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Volume 19

Physical and Computational Model Studies to Improve
Hydraulic Performance of the Primary Bypasses
at Tracy Fish Collection Facility
Tracy, California

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A 1:3 Froude-scale model study of the primary bypass transitions at Tracy Fish Collection Facility (TFCF) was conducted to identify and develop design improvements that sustain or improve existing hydraulic performance. The TFCF is located at the southern end of the Sacramento-San Joaquin Delta. Replacement of the primary bypasses has been scheduled for 2004 and was recognized as an opportunity to improve primary bypass performance and consequently the overall salvage efficiency of TFCF. Computational Fluid Dynamics (CFD) modeling was used to pre-evaluate alternatives for physical modeling and proved to be a valuable method in efficiently selecting, developing and demonstrating the final modification selected for field implementation. The results of this study allowed for identification and proof-of-concept for a bypass transition modification that eliminates the need for turning vanes to generate near-uniform velocity profiles at the bypass entrance. The selected concept includes modified cross-sectional geometry for the existing bypass transition using a choke or tapered-vertical constriction within the bypass transition that effectively increases the flow resistance near the bottom of the bypass to redistribute sink potential and produce improved uniformity of velocity distributions at the bypass entrances. The minimum cross-section width was maintained at the existing primary bypass entrance width of 6 inches. The advantages of such a modification include minimizing debris fouling within the bypasses by excluding the need for turning vanes and hence eliminating the need for extensive cleaning while at the same time ensuring adequate uniformity of entrance velocity profiles over the full range of hydraulic operating conditions at TFCF.

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TRACY FISH COLLECTION FACILITY STUDIES CALIFORNIA

Volume 19

by

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January 2003

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ABSTRACT

A 1:3 Froude-scale model study of the primary bypass transitions at Tracy Fish Collection Facility (TFCF) was conducted to identify and develop design improvements that sustain or improve existing hydraulic performance. The TFCF is located at the southern end of the Sacramento-San Joaquin Delta. Replacement of the primary bypasses has been scheduled for 2004 and was recognized as an opportunity to improve primary bypass performance and consequently the overall salvage efficiency of TFCF. Computational Fluid Dynamics (CFD) modeling was used to pre-evaluate alternatives for physical modeling and proved to be a valuable method in efficiently selecting, developing and demonstrating the final modification selected for field implementation. The results of this study allowed for identification and proof-of-concept for a bypass transition modification that eliminates the need for turning vanes to generate near-uniform velocity profiles at the bypass entrance. The selected concept includes modified cross-sectional geometry for the existing bypass transition using a choke or tapered-vertical constriction within the bypass transition that effectively increases the flow resistance near the bottom of the bypass to redistribute sink potential and produce improved uniformity of velocity distributions at the bypass entrances. The minimum cross-section width was maintained at the existing primary bypass entrance width of 6 inches. The advantages of such a modification include minimizing debris fouling within the bypasses by excluding the need for turning vanes and hence eliminating the need for extensive cleaning while at the same time ensuring adequate uniformity of entrance velocity profiles over the full range of hydraulic operating conditions at TFCF.

INTRODUCTION

This report is the first in a series of two reports describing laboratory investigations into modifications for the primary bypasses at Tracy Fish Collection Facility (TFCF) under the Tracy Fish Facilities Improvement Program (TFFIP). This report describes the physical and computational model studies conducted to establish sink characteristics of the primary bypasses and identify modifications that eliminate the need for turning vanes to generate near-uniform entrance velocity profiles. The second report will document follow-on studies geared toward investigating louver-bypass interactions immediately upstream of the bypass entrance for the purpose of identifying further modifications to the louvers that represent the potential to improve the capture performance of the primary bypasses at TFCF.

The TFCF is located at head of the Delta-Mendota Intake Channel in the southern end of the Sacramento-San Joaquin Delta near Tracy, California. Figure 1 represents a plan view schematic of the facilities that consist of a primary line of louvers designed to guide fish to one of four primary bypasses. Each of the four primary bypasses then transport fish to a secondary louver system that guides fish to a secondary bypass, subsequently concentrating them in holding tanks for collection and transport back to the delta and away from the influence of Tracy Pumping Plant (TPP). The project was constructed in the 1950's as a means of excluding fish (mainly Striped Bass and Chinook Salmon) that would otherwise be entrained at TPP. Since construction, it has been widely recognized that TFCF performance has degraded due to increases in pumping demands, changes in the target fish species, and increases in debris loads among other factors. A portion of this degradation has been attributed to primary bypass performance. The original design of the primary bypasses included turning vanes in the transitions to generate improved uniformity of velocity profiles at the bypass entrance that would otherwise be significantly skewed. Figure 2 is an elevation view schematic of the as-constructed primary bypasses at TFCF. Recent dive inspections revealed that in some cases large holes exist in the bypass transitions. Less than optimal performance was confirmed, to some degree, by entrance velocity measurements acquired by Kubitschek (2001). The results showed, in addition to the potential for holes, that significant1 non-uniformity in bypass entrance velocity profiles exist, indicating that the turning vanes were ineffective and in some cases likely altogether missing. As such, the primary bypasses at TFCF have been scheduled for replacement in 2004, an action that represents an opportunity for improvements to the design.

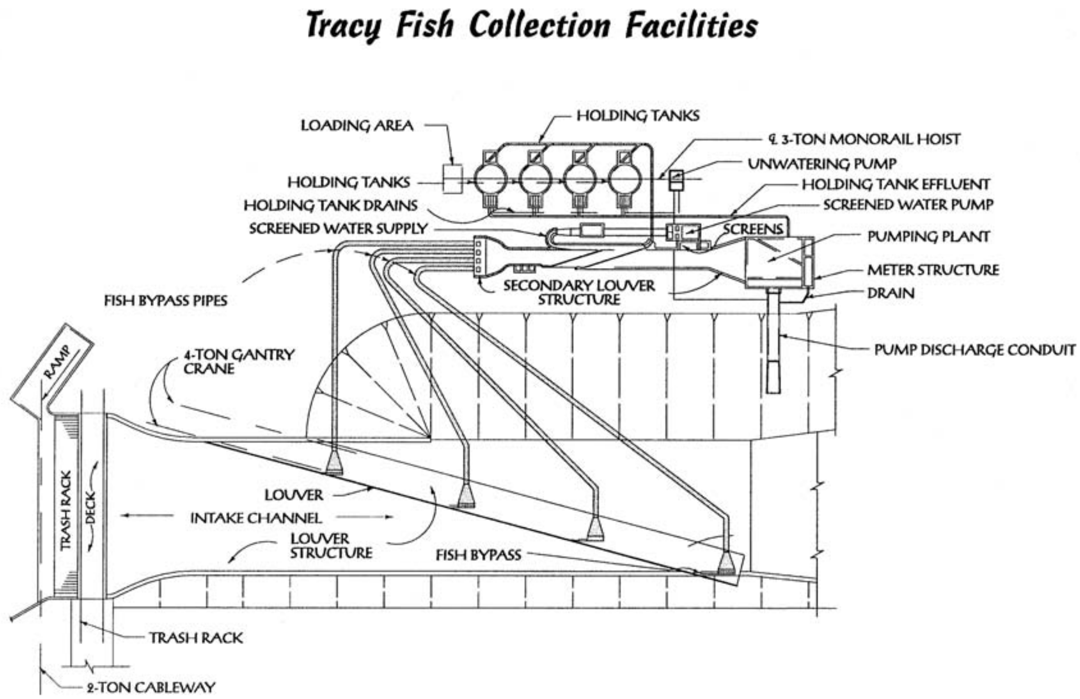


Figure 1.—Plan view schematic of TFCF showing the four primary bypasses leading to the secondary louver structure.

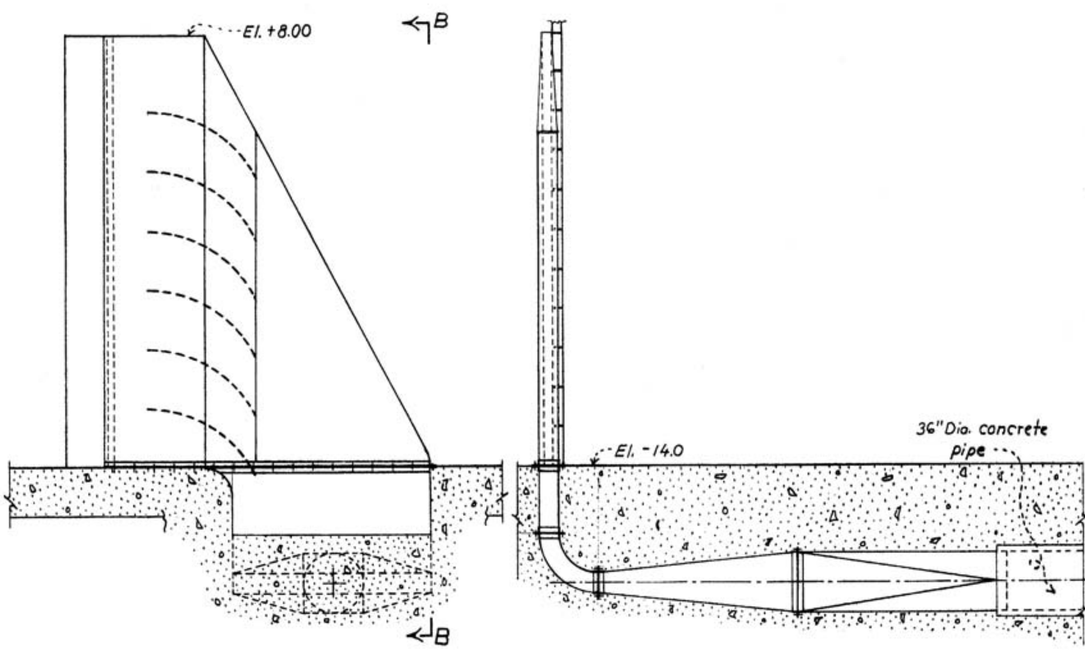


Figure 2.—Elevation view details of as-built primary bypasses at TFCF showing basic turning vane and transition geometry.

The original primary bypass design was based on a physical model study conducted by McBirney (1956), at what was then Reclamation's Hydraulics Laboratory in Denver, Colorado. A 1:4 Froude-scale physical model was used to develop turning vanes that were located inside the primary bypass transitions for the purpose of generating near-uniform velocity profiles at the bypass entrance. The hydraulic nature of the primary bypasses is driven by the geometry of the bypass transitions that consist of tall-narrow rectangular cross-sections (6-inch wide by 20-foot high) that converge while turning the flow in each bypass down vertically and around to a horizontal orientation prior to transitioning into the 36-inch-diameter primary bypass pipes that supply the secondary louver channel. This transition geometry naturally produces non-uniformity in velocity distributions at the bypass entrance since the sink potential varies with flow-path distance from the transition. That is to say that elevations closer to the bottom of the transition represent shorter flow paths and hence require less energy for fluid motion, thus producing higher local discharges or velocities. The turning vanes that were developed, were designed to span the full 6-inch width of the bypass and were located on 1-foot centers (elevation), starting 3-feet downstream of the bypass entrance. This treatment was effective since it acts to improve the sink characteristics of the transition by re-distributing the velocities at the entrance of the bypass.

Babb (1968) conducted a similar 1:6 scale physical model study of the primary bypasses for the California Department of Water Resources (DWR) proposed state fish protection facility to be located near the TFCF. The bypass transitions designed by DWR represent a more streamlined geometry than that for the primary bypasses at TFCF. However, like the TFCF, turning vanes were also required to generate improved uniformity in velocity profiles at the bypass entrances.

