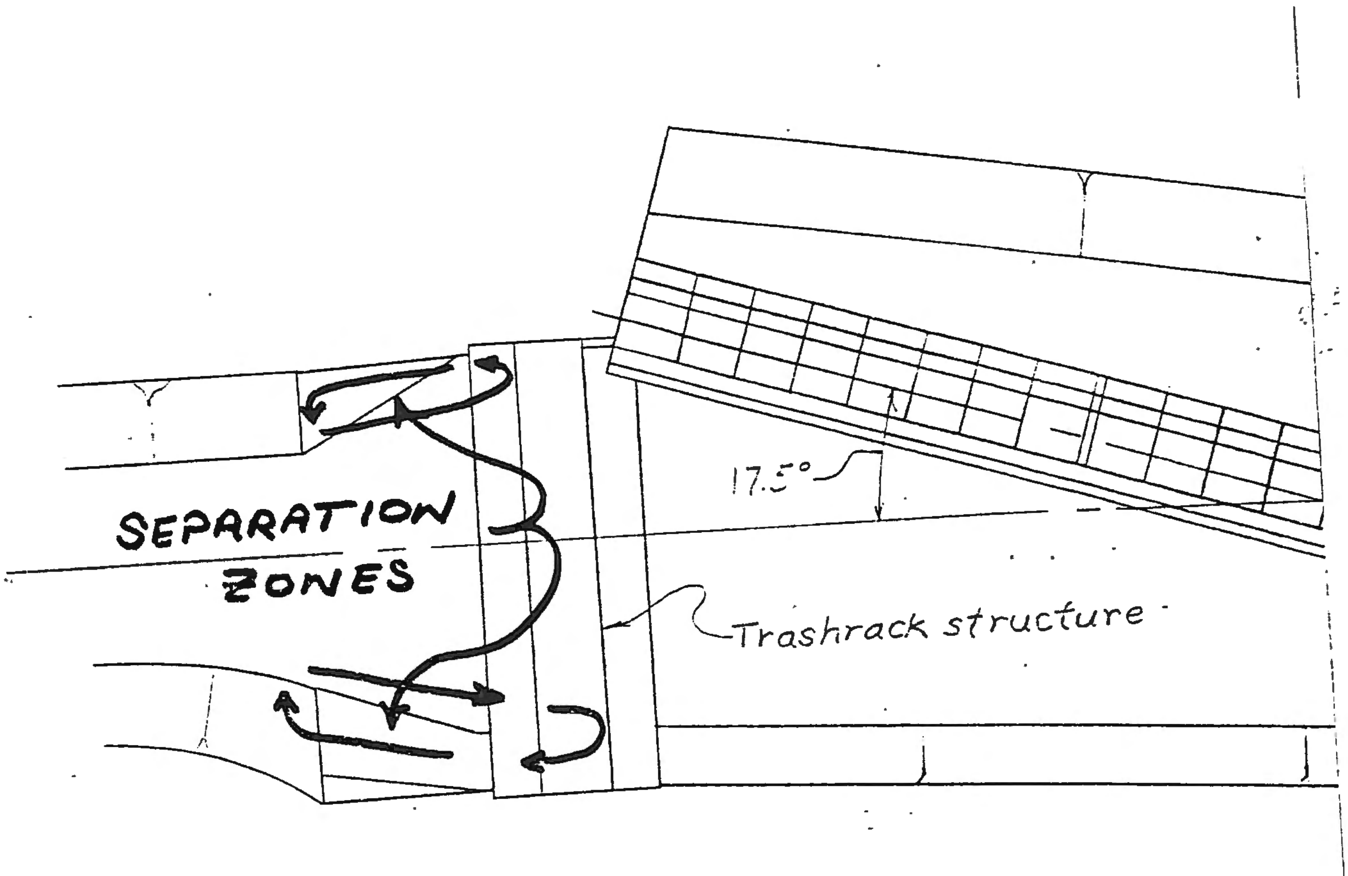


Figure 4. - Expansion-transition separations.

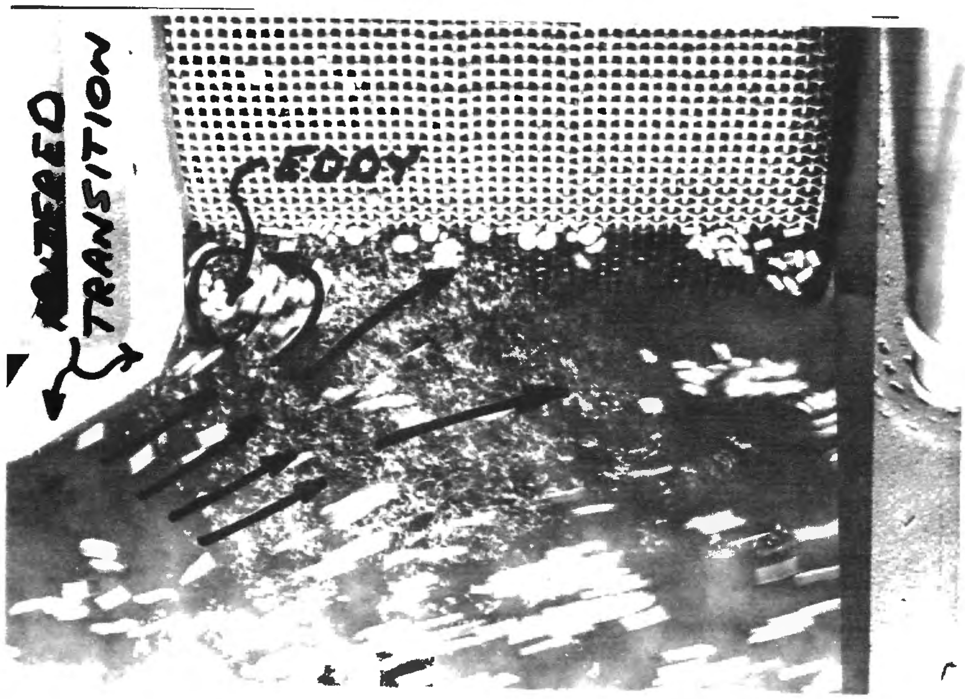


Figure 5. - Flow separation behind bypass intake.

1600 ft³/s

SCREEN VELOCITY DISTRIBUTION – INITIAL DESIGN CONCEPT

FIGURE

CHANDLER F

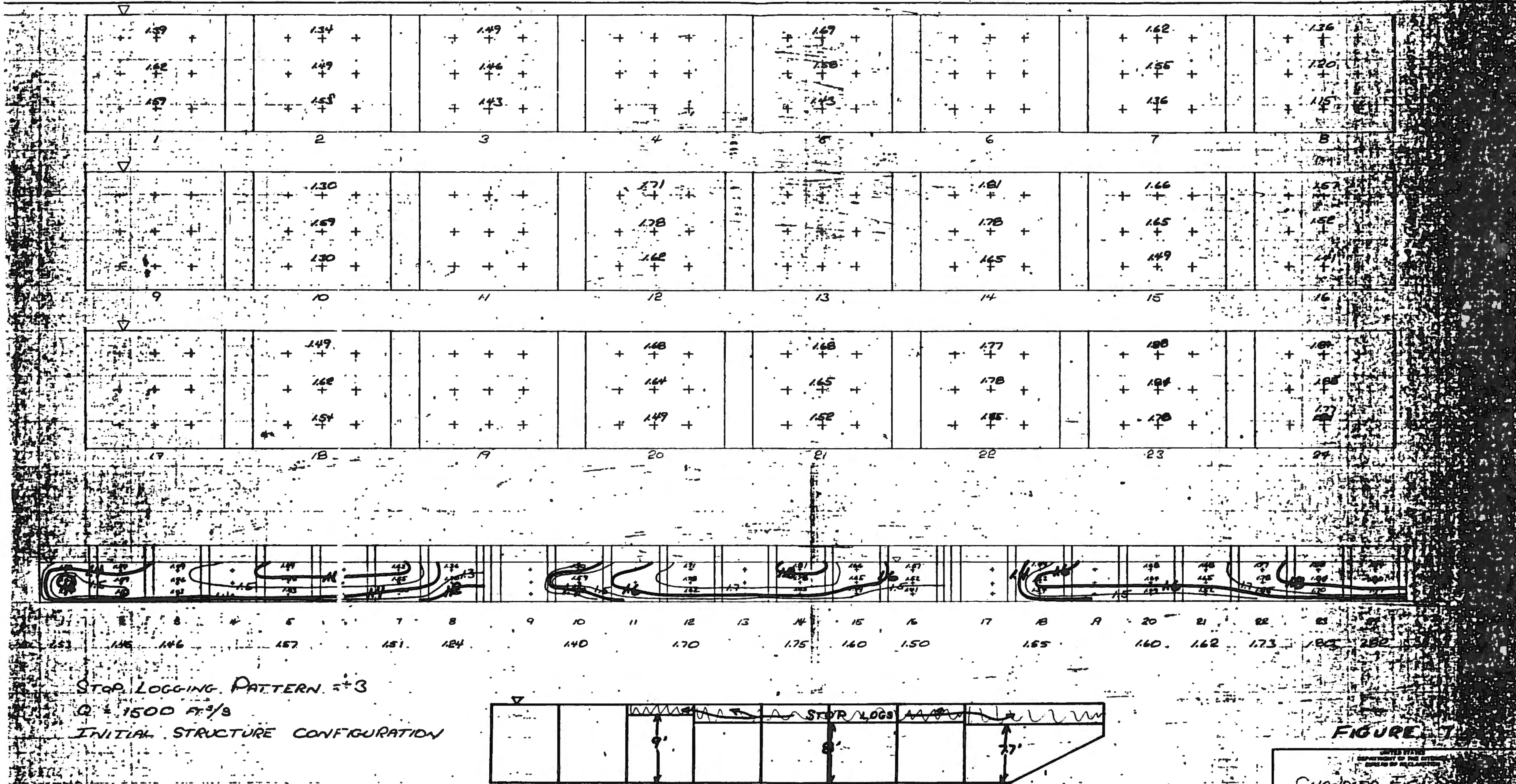
P. SULLIVAN

trashrack structure were investigated. It was concluded that a stoplogging pattern similar to that shown in figure 7 could be used to substantially improve the general flow distribution at the drum screens. In the Chandler study, stoplogging behind the drum screens was not tried as a means to improve the general flow distribution. Stoplogging behind the drums was, however, extensively tested in the Roza Fish Screen model. In the Roza Fish Screen study, it was found that extensive stoplogging had limited effectiveness in modifying the flow distribution. It appears that the flow distribution at the screens is more easily modified by adjusting structure configuration and by adjusting approach flow than by stoplogging behind the drums.

