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PHYSICAL MODEL STUDIES OF THE GCID PUMPING PLANT FISH SCREEN STRUCTURE ALTERNATIVES

Progress Report No. 1

1:30 Scale Model Investigations: Alternative D

March 1997

U.S. DEPARTMENT OF THE INTERIOR
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13. ABSTRACT *(Maximum 200 words)*

The Bureau of Reclamation constructed a positive barrier fish screen (alternative D) physical model for GCID (Glenn-Colusa Irrigation District) to evaluate, improve, and document the viability of the concept as a means to protect the fishery resource. The information included in this report is provided to the GCID Technical Advisory Group to assist in the evaluation of proposed screen alternatives and to provide design data for the selected alternative. Results demonstrate the D alternative is a viable design. The study results show the long flat plate screen concept can be designed to meet the listed objectives. A series of modifications to the screen design was identified and instituted through the model study to improve performance. Prior to completion of model testing, a final test was conducted to verify repeatability of the data. The final configuration test results showed satisfactory agreement of data.

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by

Brent Mefford and Joseph P. Kubitschek

Water Resources Research Laboratory
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UNITED STATES DEPARTMENT OF THE INTERIOR ★ BUREAU OF RECLAMATION

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U.S. Department of the Interior
Mission Statement

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally-owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

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PURPOSE

This report presents the results of the D alternative, positive barrier fish screen physical model investigations for GCID (Glenn-Colusa Irrigation District). The study was performed to evaluate, improve, and document the viability of the concept as a means to protect the fishery resource.

APPLICATION

The information included in this report is provided to the GCID TAG (Technical Advisory Group) to assist in the evaluation of proposed screen alternatives and to provide design data for the selected alternative.

INTRODUCTION

The GCID Pumping Plant is located in north-central California, about 100 miles north of Sacramento, on an oxbow of the Sacramento River. Figure 1 is a general location map. The pumping plant exports water from the Sacramento River to the west side of the Sacramento River Valley for irrigation purposes.

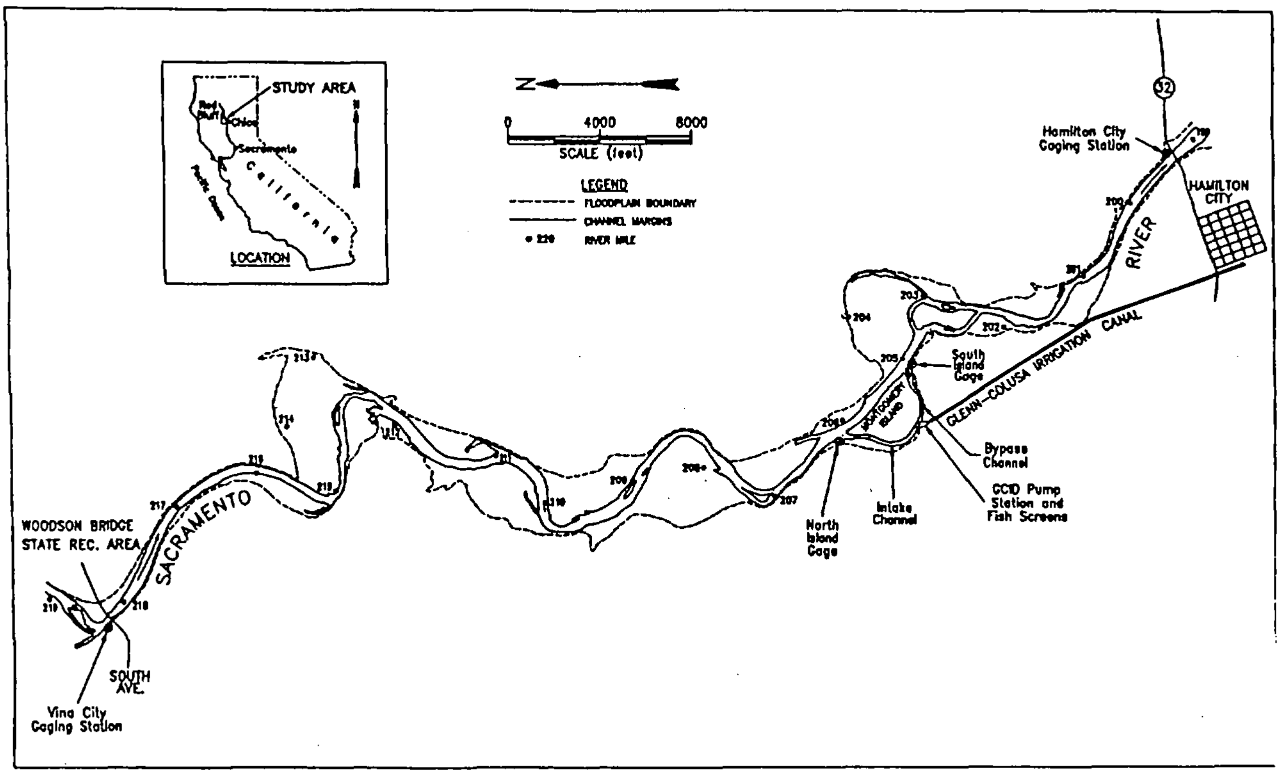

Figure 1. - General location map of GCID pumping plant and existing fish screen facilities (from report 4).

In 1972, a rotary drum screen facility was constructed to provide fish protection from pumping plant entrainment. The facility originally consisted of 40 drum screens 8 ft wide and 17 ft in diameter. In 1970, the Sacramento River experienced the largest flooding since the construction of Shasta Dam. The result was a meander cutoff downstream from Montgomery Island, which caused a decrease in river length of almost 1-1/2 miles. This meander cutoff has caused a drop in water surface elevations of about 3 ft at the north end of Montgomery Island. These changes occurred over several years as the river stabilized. Lower water surface elevations resulted in lower than desired water depths in front of the drum screens. As a result, through-screen velocities exceeded resource agency fish screening criteria during high diversions. In 1991, the NMFS (National Marine Fisheries Service) filed an injunction against the irrigation district to restrict pumping during the peak winter-run chinook salmon downstream migration period.

The district initiated an aggressive program in conjunction with resource agencies to identify options for both short- and long-term resolutions of the screening problem. To improve interim screen performance, flat panel wedge wire screens were placed in front of the drum screens in 1993. In 1995, the drum screens were removed from service.

Pursuit of a long-term solution has generated a number of screening alternatives, which have, in turn, been subjected to detailed evaluation. In 1994, HDR Engineering, Inc., prepared a draft feasibility report which reviewed eight alternatives for replacement or modification of the existing screen facilities. Since then, these alternatives have been reduced to two.

The two remaining alternatives, labeled "A" and "D" are shown as figures 2 and 3, respectively.

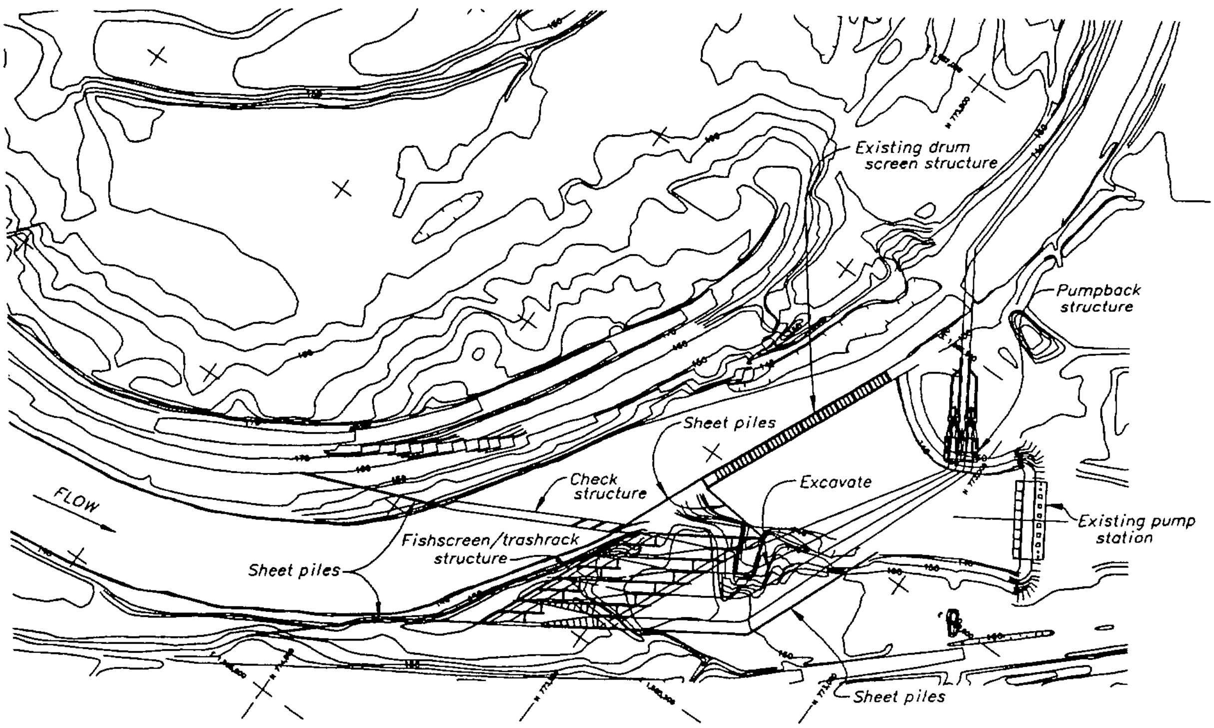

Figure 2. - Conceptual layout: plan view of proposed A alternative.

Figure 3. - Conceptual layout: plan view of proposed D alternative.

Both of these alternatives are to be investigated under this study. Alternative A consists of a new screen facility located just upstream from the existing facility. The A screen concept is a four-bay-multiple-V structure with bypass and evaluation facilities. Screen alternative D consists of modifying the existing screen facilities by increasing the length of the flat panel screen structure. The proposed screen is about 1,000 ft long, extending about 500 ft upstream from the existing structure.

Both of the previously described alternatives will initially be evaluated and optimized using a 1:30 scale physical model. Upon completion of these investigations, one or both alternatives will be modeled at a smaller scale to provide design and operation data for the prototype facility. A report series will be generated for documentation of the physical modeling of the screen alternatives. This report covers the 1:30 scale model investigations of the D alternative and constitutes the first report in the series.

OBJECTIVES OF THE MODEL STUDIES

Prior to designing a fish screening facility, the objectives and operational constraints of the facility must be established. This procedure requires identifying applicable State and Federal resource agency fish screening criteria and objectives specific to the site. This process was conducted through the GCID screen replacement TAG. The following organizations participate on the TAG:

- Glen-Colusa Irrigation District
- California Department of Fish and Game
- Fish and Wildlife Service
- California Department of Water Resources
- U.S. Army Corps of Engineers
- National Marine Fisheries Service
- Bureau of Reclamation

In conjunction with these organizations, several consultants also participate as members of the TAG. These consultants provide biological, engineering, and legal expertise.

Through this process, the following major objectives were identified for the D alternative screen concept.

- The screen design shall allow diversion of up to 3,000 ft^3/s of flow.

- The approach channel shall provide a nearly linear distribution of flow to the screen face.

- For all flow conditions, the normal velocity to the screen face measured 3 inches in front of the screen shall not exceed 0.33 ft/s, which is a State of California fish screening requirement.

- The flow velocity component parallel to the screen face, termed sweeping velocity, must be twice the normal component, which is also a State specified design criterion. However, for the D alternative, the TAG determined that high sweeping velocities would be desirable for the long flat plate screen design. A design objective of 2-ft/s sweeping velocity was chosen.

- The terminal open channel bypass should convey a minimum of 500 ft^3/s flow during river flows $\geq$ 4,000 ft^3/s. Bypass flows of $\geq$ 200 ft^3/s are required for river flows $\leq$ 4,000 ft^3/s. An average velocity of 2 ft/s should be maintained for all bypass flows.

- The oxbow intake channel, bypass channel, and screen facility should be designed to minimize or eliminate areas of reverse flow or slack water. These areas are considered predator habitat.

- The structure must allow for upstream migrants to move through the oxbow should they enter the bypass channel.

Not present in the objectives for the 1:30 model are evaluations of operating criteria, intermediate screen bypasses, and screen baffling. These topics were not included for the following reasons:

- Operating criteria depend on the flow split at the north end of Montgomery Island. This relationship is affected by changes in the river gradient along either path around the island. Changes in the river gradient can occur during major flow events and because of activities like oxbow dredging or channel stabilization efforts. For the purposes of the model, the river gradient as of a 1991 U.S. Army Corps of Engineers survey was used as the baseline for river hydraulics. The 1991 river channel survey likely represents the approximate historic minimum gradient at the site. Since the 1991 survey was conducted, several significant flood events have occurred on the river. In 1995, a limited survey of the channel bottom conducted by Ayres and Associates for the Corps of Engineers revealed the main stem river gradient along Montgomery Island has changed. The survey shows a riffle, located roughly 2,800 ft upstream from the south gauge, has aggraded as much as 2 ft since 1991 (fig. 4). Because of present uncertainty as to the appropriate river gradient for the site, 1991 river conditions were modeled. Using 1991 river topography in the model allows for screen size and diversion limitations to be identified for the worst case river conditions, based on available river topography data. The model screen performance data can be applied to other than 1991 river conditions by comparing model data based on similar water surface elevations at the fish screen.