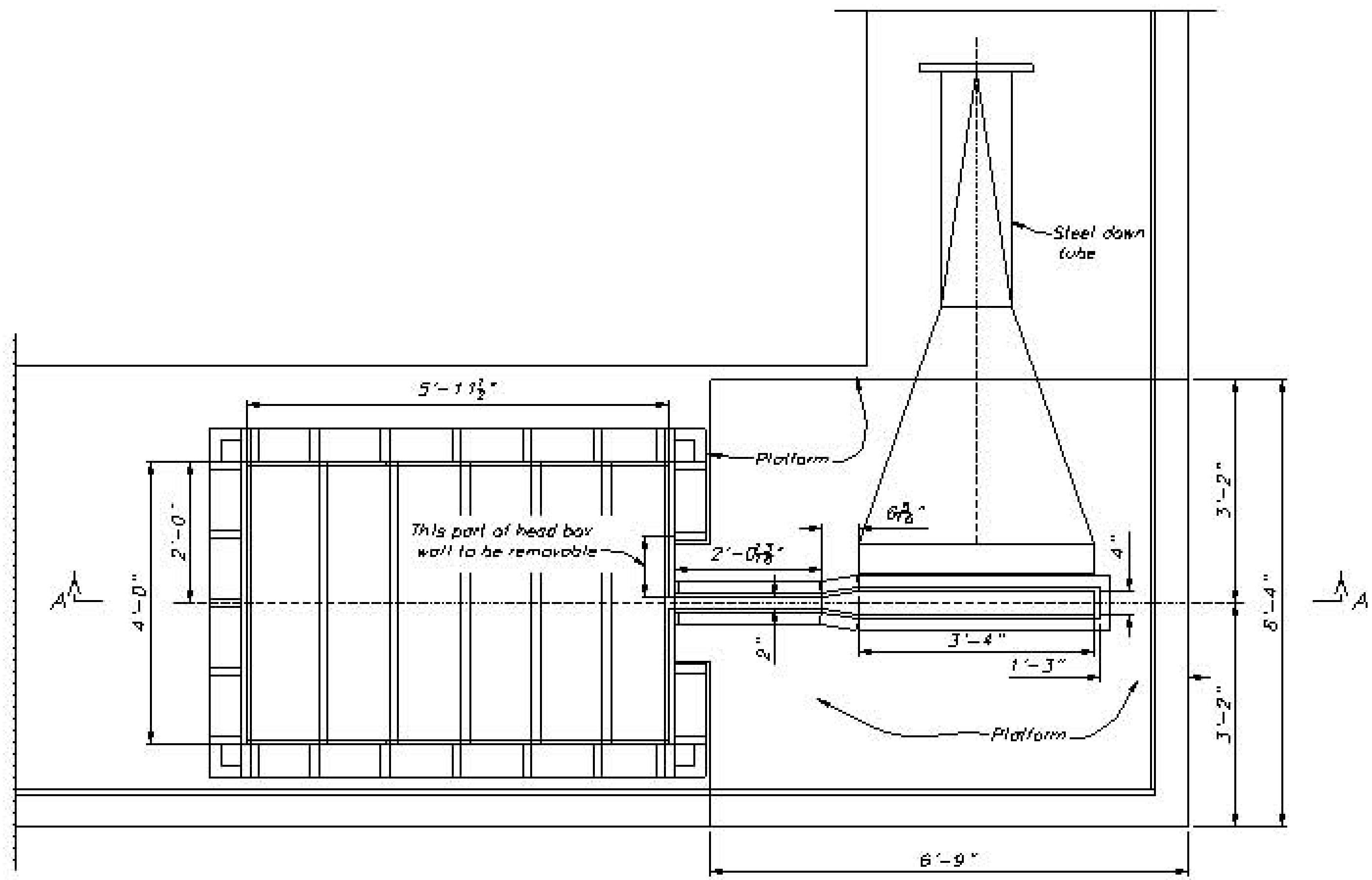
Objectives

The objectives of this study include identifying and developing modifications to the TFCF primary bypasses that improve overall primary bypass hydraulic and debris management performance by eliminating the need for turning vanes to generate uniform velocity profiles at the bypass entrances. Presently, the performance of the turning vanes of the existing primary bypasses are prone to degradation due to debris fouling or corrosive failure which compounds the degradation problem and alters the sink characteristics of the bypass. In all cases, the degradation effects combine to produce less than adequate uniformity in bypass entrance velocities making a vane-less bypass concept attractive. It is important to note that design modifications are constrained to the portion of the transitions above El. -14.0. No modifications can be made below El. -14.0 (see Figure 2) since that portion of the transition is encased in concrete, making any modification to it costly. It also is important to recognize that space constraints exist for any bypass modifications due to structural elements (i.e. deck piers) and general fit-function of the existing primary louver structure at TFCF. Thus, primary bypass modifications with regard to increased bypass widths are limited to a maximum of 9 inches to avoid major re-design of the primary louver support structure. Furthermore, it should be recognized that modifications that increase the overall bypass entrance width to greater than 6 inches also increase the corresponding cross-sectional area. Such alternatives were not considered since this would reduce the effective bypass entrance velocity for all hydraulic operating conditions and hence degrade the capture performance of the primary louver system. In other words, the primary bypass ratios, a key hydraulic operating parameter for TFCF, defined as the average bypass entrance velocity divided by the average approach channel velocity would be reduced, making it difficult or impossible to meet high-end bypass ratios at maximum pumping rates under low tidal stage conditions. Alternatively, reducing the bypass width would likely produce negative performance impacts by increasing fish avoidance potential and reducing overall bypass discharge capacity making it more difficult to maintain flow depths and velocities in the secondary louver system due to increased head loss.

METHODOLOGY

Physical Model Description

A 1:3 Froude-scale physical model of a single primary bypass was constructed at Reclamation's Water Resources Research Laboratory in Denver, Colorado. Figure 3 represents details of the physical model and shows the basic layout and figure 4 is a photograph of the physical model as constructed in the laboratory. The model layout and scale were selected to provide sufficient extent for measuring bypass entrance and transition velocities while at the same time minimizing viscous effects by providing sufficiently large Reynolds numbers. The Reynolds number provides an indication of the relative influence of viscous forces in any fluid flow field and is defined here as $Re = UL/\upsilon$, where U is a characteristics velocity, L is a characteristic length (in this case bypass width), and υ is the kinematic viscosity of water. Provided Re is sufficiently large, gravitational forces are expected to predominate and hence Froude-scale similitude achieves adequate similarity between model and prototype. The Froude-number provides an indication of the relative influence of gravitational forces that typically predominate for



PLAN

Figure 3.—Plan view layout of 1:3 Froude-scale physical model of a single TFCF primary bypass as constructed at Reclamation's Water Resources Research Laboratory in Denver, Colorado.

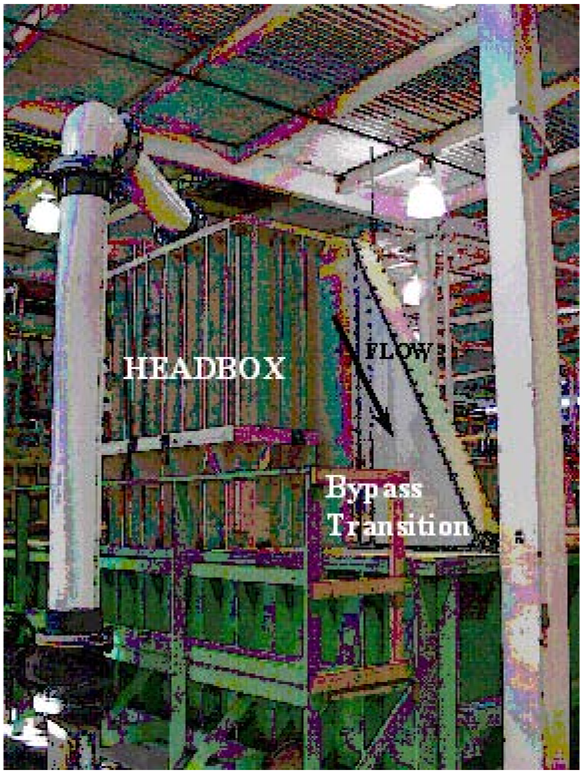


Figure 4.—Photograph of 1:3 Froude-scale physical model of a single primary bypass as constructed at Reclamation's Water Resources Research Laboratory in Denver, Colorado.

open channel or free surface flows and is defined here as $Fr = U/(gL)^{½}$, where U is a characteristic velocity, L is a characteristic length, and g is gravitational acceleration. Thus, similitude between model and prototype is achieved by the following scale relationships.

Geometric:

Length ratio, $L_r = 3.0$
Area ratio, $A_r = L_r^2 = 9.0$
Volume ratio, $V_r = L_r^3 = 27.0$

Kinematic:

Time ratio, $t_r = L_r^{1/2} = 1.7$
Velocity ratio, $u_r = L_r^{1/2} = 1.7$
Acceleration ratio, $a_r = 1.0$
Discharge ratio, $Q_r = L_r^{5/2} = 15.6$

Computational Fluid Dynamics (CFD) Model Description

Flow-3D®, a CFD software package from *Flow Science, INC.*, was used to develop a full scale, three dimensional, fully turbulent, viscous, free-surface computational model of a single primary bypass transition for comparison with the physical model and subsequent pre-evaluation of potential modifications. The CFD model effectively allowed for pre-screening of potential alternatives by targeting the most promising concepts prior to subsequent construction and testing in the physical model. Geometry for the physical model was generated using AutoCAD and exported to Stereo Lithography (STL) format. Although not required by Flow-3D®, the STL format is an efficient way of importing relatively complex boundary geometry. Figure 5 is an image of the STL geometry file that was used for the CFD model. The model was then meshed using a non-uniform grid to obtain sufficient flow structure resolution within the relatively small bypass transition section. The initial and boundary conditions used for the CFD model consisted of the head box depth and exit pipe velocity to satisfy continuity for the corresponding physical model conditions to be tested.

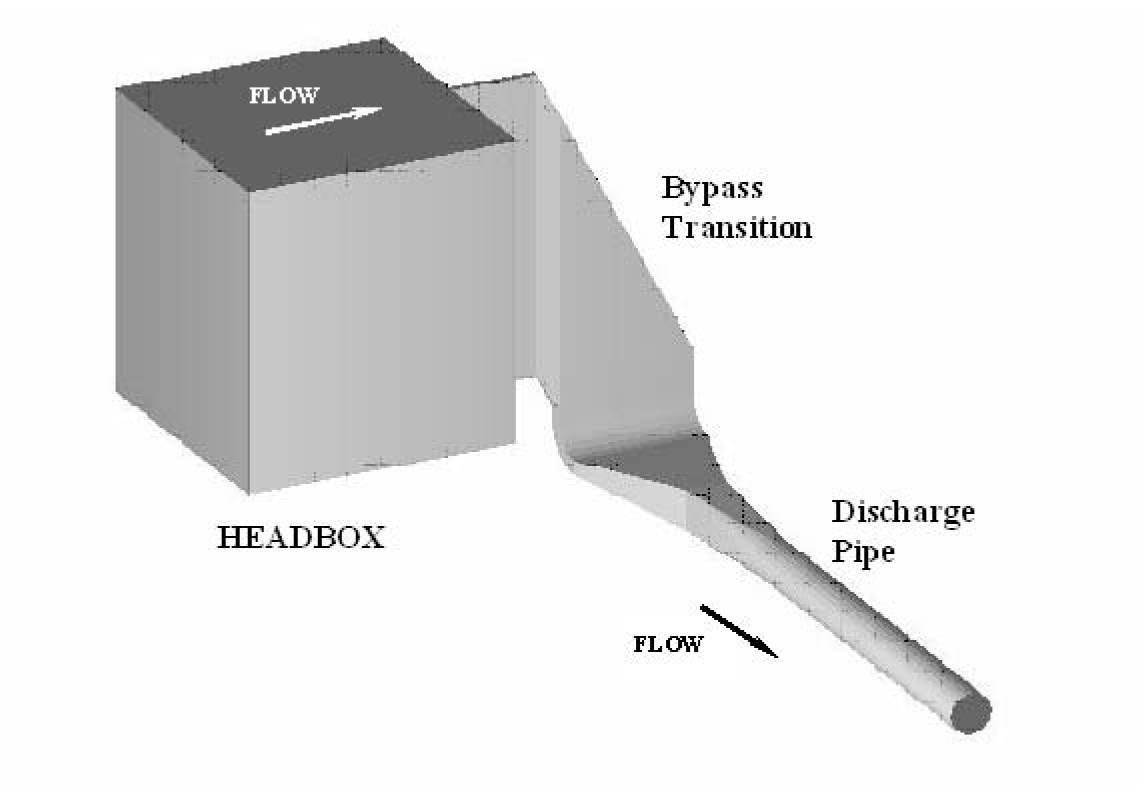


Figure 5.—STL model of primary bypass transition used for CFD geometry.

Physical Model Testing

Testing consisted of evaluating the bypass and associated transition sink characteristics over the full range of prototype flow depths and discharges. The hydraulic operating conditions vary at TFCF due to tidal influences and TPP pumping rates. The minimum prototype primary channel flow depth is not less than 16 feet while the maximum flow depth is not more than 21 feet under normal operating conditions. Since the primary bypass flow rates are gravity driven and so governed by the head differential between the primary channel and the secondary channel less the head loss attributed to the bypass system, the primary bypass discharges will vary depending upon the number of secondary channel control pumps being operated. However, during low tide, the discharge capacity of the primary bypasses is typically reduced due to reduced pump capacity in the secondary channel and reduced head differential between primary and secondary channels. Given the broad range of hydraulic operating conditions at TFCF, it was reasoned that adequate representation of any modification to the primary bypasses would be achieved by bracketing the extreme conditions of operation including maximum flow depth at minimum and maximum discharge and minimum flow depth at minimum and maximum discharge. Table 1 shows test conditions used to bracket the upper and lower ranges of bypass depth and discharge corresponding with prototype conditions. It should be recognized that the maximum bypass discharge of 40 ft^3/s rarely occurs during normal prototype operation. However, developing modifications that perform well at the maximum possible discharge will not only provide future operational flexibility should it be needed, but also guarantee adequate performance at lower discharges, since sink potential generated by the transition produces greatest non-uniformity at the largest discharges.

Table 1.—Model test conditions and corresponding prototype conditions

Model Depth (ft)	Model Discharge (ft^3/s)	Prototype Depth (ft)	Prototype Discharge (ft^3/s)
5.333	1.28	16.0	20
	2.57		40
6.667	1.28	20.0	20
	2.57		40

During physical model testing, velocities were measured within the bypass transition using a two-dimensional Dantec® Laser Doppler Anemometer (LDA). The advantage of using the LDA is that it is not flow intrusive and hence does not affect the flow passage (i.e. the physical model 2-inch bypass width) in which measurements were acquired. The critical velocity measurement locations were selected consistent with previous physical model studies conducted by McBirney (1956) in the 1950's to develop the bypass transition turning vanes. Doing so provided a baseline for comparison with previous work. Measurements were acquired at a location 1-foot (prototype scale) downstream of the bypass entrance on 1-foot (prototype scale) incremental elevations.

It should be noted that flow in the bypasses is turbulent. However, levels of turbulence intensity as measured by the magnitudes of velocity fluctuations were not investigated during this study and hence velocity data were presented as the time-averaged mean.