Although stoplogging at the trashracks appeared to have some promise it was felt that modification of the approach channel alignment with modification of the canal section containing the screen structure was a cleaner approach to the problem. Consequently, various realignments and transitions in the approach channel were tested. It was concluded that to significantly modify the approach flow distribution a fairly long modification was required. An initial effort which increased the length of the left bank expansion-transition from 40 ft to 80 ft was found to have little influence on the flow distribution at the screen. Increasing the length of the left bank expansion-transition to 250 ft (figure 8) significantly increased the discharge to the first three drums. In addition, studies indicated that continuity (velocity = discharge/cross-sectional area) significantly influenced flow distribution along the structure. Consequently, to maintain a uniform flow distribution it was desirable to maintain a constant channel cross-sectional area over the length of the screen structure. Therefore, the exit channel behind the drums was widened to reduce velocities at the lower end of the screen structure. This arrangement with a 250-ft-long approach channel expansion-transition and with an enlarged exit channel (figure 8) was tested and found to yield a good velocity distribution.

In addition, the localized influences of the bypass intakes were addressed. The guidewalls were realigned at the 12° angle and the back sides of the guide walls were extended, with only a slight break, to an intersection with the screens (figure 9). The extension of the walls required an additional 6-ft displacement of the downstream screen at each of the intermediate bypass intakes (a 12-ft total increase in structure length). The extension and realignment of the guidewalls, however, eliminated a majority of the separation zone behind the intake and created a much improved flow across the trailing screens (figure 9).

With these modifications a potential final structure configuration was obtained. The resulting flow field at the 1,500 ft^3/s discharge was studied in detail. Figure 10 shows resultant velocity, normal velocity component, and sweeping component to normal component ratios observed across the screen face. Figure 11 is a time lapse surface streak photograph of the screens which shows the basic flow patterns observed. Figure 12 shows observed 0.2, 0.5, and 0.8 depth entrance and exit channel velocities which correspond to the flow patterns shown in figure 11. As can be seen in figure 10 the first four drums still experienced reduced flows with average velocities ranging from 1.14 to 1.33 ft/s. Average velocities

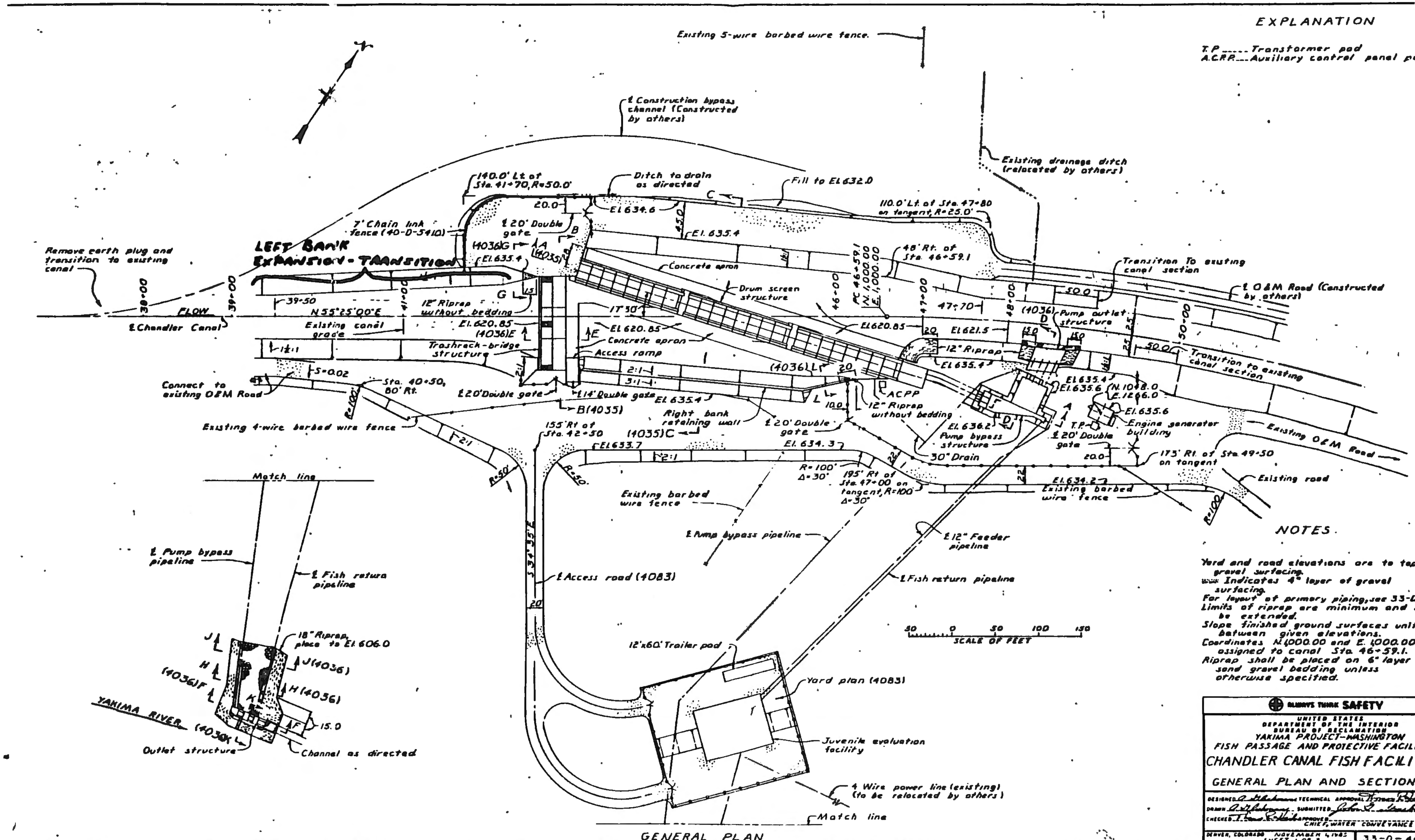


Stop Logging Pattern #3
Q = 1500 ft³/s
Initial Structure Configuration

FIGURE 7

Chandler Fish Sc...

D. Johnson



EXPLANATION

T.P. ---- Transformer pad
A.C.P.P. --- Auxiliary control panel pad

NOTES

Yard and road elevations are to top of gravel surfacing.
Indicates 4" layer of gravel surfacing.
For layout of primary piping, see 33-D-4068.
Limits of riprap are minimum and may be extended.
Slope finished ground surfaces uniformly between given elevations.
Coordinates N. 1,000.00 and E. 1,000.00 are assigned to canal Sta. 46+59.1.
Riprap shall be placed on 6" layer of sand gravel bedding unless otherwise specified.

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UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
YAKIMA PROJECT—WASHINGTON
FISH PASSAGE AND PROTECTIVE FACILITIES

CHANDLER CANAL FISH FACILITIES

GENERAL PLAN AND SECTIONS

DESIGNED ... TECHNICAL APPROVAL ...
DRAWN ... SUBMITTED ...
CHECKED ... APPROVED ... CHIEF, WATER CONVEYANCE BRANCH
DENVER, COLORADO NOVEMBER 4, 1985 SHEET 1 OF 3 | 33-D-4034