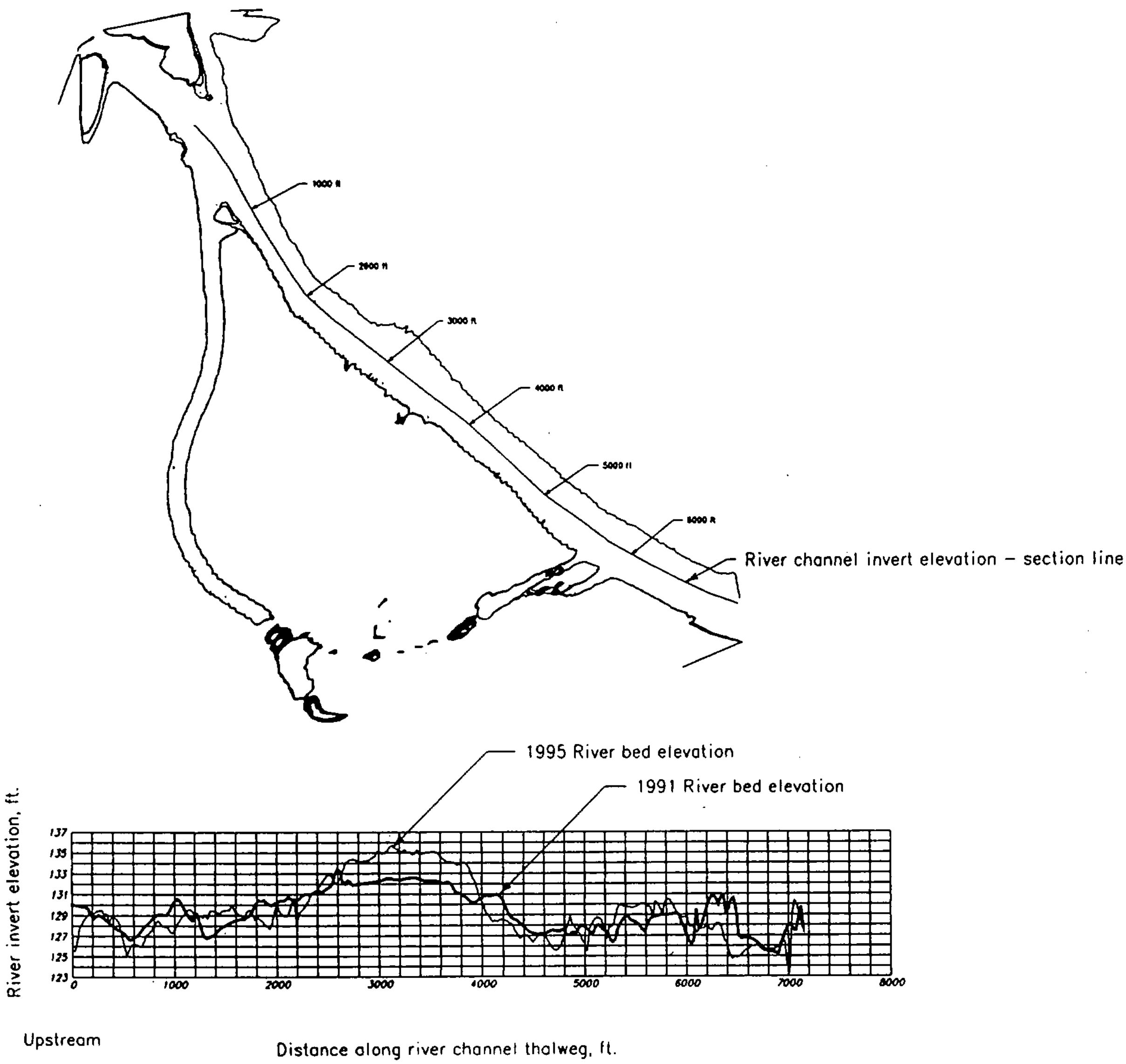

Figure 4. - Sacramento River main channel invert elevations at Montgomery Island for the years 1991 and 1995.

- National Marine Fisheries screen criteria specify intermediate fish bypasses should be used to limit time of screen exposure to ≤ 60 seconds. The passage time in front of the D alternative screen, assuming a sweeping velocity of 2 ft/s, is about 500 seconds. The original D alternative screen concept as presented to the TAG recognized this limitation of the concept. However, the concept had sufficient merit to initially pursue a model investigation of the screen structure without intermediate bypasses. Hydraulic data obtained from the model will be used to assess the need for or spacing of intermediate bypasses at a future time. Bypass designs will then be tested in the subsequent smaller scale (larger size) model of the D alternative.

- Baffling of screen bays was not including in the scope of these investigations. Although baffling may be pursued in future investigations to further improve and maintain good velocity distributions under changing hydraulic conditions, this effort focuses on minimizing the need for screen baffling.

CONCLUSIONS

The results of these investigations demonstrate that the D alternative is a viable design. The study results show the long flat plate screen concept can be designed to meet the listed objectives. A series of modifications to the screen design was identified and instituted through the model study to improve performance. These screen modifications and the final design are shown on figure 9. A brief summary of screen performance versus objectives for the final D alternative screen configuration is given below.

- Diversion capacity - The minimum screen area required to comply with the 0.33-ft/s maximum velocity approaching the screen is 9,091 ft^2. Assuming the existing screen invert elevation of 127.3, the following screen lengths are required for 3,000 ft^3/s diversion:

Screen Length (ft)	Screen Water Surface (ft)	River Flow - North gauge (Based on 1991 river topography) (ft^3/s)
1,123	135.4	9,000
1,057	135.9	10,000

  The final screen length chosen may be longer or shorter depending on the final elevations selected for the screen invert and water surface. Increasing the water surface elevation (which requires constructing a gradient control structure on the river main stem) will also lower the river flow for which 3,000 ft^3/s can be diverted. The upstream extent of the screen should be limited to about 530 ft upstream from the existing structure. This limitation allows the flow to turn through the upstream bend before encountering the screen structure. If required, additional screen area can be added by lowering the invert of the proposed extension to the existing screen, extending upstream with baffling, or extending downstream from the existing structure.

- Approach flow conditions - A good distribution of flow to the screen face is achieved by adding an opposite bank guide wall and providing two 4° bends in the screen alignment (fig. 9).

- Screen approach velocity - The good uniformity of velocity along the length of the screen documented in the model testing indicates the D alternative screen concept can be designed to meet the 0.33-ft/s approach velocity criteria for a large portion of normal operating conditions. However, unfavorable conditions can occur under high river flow. During high river conditions, excess flow passes through the upstream end of the screen and reverse flow passes out the downstream end. This condition can result in approach velocities along approximately the upstream one-third of the screen exceeding the 0.33-ft/s approach velocity criteria (fig. 24). Screen baffling or screen covers will be needed to improve this condition.

- Screen sweeping velocity - Sweeping velocity in front of the screen exceeds twice the approach velocity for all conditions. Depending on river and pumping combinations, sweeping velocities range from about 0.75 ft/s to over 3.0 ft/s. Low pumping and low river conditions yield the lowest sweeping velocities. Sweeping velocities of between 1.5 and 2.0 ft/s were achieved for most flow combinations.

- Bypass flow - For 1991 river conditions, the 500-ft^3/s bypass flow objective requires a trapezoidal channel (2:1 side slopes) with a bottom width of 14 ft at invert elevation 127.0. For this channel, bypass flows greater than 500 ft^3/s can be attained when pumping 3,000 ft^3/s for north gauge river elevations higher than about 136.5. At lower river elevations, target bypass flow can be achieved under reduced pumping.

- Predator habitat - Transitions upstream and downstream from the screen structure were added to the design to eliminate reverse flow and slack water zones. Under weak pumping conditions or high river conditions, reverse flow conditions do occur near the downstream end of the screen. This condition occurs when flow in excess of pumping demand moves through the upstream portion of the screen. However, this condition does not create likely predator habitat. Flow exiting the screen merges smoothly with flow entering the bypass channel.

- Fish passage - The open channel bypass design allows free upstream/downstream movement of fish.

SIMILITUDE

The physical model of the D alternative must resemble the prototype geometrically and kinematically to predict prototype performance under specified operating conditions (Bureau of Reclamation, 1986). Geometric similarity is achieved with the ratios of all prototype to model geometric parameters being equal. Kinematic similarity is achieved with the ratios of all prototype to model velocities being equal. Froude law similitude is employed to establish the kinematic relationship between model and prototype. This similitude is based on maintaining model and prototype Froude numbers, which are equal in all cases. The required geometric and kinematic ratios for this 1:30 Froude scale model are as follows:

Geometric

$L_r = L_p/L_m = 30$

$A_r = (L_r)^2 = 900$

$V_r = (L_r)^3 = 2,700$

where:
L_p = prototype characteristic length
L_m = model characteristic length
L_r = length ratio
A_r = area ratio
V_r = volume ratio

Kinematic

$t_r = (L_r)^{1/2} = 5.48$

$v_r = (L_r)^{1/2} = 5.48$

$a_r = 1$

$Q_r = (L_r)^{5/2} = 4,930$

where:

t_r = time ratio
v_r = velocity ratio
a_r = acceleration ratio
Q_r = discharge ratio

PHYSICAL MODEL

The fish screen model was constructed at the Bureau of Reclamation WRRL (Water Resources Research Laboratory) in Denver, Colorado. The 1:30 scale model covered about 3,000 ft of the oxbow channel, including the D alternative screen structure, the pumping plant, and part of the downstream bypass channel. The scale was chosen to achieve the study objectives and yield efficiency of model operation. Froude number similitude criteria were used to establish kinematic similarity between model and prototype. Figure 5 is a photograph of the river model for the D alternative as constructed in the laboratory.

Figure 5. - Photograph of the D alternative physical model as constructed in the laboratory.

Modeling of the screen under this investigation merits some important considerations. The prototype screen is sized such that it consists of 0.071-in wedge wire on 0.164-in centers, representing a 3/32-inch slot opening, which yields an open area of about 55 percent. The size of the prototype screen prevents modeling this detail at a 1:30 scale. However, for the modeling purposes of this application, representing only the resistance characteristics of the screen is important. The resistance characteristics of the prototype, which are defined by the head loss versus discharge relationship, can be adequately modeled, provided the Re (Reynolds number) of the through-screen flow regimen is sufficiently high. Reynolds number is a non-dimensional ratio of inertial forces to viscous forces, expressed as:

$$VD\frac{\rho}{\mu}$$

where: V = velocity
D = reference length
ρ = fluid density
μ = fluid viscosity

Previous work performed by Yeh et al. (1988) in this area has indicated that for Re $\geq$ 250, the screen head loss coefficient is not significantly sensitive to large changes in approach velocity. An evaluation similar to Yeh et al. (1988) was conducted for the GCID model in a WRRL flume. However, to evaluate model scale effects, through-screen velocity was used rather than approach velocity. Figure 6 illustrates head loss versus Re relationship for a screen angled 10° to the flow. These results show that a minimum Reynolds number of 80 (based on the through-screen velocity) is adequate for representing the prototype screen resistance. Therefore, to adequately model the prototype screen requires similarity of screen porosity and a through-screen Re of greater than about 80. This condition was achieved in the model by using 3/16-in perforated plate having a 56-percent open area to model the prototype screen. Model through-screen velocity for a 0.33-ft/s approach velocity gives an Re of about 120.

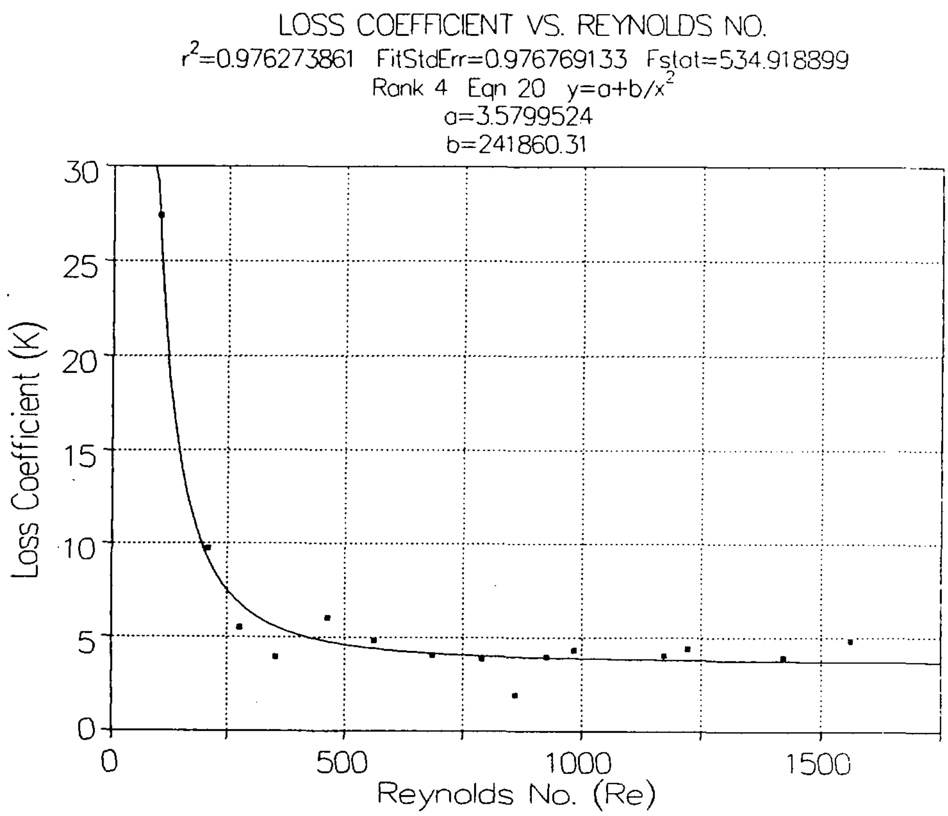

Figure 6. - Head loss coefficient versus Reynolds number relationship for an angled, vertical wedge-wire, screen configuration.

NUMERICAL MODEL

The river system hydraulics near GCID were estimated using the hydrodynamic model RMA2[1], which is a two-dimensional, depth-averaged, finite element model developed by the U.S. Army Corps of Engineers. Numerical modeling was performed under contract by Ayres Associates. Much of the model development had previously been conducted by Ayres (Resource Consultants and Engineers, 1994) as part of an effort to study options for a gradient restoration structure across from Montgomery Island.

Numerical flow simulations were conducted to provide hydraulic data on river flow splits around Montgomery Island and determine estimated water surface elevations within the oxbow channel. These data were needed to establish entrance and exit boundary conditions for operation of the physical model. A total of 15 flow scenarios were run for the D alternative screening concept. Of these scenarios , 13 flow combinations were identified to establish the system (river and pumping plant) hydraulics assuming no gradient restoration structure in the main river channel. Table 1 lists the flow combinations modeled and the major hydraulic data derived for each. These simulations were conducted using 1991 main river and bank topography data. The main channel data are considered to represent recent low river gradient conditions at Montgomery Island. The oxbow channel was modeled as a trapezoidal channel, 2:1 side slopes, with a 145-ft-wide bottom at elevation 128.0. At about 200 ft upstream from the screen structure, the oxbow invert elevation was lowered to elevation 127.0. Simulations 1 to 11 were each repeated using three values of channel rugosity corresponding to Mannings *n* values of 0.02, 0.025, and 0.03. These roughness values cover the expected range of channel conditions and, therefore, give the likely range of hydraulic parameters.

To assess the impact of the riffle aggradation identified in the 1995 main channel survey on the system hydraulics, two additional simulations were conducted. The riffle was modeled as a broad-crested weir placed at the location of the natural riffle. The simplified riffle was depicted as a rock structure with a 20-ft-wide (stream-wise direction) crest and a 1:100 downstream slope. The riffle was superimposed on the 1991 river topography as shown on figure 7. Weir crest elevations of 133.0 and 134.0 were run for the condition of 7,000-ft^3/s river (north gauge) and 3,000-ft^3/s pumping at GCID. Table 2 gives the major hydraulic parameters with the simplified riffle in the main channel. The numerical simulations of the riffle were conducted to provide limited data indicating main channel aggradation impacts on operation. The flow conditions given in table 2 were not modeled in the physical model.