RESULTS AND DISCUSSION

Baseline Results

Initial baseline testing for the physical model consisted of acquiring bypass vertical velocity profiles at a location 1-foot downstream of the bypass entrance for the transition without turning vanes. Figures 6 and 7 show the baseline results obtained by McBirney (1956) without turning vanes and with turning vanes, respectively at prototype depths of 16 and 20 feet. Figure 8 shows the comparison of CFD and physical model entrance velocity profiles and indicates that adequate simulation of the physical model is achieved using the CFD model. Furthermore, comparison of Figure 8 with Figure 7 shows strong similarity in velocity profile shapes indicating that agreement with the previous investigations conducted by McBirney (1956) was also adequately achieved. Figures 10-13 show those velocity profiles obtained during this physical model study for the four hydraulic operating conditions bracketing those expected for the prototype as given in table 1.

CFD Model Results

After establishing the baseline for comparison between the physical model, CFD model, and previous investigations various alternatives were evaluated at each of the specified hydraulic operating conditions using the CFD model. Those alternatives included

- Modified bypass cross-sectional geometry using a weir treatment inside the bypass transition

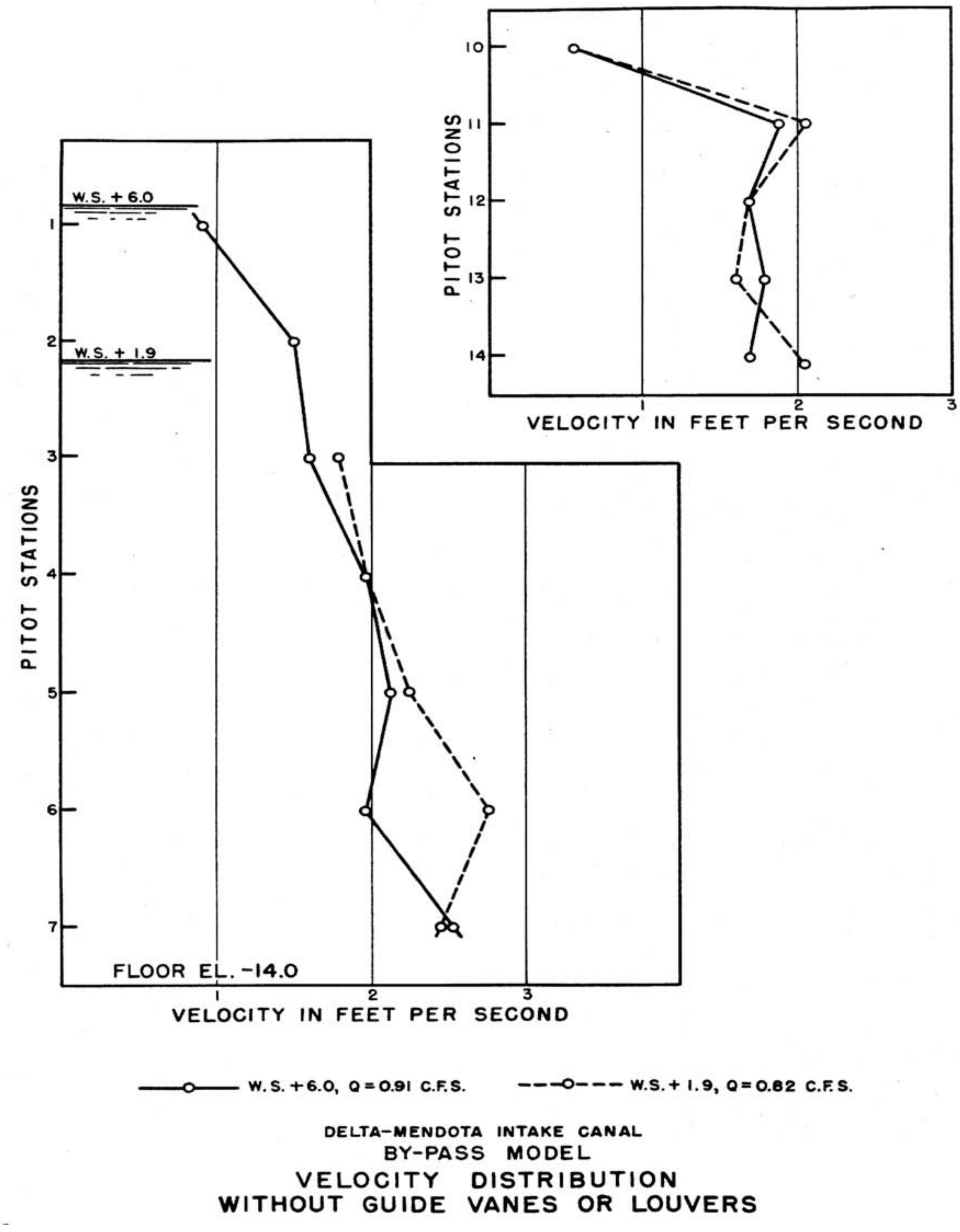


Figure 6.—Bypass velocity profiles acquired 13.5-inches downstream of bypass entrance. Results obtained by McBirney (1956) from his 1:4 scale physical model of the bypass transition without turning vanes for 16- and 20-foot flow depths and corresponding 26 and 29 ft^3/s flow rates.

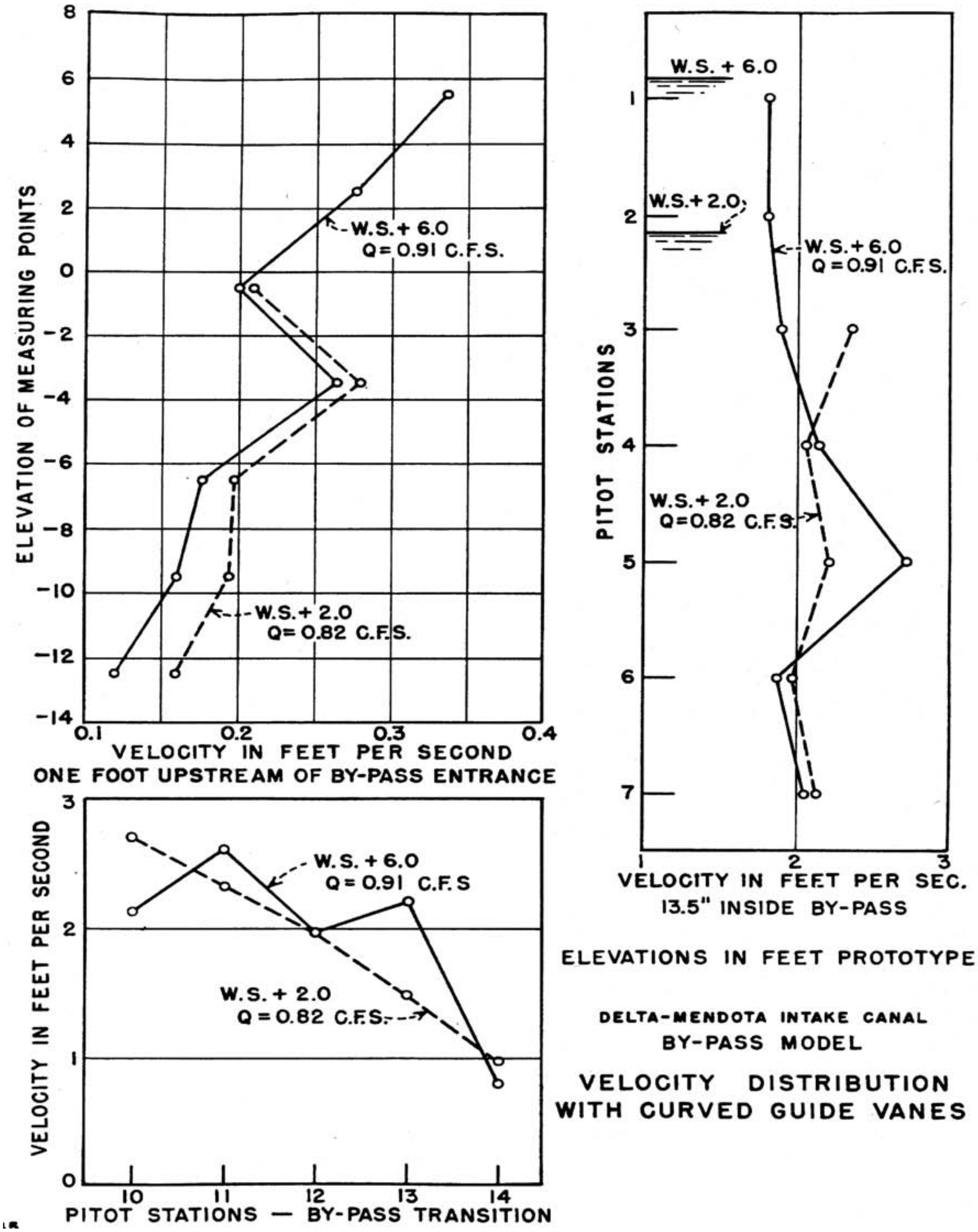


Figure 7.— Bypass velocity profiles acquired 1-foot upstream of bypass entrance and 13.5-inches downstream of bypass entrance. Results obtained by McBirney (1956) with curved turning vane treatment for 16- and 20-foot flow depths and corresponding 26 and 29 ft^3/s flow rates.

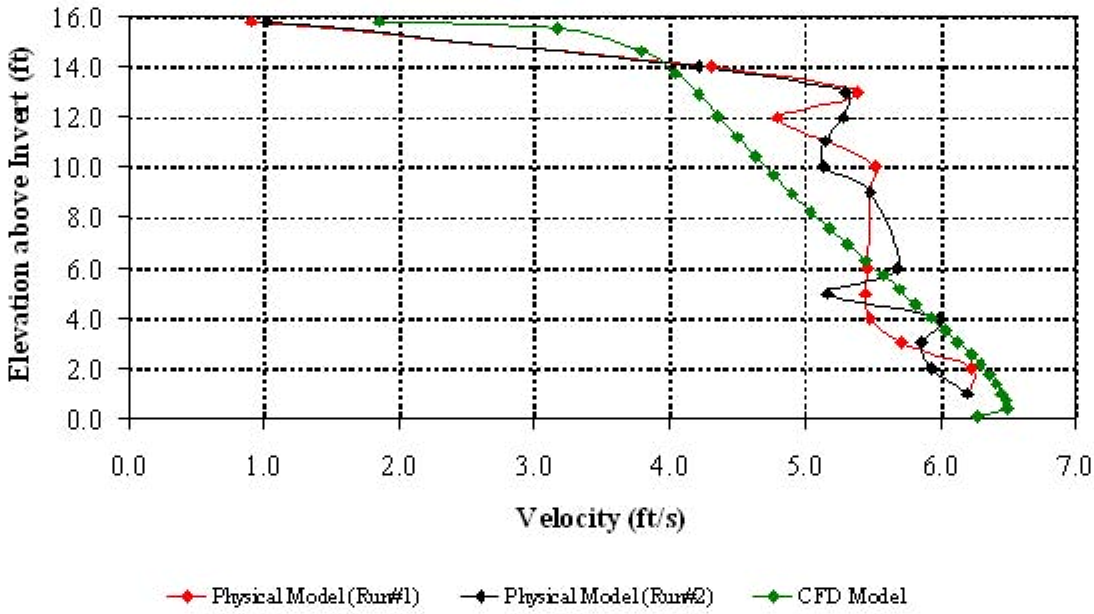


Figure 8.—Comparison of baseline bypass entrance velocity profiles (existing primary bypass transition without turning vanes) between the present 1:3 Froude-scale physical model and the CFD model at a flow depth of 16 feet and a bypass discharge of 40 ft^3/s.

- Modified bypass cross-sectional geometry using a ramped invert inside the bypass transition
- Modified bypass cross-sectional geometry using a step-widened bypass transition and a vertical tapered-choke section
- Refinements to vertical tapered-choke section including vertical ramp transition from step-widened transition to minimize separation zones
- Development of end-plate modifications to minimize or eliminate low velocity zones within the bypass transition

Figure 9 shows the transition modification that was developed using the CFD and physical models and was ultimately selected for recommendation. Appendix A includes velocity magnitude color contour plots of two-dimensional resultant velocities along the centerline of the bypass transition for all modifications that were evaluated using the CFD model.

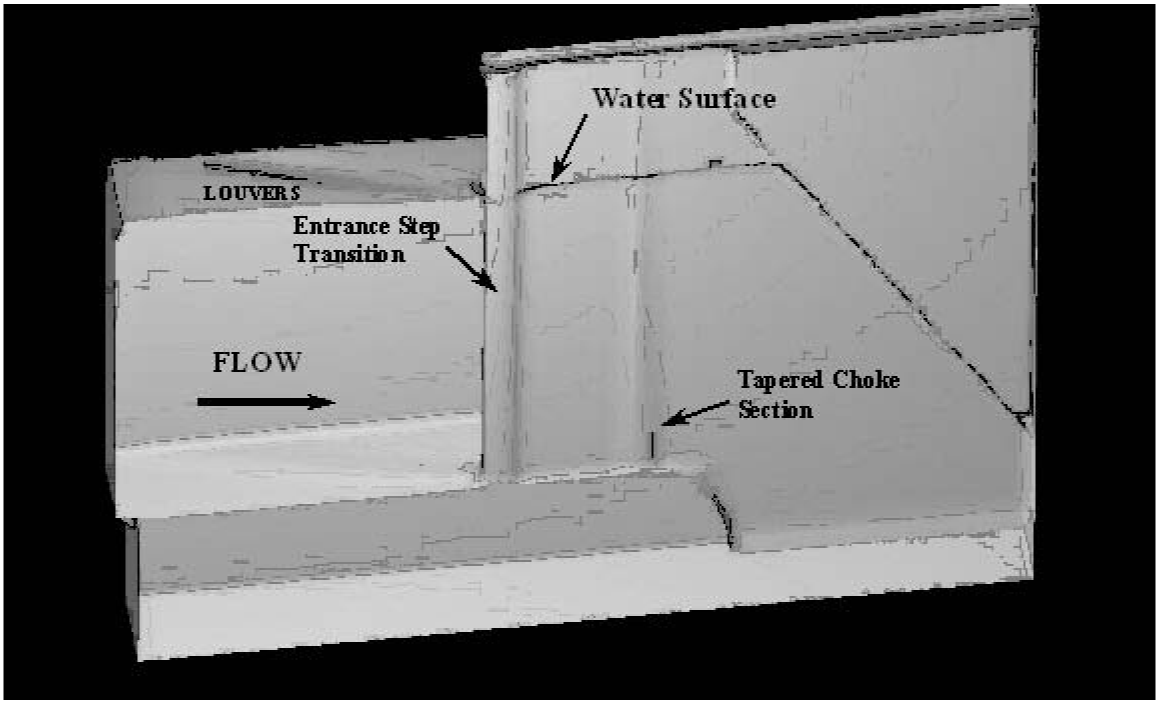


Figure 9.—Sectional cut from the three-dimensional CFD model boundary geometry along the centerline of the bypass transition. Image shows vertical step-widened entrance and vertical choke cross-sectional modification downstream of the entrance.