FIGURE 8 NOV 26

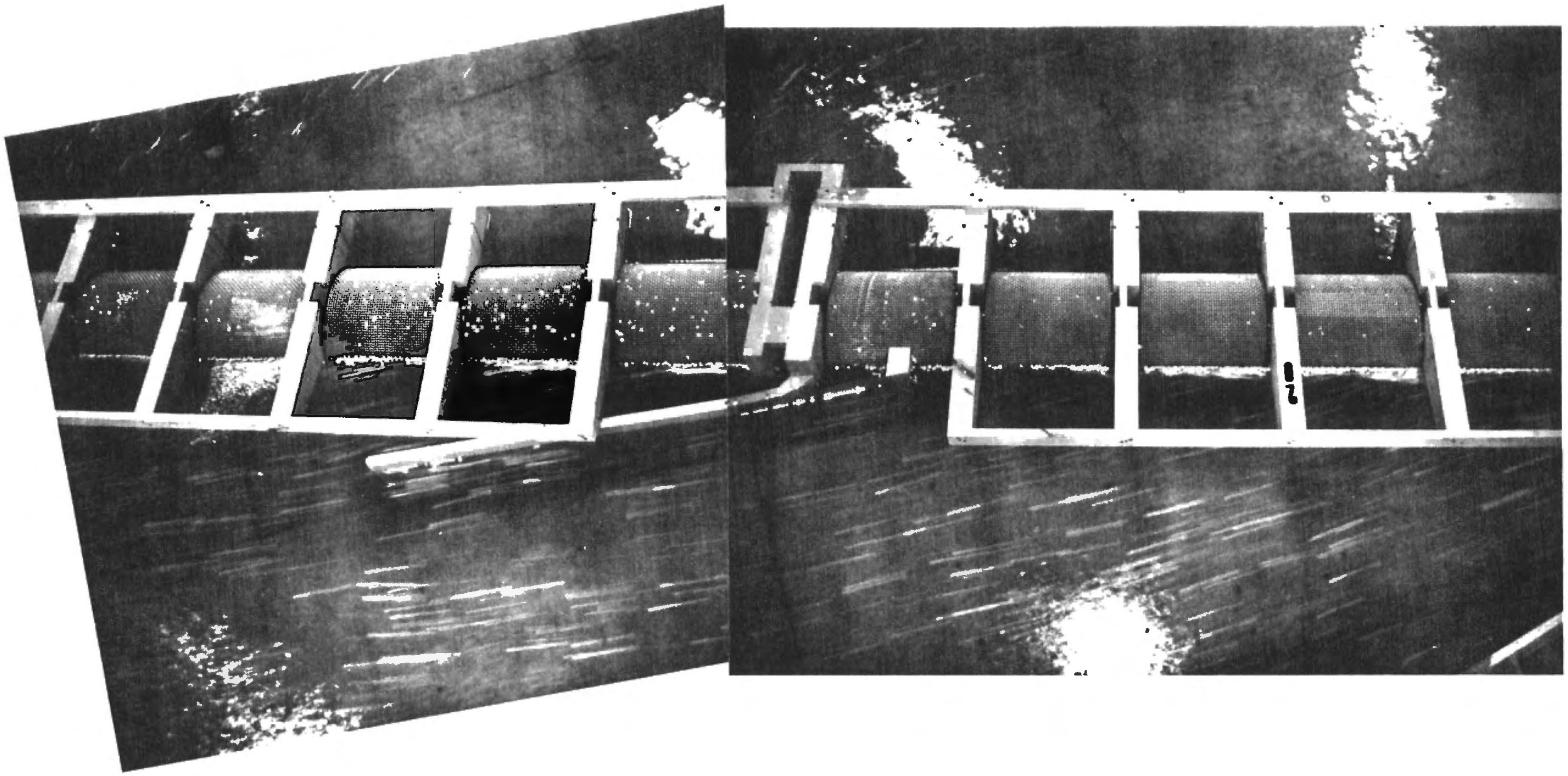


Figure 9. - Time lapse photograph of flow past modified bypass intake with guidewalls positioned at 12° to the structure.

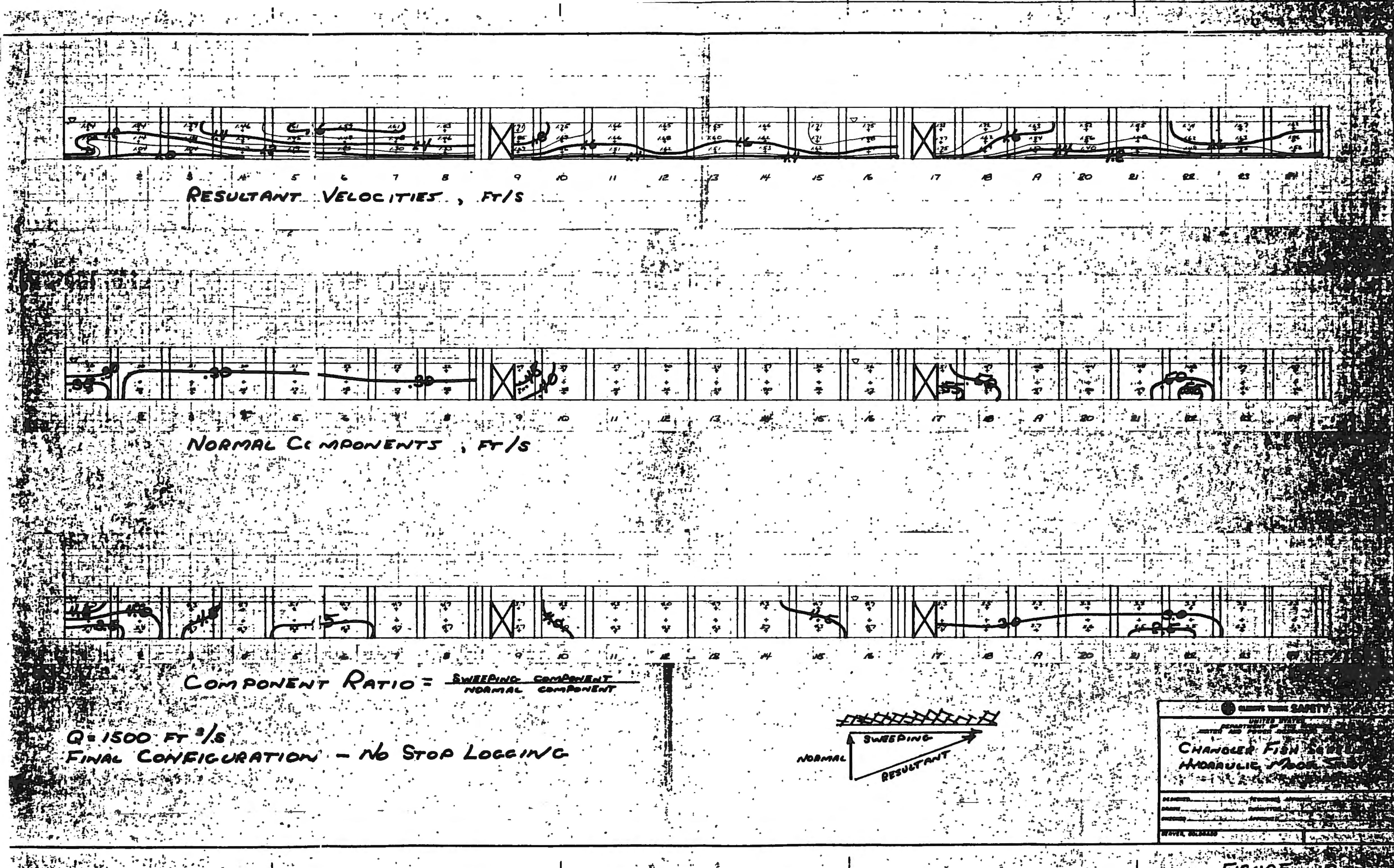

RESULTANT VELOCITIES, FT/S
NORMAL COMPONENTS, FT/S
COMPONENT RATIO = SWEEPING COMPONENT / NORMAL COMPONENT
Q=1500 FT³/S
FINAL CONFIGURATION - NO STOP LOGGING
SWEEPING
NORMAL
RESULTANT
CHANDLER FISH
HYDRAULIC MODEL