TEST SETUP

Water is supplied to the model from a 250,000-gallon sump via the laboratory pumping system. Discharge delivered to the model is measured using the laboratory venturi meters. The system uses a flow controller to maintain desired flow rate. Model tailwater elevations are maintained using stoplogs at the downstream end of the bypass channel. Model water surface elevations are monitored using point gages set at specific locations (i.e., intake channel, screen structure forebay, bypass channel entrance). The pumping plant was simulated using three separate pump and manifold systems in the model. Pump intakes 1 and 2, 3 to 8, and 9 and 10 were manifolded to separate pumps. Pumped discharges were measured using a Controlotron ultrasonic flowmeter for pumps 3 through 8 and paddle wheel type flowmeters for pumps 1 and 2 and pumps 9 and 10. The bypass discharge was measured using a 12.5° v-notch weir. Model velocities were measured using an ADV (Acoustic Doppler Velocimeter).

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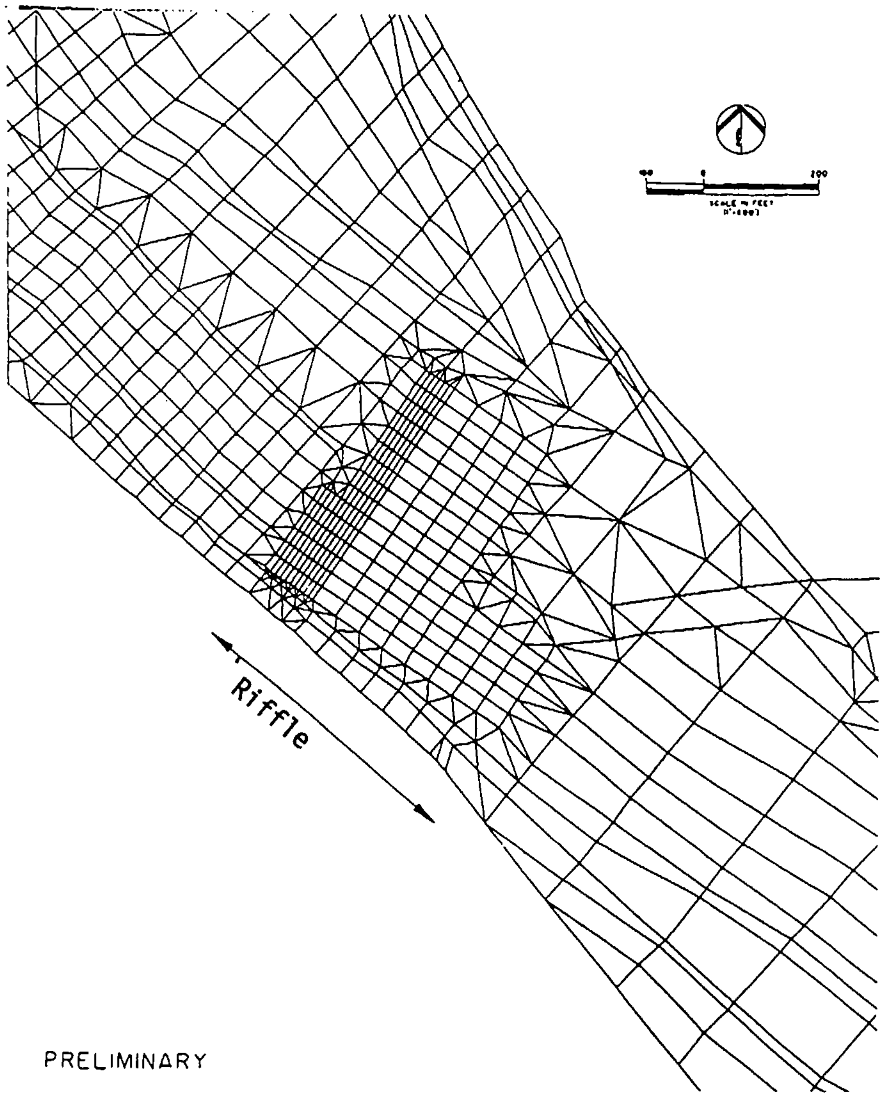
[1] RMA2 is marketed under the name Boss FastTabs by Boss International.

Table 1. - GCID Screening option D-3—2-dimensional simulation results ($n = 0.025$ for the river channel).

Run No.	Q_{river}	Q_{pump}	$Q_{Hamilton\ City}$	Manning "n" (Bypass channel)	Q_{intake}	Q_{bypass}	Water Surface Elevation (ft) North Gage	South Gage	GCID Screens
	(Input)						(Output)		
1	7,000	2,000	5,000	0.03	2,534	534	135.9	134.5	135.4
				0.025	2,578	578	135.9	134.5	135.3
				0.02	2,629	629	135.9	134.5	135.3
2	7,000	2,500	4,500	0.025	2,914	414	135.8	134.4	134.9
				0.02	2,945	445	135.8	134.4	134.9
3	8,000	2,400	5,600	0.03	2,928	528	136.2	134.8	135.5
				0.025	2,970	570	136.2	134.8	135.5
				0.02	3,018	618	136.2	134.8	135.4
4	8,000	2,850	5,150	0.025	3,262	412	136.1	134.6	135.1
				0.02	3,292	442	136.0	134.6	135.0
5	9,000	2,750	6,250	0.03	3,285	535	136.5	135.0	135.7
				0.025	3,325	575	136.5	135.0	135.6
				0.02	3,375	624	136.5	135.0	135.6
6	9,000	3,000	6,000	0.025	3,480	480	136.4	134.9	135.4
				0.02	3,520	520	136.4	134.9	135.4
7	10,000	3,000	7,000	0.03	3,570	570	136.8	135.2	135.9
				0.025	3,615	615	136.8	135.2	135.9
				0.02	3,665	665	136.8	135.2	135.8
8	12,000	3,000	9,000	0.03	3,800	800	137.5	135.8	136.7
				0.025	3,872	872	137.5	135.8	136.7
				0.02	3,948	948	137.4	135.8	136.6
9	20,000	3,000	17,000	0.03	4,652	1,652	139.9	138.2	139.5
				0.025	4,793	1,793	139.9	138.2	139.4
				0.02	4,950	1,950	139.9	138.2	139.4
10	40,000	3,000	37,000	0.03	7,230	4,240	144.5	142.8	144.2
				0.025	7,404	4,415	144.5	142.8	144.2
				0.02	7,572	4,584	144.5	142.8	144.1
11	60,000	1,000	59,000	0.03	9,060	8,088	148.5	146.7	148.3
				0.025	9,255	8,275	148.5	146.7	148.3
				0.02	9,427	8,440	148.5	146.7	148.2
12	8,000	300	7,700	0.025	1,364	1,064	137.0	135.4	136.8
				0.02	1,474	1,174	136.9	135.4	136.8
13	5,000	1,000	4,000	0.025	1,611	611	135.5	134.2	135.2
				0.02	1,670	670	135.4	134.2	135.1

Table 2. - GCID screening option D-3—2-dimensional simulation results—simulated riffle ($n = 0.025$ for the river channel) (GMF = gradient maintenance facility).

Run No.	Q_{river}	Q_{pump}	$Q_{Hamilton\ City}$	Manning "n" (Bypass channel)	Riffle Crest Elevation	Discharge Intake	Bypass	Water Surface Elevation (ft) Up-stream from GMF	Down stream from GMF	North Gage	South Gage	GCID Screen
14	7,000	3,000	4,000	0.025	134	3,612	612	136.2	134.3	136.3	134.2	135.2
15	7,000	3,000	4,000	0.025	133	3,420	420	135.8	134.3	135.9	134.2	134.8



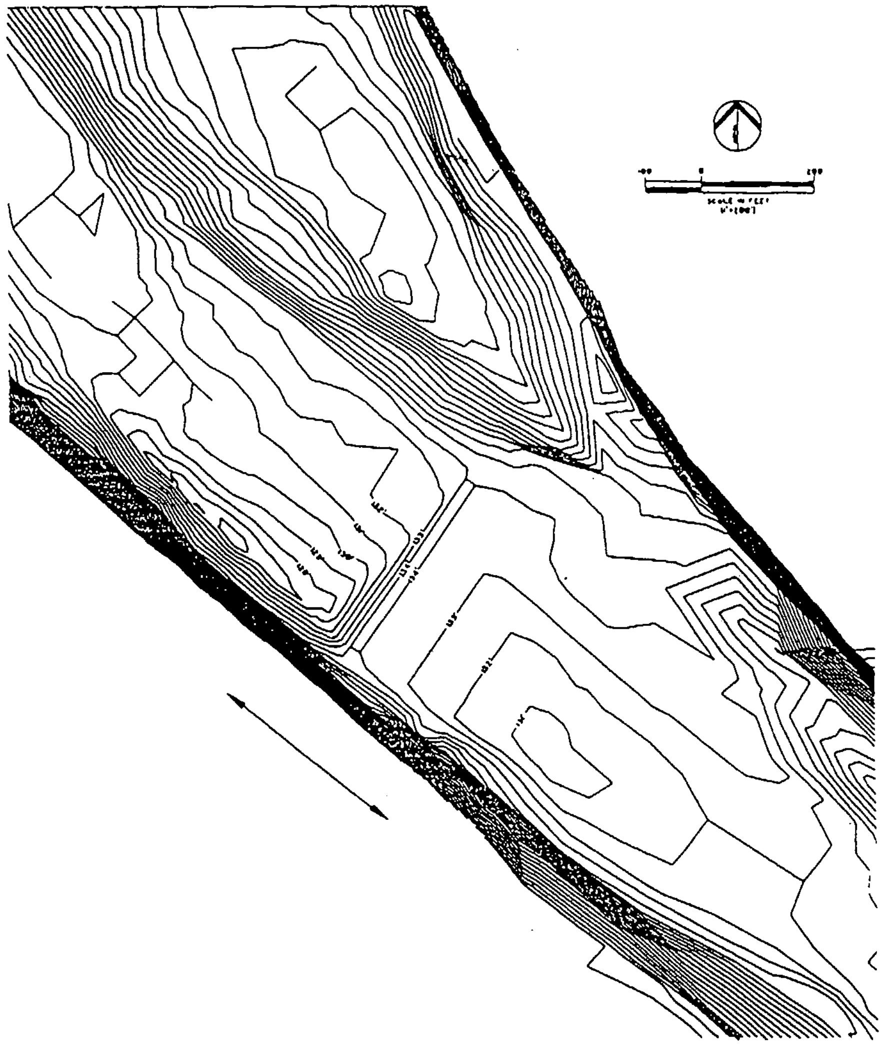


Figure 7. - RMA2 numerical simulation of a simplified riffle in the main river channel along Montgomery Island. Riffle location and size are based on 1995 channel survey data. Simulation conducted by Ayers Associates.

TESTING

Testing under this phase of the hydraulic model study has been consistent with achieving the required objectives. Both dye and confetti tests were performed for flow visualization purposes to determine general flow patterns associated with this alternative. Velocity measurements were conducted to quantify near-screen hydraulic conditions. The results of these flow visualization and velocity measurement tests lead to modifications that will improve performance of the D alternative screen.

Flow Visualization

Flow visualization tests were conducted to evaluate the upstream transition from the channel to the screen structure, the opposite bank guidewall orientation, and the downstream transition from the screen structure to the bypass channel. These tests employed both confetti and dye to establish surface and sub-surface flow patterns, respectively. Tests were documented using video taping and photographs.

Velocity Measurements

All velocity measurements were acquired using a Sontek ADV (Acoustic Doppler Velocimeter). Figure 8 is a photograph of the ADV setup used for acquiring velocity measurements along the screen for this investigation. The ADV instrument can measure local velocities in water to a resolution of 0.001 ft/s and has a maximum sampling rate of 200 Hz and an accuracy of $\pm$0.5 percent of the measured value. For the model study, each velocity reported was an average of about 750 samples obtained at 25 Hz.

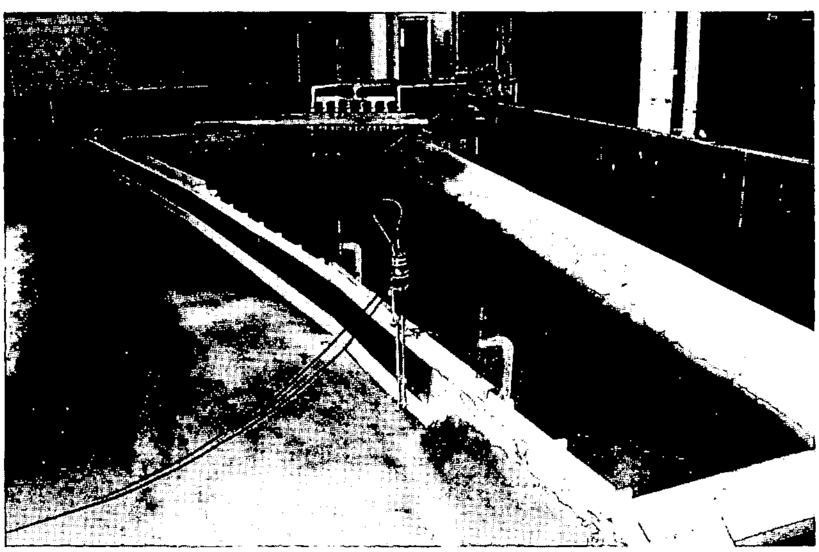


Figure 8. - Photograph of the ADV setup for velocity measurements along the screen.

The relatively large measurement sample size was selected to reduce the uncertainty associated with measuring the normal velocity component in the presence of a strong sweeping velocity field. Measurement uncertainty is proportional to the inverse square root of the number of the sample size, or simply, the greater the sample size the lower the uncertainty of the estimate of the population mean.

Velocity data measured in the study are reported as the mean value of the data sample. The mean value was determined as:

$$\bar{u} = (u_i + \ldots\ldots + u_N)/n$$

where: $\bar{u}$ = mean value of n measurements
u_i = values of the measured x-component of velocity
n = sample size

The average uncertainty of each measurement can be characterized by the standard deviation, which is defined as:

$$\sigma_u = \sqrt{\sum (u_i - \bar{u})^2/(n-1)}$$

where: σ_u = standard deviation of n measurements of u
u_i = measured values of u
$\bar{u}$ = mean value of n measurements of u
n = sample size

The standard deviation represents the average uncertainty of the separate measurements of $u_1,\ldots,u_n$. The uncertainty of the mean or best estimate of velocity is the standard deviation of the mean or probable error. The value of $\bar{u}$ can be considered more reliable than any one measurement considered separately because it is comprised of all n measurements of u. The uncertainty in any set of n measurements is defined as:

$$\sigma_{\bar{u}} = \frac{\sigma_u}{\sqrt{n}}$$

Thus, the best estimate of u is reported as the mean, $\bar{u} \pm$ the standard deviation of the mean, $\sigma_{\bar{u}}$.