Physical Model Results

Following CFD modeling, the physical model was modified to incorporate the CFD developed step-widened, choke-transition modification for final testing. Figures 10-13 show velocity profiles inside the modified bypass transition for each of the hydraulic conditions tested. Figures 14-17 show the vector field plots of the two-dimensional velocities obtained along the centerline of the modified bypass transition. The results indicate the effect of the bypass transition in turning and accelerating the flow. The results also provide an indication of the eddy or low-velocity zone extent near the surface, at the end plate for each of the hydraulic operating conditions tested. It is obvious from this data that the eddy zone observed is greatest in extent for small flow depths and large discharges, but diminishes at greater flow depths and smaller discharges. Consequently, modification to the end plate was proposed and investigated using the CFD model. Figures 18 and 19 show the velocity magnitudes in the bypass transition for pre and post end plate modifications, respectively. These results would indicate that significant improvement in limiting or eliminating the extent of the eddy zone may be achieved at the maximum flow depth, but limited influence at lower flow depths was observed using the CFD model. Never the less, the end plate modification recommended based on these results is likely the best that can be achieved given the design constraints for the bypass modification.

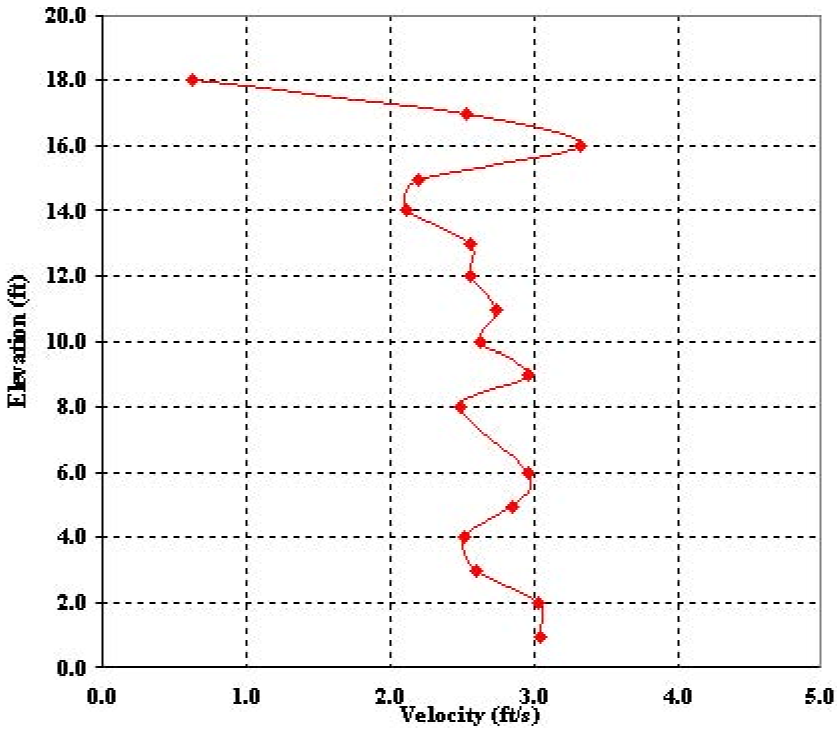


Figure 10.—Profile for horizontal component of mean centerline velocity 1-foot downstream of bypass entrance. Results obtained from the physical model for the recommended step-widened, vertical-tapered choke bypass transition modifications at a discharge of 40 ft^3/s and a flow depth of 20 feet.

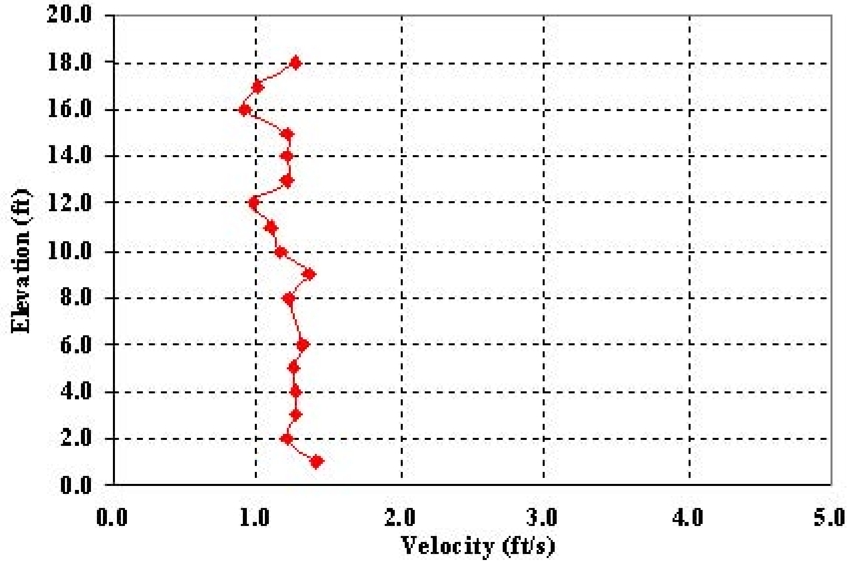


Figure 11.—Profile for horizontal component of mean centerline velocity 1-foot downstream of bypass entrance. Results obtained from the physical model for the recommended step-widened, vertical-tapered choke bypass transition modifications at a discharge of 20 ft^3/s and a flow depth of 20 feet.

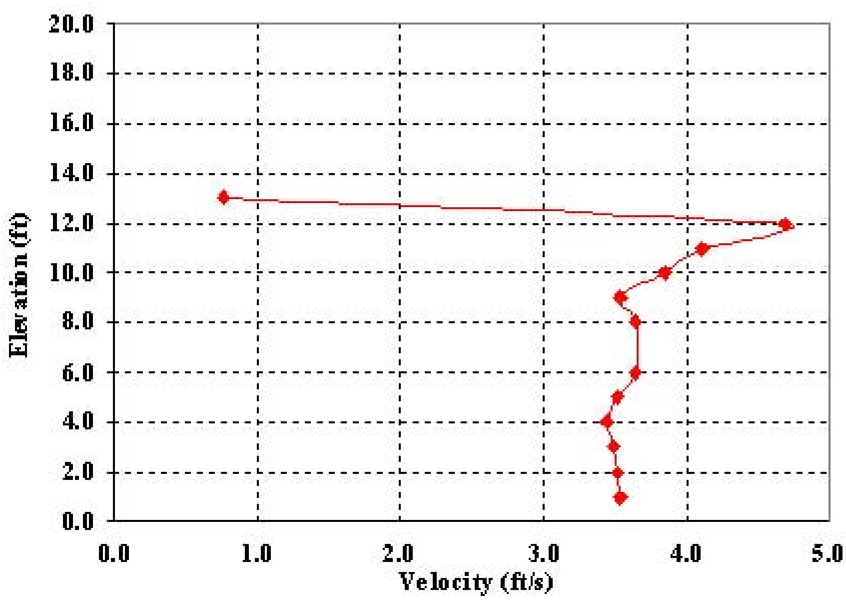


Figure 12._Profile for horizontal component of mean centerline velocity 1-foot downstream of bypass entrance. Results obtained from the physical model for the recommended step-widened, vertical tapered choke bypass transition modifications at a discharge of 40 ft^3/s and a flow depth of 16 feet.

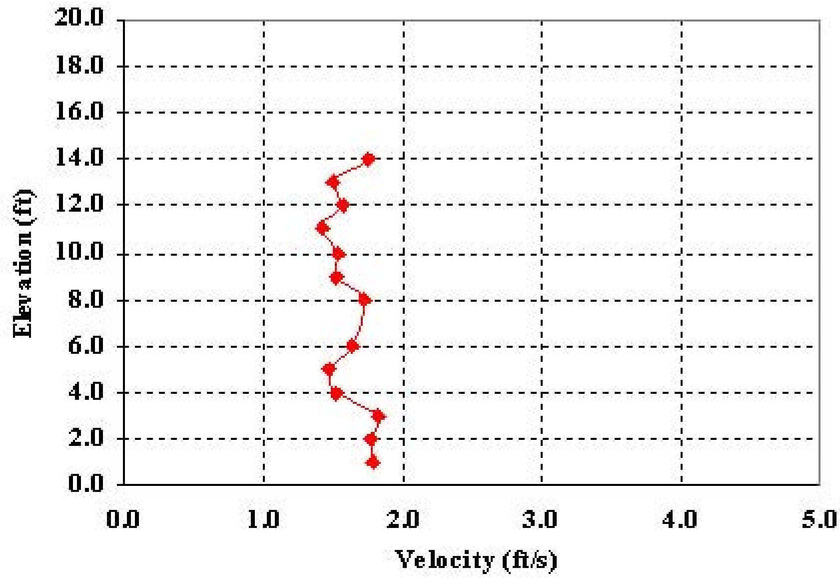


Figure 13.—Profile for horizontal component of mean centerline velocity 1-foot downstream of bypass entrance. Results obtained from the physical model for the recommended step-widened, vertical-tapered choke bypass transition modifications at a discharge of 20 ft^3/s and a flow depth of 16 feet.

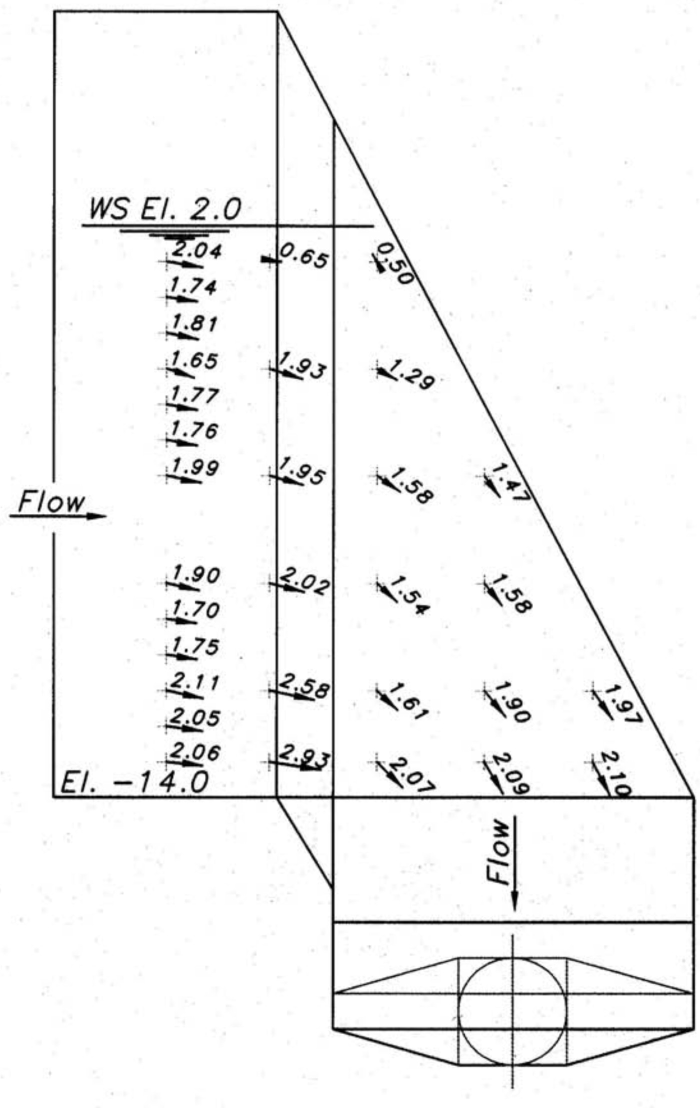


Figure 14.—Vector field plot of mean centerline velocities for recommended bypass modification. Model operated at a discharge of 20 ft^3/s and a flow depth of 16 feet.