FIGURE 10

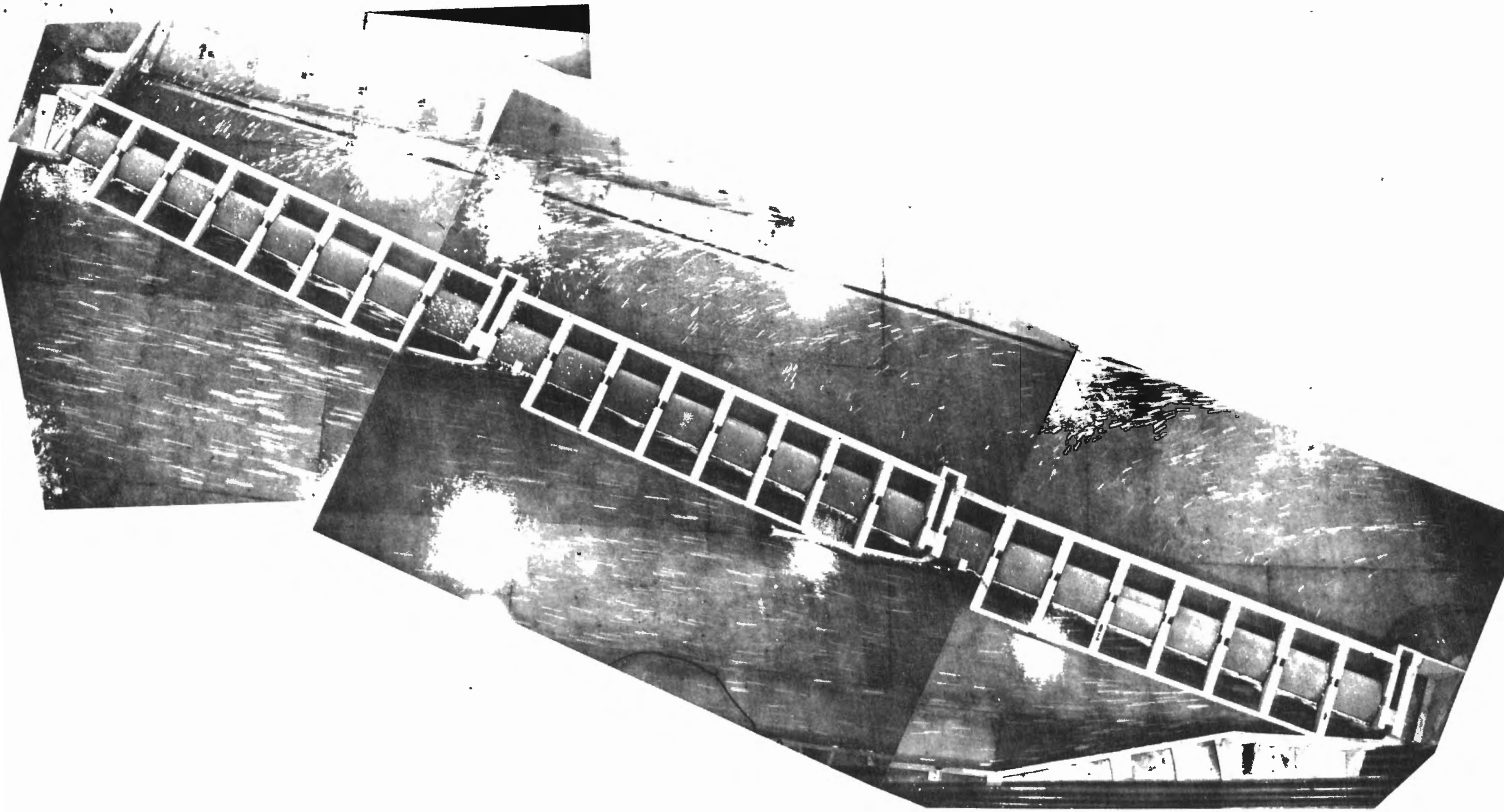
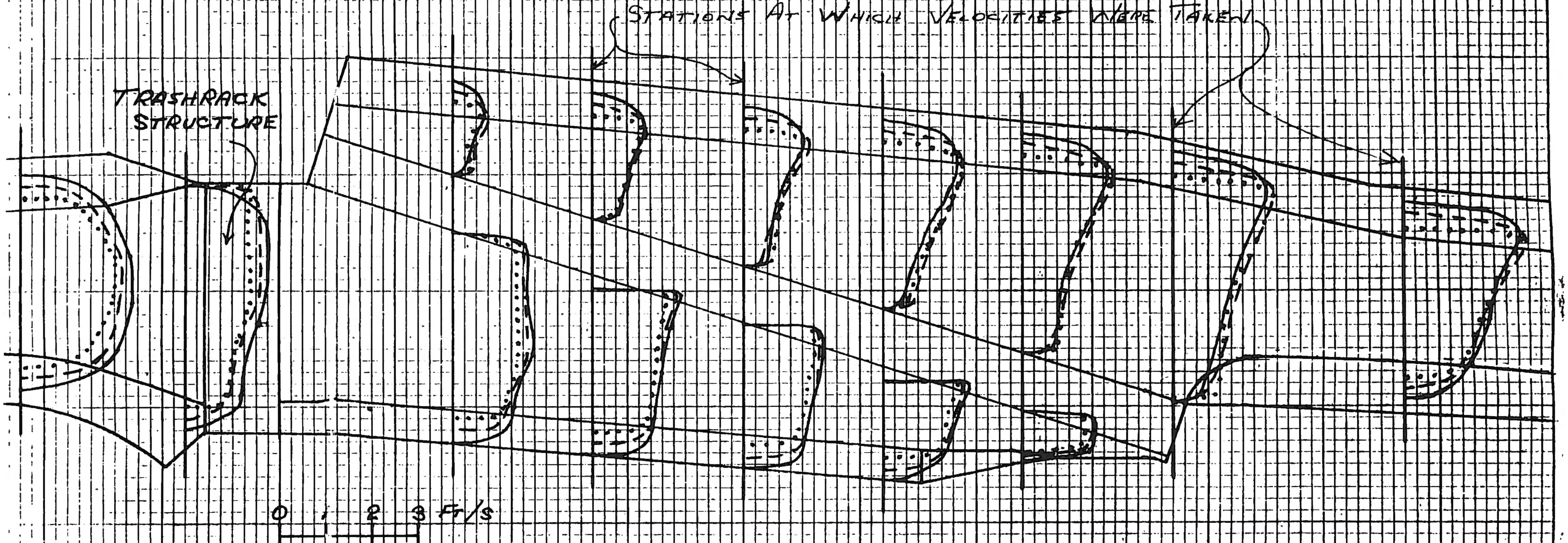


Figure 11. - Time lapse surface streaks 1,500 ft^3/s, no stoplogging.



OBSERVED FLOW PATTERNS
WITH NO STOP LOGGING
1500 FT³/S

FIGURE 12

over the remainder of the structure ranged from 1.42 to 1.68 ft/s with superimposed localized flow concentrations immediately downstream of each intermediate bypass intake. This is a quite uniform distribution. In addition the angle of attack of the flow to the screen was measured at the centerline of each drum for 0.2 and 0.8 depth. With these angles and the resultant velocities, normal and sweeping velocity components and the ratios of these components were calculated. As can be seen in figure 10, observed normal velocity components increased as the flow progressed down the structure. There were very limited (less than 10 percent of total area) zones in which the 0.5 ft/s criteria was exceeded. The maximum normal component observed was 0.57 ft/s. Recognizing that these values were observed at the maximum possible discharge of 1,500 ft^3/s (which is a limited occurrence) the performance was considered acceptable. A review of observed sweeping to normal component ratios (figure 10) shows the values to be well in excess of the 2.0 minimum criteria. With all this in mind the hydraulic performance of the modified screen structure was deemed to be very good.

As an option, a similar evaluation was done on the modified design but with stoplogging at the trashracks. Various stoplogging patterns were tried in an effort to increase flow to the first four drums. The stoplogging pattern shown on figure 13 was found to be effective. The stoplogs were placed off the bottom to allow sediment passage and below the surface to allow floating debris passage. Figure 13 shows observed resultant velocities, normal velocity components, and sweeping to normal component ratios. Figure 14 shows observed entrance and exit channel velocities. Note that the stoplogging did increase velocities at the first four drums and that average velocities over the entire structure length ranged between 1.42 and 1.70 ft/s with localized flow concentrations following the intermediate bypass intakes. This is a very uniform distribution. Observation of the normal components (figure 13) shows an increased zone over which the 0.5 ft/s criteria was exceeded. However, the maximum observed component was 0.57 ft/s which is not greatly over the criteria. This also represents acceptable performance. Again minimum observed component ratios (figure 13) were approximately 2.5, which is well within compliance.

In summary, it appears that the structure configuration as shown in figure 8 yields satisfactory flow conditions either with or without stoplogging at the trashrack structure. If it is considered desirable or necessary to increase flows to the first drums, stoplogging at the trashrack structure may be used.

One final consideration was potential deposition at the screen structure and ways to minimize deposition in the immediate vicinity of the screens. It is felt that due to the drum rotation and due to the restriction of the flow path by the screen fabric and frame, deposition right at the screens will not occur. However, in the area immediately behind the screens, but still between the piers, velocities are very low (less than 0.5 ft/s). Deposition is quite likely in this area. Likewise, this is an area that is not easily cleaned and it is an area in which if deposition should occur it could influence screen performance. As a possible solution stoplogging behind the drums was considered. A uniform 67 percent