Velocity measurements were acquired along the screen structure for two baseline flow simulations prior to and after each successive modification to the model. Baseline flow simulations consisted of pumping plant discharges of 2,000 ft^3/s and 3,000 ft^3/s, both with bypass discharges of 500 ft^3/s. Minimum water surface elevations and corresponding river flows were estimated for these pumping conditions using available numerical data from the gradient restoration feasibility study (Resource Consultants and Engineers, 1994). Estimated values used for the physical model are given in table 3. Better estimates of the river flows for these conditions were obtained following completion of RMA2 numerical modeling. These values are shown in parentheses below the estimated values in table 3. For consistency in comparison of modifications, the river values given as the upper values in table 3 were carried through the model study. The simulation number given in table 3 corresponds to the sequencing of numerical simulations of table 1.

Table 3. - Initial testing flow simulation set points.

Simulation No.	Q_{river} (ft^3/s)	$Q_{pumping}$ (ft^3/s)	Q_{intake} (ft^3/s)	Q_{bypass} (ft^3/s)	w.s.el.$_{screens}$ (ft)
1	7,000 (7,500)	2,000	2,500	500	135.5
7	10,000 (12,000)	3,000	3,500	500	136.7

Velocities were measured at the centerline of each 40-ft-wide bay for the new screen structure and at the centerline of every fifth bay along the existing structure. Point velocities were measured at the 0.6 depth, thus representing the approximate vertical average velocity.

Evaluation of flow visualization and velocity data guided modifications tested in the model. This approach resulted in tests of:

- The original screen configuration
- An expanded opposite bank guidewall
- A 4° bend in the upstream screen orientation
- Reduced pumping plant forebay area
- Reduced screen length
- Transitions to the bypass channel entrance

Each of these modifications was developed based upon the results of previous tests. Again, screen velocity measurements were used to identify possible causes of poor screen performance. Figure 9 is a conceptual layout identifying the associated modifications.

The final screen concept configuration was tested under a wide range of flow conditions. These hydraulic conditions tested are included as table 4.

RESULTS

The primary result of the testing is the realization of improved screen performance for the D alternative screen. This improved performance is demonstrated by the increase in screen effectiveness for the upstream 300 ft of screen area, the elimination of eddy zones on both sides of the channel transition to screen forebay, and the establishment of near-uniform screen velocity distributions under non-baffled conditions.

The major results of the model study are presented as *x-y* velocity plots for each configuration tested. The dependent variable is given as the measurement location along the screen structure and the independent variable represents the magnitude of velocity at each measurement location. Sweeping and normal components of velocity are plotted for each test (figs. 10 to 29). Velocity data for each test in tabular form are included in the appendix. The tabular data also provide measurement sample size, SDEV (standard deviation), and SDOM (standard deviation of the mean) (normal velocity component only).

Table 4. - Expanded testing program for the final screen concept design.

Simulation No. (reference table 1)	Q_{river} (ft³/s)	$Q_{pumping}$ (ft³/s)	Q_{intake} (ft³/s)	Q_{bypass} (ft³/s)	w.s.el.$_{screens}$ (ft)
1	7,000	2,000	2,500	500	135.5
7	10,000	3,000	3,500	500	136.7
9	20,000	3,000	5,029	2,029	139.6
10	40,000	3,000	8,090	5,090	144.7
11	60,000	1,000	10,350	9,350	148.7
12	4,000	500	1,100	600	135.1
13	5,000	1,000	1,650	650	135.3
14	8,000	300	1,400	1,100	136.9

Test Results

The original D alternative screen configuration was tested under flow simulation 7. Figure 10 represents the results of test No. 1. The normal and sweeping velocity components are shown by open circles and solid circles, respectively, for all data plots. As shown, the normal component screen velocity distribution is non-uniform. Negative sweeping and normal component velocities existed along the first upstream bay. Dye tests indicated that this condition was a result of a large eddy zone generated by the upstream channel transition to the screen structure. Flow visualization tests also showed approach flow separated from the opposite bank at the upstream end of the screen structure and impinged largely on the upstream one-third of the screen. As a result, a large eddy zone existed along the opposite bank guidewall.

The opposite bank guidewall was extended into the channel and shaped to turn the approach flow and align it with the screen structure. The guidewall was shaped until dye traces indicated approach flow remained attached along its full length. The reshaped guidewall provided good uniformity of approach channel flow along the screen. Dye injected into the oxbow channel upstream from the screen at three points across the channel tracked nearly parallel along the screen length. Near-bank flow entered the screen within the first quarter of the screen length, mid-channel flow entered the screen over the middle half of the screen, and opposite-bank flow moved parallel to the opposite bank entering the screen along the downstream one-quarter of its length.

The modified opposite bank guidewall was then tested under flow simulations 1 and 7. Figures 11 and 12 represent the results of these tests. Approach and sweeping velocities improved because of the guidewall changes. However, poor flow conditions persisted near the upstream transition to the screen.

To improve flow conditions at the screen's upstream end, the leading 300 ft of screen structure was angled 4° into the approach flow (fig. 9). This modification improved the alignment of the approach channel and screen. Figures 13 and 14 show the effects of this modification. The screen realignment eliminated the eddy in front of the first bay. However, screen approach velocities on the first two screen bays exceeded allowable criteria. The high velocities were caused by the close proximity of the upstream bend in the oxbow channel. Flow leaving the channel bend approached the upstream end of the screen before completing the turn. This condition caused the angle of attack on the screen to be significantly larger near the upstream end of the screen.

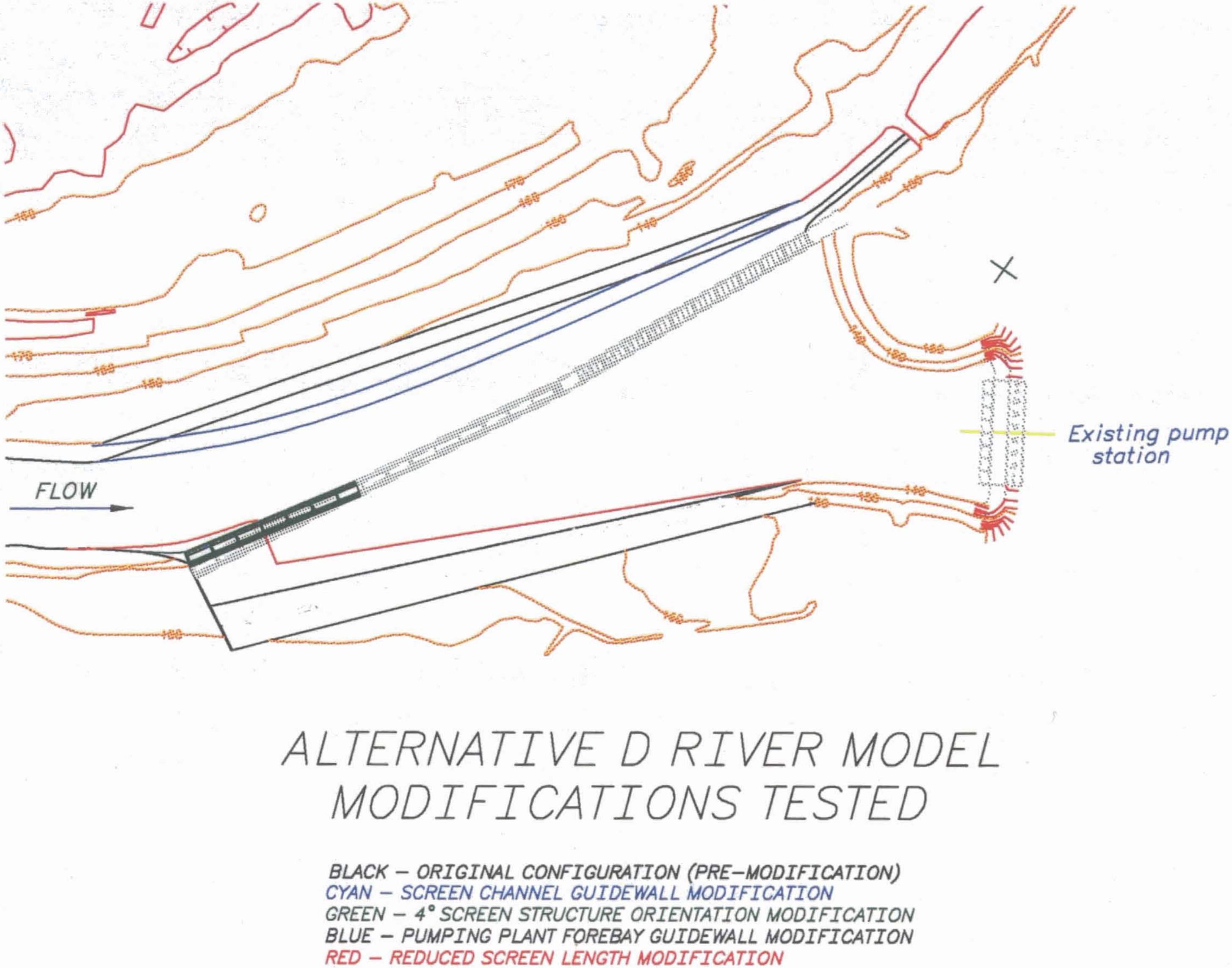


Figure 9. - Conceptual layout of the D-alternative screen configuration and associated modifications.

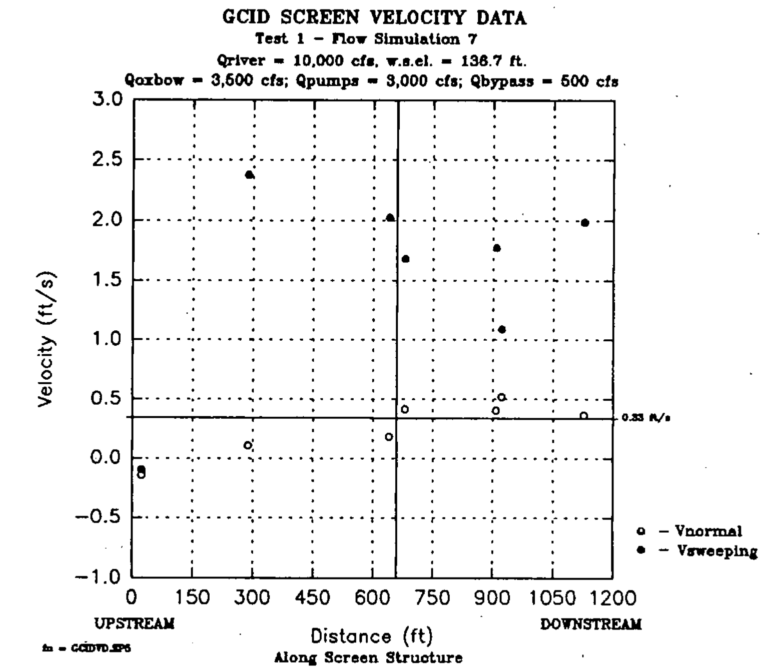


Figure 10. - Original D alternative screen configuration test results, flow simulation 7.

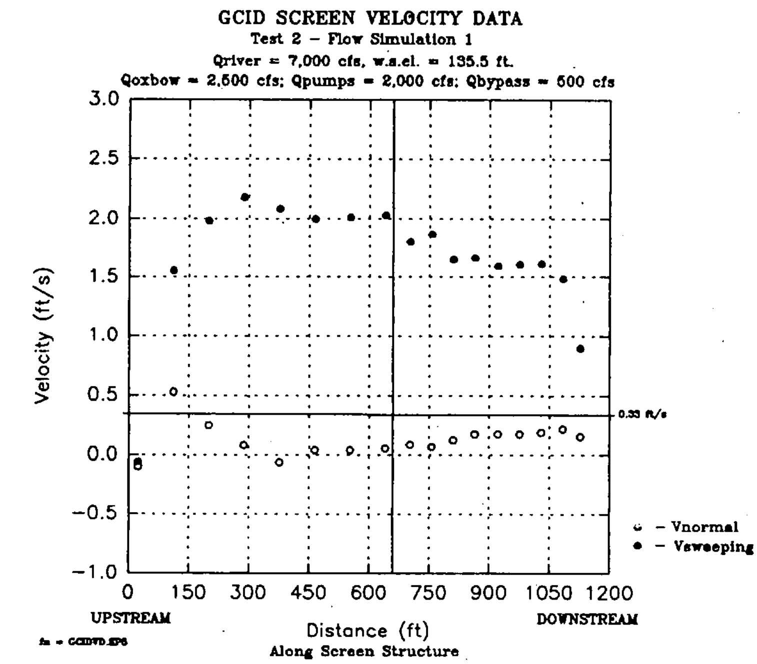


Figure 11. - Opposite bank guidewall modification test results, flow simulation 1.

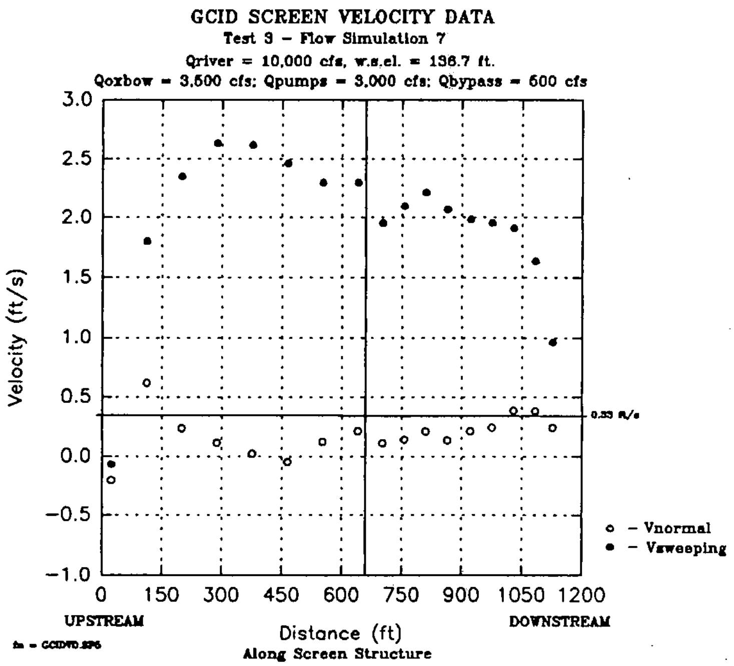


Figure 12. - Opposite bank guidewall modification test results, flow simulation 7.