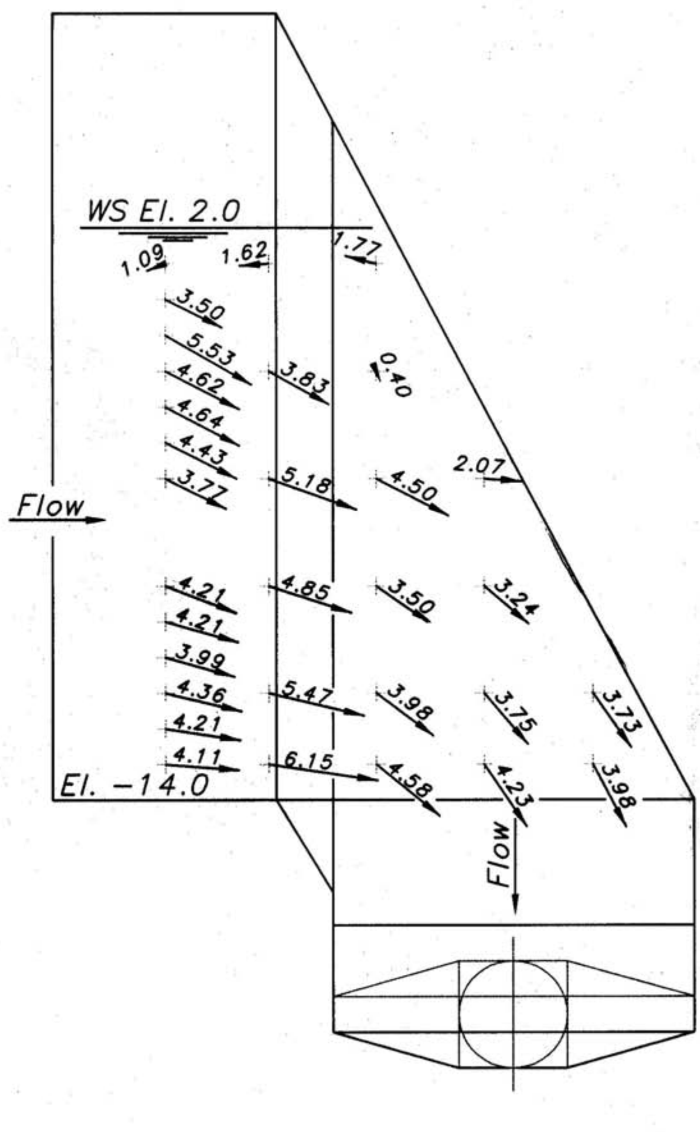


Figure 15.—Vector field plot of mean centerline velocities for recommended bypass modification. Model operated at a discharge of 40 ft^3/s and a flow depth of 16 feet.

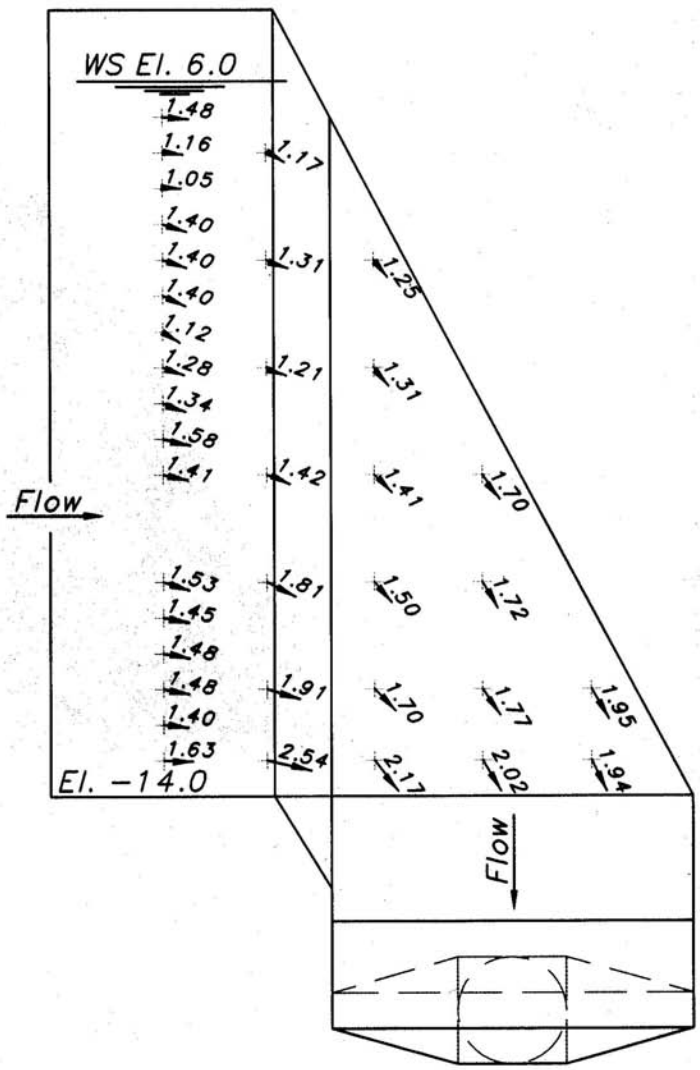


Figure 16.—Vector field plot of mean centerline velocities for recommended bypass modification. Model operated at a discharge of 20 ft^3/s and a flow depth of 20 feet.

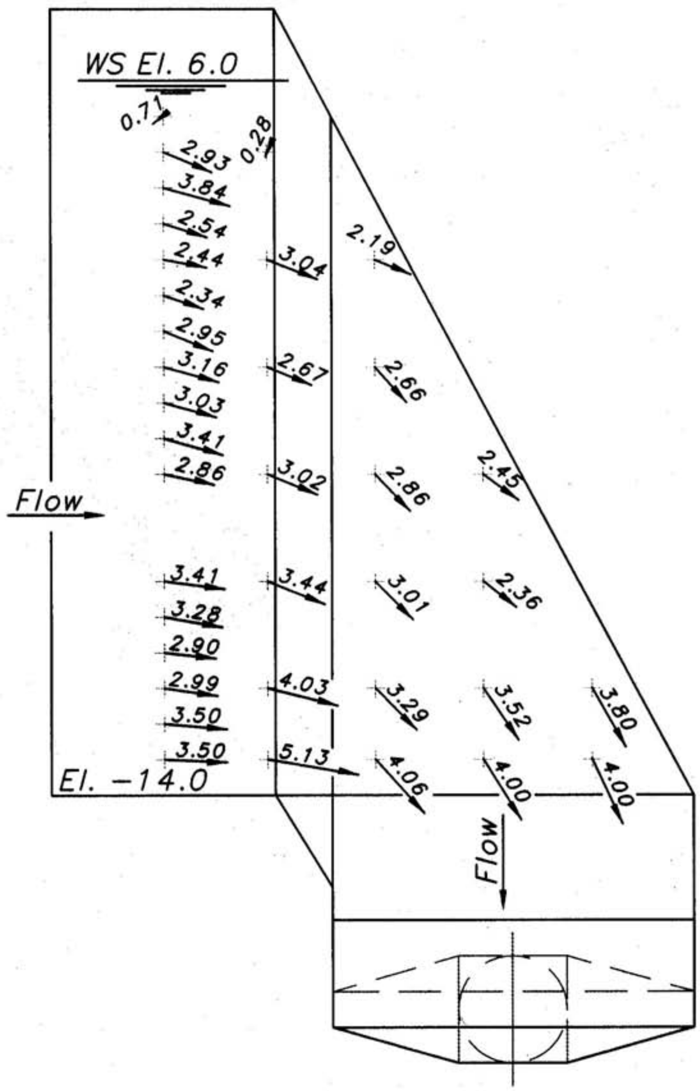


Figure 17.—Vector field plot of mean centerline velocities for recommended bypass modification. Model operated at a discharge of 40 ft^3/s and a flow depth of 20 feet.

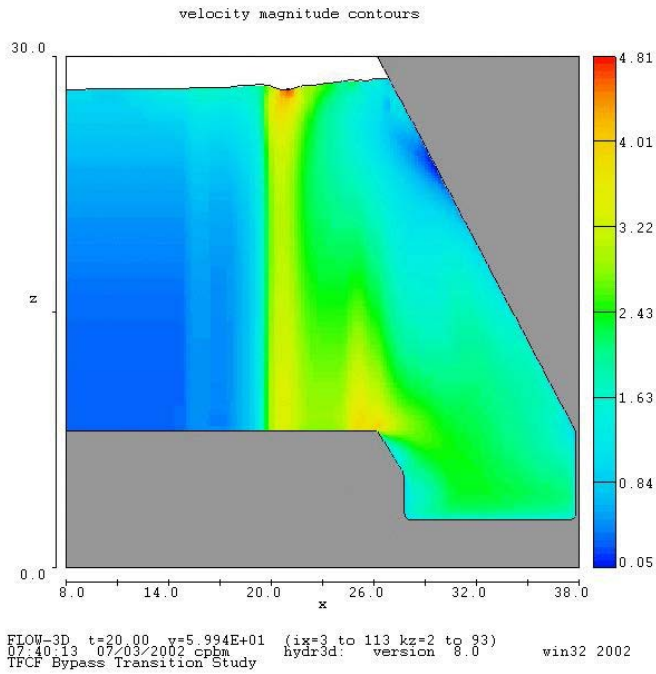


Figure 18.—CFD model results: Color contour plot of velocity magnitudes along centerline of vane-less step-widened, vertical-tapered choke bypass transition modifications for a flow depth of 20 feet and a discharge of 20 ft^3/s.

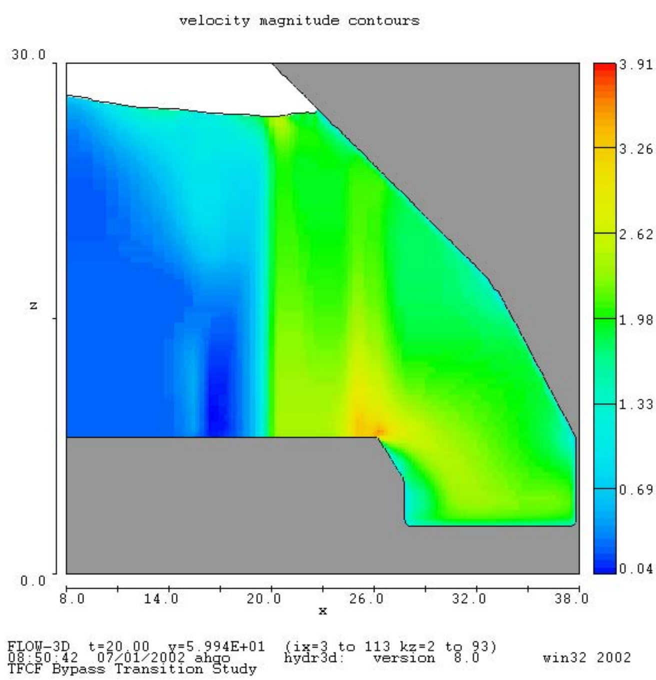


Figure 19.—CFD model final results: Color contour plot of velocity magnitudes along centerline of vane-less step-widened, vertical-tapered choke bypass transition including end-plate modifications for a flow depth of 20 feet and a discharge of 20 ft^3/s. Note the reduced extent of the low-velocity zone that was otherwise encountered without end-plate modifications (Figure 18).

Slight lateral non-uniformity in entrance velocity profiles was observed during testing of the final concept, but was improved by including an 8-degree vertical ramped transition along the sidewall from the 6-inch bypass entrance to the 9-inch widened section. The prototype is expected to have even less lateral non-uniformity in entrance profiles due to the fact that approach velocities are more or less directed into the bypass. The 8-degree vertical ramp not only minimizes separation downstream of the step-widened bypass entrance, but also reduces the potential for predation and fish holding zones within the bypass entrance. Other refinements were also made based on qualitative results from flow visualization techniques in an attempt to minimize predation zones in other locations of the bypass transition (see end plate modifications figure 19).

Flow Visualization

Florescene dye was injected during physical model testing at various vertical locations just upstream of the bypass entrance to obtain a further, qualitative understanding of flow structure within the bypass. This flow visualization technique revealed the existence of a large eddy zone located near the flow surface inside the transition as shown by Figure 20. These results indicate the extent of the low-velocity zone within the bypass transition (dye-filled region) and provided an indication of potential end-plate modifications necessary to reduce these potential predation and fish holding zones. Subsequent CFD modeling suggested that this zone could indeed be reduced and under certain operating condition, altogether eliminated by modifying the end plate such that the boundary of the bypass transition was near the eddy zone boundary (see Figure 19—Modified End Plate). The effect of such end plate modifications does not alter the hydraulic performance of the bypasses from neither a head loss standpoint nor entrance velocity profile standpoint since the eddy zone represents an inefficiency that reduces the effective area of the bypass. Ideally, the eddy zone boundary could be matched exactly, however such geometry would be costly to construct in comparison with the selected end plate modification. The flow visualization results observed during testing for the baseline and modified (step-widened, vertical-tapered choke) bypass transitions are also included in Appendix B for various hydraulic operating conditions tested.