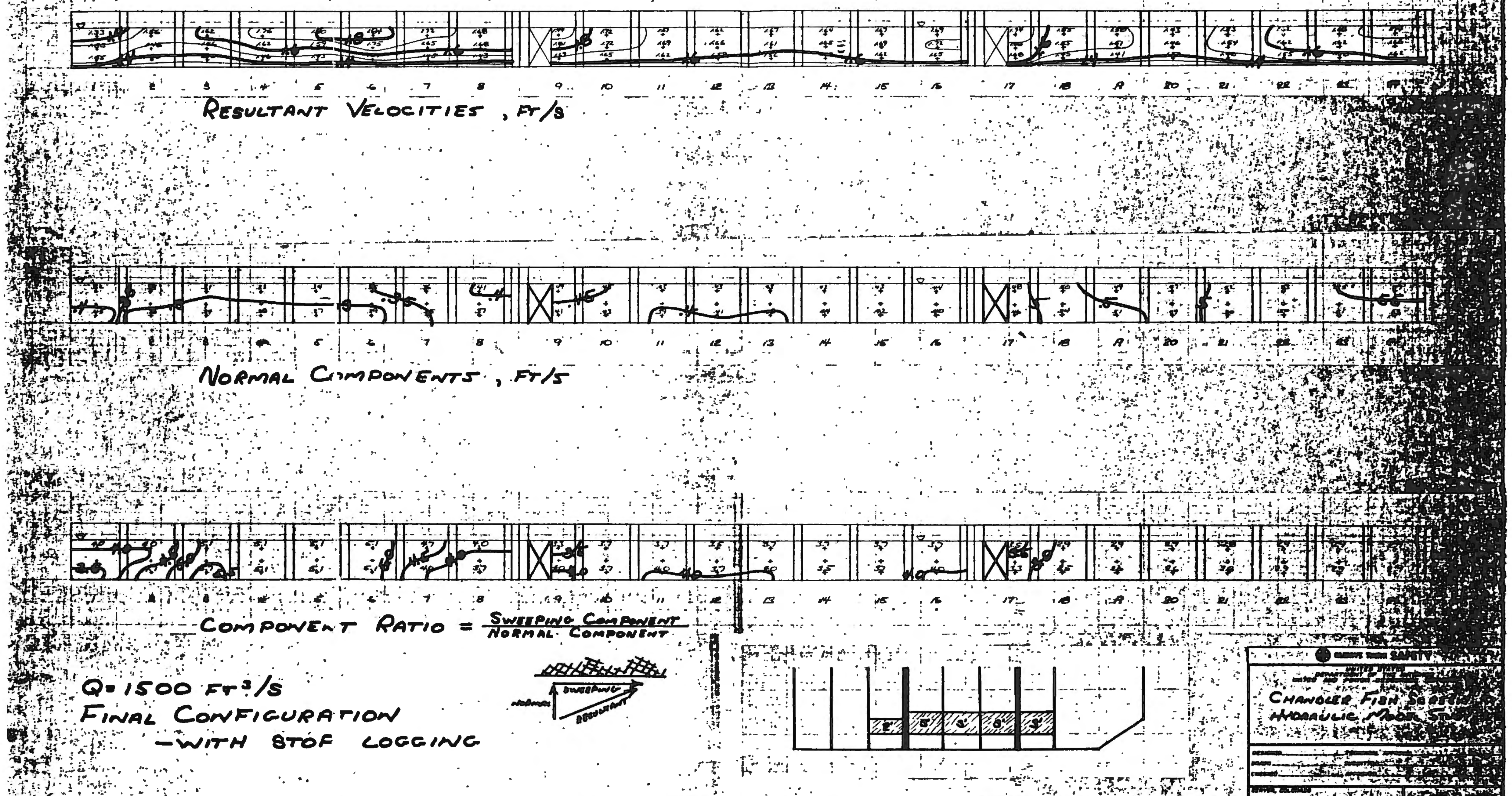
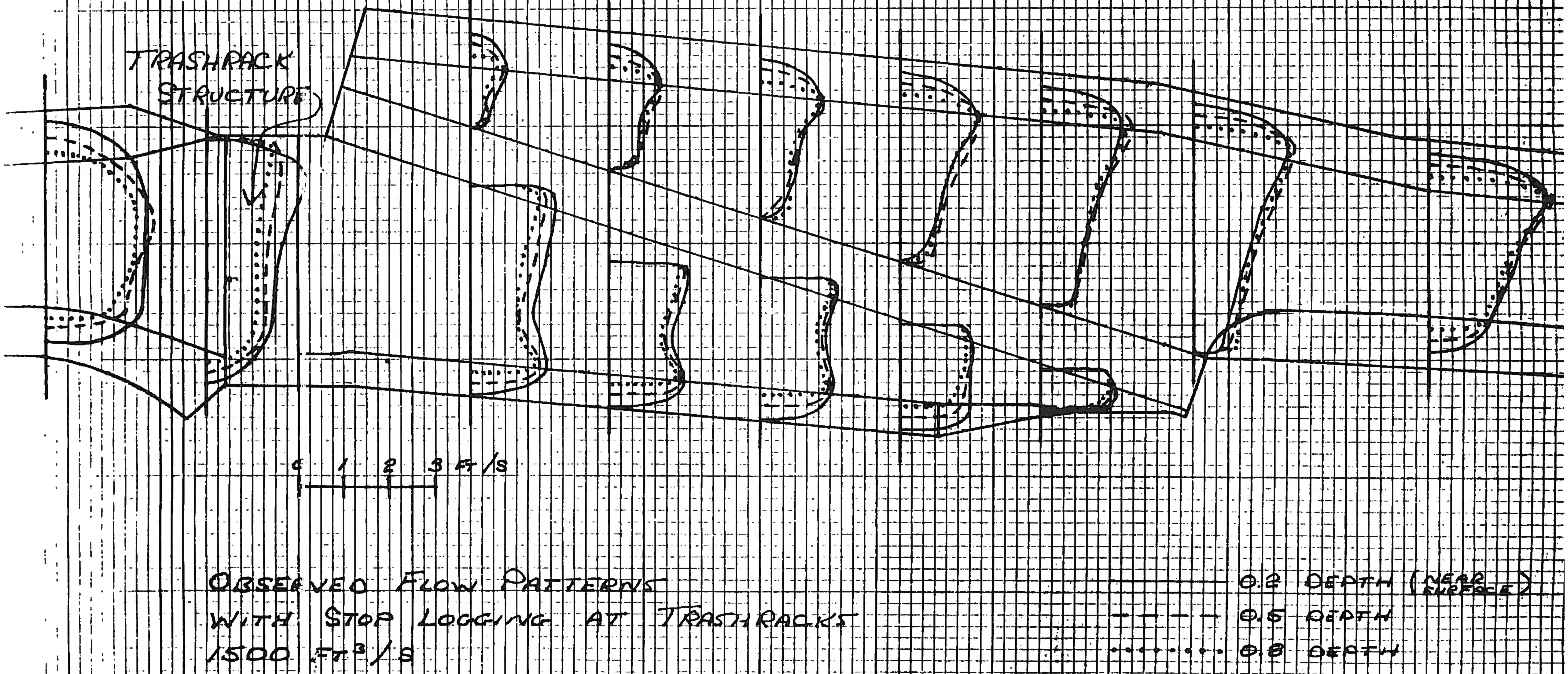

RESULTANT VELOCITIES , FT/S
NORMAL COMPONENTS , FT/S
COMPONENT RATIO = SWEEPING COMPONENT / NORMAL COMPONENT
Q=1500 FT³/S
FINAL CONFIGURATION
-WITH STOP LOGGING
SWEEPING
NORMAL
RESULTANT
CHANDLER FISH SCREEN
HYDRAULIC MODEL ST

FIGURE 13



OBSERVED FLOW PATTERNS
WITH STOP LOGGING AT TRASHRACKS
1500 FT^3/S

FIGURE 14

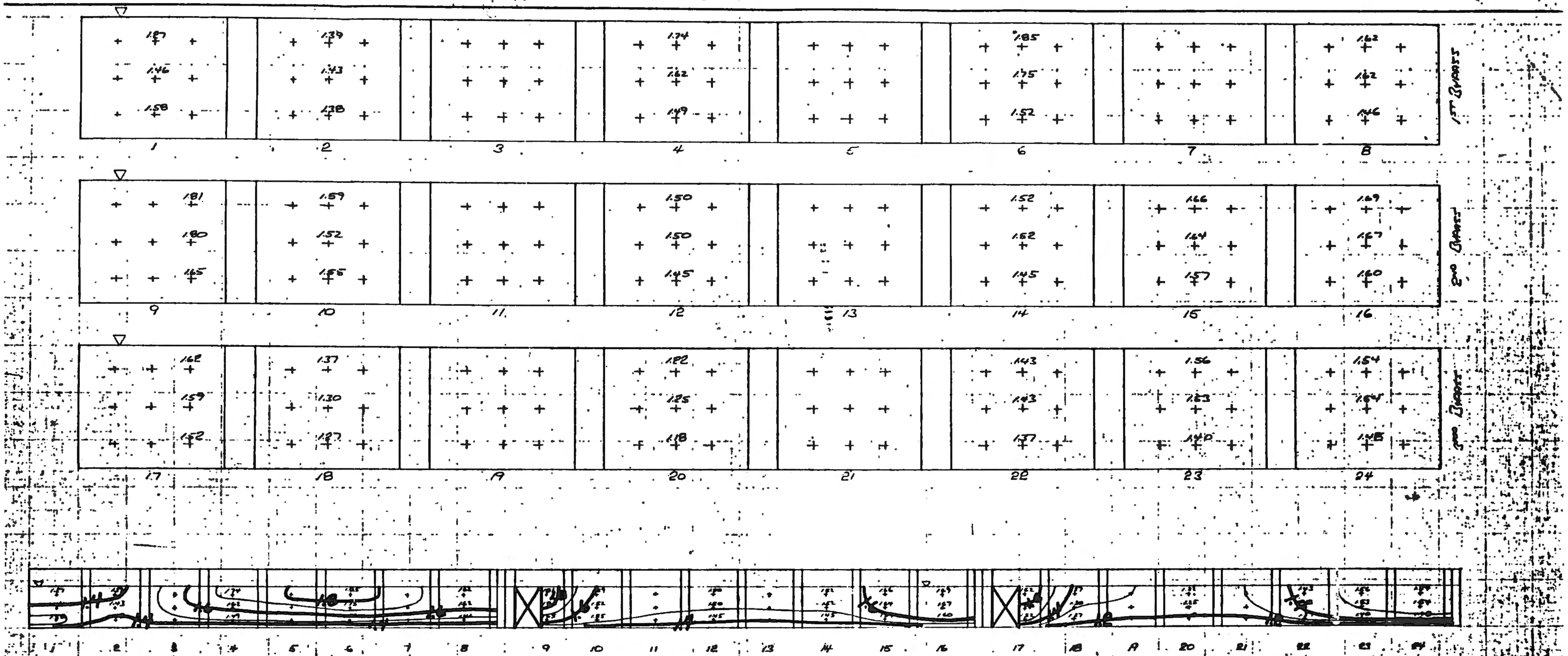
blockage behind all screens was evaluated. Such stoplogs should be positioned off of the bottom to allow sediment passage and below the water surface to allow floating debris passage. A 67 percent blockage will triple velocities and should yield good sluicing action to move sediment away from the structure. The stoplogs were installed and the resulting influence on flow distribution over the screen structure length evaluated. Figure 15 shows the flow distribution observed at a discharge of 1,500 ft^3/s. This test was done with stoplogging at the trashracks and thus the results in figure 15 can be compared to those in figure 13. Note that the 67 percent blockage has only minor influence on the flow distribution. It can be concluded that stoplogging behind the drums does not materially alter the flow distribution and is an acceptable technique for sluicing sediment.