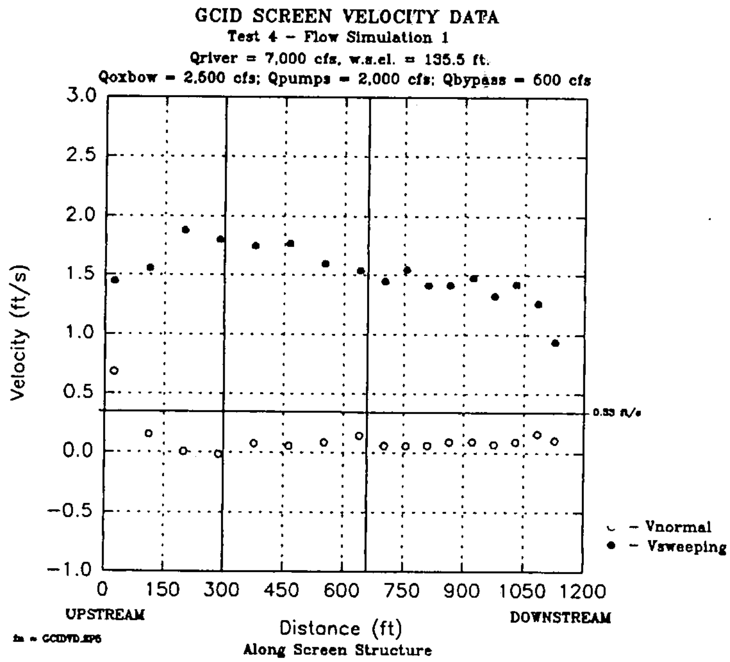


Figure 13. - 4° screen orientation modification test results, flow simulation 1.

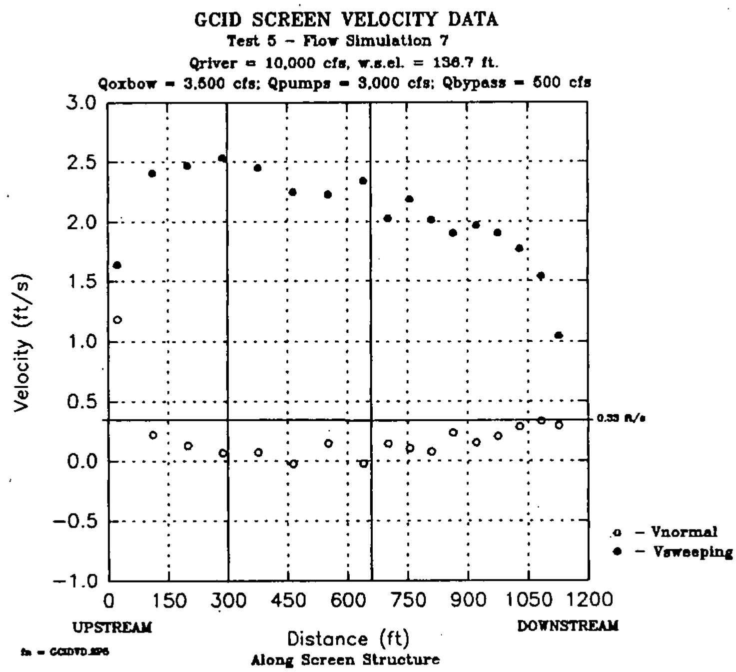


Figure 14. - 4° screen orientation modification test results, flow simulation 7.

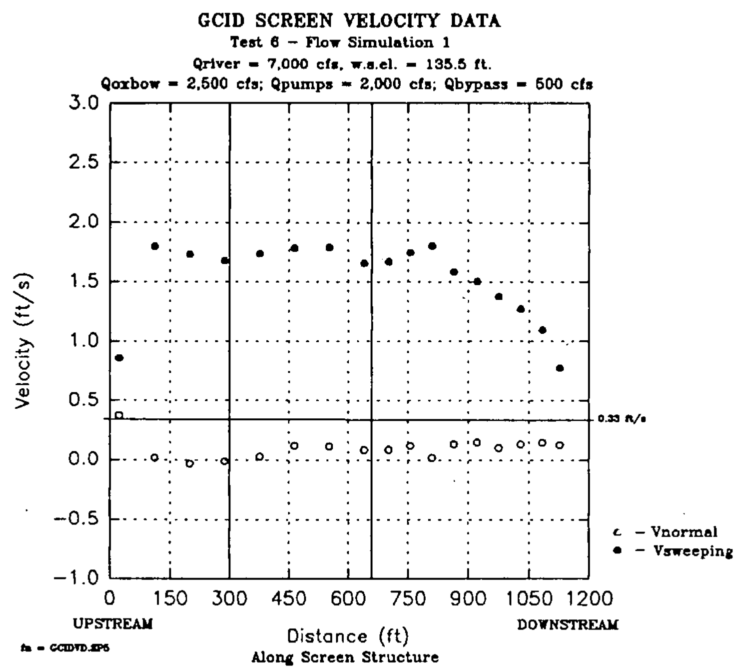


Figure 15. - Pumping plant forebay guidewall modification test results, flow simulation 1.

Two modifications were tested to further improve screen approach velocities. First, the pumping plant forebay guidewall was moved closer to the screen structure, thus reducing the forebay area, particularly at the upstream end of the screen structure (see fig. 9). Figure 15 shows the resulting screen velocity distribution for flow simulation 1. Reducing the forebay area improved the overall uniformity of approach flow along the screen but fell short of achieving the uniformity of approach velocity needed at the upstream end of the screen. The testing clearly showed the screen had to be shortened or moved downstream to avoid the direct influence of the channel bend. To test this assumption, the screen length was reduced by 150 ft (fig. 9). This reduction resulted in a screen length of 1,003 ft and a screen area of about 9,100 ft^2 at a water surface elevation of 136.4. Figures 16 and 17 show the improvement in the screen velocity distribution obtained.

The final modification to the D alternative screen tested in the 1:30 scale model consisted of changing the bypass channel entrance geometry. This effort was undertaken to increase sweeping velocity on the downstream most screen bays. A submerged berm was placed along the opposite bank guidewall near the entrance to the bypass channel. The berm was designed to reduce the channel area and provide a smooth transition to the bypass channel. The berm tested increased near-screen sweeping velocities by about 30 percent at the downstream end of the screen (fig. 18). Additional efforts in this area were not considered warranted for the objectives of the 1:30 model. Final geometry of the bypass intake will depend on the final screen length chosen for the design.

Final Concept Testing

Upon completion of the initial modifications, tests were conducted to document screen performance for a wide range of river and pumping flow combinations. The flow combinations tested are listed in table 4. Figures 19 through 26 show the results of these tests. Of special note are reverse flow conditions that occur near the downstream end of the screen during low pumping (figs. 21 through 23) or high river flow conditions (figs. 24 through 26). Reverse flow is indicated on the figures by negative values of the normal velocity component. Reverse flow conditions occur when flow in excess of pumping demand moves through the upstream portion of the screen. This condition is accentuated by the curvature of the oxbow channel. Figure 27 shows velocity vectors measured at several cross sections along the oxbow channel. Flow is directed into the near bank as it moves around the bend upstream from the screen structure. The angle at which flow approaches the screen, and therefore, flow through the screen, is greatest at the upstream end. Flow combinations that result in large bypass flows will likely result in some reverse flow at the lower end of the screen structure. Dye was injected in the regions of reverse flow to determine if the condition created eddies or slack water conditions in front of the screen that might favor predators. The reverse flow through the screen was found to merge smoothly with flow entering the bypass channel moving continuously downstream.

Prior to completion of model testing, a final test was conducted to verify repeatability of the data. The final configuration was again tested under flow simulation 7 conditions. Figure 28 represents the results of this test. These results were then compared with the results obtained for test No. 11 shown on figure 20. Figure 29 represents the comparison plot of these two tests. The results show a satisfactory agreement of data.

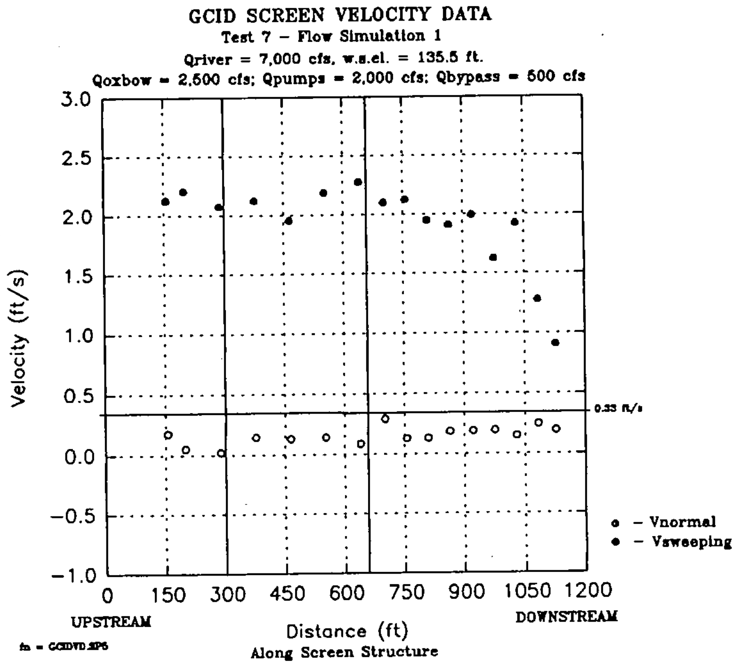


Figure 16. - Reduced screen length modification test results, flow simulation 1.

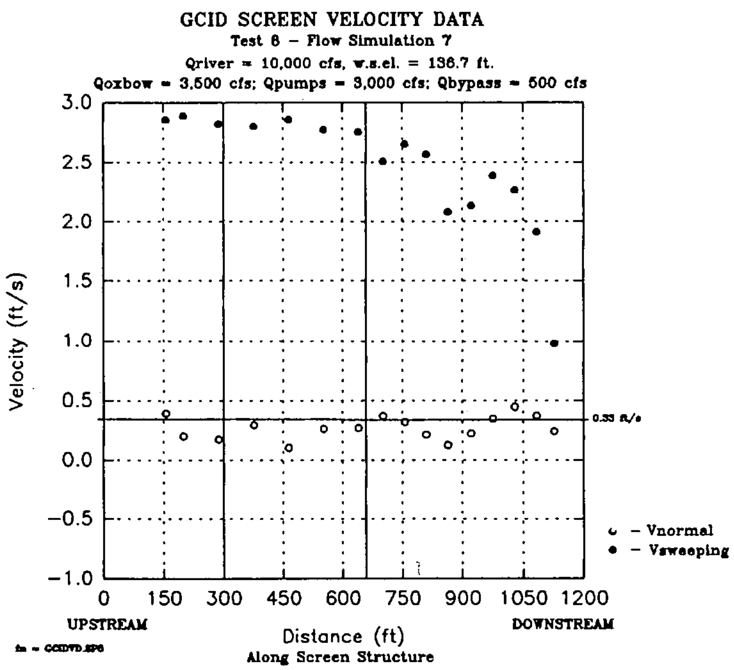


Figure 17. - Reduced screen length modification test results, flow simulation 7.

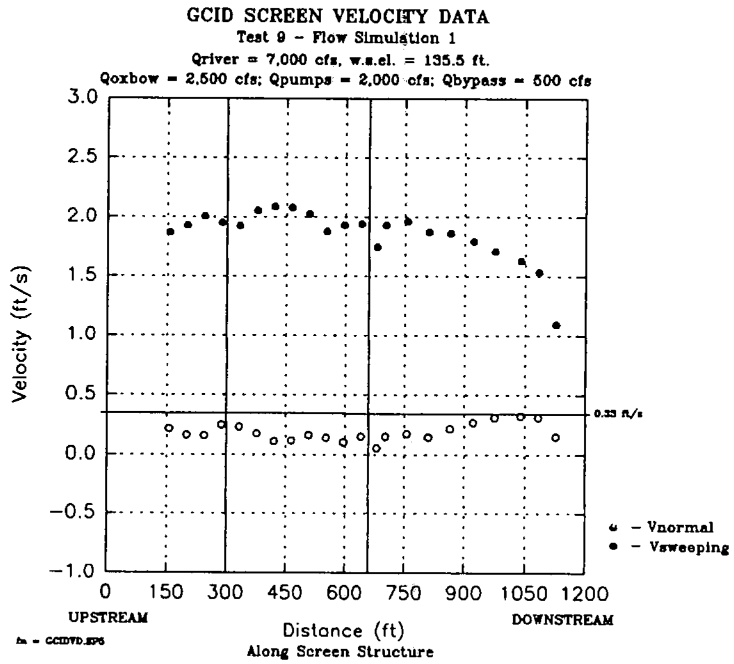


Figure 18. - Bypass channel entrance modification test results, flow simulation 1.

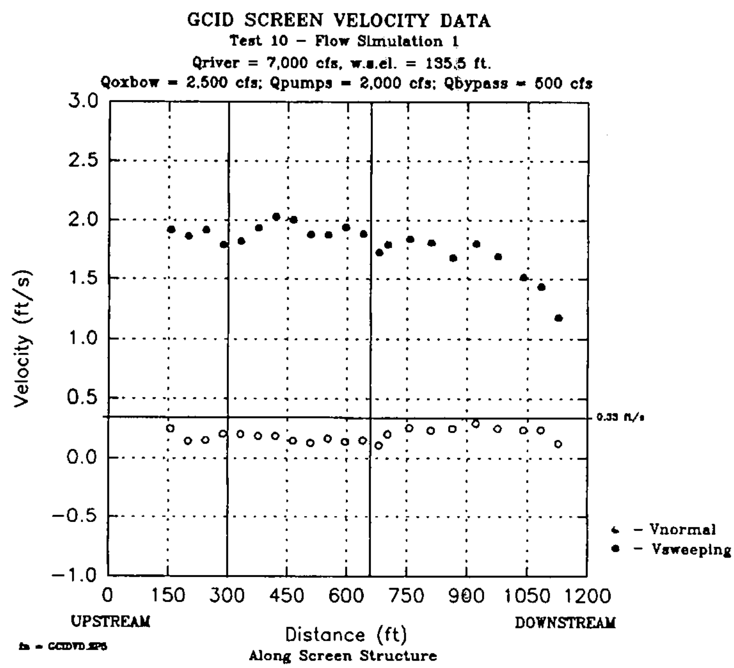


Figure 19. - Final test results, flow simulation 1.

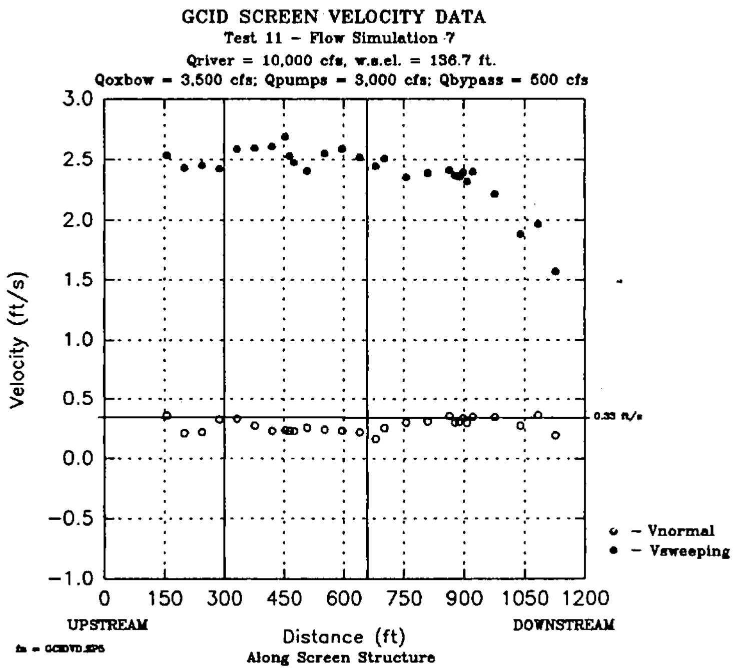


Figure 20. - Final test results, flow simulation 7.