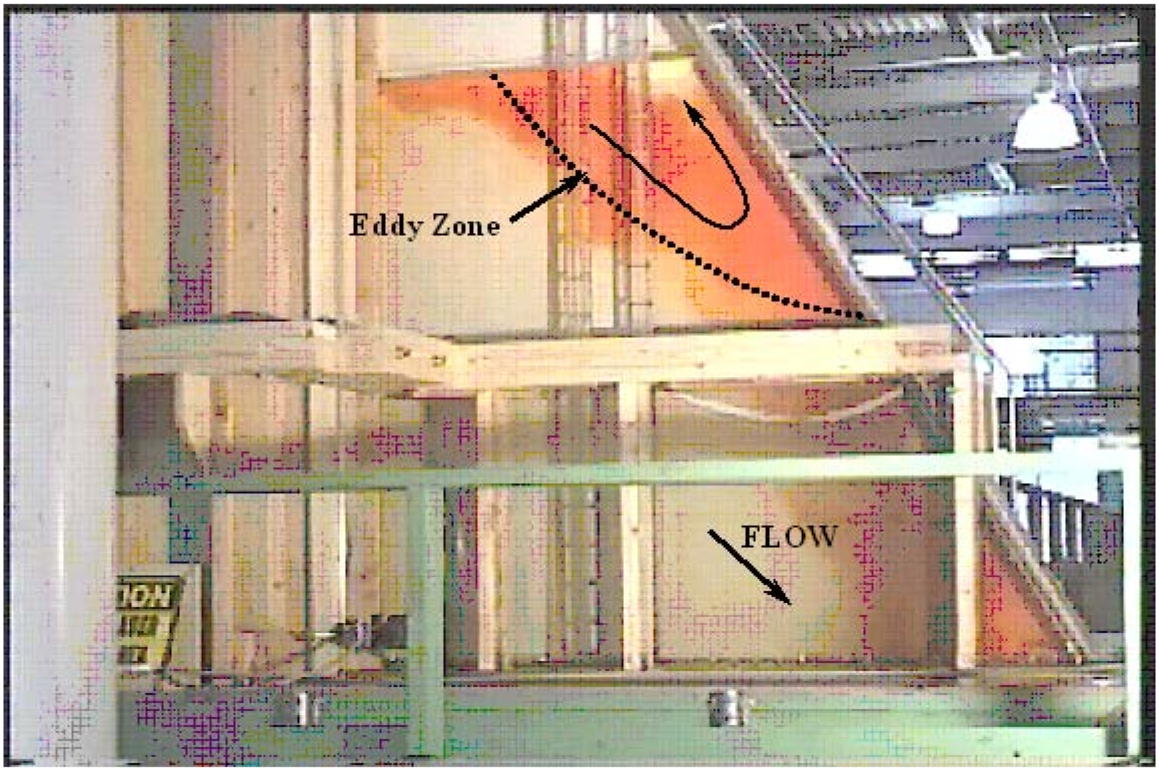


Figure 20.—Flow visualization testing at a flow depth of 16 feet and discharge of 20 ft^3/s. Step-widened, vertical choke transition bypass modifications showing extent of low- velocity eddy zone located near the surface at the end-plate boundary. Subsequent end plate modifications were developed using the CFD model to reduce and in some cases eliminate this zone.

CONCLUSIONS

Turning vanes are not required to generate near-uniform velocity profiles at the primary bypass entrances provided the cross-sectional geometry is modified in accordance with the findings of these investigations.

The results of this physical model study demonstrate proof-of-concept for the vane-less transition modifications in achieving adequate hydraulic performance as measured by entrance velocity profiles over the full range of hydraulic operating conditions at TFCF. It should be noted that the recommended concept reduces local internal velocities at a section just downstream of the bypass entrance. This characteristic has the potential to produce an avoidance or holding response. However, the trade-off of eliminating the turning vanes within the bypass entrance is thought to be positive in consideration of potential avoidance or holding due to a local reduction in velocity within the bypass transition.

The identified bypass transition modifications are expected to improve or at least sustain the hydraulic performance and thereby improve salvage performance of the primary bypasses at TFCF while at the same time improving debris management through improved capability in passing debris. The recommended concept includes a geometry for simplified primary bypass transition fabrication and installation.

Alternative vane-less bypass transitions that used an internal ramped or weir section were found to require excessive vertical displacement (or cross sectional area reduction) and increased variability in transition velocities to generate near uniform entrance velocity profiles. Thus, these options do not appear to be viable vane-less concepts for this application.

RECOMMENDATIONS

Bypass transition turning vanes may be eliminated without loss of bypass entrance velocity profile uniformity by modifying the cross-sectional geometry as developed using the CFD and physical models and specified in detail as Figure 18. The primary features of the modifications include stepping the transition from the 6-inch entrance width to a 9-inch width using an 8-degree ramped transitions along the sidewall to minimize separation, and introducing a cross-sectional modification consisting of a choke element that maintains the 9-in width near the top, but transitions down to a 6-inch width at the bottom of the bypass transition.

Further physical model investigations are required (as scheduled for phase II) to understand the influence of louver hydraulics in the immediate vicinity of the bypass entrance. Modifications to the louvers themselves, immediately upstream of the bypass entrances, may provide additional hydraulic performance enhancements of the primary louver structure at TFCF.

The end plate of the bypass transition should be modified according to Figure 21 (see modified end-plate details) to eliminate or minimize zones that could potentially provide predation habitat.

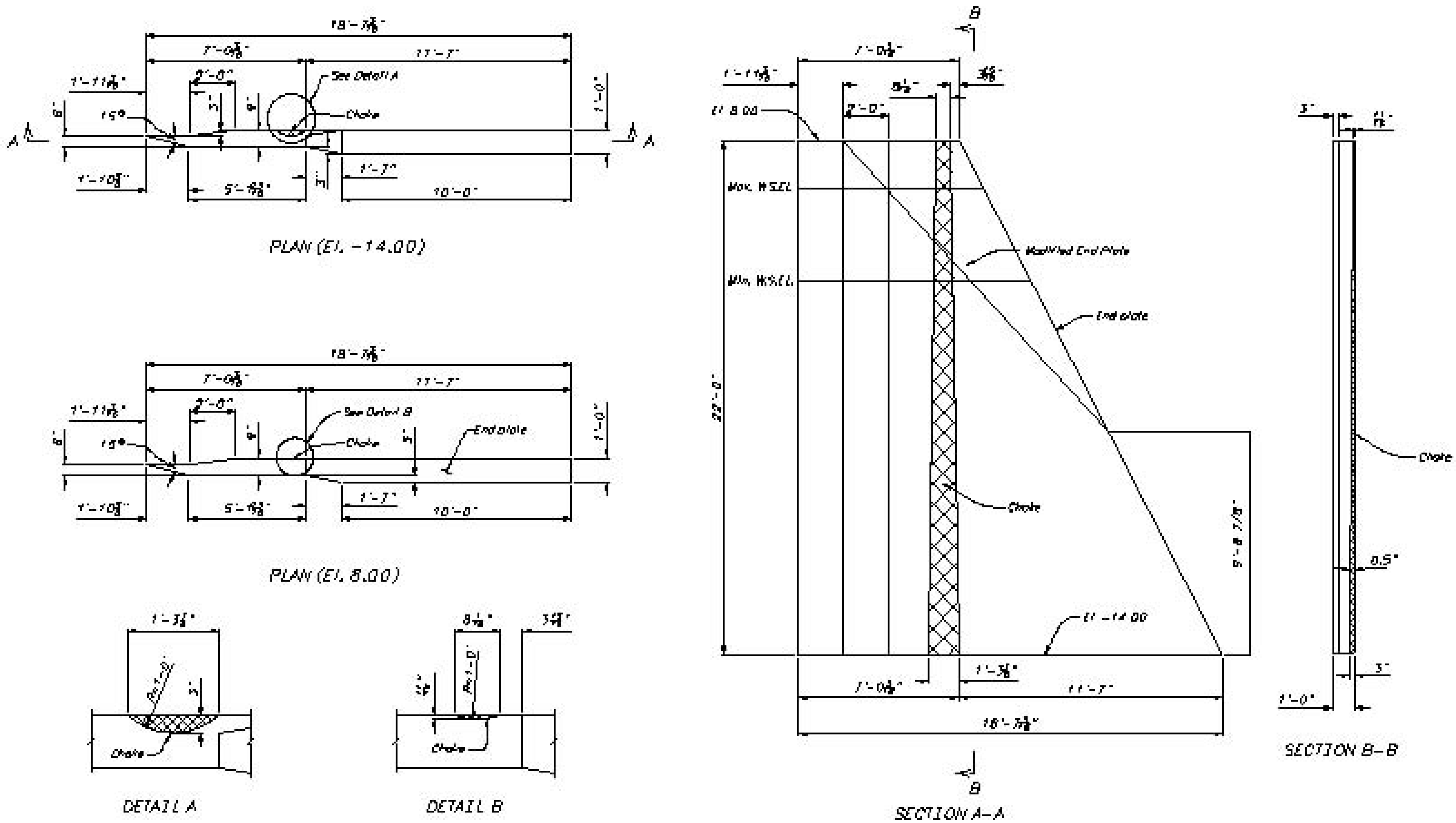


Figure 21.—Conceptual design details for recommended modifications to primary bypasses at TFCF.

ACKNOWLEDGMENTS

The initial phase of this study was supported in part by Reclamation's Science and Technology (S&T) Program and allowed for demonstration of capabilities to pursue these investigations using the combined physical and Computational Fluid Dynamics modeling approach. The remainder of funding was provided for through the Tracy Fish Facilities Improvement Program (TFFIP) under the Central Valley Projects Improvement Act (CVPIA). Perry Johnson, P.E. who has been involved with TFFIP for many years, provided direction and critical peer review for this study. Jim Higgs, Hydraulic Engineer, developed the CFD model and was responsible for identifying and demonstrating the potential of final concept via CFD model results. Rudy Campbell, Hydraulic Engineering Technician, provided physical model design drawings, instrumentation set-up, and data collection for this study. Manual Flores and Jason Black, Shops Craftsmen, constructed the physical model and subsequent modifications.

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McBirney, W.B., 1956. Hydraulic Studies of Fish Collecting Facilities B Delta-Mendota Intake Canal, Central Valley Project, California, U.S. Department of the Interior, Bureau of Reclamation, Hydraulic Laboratory Report Hyd-410.

Appendix 1 - CFD Results: Bypass Transition

Color Contour Velocity Magnitude Plots

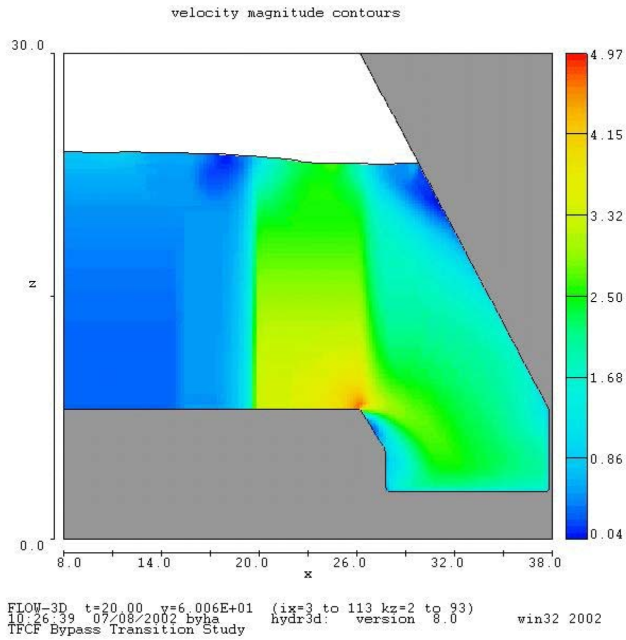

Figure A1-1.—Baseline CFD Results: Centerline of existing bypass transition without guide vanes or guide wall, operated at a flow depth of 16 feet and a discharge of 20 ft^3/s.

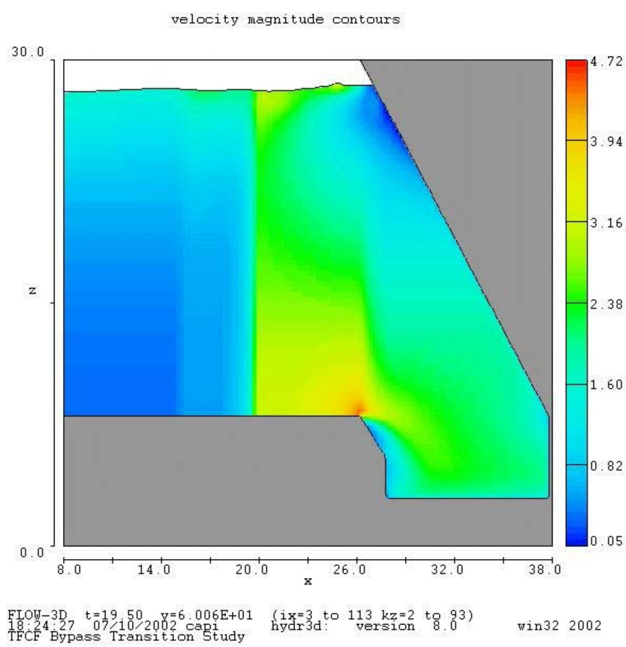

Figure A1-2.—Baseline CFD Results: Centerline of existing bypass transition without guide vanes or guide wall, operated at a flow depth of 20 feet and a discharge of 20 ft^3/s.

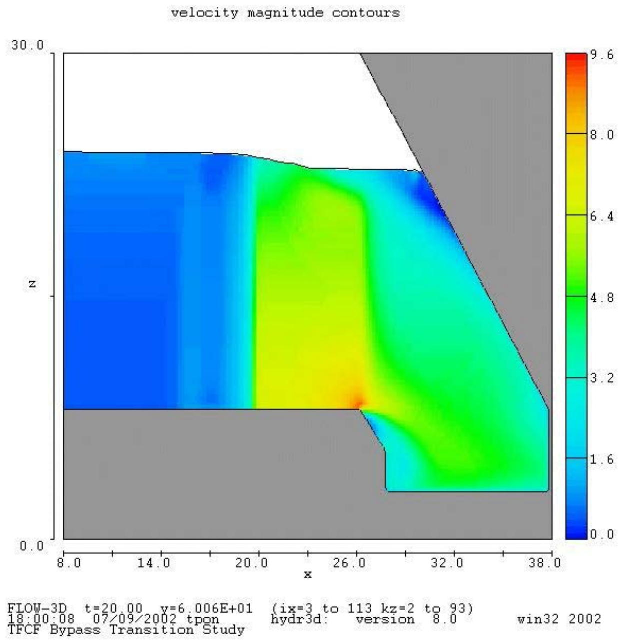

Figure A1-3.—Baseline CFD Results: Centerline of existing bypass transition without guide vanes or guide wall, operated at a flow depth of 16 feet and a discharge of 40 ft^3/s.