With completion of testing of the main drum screen structure efforts were directed at evaluating and refining flow conditions through the pumpback bypass structure. The pumpback bypass structure (figure 16) is used to concentrate the diverted fish in a reduced discharge and return a portion of the bypass flow back to the canal. Figures 17 and 18 show the dry and operating model. The discharge withdrawn at each bypass intake of the drum screen structure is a function of the intake cross-sectional area (a 2-ft-wide vertical slot running the full water column depth) and the required intake velocity of 2 ft/s. With a 11.0-ft water depth at the drum screens, the resulting required discharge per bypass is 44.0 ft^3/s. The total bypass discharge for all three intakes is thus 132 ft^3/s. Because of demands on the canal discharge, 132 ft^3/s represents an unacceptably large return discharge to the river. Consequently, the pumpback bypass structure is required.

Flow from the three bypass intakes enters the pumpback bypass structure through individual, adjustable weir controlled, up-wells. The flow then passes over the adjustable weirs and into a transition section in which turbulence is dissipated. The flow then passes two vertical traveling screens. Of the initial 132 ft^3/s, 100 ft^3/s is drawn through these traveling screens and into pumps which return the flow to the canal. The remaining 32 ft^3/s, which contains all of the diverted fish, passes over an adjustable weir and into a pipeline which carries the fish to the juvenile facility and then back to the river.

Desirable flow conditions through the structure include minimized large scale turbulence which could disorient or impinge the fish against walls or screens. In addition, efforts were made to minimize separation, eddy, and backwater zones; and in particular to create uniform, one direction sweeping flow through the structure and across the faces of the vertical traveling screens. As with the drum screens, velocity criteria for the traveling screens required that the maximum magnitude of the velocity component normal to the screen face be no greater than 0.5 ft/s and the magnitude of the velocity component parallel to the screen face be at least twice the magnitude of the normal component.

Ramps (figure 16) placed in the up-wells, between the up-wells and the traveling screen, and between the traveling screens and the exit down-well



RESULTANT VELOCITIES, FT/S

Q = 1500 FT³/S

FINAL CONFIGURATION - WITH TRASHRACK STOP LOGGING

2/3 STOP LOGGING BEHIND ALL DRUMS FOR SLUICING

FIGURE 15

UNITED STATES DEPARTMENT OF THE INTERIOR BUREAU OF RECLAMATION

CHANDLER FISH SCREEN

P. JOHNSON X66160

PLAN AND SECTION
PUMPBACK - BYPASS STRUCTURE

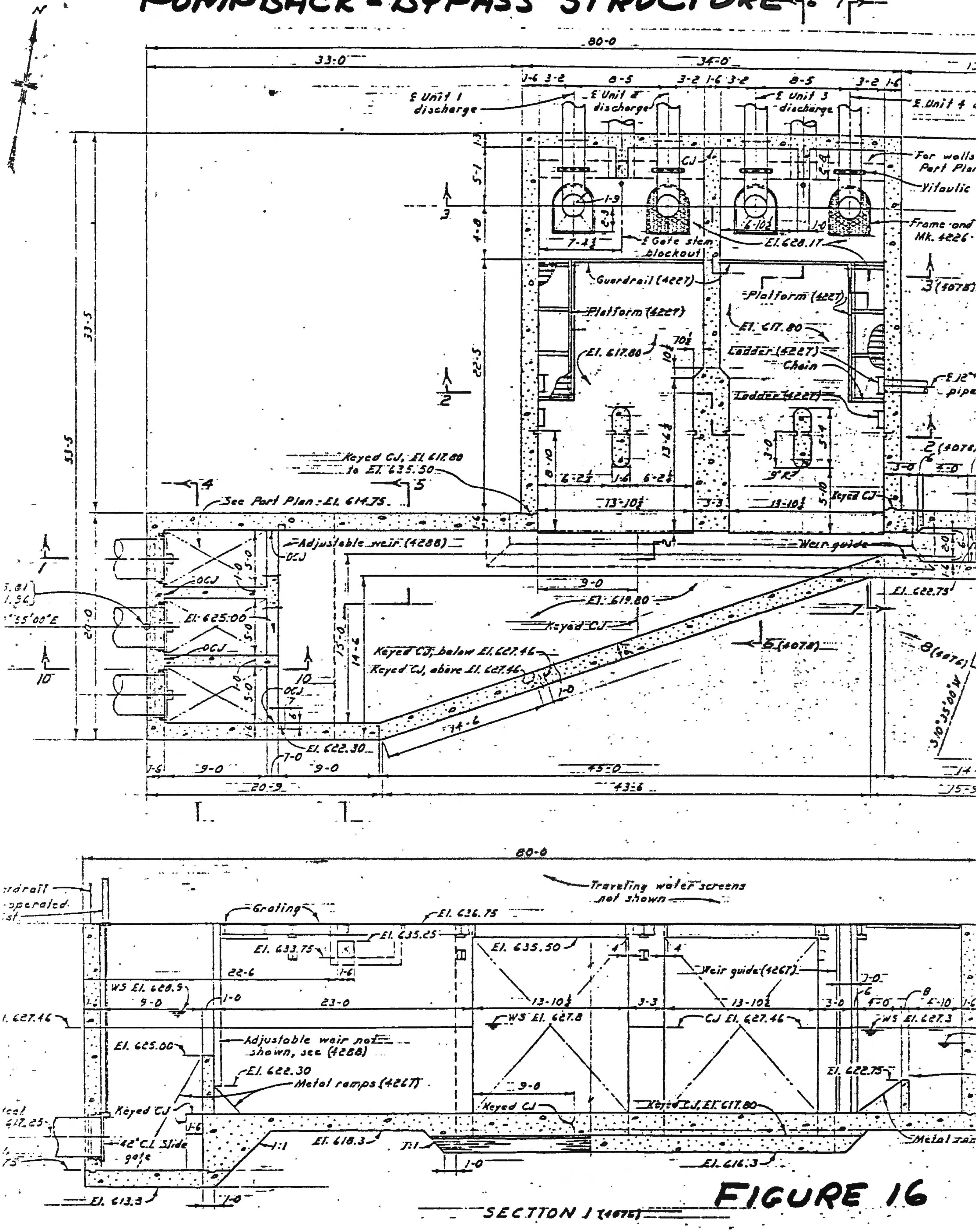


FIGURE 16

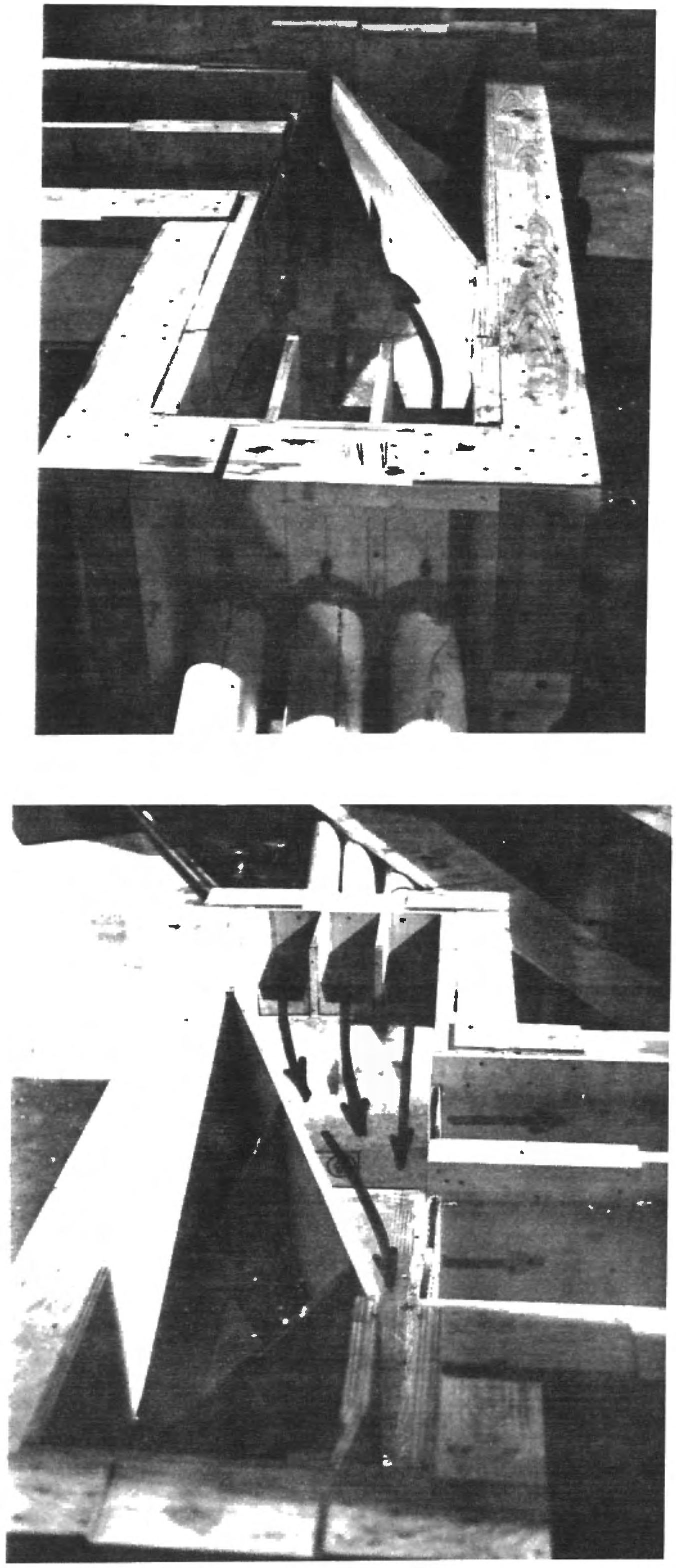


Figure 17. - Model of pumpback-bypass structure.