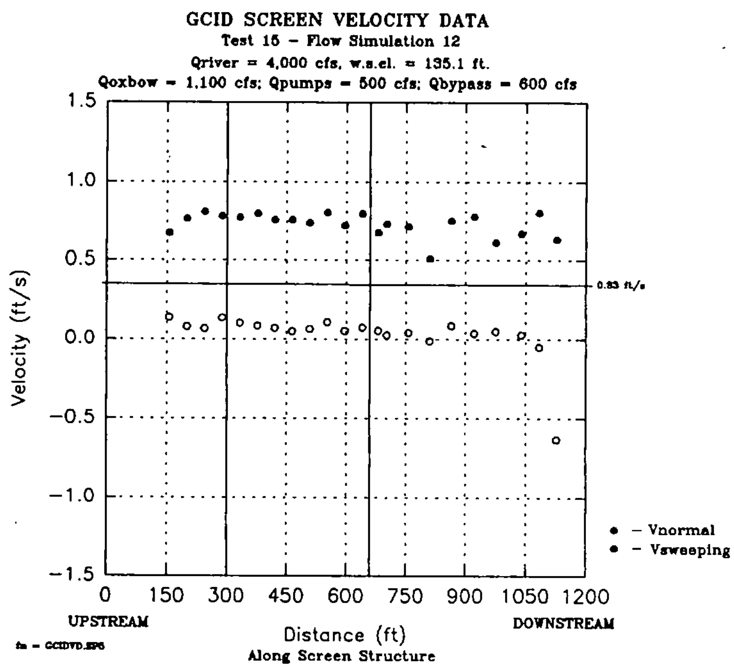


Figure 21. - Final test results, flow simulation 12.

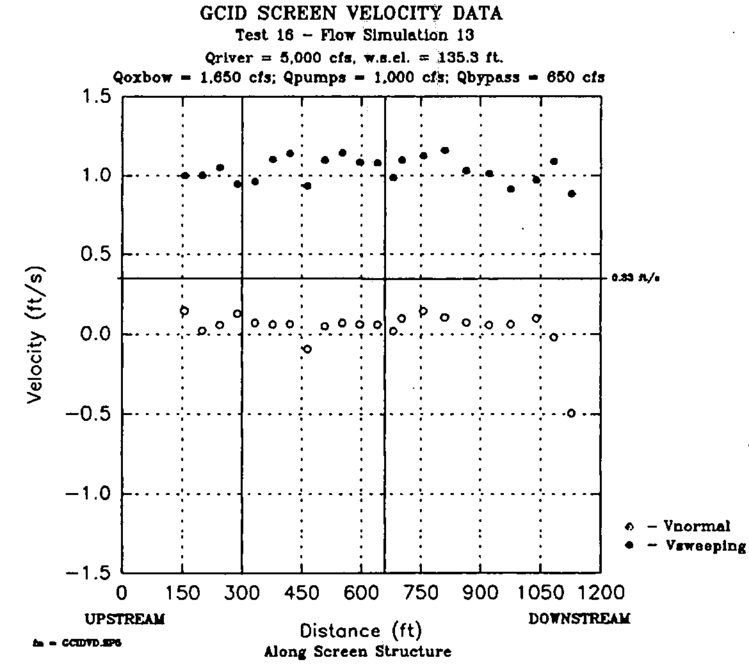


Figure 22. - Final test results, flow simulation 13.

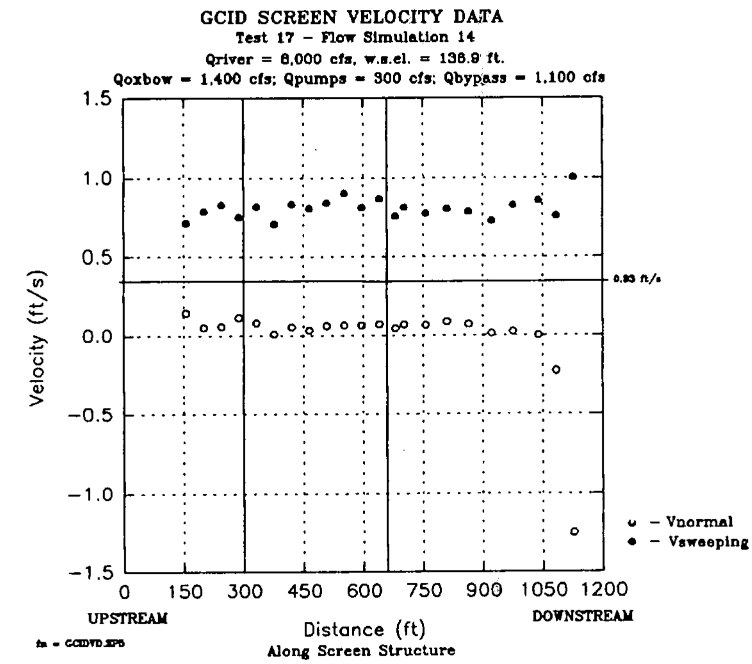


Figure 23. - Final test results, flow simulation 14.

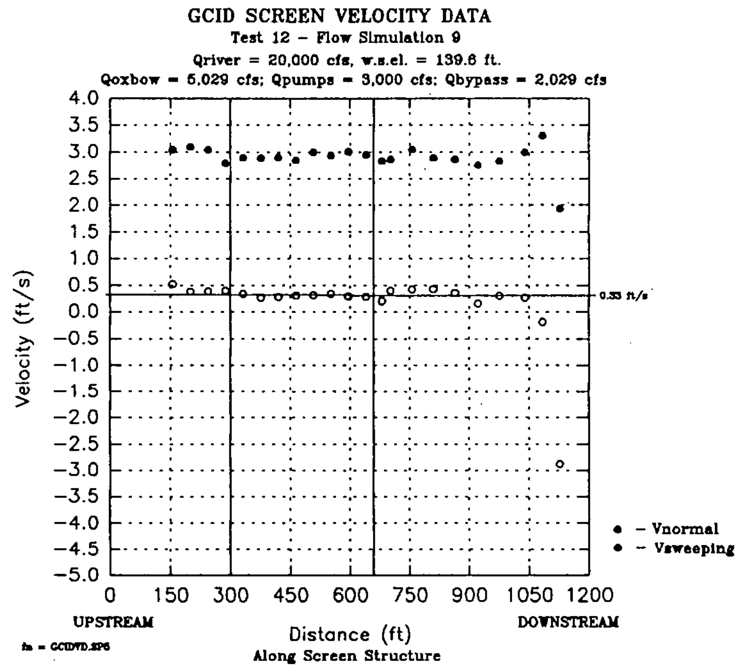


Figure 24. - Final test results, flow simulation 9.

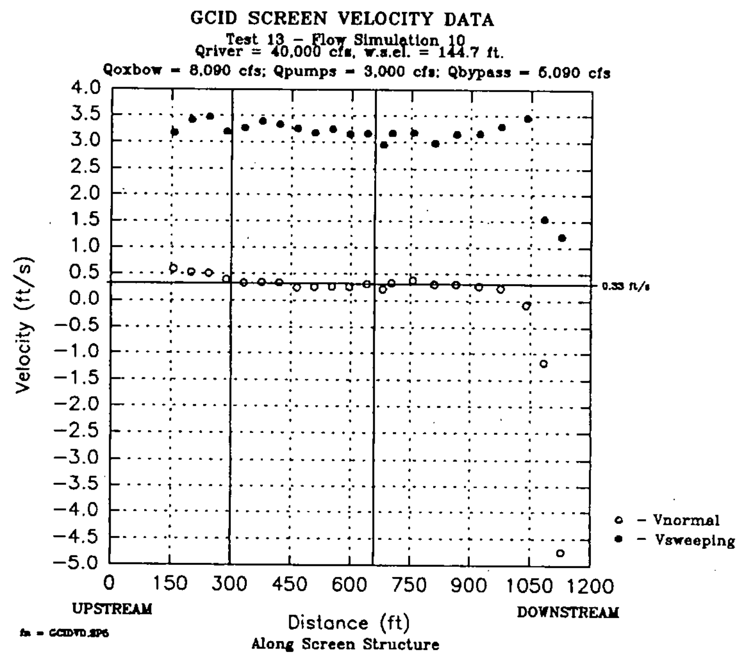


Figure 25. - Final test results, flow simulation 10.

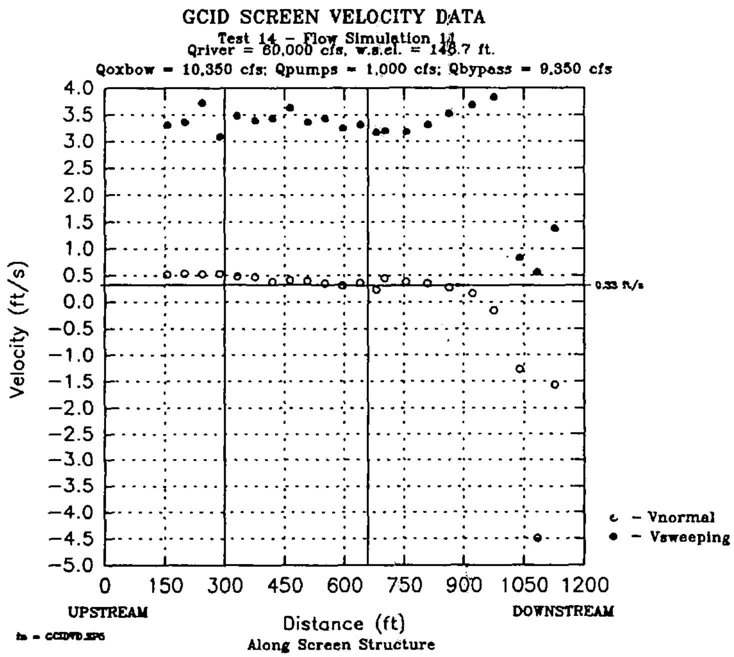


Figure 26. - Final test results, flow simulation 11.

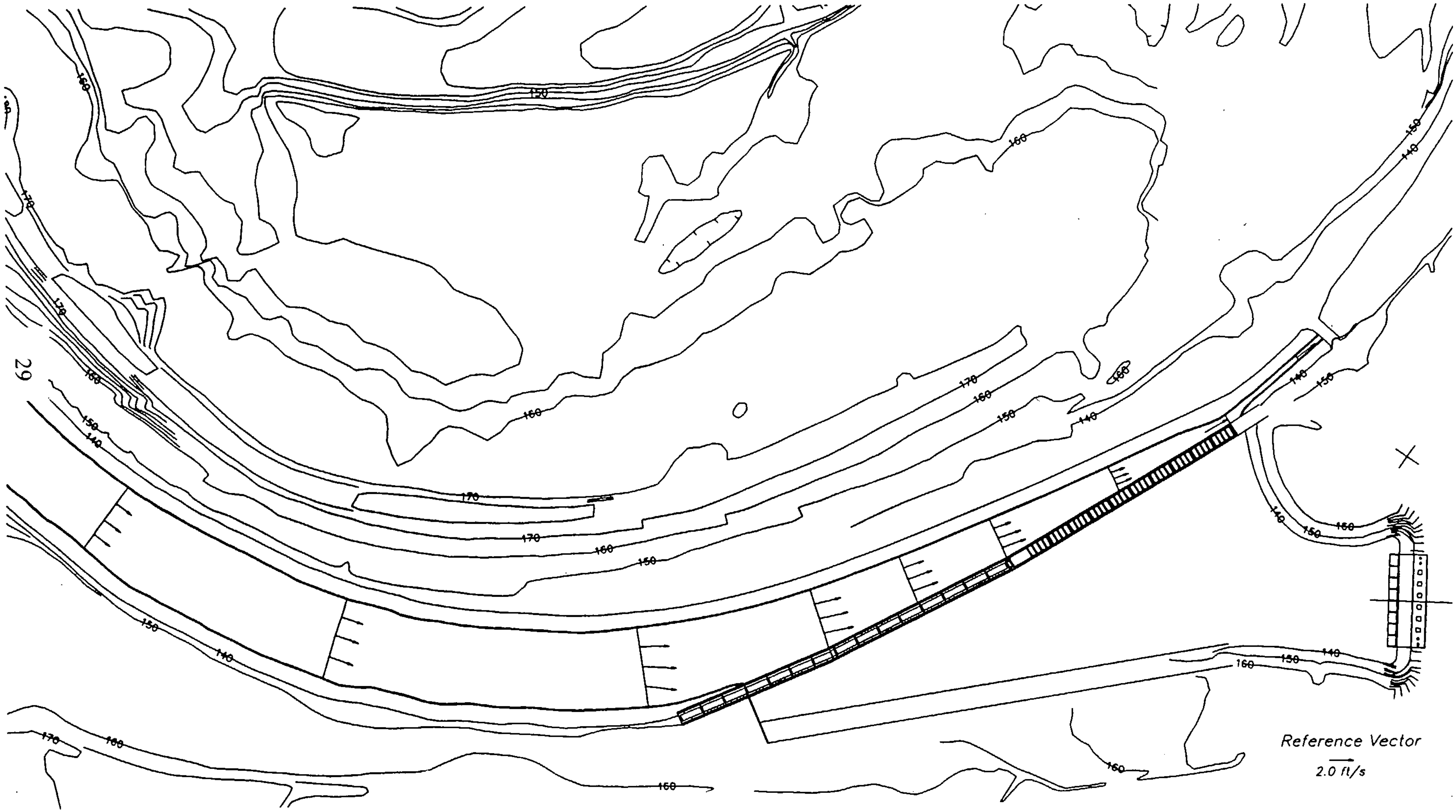


Figure 27. - Plan view of the D alternative fish screen showing oxbow channel flow velocity vectors in the vicinity of the screen.