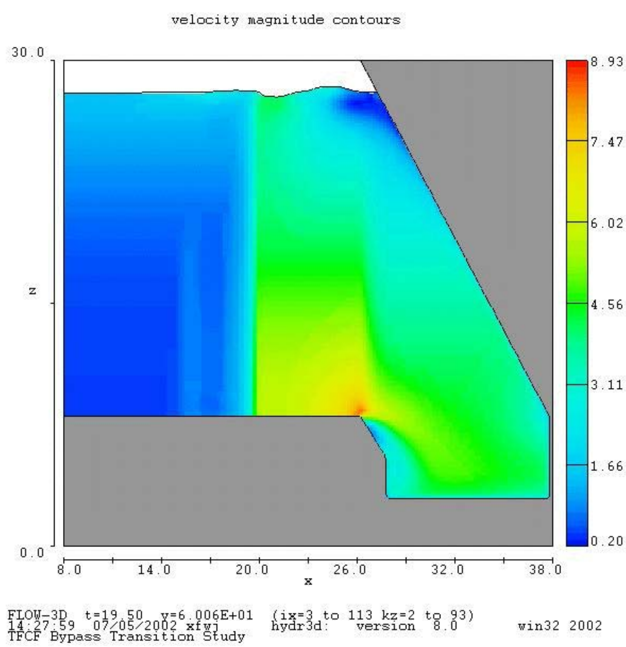

Figure A1-4.—Baseline CFD Results: Centerline of existing bypass transition without guide vanes or guide wall, operated at a flow depth of 20 feet and a discharge of 40 ft^3/s.

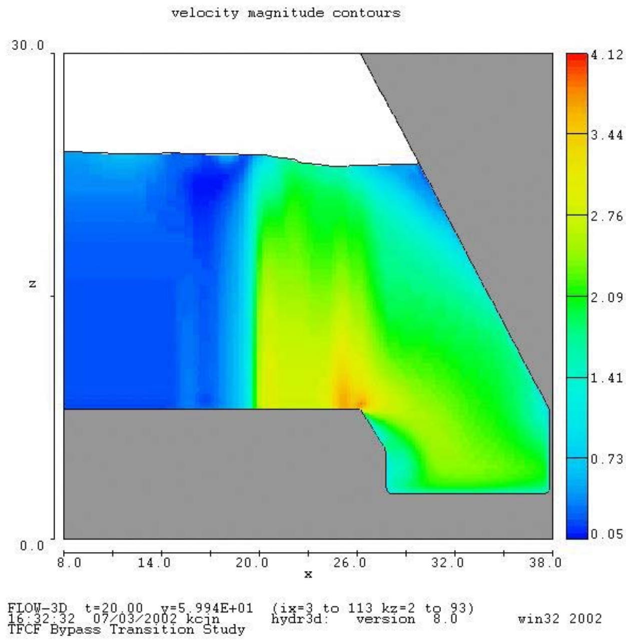

Figure A1-5.—CFD Results: Centerline of step-widened, vertical-tapered choke modified bypass transition operated at a flow depth of 16 feet and a discharge of 20 ft^3/s.

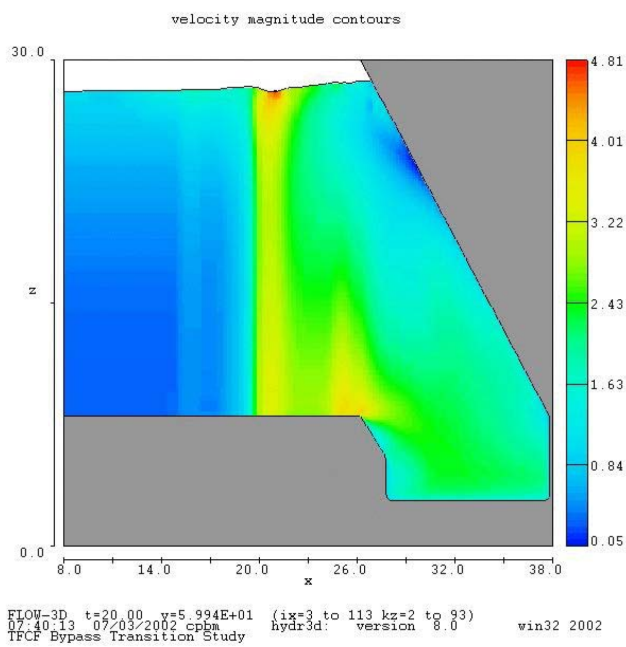

Figure A1-6.—CFD Results: Centerline of step-widened, vertical-tapered choke modified bypass transition operated at a flow depth of 20 feet and a discharge of 20 ft^3/s.

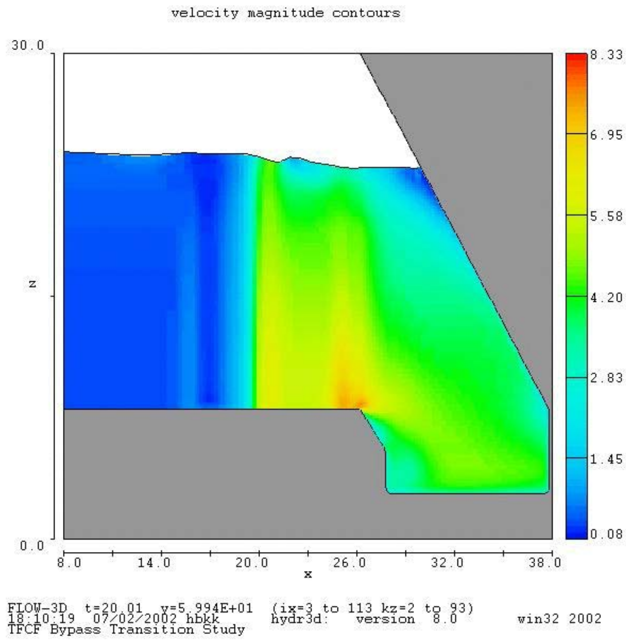

Figure A1-7.—CFD Results: Centerline of step-widened, vertical-tapered choke modified bypass transition operated at a flow depth of 16 feet and a discharge of 40 ft^3/s.

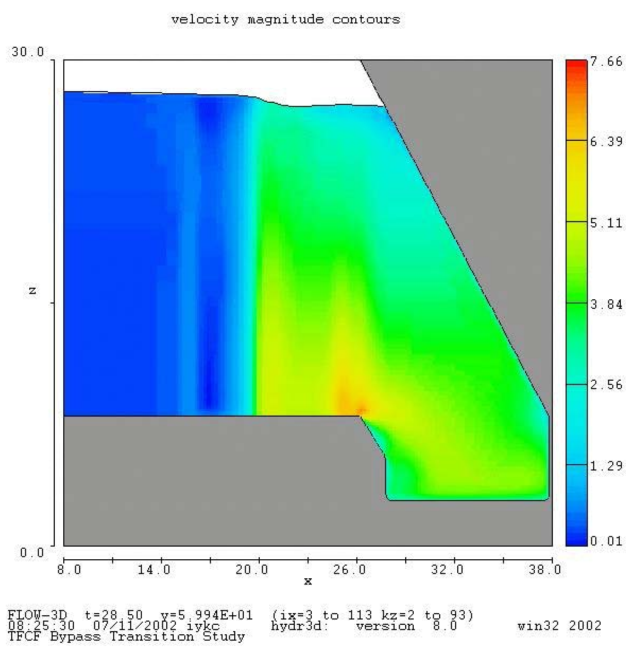

Figure A1-8.—CFD Results: Centerline of step-widened, vertical-tapered choke modified bypass transition operated at a flow depth of 20 feet and a discharge of 40 ft^3/s.

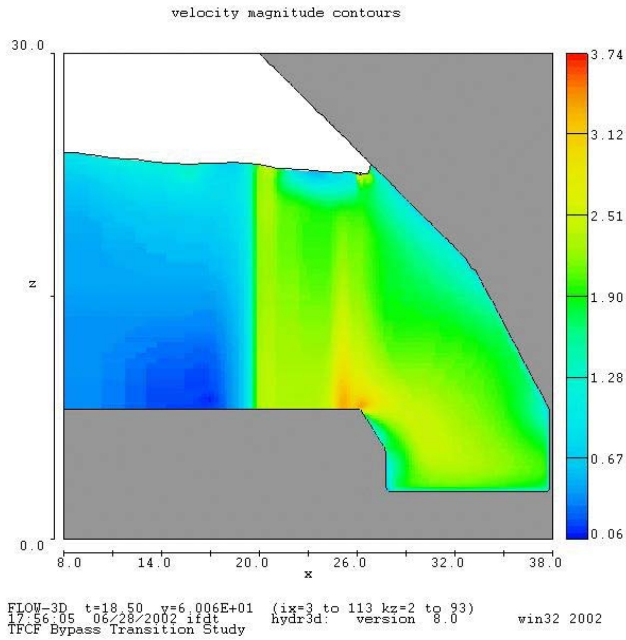

Figure A1-9.—CFD Results: Final bypass transition with step-widened, vertical-tapered choke transition and end plate modifications, operated at a flow depth of 16 feet and a discharge of 20 ft^3/s.

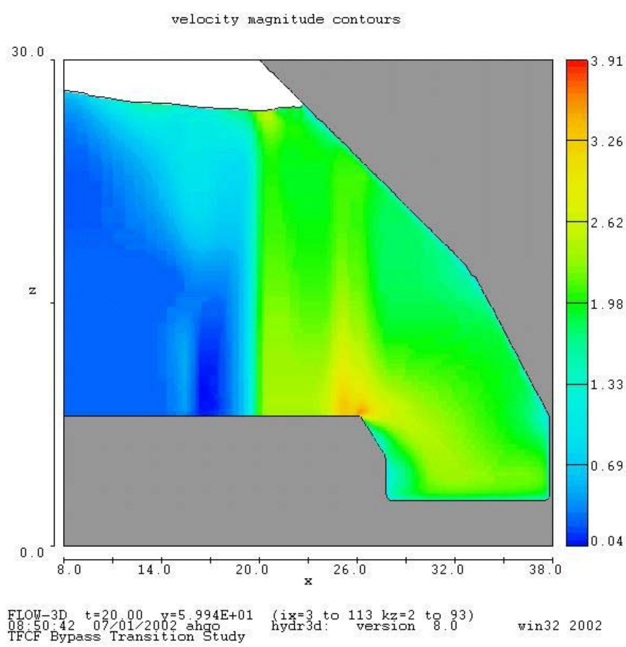

Figure A1-10.—CFD Results: Final bypass transition with step-widened, vertical-tapered choke transition and end plate modifications, operated at a flow depth of 20 feet and a discharge of 20 ft^3/s.

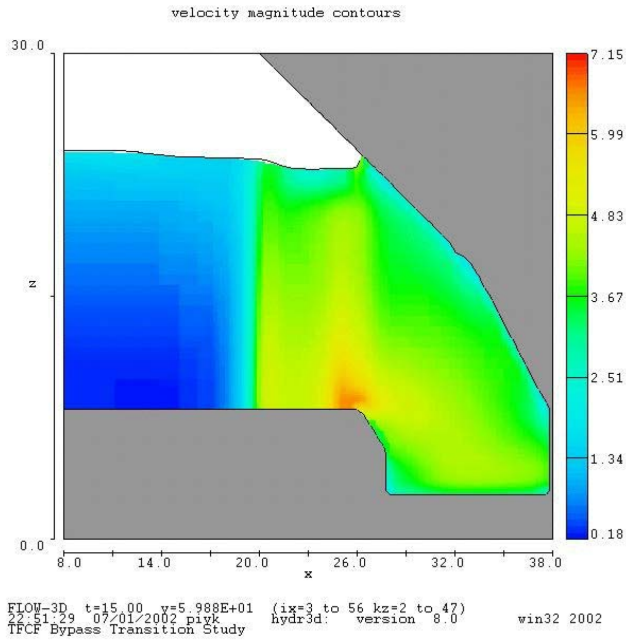

Figure A1-11.—CFD Results: Final bypass transition with step-widened, vertical-tapered choke transition and end plate modifications, operated at a flow depth of 16 feet and a discharge of 40 ft^3/s.

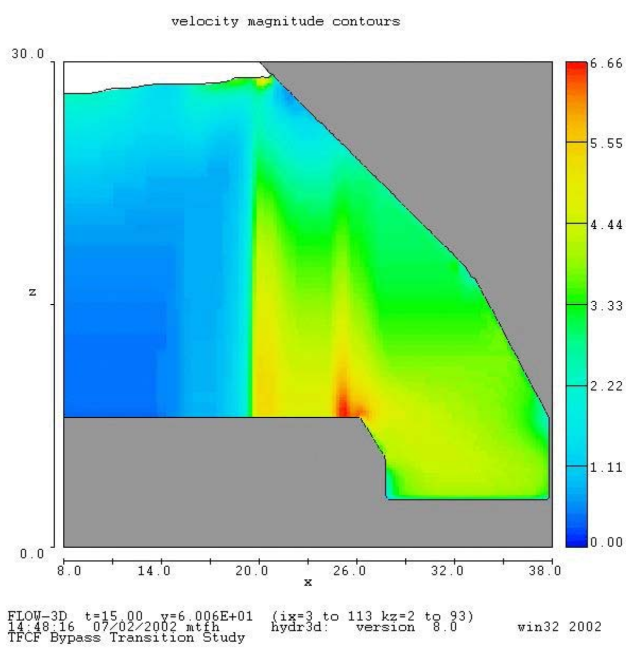

Figure A1-12.—CFD Results: Final bypass transition with step-widened, vertical-tapered choke transition and end plate modifications, operated at a flow depth of 20 feet and a discharge of 40 ft^3/s.