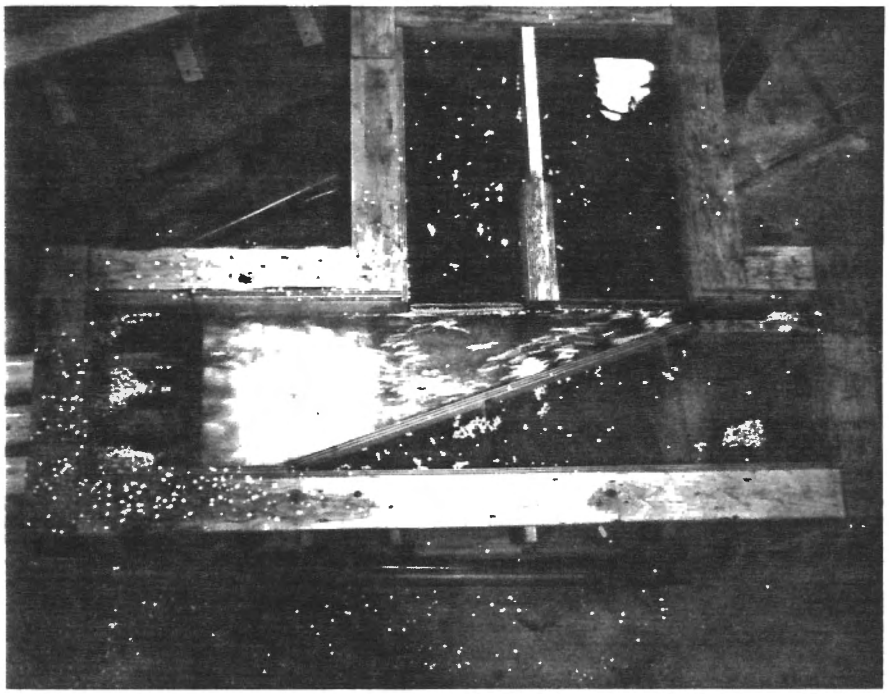


Figure 18. - Operating pumpback-bypass structure.

were used to modify flow patterns through the structure. The ramps function to streamline boundary geometries, eliminating corner separation and eddy zones. It was found that the positions of the ramps in the entrance up-wells and ahead of the exit down-well were not critical. The ramps shown in figure 16 were found to be adequate; however, other similar configurations would also be acceptable. The down-ramp located between the up-wells and the traveling screens was found to significantly influence flow patterns. This ramp not only functions to eliminate the corner separation zone (immediately downstream and below the adjustable weirs) but will also, if properly designed, function as a diffuser, spreading the flow and minimizing large scale shear turbulence.

Flow patterns created by this ramp were strongly dependent on the relative water surface elevations above and below the adjustable weirs. If the tailwater elevation is too low, the flow plunges off of the weirs and creates a bottom jet with a surface back roller. Thus, a surface eddy zone which cannot be eliminated by the ramp results. On the other hand, if the tailwater is sufficiently high a surface jet results. Such a surface jet may have a back eddy beneath it. However, if the ramp is correctly designed, this lower eddy zone can be eliminated. Because model friction losses do not exactly represent the losses that will occur in the prototype, exact operating water surface elevations cannot be recommended. It is suggested that the weirs in the prototype structure be adjusted to yield the desired surface flow condition. The water surface elevations tested in the model are noted with the data and may give some guidance to initial prototype operation.

Three down-ramp designs studied in the model, with resulting flow patterns, are shown in figure 19. More detailed flow patterns for the three ramps are shown in figures 20, 21, and 22. Note that the short down-ramp (figures 19a and 20) was ineffective in both elimination of the separation zone and minimization of large scale turbulence. The longer flat ramp (figures 19b and 21) showed improved performance, although an eddy zone and large scale turbulence were still present. The down-ramp with an included vertical curve (figures 19c and 22) yielded the best performance. The eddy zone was eliminated and the ramp functioned as an effective diffuser minimizing large scale turbulence along the traveling screen faces.

It is felt that the flow patterns across the traveling vertical screen faces with the curved down-ramp are satisfactory and that no additional flow modification is required. In general, the angle between the main stream flow and the screen face was very flat (less than 10°). Because flow passage through the flush mounted screens is in response to the pumping action and is not due to impingement of flow on the screen, the flat angle between the flow and the screen is maintained very close to the screen face. The exception to this was on the lower downstream quarter of the first traveling screen face. In this zone the angle of attack of the flow to the screen was approximately 20°. With the resultant velocity magnitude in this zone being 1.4 ft/s or less, the component of the velocity normal to the screen is 0.48 ft/s or less. This is acceptable. This zone of increased angle of attack is due to the angled wall

FIGURE 19a – FLOW PATTERNS WITH INITIAL FLAT DOWN-RAMP

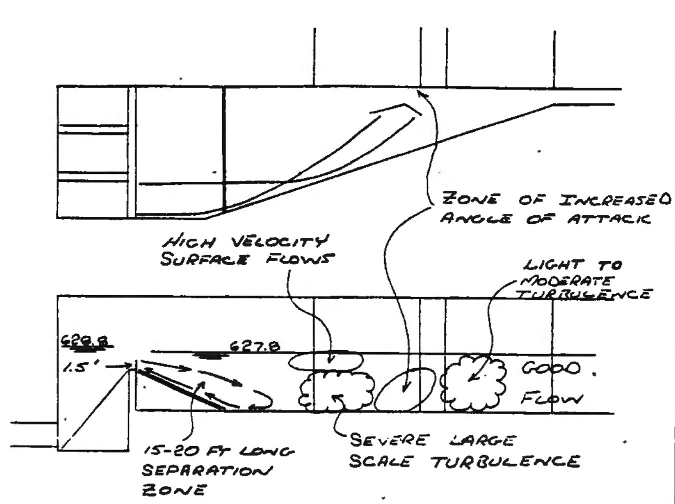


FIGURE 19b – FLOW PATTERNS WITH EXTENDED FLAT DOWN-RAMP

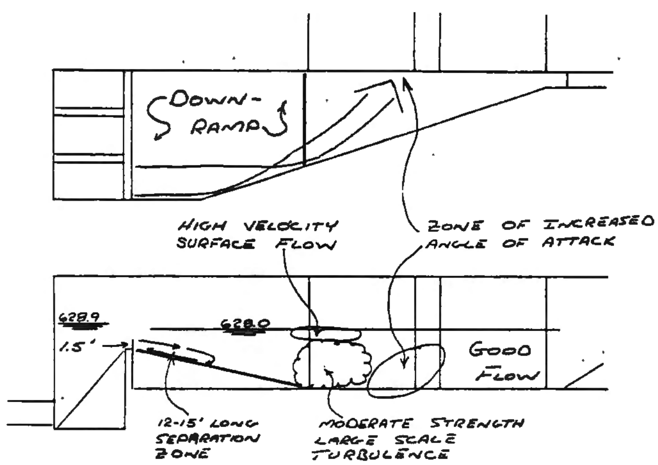
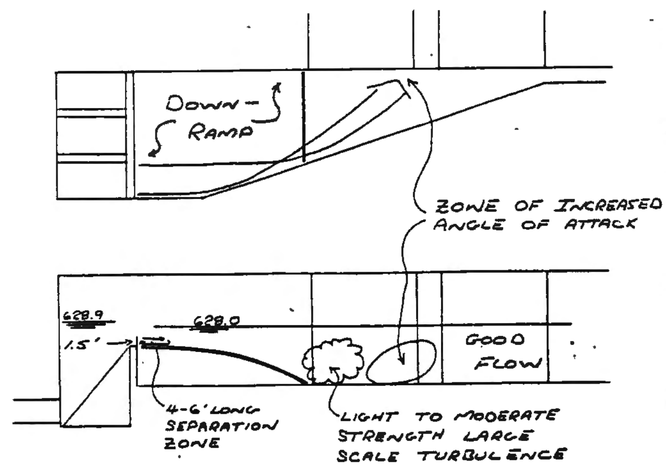