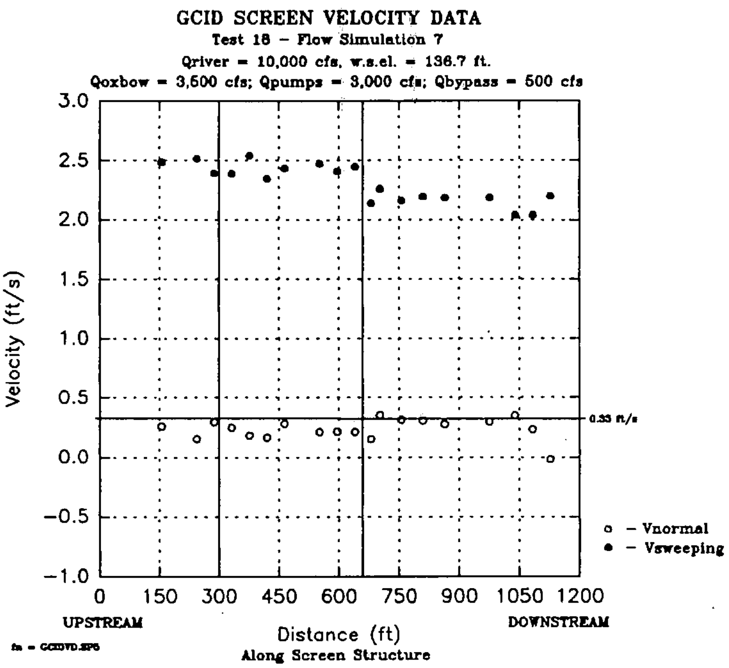


Figure 28. - Repeatability verification results, flow simulation 7.

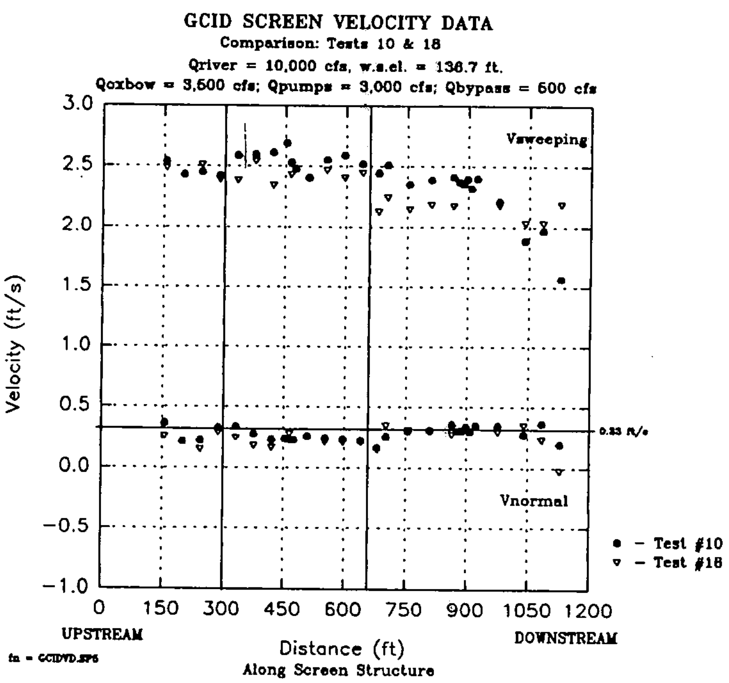


Figure 29 - Repeatability verification results. Comparison between results obtained from tests 10 and 18.

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APPENDIX

Screen Velocity Data

TEST #1 - Original Screen Configuration (Pre-modification)
Flow Simulation 7:
Qriver = 10,000 ft3/s w.s.el. = 136.7 ft
Qapproach = 3,500 ft3/s
Qpump = 3,000 ft3/s
Qbypass = 500 ft3/s

Bay No.	Vnormal (ft/s)	Vsweeping (ft/s)	No. of samples	SDEVnormal	SDOMnormal
55	-0.142	-0.097	1747	0.286	0.007
50	0.105	2.375	928	0.199	0.007
45	0.181	2.021	1210	0.224	0.006
44	0.415	1.681	984	0.145	0.005
25	0.403	1.773	813	0.186	0.007
24	0.522	1.088	747	0.103	0.004
2	0.365	1.986	843	0.184	0.006

fn = gcidrsum.wk3

TEST #2 - Screen Guidewall Modification
Flow Simulation 1:
Qriver = 7,000 ft3/s w.s.el. = 135.5 ft
Qapproach = 2,500 ft3/s
Qpump = 2,000 ft3/s
Qbypass = 500 ft3/s

Bay No.	Vnormal (ft/s)	sweeping (ft/s	No. of samples	SDEVnormal	SDOMnormal
b55	-0.099	-0.059	1530	0.190	0.005
b53	0.528	1.553	808	0.242	0.009
b51	0.249	1.984	796	0.170	0.006
b49	0.083	2.179	1546	0.155	0.004
b47	-0.061	2.085	818	0.168	0.006
b45	0.040	1.999	798	0.156	0.006
b43	0.041	2.013	773	0.154	0.006
b41	0.057	2.033	746	0.146	0.005
b40	0.088	1.802	809	0.154	0.005
b35	0.069	1.869	774	0.153	0.006
b30	0.127	1.649	1197	0.174	0.005
b25	0.176	1.662	754	0.133	0.005
b20	0.178	1.593	759	0.138	0.005
b15	0.177	1.606	733	0.227	0.008
b10	0.190	1.612	680	0.133	0.005
b5	0.219	1.483	760	0.123	0.004
b1	0.155	0.894	780	0.149	0.005

fn = gcidrsum.wk3

TEST #3 - Screen Guidewall Modification

Flow Simulation 7:

Qriver = 10,000 ft3/s w.s.el. = 136.7 ft

Qapproach = 3,500 ft3/s

Qpump = 3,000 ft3/s

Qbypass = 500 ft3/s

Bay No.	Vnormal (ft/s)	Vsweeping (ft/s)	No. of samples	SDEVnormal	SDOMnormal
b55	-0.203	-0.069	618	0.167	0.007
b53	0.617	1.800	400	0.292	0.015
b51	0.236	2.349	488	0.259	0.012
b49	0.112	2.629	429	0.242	0.012
b47	0.022	2.615	482	0.181	0.008
b45	-0.048	2.462	480	0.167	0.008
b43	0.122	2.296	403	0.192	0.010
b41	0.213	2.297	597	0.177	0.007
b40	0.110	1.952	375	0.197	0.010
b35	0.141	2.095	405	0.174	0.009
b30	0.209	2.213	487	0.172	0.008
b25	0.134	2.067	568	0.143	0.006
b20	0.211	1.982	433	0.139	0.007
b15	0.242	1.953	399	0.151	0.008
b10	0.386	1.910	426	0.128	0.006
b5	0.382	1.639	426	0.149	0.007
b1	0.242	0.958	400	0.198	0.010

fn = gcidrsum.wk3

TEST #4 - 4 Degree Screen Orientation Modification

Flow Simulation 1:

Qriver = 7,000 ft3/s w.s.el. = 135.5 ft

Qapproach = 2,500 ft3/s

Qpump = 2,000 ft3/s

Qbypass = 500 ft3/s

Bay No.	Vnormal (ft/s)	Vsweeping (ft/s)	No. of samples	SDEVnormal	SDOMnormal
b55	0.682	1.446	814	0.223	0.008
b53	0.150	1.559	788	0.148	0.005
b51	0.004	1.884	824	0.161	0.006
b49	-0.015	1.805	846	0.155	0.005
b47	0.071	1.751	871	0.158	0.005
b45	0.052	1.773	844	0.119	0.004
b43	0.083	1.599	855	0.138	0.005
b41	0.142	1.540	795	0.128	0.005
b40	0.056	1.447	779	0.153	0.005
b35	0.054	1.547	791	0.117	0.004
b30	0.059	1.413	832	0.126	0.004
b25	0.087	1.413	858	0.124	0.004
b20	0.090	1.475	772	0.115	0.004
b15	0.070	1.325	843	0.138	0.005
b10	0.090	1.424	826	0.121	0.004
b5	0.155	1.260	1011	0.139	0.004
b1	0.104	0.937	806	0.127	0.004

fn = gcidrsum.wk3

TEST #5 - 4 Degree Screen Orientation Modification

Flow Simulation 7:
Qriver = 10,000 ft3/s w.s.el. = 136.7 ft
Qapproach = 3,500 ft3/s
Qpump = 3,000 ft3/s
Qbypass = 500 ft3/s

Bay No.	Vnormal (ft/s)	Vsweeping (ft/s)	No. of samples	SDEVnormal	SDOMnormal
b55	1.183	1.637	744	0.282	0.010
b53	0.219	2.408	738	0.215	0.008
b51	0.128	2.468	752	0.191	0.007
b49	0.066	2.532	726	0.202	0.007
b47	0.072	2.451	738	0.179	0.007
b45	-0.025	2.249	731	0.164	0.006
b43	0.145	2.229	743	0.164	0.006
b41	-0.021	2.340	760	0.168	0.006
b40	0.143	2.028	752	0.180	0.007
b35	0.105	2.187	720	0.168	0.006
b30	0.077	2.014	744	0.178	0.007
b25	0.237	1.903	719	0.172	0.006
b20	0.152	1.966	732	0.165	0.006
b15	0.203	1.904	732	0.161	0.006
b10	0.286	1.769	745	0.165	0.006
b5	0.334	1.539	746	0.165	0.006
b1	0.294	1.045	775	0.152	0.005

fn = gcidrsum.wk3

TEST #6 - Pumping Plant Forebay Guidewall Modification

Flow Simulation 1:
Qriver = 7,000 ft3/s w.s.el. = 135.5 ft
Qapproach = 2,500 ft3/s
Qpump = 2,000 ft3/s
Qbypass = 500 ft3/s

Bay No.	Vnormal (ft/s)	Vsweeping (ft/s)	No. of samples	SDEVnormal	SDOMnormal
b55	0.375	0.858	962	0.198	0.006
b53	0.015	1.793	817	0.160	0.006
b51	-0.034	1.727	834	0.144	0.005
b49	-0.012	1.673	821	0.160	0.006
b47	0.028	1.733	967	0.156	0.005
b45	0.121	1.781	776	0.152	0.005
b43	0.114	1.787	800	0.154	0.005
b41	0.084	1.653	791	0.155	0.006
b40	0.087	1.666	775	0.147	0.005
b35	0.120	1.744	725	0.139	0.005
b30	0.019	1.800	794	0.132	0.005
b25	0.135	1.585	587	0.125	0.005
b20	0.149	1.501	637	0.145	0.006
b15	0.103	1.378	448	0.140	0.007
b10	0.133	1.267	409	0.159	0.008
b5	0.147	1.093	404	0.138	0.007
b1	0.126	0.777	418	0.132	0.006

fn = gcidrsum.wk3

TEST #7 - Reduced Screen Length Modification

Flow Simulation 1:

Qriver = 7,000 ft3/s   w.s.el. = 135.5 ft

Qapproach = 2,500 ft3/s

Qpump = 2,000 ft3/s

Qbypass = 500 ft3/s

Bay No.	Vnormal (ft/s)	Vsweeping (ft/s)	No. of samples	SDEVnormal	SDOMnormal
b52	0.177	2.128	732	0.136	0.005
b51	0.052	2.205	725	0.156	0.006
b49	0.022	2.076	717	0.157	0.006
b47	0.144	2.124	748	0.148	0.005
b45	0.131	1.956	749	0.167	0.006
b43	0.142	2.186	744	0.191	0.007
b41	0.085	2.273	760	0.163	0.006
b40	0.289	2.101	736	0.167	0.006
b35	0.128	2.124	733	0.153	0.006
b30	0.131	1.949	723	0.163	0.006
b25	0.185	1.911	751	0.147	0.005
b20	0.190	1.993	740	0.157	0.006
b15	0.192	1.624	721	0.149	0.006
b10	0.149	1.924	728	0.155	0.006
b5	0.245	1.277	744	0.162	0.006
b1	0.192	0.902	733	0.163	0.006

fn = gcidrsum.wk3

TEST #8 - Reduced Screen Length Modification

Flow Simulation 7:

Qriver = 10,000 ft3/s   w.s.el. = 136.7 ft

Qapproach = 3,500 ft3/s

Qpump = 3,000 ft3/s

Qbypass = 500 ft3/s

Bay No.	Vnormal (ft/s)	Vsweeping (ft/s)	No. of samples	SDEVnormal	SDOMnormal
b52	0.394	2.857	864	0.253	0.009
b51	0.198	2.889	1257	0.232	0.007
b49	0.173	2.824	478	0.203	0.009
b47	0.293	2.803	763	0.213	0.008
b45	0.102	2.859	903	0.189	0.006
b43	0.262	2.776	841	0.205	0.007
b41	0.270	2.757	810	0.192	0.007
b40	0.375	2.509	786	0.204	0.007
b35	0.323	2.653	783	0.197	0.007
b30	0.212	2.566	816	0.200	0.007
b25	0.125	2.081	482	0.214	0.010
b20	0.222	2.132	334	0.205	0.011
b15	0.351	2.389	787	0.187	0.007
b10	0.450	2.263	872	0.166	0.006
b5	0.376	1.915	811	0.177	0.006
b1	0.241	0.978	2172	0.207	0.004

fn = gcidrsum.wk3

TEST #9 - Modified Bypass Entrance Testing.