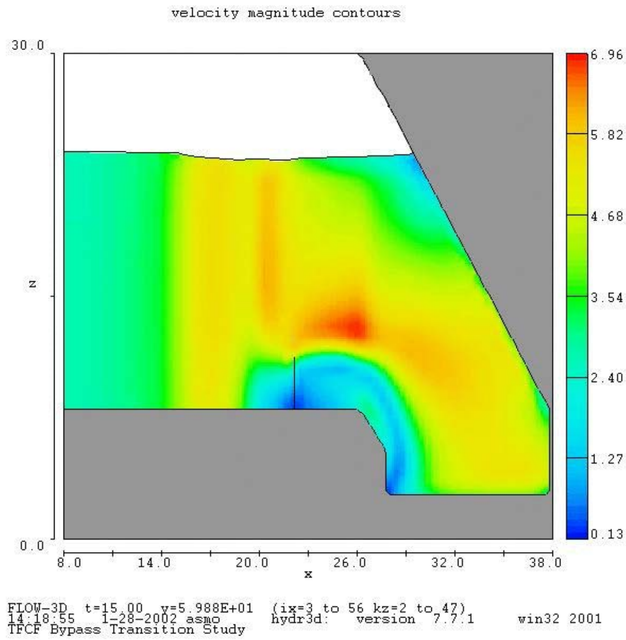

Figure A1-13.—CFD Results: Initial test with bypass transition weir modification, operated at a flow depth of 16 feet and a discharge of 40 ft^3/s.

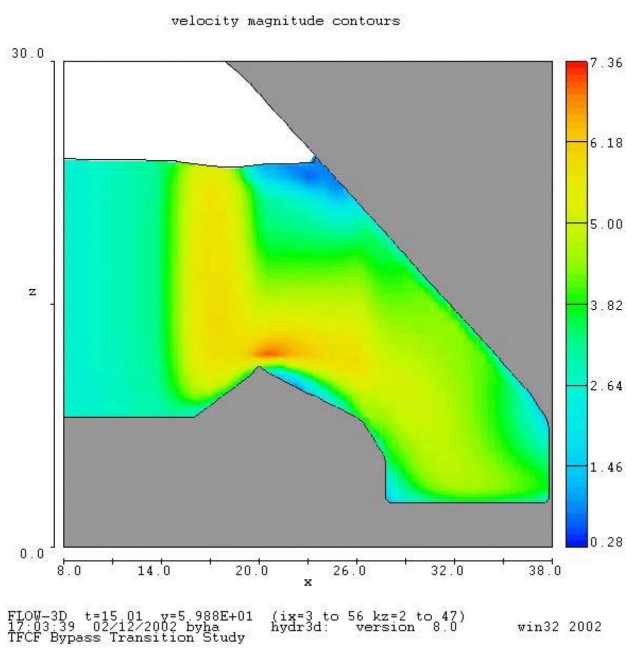

Figure A1-14.—CFD Results: Initial testing with bypass transition ramp and end plate modifications operated at a flow depth of 16 feet and a discharge of 40 ft^3/s.

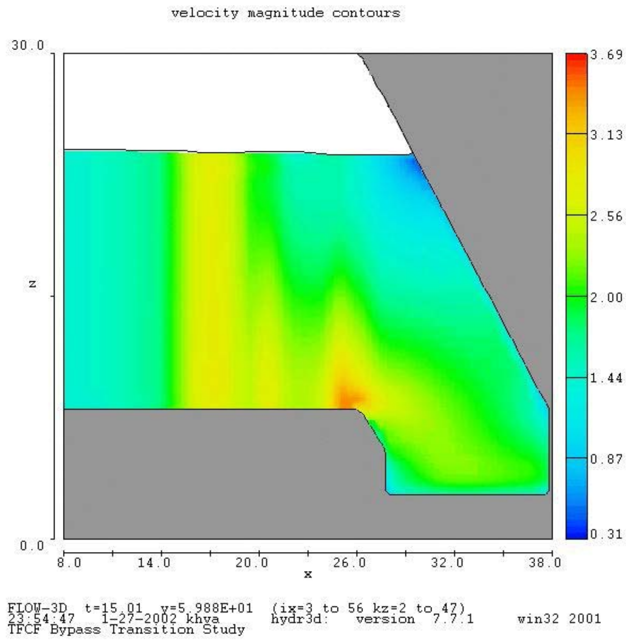

Figure A1-15.—CFD Results: Bypass transition with step-widened, vertical tapered choke modifications, operated at a flow depth of 16 feet and a discharge of 20 ft^3/s. Model includes louver effects at a first step toward phase II investigations.

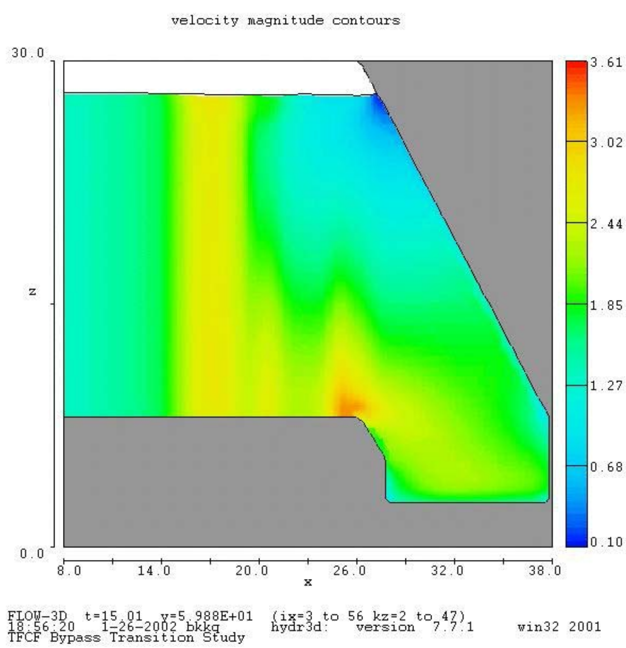

Figure A1-16.—CFD Results: Bypass transition with step-widened, vertical tapered choke modifications, operated at a flow depth of 20 feet and a discharge of 20 ft^3/s. Model includes louver effects at a first step toward phase II investigations.

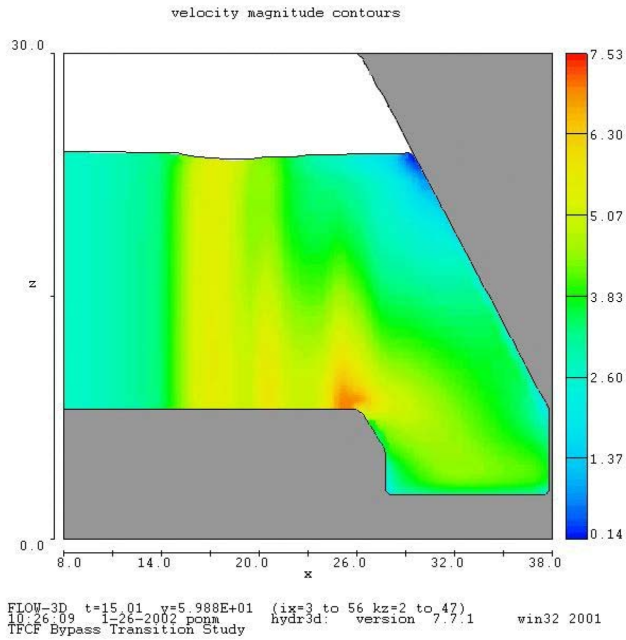

Figure A1-17.—CFD Results: Bypass transition with step-widened, vertical tapered choke modifications, operated at a flow depth of 16 feet and a discharge of 40 ft^3/s. Model includes louver effects at a first step toward phase II investigations.

Appendix 2 - Bypass Transition Physical Model Flow Visualization Images

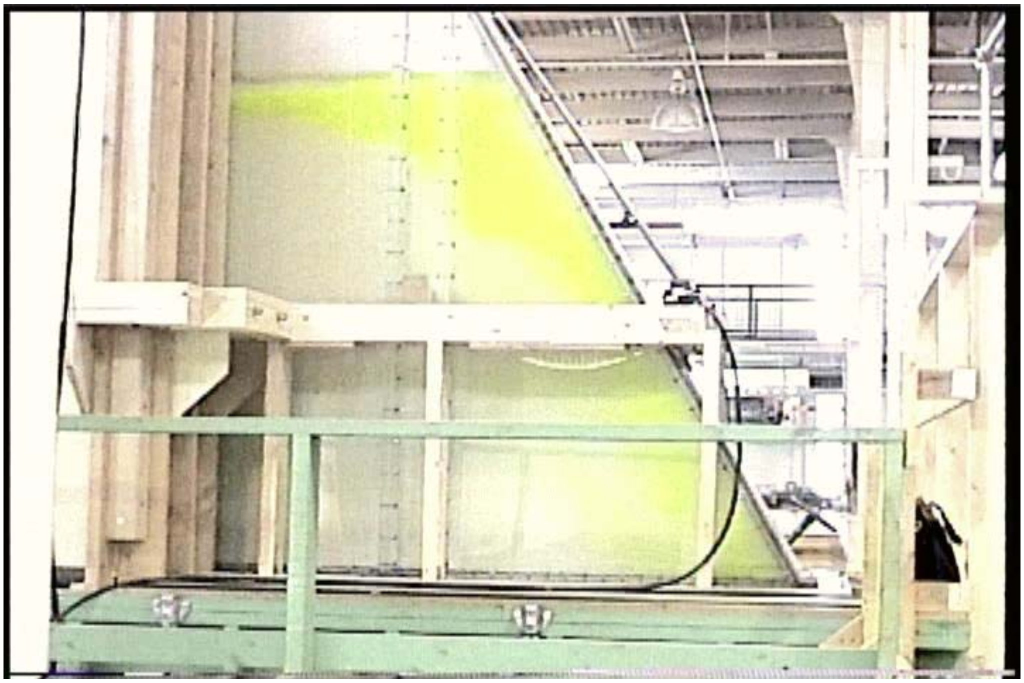

Figure A2-1.—Baseline Flow Visualization. Model operated at a flow depth of 16 feet and a discharge of 20 ft^3/s.

Figure A2-2.—Baseline Flow Visualization. Model operated at a flow depth of 20 feet and a discharge of 20 ft^3/s.

Figure A2-3.—Baseline Flow Visualization. Model operated at a flow depth of 20 feet and a discharge of 40 ft^3/s.

Figure A2-4.— Final Flow Visualization testing for step-widened, vertical choke transition bypass modifications. Model operated at a flow depth of 16 feet and a discharge of 20 ft^3/s.

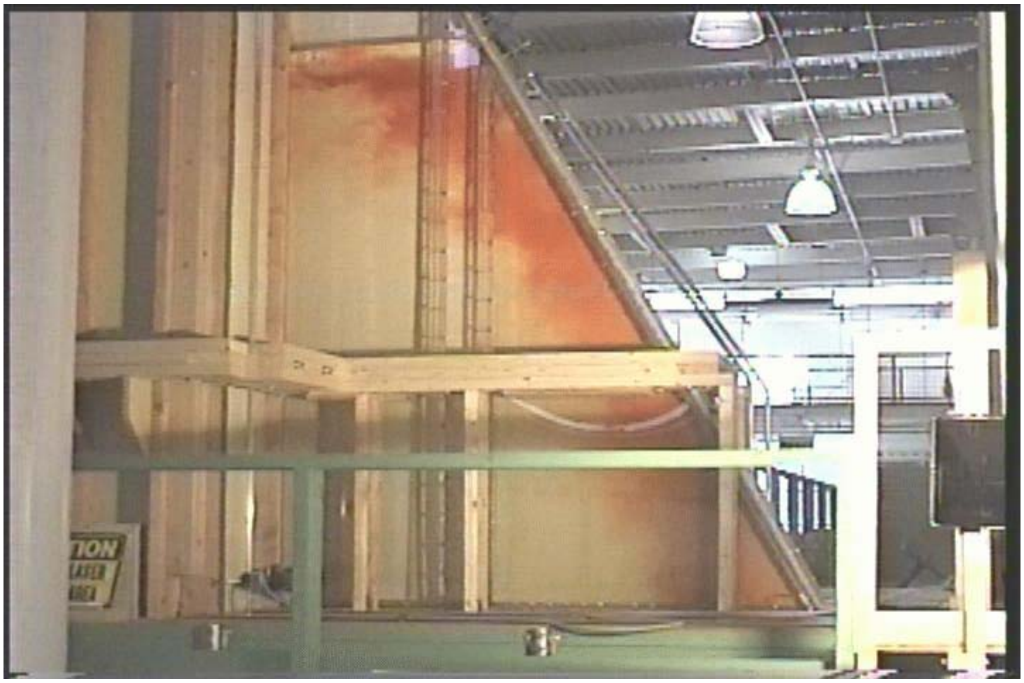

Figure A2-5.—Final Flow Visualization testing for step-widened, vertical choke transition bypass modifications. Model operated at a flow depth of 20 feet and a discharge of 20 ft^3/s.

Figure A2-6.—Final Flow Visualization testing for step-widened, vertical choke transition bypass modifications. Model operated at a flow depth of 20 feet and a discharge of 40 ft^3/s.