FIGURE 19c – FLOW PATTERNS WITH CURVED DOWN-RAMP

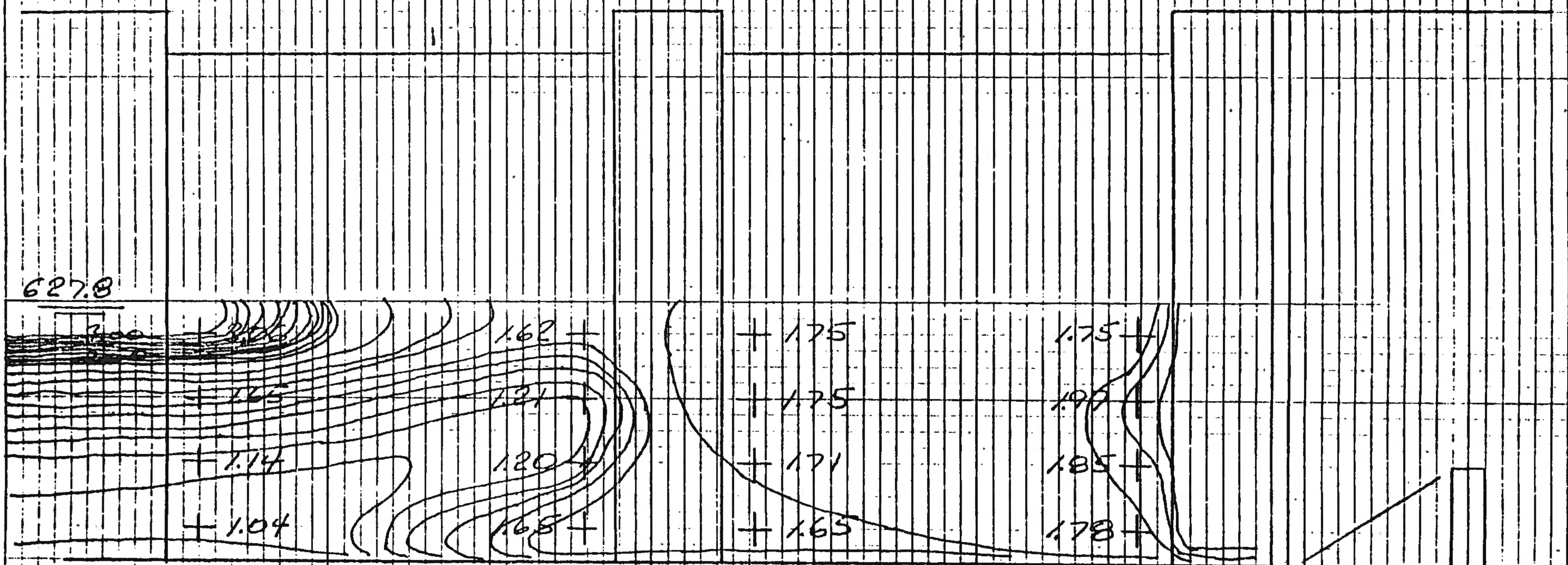


COMPUTATION SHEET

UNITED STATES DEPARTMENT OF THE INTERIOR BUREAU OF RECLAMATION

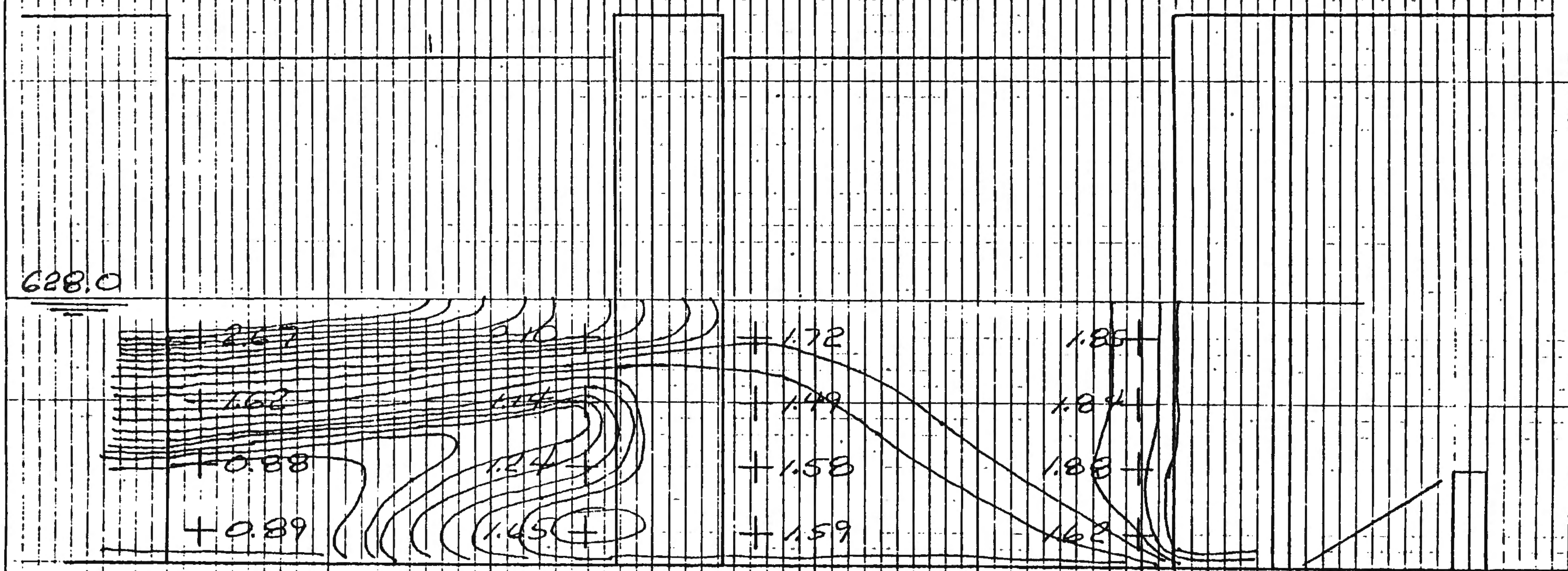
DESIGNED .... TECHNICAL APPROVAL ....
DRAWN .... SUBMITTED ....
CHECKED .... APPROVED ....
DENVER, COLORADO

FIGURE 19



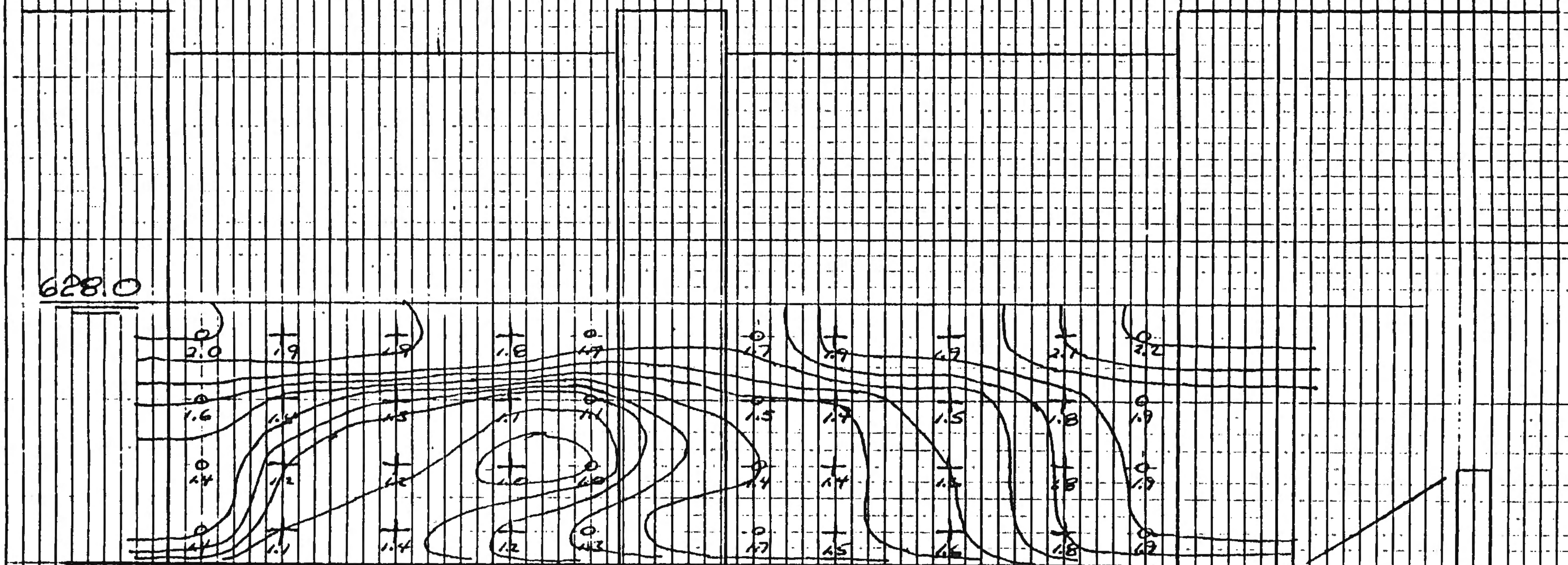
RESULTANT PROTOTYPE VELOCITIES IN FT/S

FIGURE 20 – FLOW VELOCITIES ACROSS TRAVELING SCREEN FACES WITH SHORT FLAT DOWN-RAMP



RESULTANT PROTOTYPE VELOCITIES IN FT/S

FIGURE 21 - FLOW VELOCITIES ACROSS TRAVELING SCREEN FACES WITH EXTENDED FLAT DOWN-RAMP



RESULTANT PROTOTYPE VELOCITIES IN FT/S

FIGURE 22 - FLOW VELOCITIES ACROSS TRAVELING SCREEN FACES - WITH CURVED DOWN-RAMP

that reduces the flow cross-section area. Flow on the right side (looking downstream) coming off of the adjustable weir impinges on the angled wall, causing a diving spiral secondary current that crosses the channel bottom and flows to the screen face (figure 19).

With respect to the sweeping or parallel velocity component of the flow, because of the very flat angle of attack of the flow to the screen (generally less than 10° and no greater than 20°) the magnitude of the parallel component is well in excess of twice the magnitude of the normal component. From trigonometric relationships the 20° angle yields a component ratio of 2.75 and the 10° angle yields a component ratio of 5.67. These ratios are in compliance with the design criteria.

One final point should be noted. All down-ramps had the top edge of the ramp positioned at elevation 625, the elevation of the top of the concrete wall. This was 1.5 ft prototype below the adjustable weir crests in the model test. Observations, however, indicate that if the top edge of the curved ramp is moved nearer to the weir crest, improved vertical flow dispersion will be obtained. Consequently, it is recommended that the top edge of the ramp be placed as high as possible without interfering with weir operation.

REFERENCES

1. Northwest Public Power Association, "Projects Slated for Yakima Basin to Improve Salmon Runs," Northwest Public Power Bulletin, Vol. 39, No. 1, January 1985, p. 11.

2. Stone and Webster Engineering Corporation, "Assessment of Downstream Migrant Fish Protection Technologies for Hydroelectric Application," Electric Power Research Institute, Research Project 2694-1, 1986.