Flow Simulation 1:

Qriver = 7,000 ft3/s — w.s.el. = 135.4 ft (@entrance to screen forebay)

Qapproach = 2,500 ft3/s — w.s.el. = 135.2 ft (@bypass channel entrance)

Qpump = 2,000 ft3/s

Qbypass = 500 ft3/s

Bay No.	Vnormal (ft/s)	Vsweeping (ft/s)	No. of samples	SDEVnormal	SDOMnormal
B52	0.216	1.869	731	0.201	0.007
B51	0.163	1.928	781	0.221	0.008
B50	0.158	2.007	721	0.198	0.007
B49	0.248	1.951	745	0.208	0.008
B48	0.230	1.926	737	0.209	0.008
B47	0.175	2.054	720	0.199	0.007
B46	0.111	2.086	741	0.241	0.009
B45	0.118	2.081	740	0.190	0.007
B44	0.161	2.027	743	0.246	0.009
B43	0.141	1.876	729	0.228	0.008
B42	0.105	1.931	738	0.223	0.008
B41	0.151	1.941	781	0.283	0.010
DB	0.055	1.744	868	0.259	0.009
B40	0.151	1.931	731	0.198	0.007
B35	0.175	1.962	732	0.183	0.007
B30	0.146	1.872	735	0.189	0.007
B25	0.216	1.860	747	0.222	0.008
B20	0.267	1.793	742	0.216	0.008
B15	0.308	1.710	835	0.212	0.007
B10	0.323	1.630	729	0.176	0.007
B5	0.311	1.537	721	0.199	0.007
B1	0.150	1.092	744	0.212	0.008
B45-1	0.171	2.097	731	0.236	0.009
B45-2	0.143	1.936	736	0.244	0.009
B45-3	0.138	1.955	723	0.227	0.008
B20	0.274	1.754	747	0.169	0.006
B21	0.280	1.793	732	0.195	0.007
B22	0.251	1.734	705	0.231	0.009
B23	0.232	1.812	741	0.372	0.014
B24	0.260	1.806	738	0.166	0.006
B25	0.230	1.762	712	0.193	0.007

fn = gcidrsum.wk3

TEST #10 - Final Testing.
Flow Simulation 1:

Qriver = 7,000 ft3/s
Qapproach = 2,500 ft3/s
Qpump = 2,000 ft3/s
Qbypass = 500 ft3/s

w.s.el. = 135.4 ft (@entrance to screen forebay)
w.s.el. = 135.2 ft (@bypass channel entrance)

Bay No.	Vnormal (ft/s)	Vsweeping (ft/s)	No. of samples	SDEVnormal	SDOMnormal
B52	0.250	1.920	729	0.215	0.008
B51	0.147	1.866	726	0.180	0.007
B50	0.154	1.919	729	0.198	0.007
B49	0.206	1.793	714	0.218	0.008
B48	0.204	1.824	707	0.249	0.009
B47	0.188	1.939	754	0.188	0.007
B46	0.190	2.035	725	0.171	0.006
B45	0.148	2.008	746	0.157	0.006
B44	0.129	1.882	754	0.175	0.006
B43	0.168	1.881	728	0.206	0.008
B42	0.139	1.944	759	0.205	0.007
B41	0.153	1.887	722	0.204	0.008
DB	0.109	1.727	726	0.213	0.008
B40	0.204	1.795	771	0.216	0.008
B35	0.257	1.842	713	0.216	0.008
B30	0.235	1.810	747	0.176	0.006
B25	0.250	1.681	750	0.171	0.006
B20	0.294	1.802	746	0.176	0.006
B15	0.252	1.694	743	0.180	0.007
B10	0.239	1.515	752	0.137	0.005
B5	0.239	1.438	736	0.176	0.006
B1	0.124	1.182	753	0.150	0.005

TEST #11 - Final Testing.
Flow Simulation 7:
Qriver = 10,000 ft3/s
Qapproach = 3,500 ft3/s
Qpump = 3,000 ft3/s
Qbypass = 500 ft3/s

w.s.el. = 136.3 ft (@entrance to screen forebay)
w.s.el. = 136.2 ft (@bypass channel entrance)

Bay No.	Vnormal (ft/s)	Vsweeping (ft/s)	No. of samples	SDEVnormal	SDOMnormal
T8B52	0.360	2.538	1104	0.202	0.006
T8B51	0.213	2.428	866	0.245	0.008
T8B50	0.221	2.450	725	0.266	0.010
T8B49	0.325	2.422	727	0.222	0.008
T8B48	0.332	2.587	801	0.265	0.009
T8B47	0.275	2.596	730	0.271	0.010
T8B46	0.230	2.610	726	0.229	0.008
T8B45	0.214	2.544	735	0.245	0.009
T8B45-1	0.236	2.690	730	0.197	0.007
T8B45-2	0.230	2.529	748	0.227	0.008
T8B45-3	0.228	2.474	744	0.223	0.008
T8B44	0.257	2.405	735	0.235	0.009
T8B43	0.241	2.551	777	0.267	0.010
T8B42	0.232	2.589	748	0.238	0.009
T8B41	0.220	2.518	744	0.250	0.009
T8DB	0.334	2.443	747	0.284	0.010
T840	0.255	2.510	749	0.248	0.009
T8B35	0.299	2.353	716	0.214	0.008
T8B30	0.308	2.387	731	0.218	0.008
T8B25	0.356	2.410	743	0.232	0.009
T8B24	0.301	2.369	736	0.198	0.007
T8B23	0.306	2.354	740	0.199	0.007
T8B22	0.337	2.394	735	0.213	0.008
T8B21	0.297	2.317	762	0.202	0.007
T8B20	0.349	2.398	724	0.220	0.008
T8B15	0.344	2.215	750	0.241	0.009
T8B10	0.273	1.884	724	0.245	0.009
T8B5	0.364	1.968	722	0.176	0.007
T8B1	0.195	1.570	746	0.173	0.006

fn = gcidrsum.wk3

TEST #12 - Final Testing.
Flow Simulation 9:
Qriver = 20,000 ft3/s   w.s.el. = 139.8 ft (@bypass channel entrance)
Qapproach = 5,029 ft3/s
Qpump = 3,000 ft3/s
Qbypass = 2,029 ft3/s

Bay No.	Vnormal (ft/s)	Vsweeping (ft/s)	No. of samples	SDEVnormal	SDOMnormal
B52	0.521	3.036	547	0.176	0.008
B51	0.380	3.095	720	0.216	0.008
B50	0.384	3.039	741	0.238	0.009
B49	0.395	2.788	700	0.235	0.009
B48	0.341	2.892	591	0.254	0.010
B47	0.268	2.886	714	0.238	0.009
B46	0.277	2.898	714	0.240	0.009
B45	0.304	2.843	364	0.220	0.012
B44	0.315	2.990	739	0.158	0.006
B43	0.340	2.929	689	0.256	0.010
B42	0.289	3.004	740	0.216	0.008
B41	0.283	2.943	742	0.199	0.007
DB	0.400	2.811	709	0.171	0.006
B40	0.400	2.857	707	0.198	0.007
B35	0.424	3.043	596	0.247	0.010
B30	0.429	2.888	398	0.351	0.018
B25	0.357	2.860	746	0.224	0.008
B20	0.159	2.750	701	0.561	0.021
B15	0.301	2.831	699	0.189	0.007
B10	0.264	2.990	676	0.199	0.008
B5	-0.191	3.300	695	0.180	0.007
B1	-2.876	1.930	463	0.310	0.014

fn = gcidrsum.wk3

TEST #13 - Final Testing.
Flow Simulation 10:
Qriver = 40,000 ft3/s
Qapproach = 8,090 ft3/s
Qpump = 3,000 ft3/s
Qbypass = 5,090 ft3/s

w.s.el. = 144.7 ft (@bypass channel entrance)

Bay No.	Vnormal (ft/s)	Vsweeping (ft/s)	No. of samples	SDEVnormal	SDOMnormal
B52	0.586	3.166	621	0.238	0.010
B51	0.523	3.412	733	0.216	0.008
B50	0.509	3.465	648	0.212	0.008
B49	0.390	3.189	718	0.174	0.006
B48	0.328	3.261	717	0.168	0.006
B47	0.338	3.383	511	0.318	0.014
B46	0.331	3.325	708	0.204	0.008
B45	0.238	3.251	675	0.243	0.009
B44	0.252	3.165	863	0.195	0.007
B43	0.258	3.245	707	0.238	0.009
B42	0.258	3.149	656	0.230	0.009
B41	0.305	3.162	712	0.216	0.008
DB	0.418	2.926	832	0.251	0.009
B40	0.327	3.167	704	0.235	0.009
B35	0.378	3.175	609	0.245	0.010
B30	0.304	2.976	677	0.221	0.008
B25	0.299	3.147	626	0.183	0.007
B20	0.263	3.157	770	0.174	0.006
B15	0.230	3.293	696	0.171	0.006
B10	-0.081	3.459	686	0.209	0.008
B5	-1.167	1.542	728	0.315	0.012
B1	-4.737	1.213	29	3.507	0.651

fn = gcidrsum.wk3

TEST #14 - Final Testing.
Flow Simulation 11:
Qriver = 60,000 ft3/s w.s.el. = 148.7 ft (@bypass channel entrance)
Qapproach = 10,350 ft3/s
Qpump = 1,000 ft3/s
Qbypass = 9,350 ft3/s

Bay No.	Vnormal (ft/s)	Vsweeping (ft/s)	No. of samples	SDEVnormal	SDOMnormal
B52	0.514	3.308	623	0.261	0.010
B51	0.537	3.363	706	0.204	0.008
B50	0.529	3.725	805	0.263	0.009
B49	0.535	3.085	727	0.194	0.007
B48	0.482	3.481	721	0.183	0.007
B47	0.467	3.391	750	0.169	0.006
B46	0.377	3.432	742	0.166	0.006
B45	0.411	3.629	727	0.238	0.009
B44	0.396	3.366	682	0.217	0.008
B43	0.349	3.433	732	0.200	0.007
B42	0.306	3.249	732	0.198	0.007
B41	0.357	3.315	731	0.199	0.007
DB	0.452	3.145	732	0.214	0.008
B40	0.448	3.199	731	0.182	0.007
B35	0.378	3.176	730	0.159	0.006
B30	0.350	3.311	744	0.190	0.007
B25	0.270	3.517	628	0.204	0.008
B20	0.161	3.687	672	0.190	0.007
B15	-0.160	3.825	731	0.204	0.008
B10	-1.276	0.820	741	0.363	0.013
B5	-4.489	0.556	732	0.678	0.025
B1	-1.560	1.375	28	9.173	1.734

fn = gcidrsum.wk3

TEST #15 - Final Testing.
Flow Simulation 12:
Qriver = 4,000 ft3/s
Qapproach = 1,100 ft3/s
Qpump = 500 ft3/s
Qbypass = 600 ft3/s

w.s.el. = 135.1 ft (@bypass channel entrance)

Bay No.	Vnormal (ft/s)	Vsweeping (ft/s)	No. of samples	SDEVnormal	SDOMnormal
B52	0.136	0.668	799	0.146	0.005
B51	0.078	0.761	836	0.190	0.007
B50	0.066	0.805	760	0.123	0.004
B49	0.134	0.776	726	0.124	0.005
B48	0.101	0.769	730	0.128	0.005
B47	0.083	0.793	745	0.143	0.005
B46	0.068	0.754	733	0.227	0.008
B45	0.048	0.753	729	0.232	0.009
B44	0.062	0.734	736	0.219	0.008
B43	0.106	0.802	665	0.254	0.010
B42	0.051	0.718	601	0.345	0.014
B41	0.072	0.793	652	0.215	0.008
DB	0.100	0.666	597	0.199	0.008
B40	0.025	0.727	722	0.239	0.009
B35	0.041	0.711	564	0.300	0.013
B30	-0.013	0.508	647	0.289	0.011
B25	0.085	0.748	752	0.167	0.006
B20	0.036	0.776	695	0.318	0.012
B15	0.049	0.609	779	0.144	0.005
B10	0.027	0.666	740	0.201	0.007
B5	-0.051	0.800	710	0.234	0.009
B1	-0.635	0.631	871	0.154	0.005

fn = gcidrsum.wk3

TEST #16 - Final Testing.
Flow Simulation 13:
Qriver = 5,000 ft3/s
Qapproach = 1,650 ft3/s
Qpump = 1,000 ft3/s
Qbypass = 650 ft3/s

w.s.el. = 135.3 ft (@bypass channel entrance)

Bay No.	Vnormal (ft/s)	Vsweeping (ft/s)	No. of samples	SDEVnormal	SDOMnormal
B52	0.143	0.999	488	0.270	0.012
B51	0.022	1.000	714	0.227	0.008
B50	0.058	1.051	742	0.163	0.006
B49	0.125	0.944	810	0.186	0.007
B48	0.070	0.962	746	0.168	0.006
B47	0.059	1.101	724	0.152	0.006
B46	0.062	1.140	721	0.125	0.005
B45	-0.090	0.934	571	0.185	0.008
B44	0.050	1.095	654	0.168	0.007
B43	0.069	1.144	597	0.243	0.010
B42	0.059	1.083	675	0.245	0.009
B41	0.059	1.077	735	0.211	0.008
DB	0.086	0.982	712	0.304	0.011
B40	0.097	1.096	746	0.195	0.007
B35	0.141	1.123	727	0.164	0.006
B30	0.102	1.158	745	0.162	0.006
B25	0.073	1.029	720	0.238	0.009
B20	0.057	1.010	728	0.204	0.008
B15	0.060	0.910	722	0.208	0.008
B10	0.096	0.967	731	0.205	0.008
B5	-0.019	1.087	735	0.239	0.009
B1	-0.493	0.882	730	0.168	0.006

fn = gcidrsum.wk3

TEST #17 - Final Testing.
Flow Simulation 14:
Qriver = 8,000 ft3/s
Qapproach = 1,400 ft3/s
Qpump = 300 ft3/s
Qbypass = 1,100 ft3/s

w.s.el. = 136.9 ft (@bypass channel entrance)

Bay No.	Vnormal (ft/s)	Vsweeping (ft/s)	No. of samples	SDEVnormal	SDOMnormal
B52	0.147	0.711	465	0.297	0.014
B51	0.053	0.783	800	0.173	0.006
B50	0.061	0.825	838	0.218	0.008
B49	0.117	0.746	820	0.157	0.005
B48	0.085	0.814	1165	0.236	0.007
B47	0.010	0.702	768	0.241	0.009
B46	0.055	0.828	780	0.207	0.007
B45	0.034	0.801	769	0.207	0.007
B44	0.064	0.837	801	0.133	0.005
B43	0.067	0.901	695	0.269	0.010
B42	0.067	0.807	819	0.208	0.007
B41	0.073	0.863	915	0.169	0.006
DB	0.099	0.746	776	0.190	0.007
B40	0.072	0.807	746	0.222	0.008
B35	0.068	0.769	639	0.230	0.009
B30	0.091	0.798	756	0.166	0.006
B25	0.074	0.779	788	0.210	0.007
B20	0.012	0.721	794	0.167	0.006
B15	0.025	0.821	794	0.206	0.007
B10	-0.001	0.853	746	0.146	0.005
B5	-0.226	0.754	788	0.228	0.008
B1	-1.257	1.001	1329	0.224	0.006

fn = gcidrsum.wk3

TEST #18 - Final Testing
Flow Simulation 7:
Qriver = 10,000 ft3/s w.s.el. = 136.2 ft (@bypass channel entrance)
Qapproach = 3,500 ft3/s
Qpump = 3,000 ft3/s
Qbypass = 500 ft3/s

Bay No.	Vnormal (ft/s)	Vsweeping (ft/s)	No. of samples	SDEVnormal	SDOMnormal
B52	0.260	2.486	1444	0.232	0.006
B51					
B50	0.155	2.516	1136	0.270	0.008
B49	0.295	2.392	1176	0.371	0.011
B48	0.250	2.389	876	0.219	0.007
B47	0.185	2.542	865	0.237	0.008
B46	0.167	2.344	899	0.213	0.007
B45	0.283	2.434	988	0.253	0.008
B44					
B43	0.214	2.472	838	0.193	0.007
B42	0.216	2.407	912	0.214	0.007
B41	0.213	2.448	912	0.213	0.007
DB	0.225	2.133	836	0.238	0.008
B40	0.353	2.254	879	0.282	0.010
B35	0.314	2.154	836	0.222	0.008
B30	0.306	2.188	836	0.207	0.007
B25	0.277	2.179	825	0.300	0.010
B20					
B15	0.298	2.183	855	0.198	0.007
B10	0.352	2.038	912	0.195	0.006
B5	0.235	2.037	878	0.186	0.006
B1	-0.019	2.195	899	0.222	0.007

Mission

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American Public.