APPENDIX C - HYDRAULIC AND HYDROLOGIC

GRR HYDRAULIC APPENDIX

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GRR Hydraulic Appendix

Introduction

Purpose. The purpose of this appendix is to present the results from a 35% level hydrologic and hydraulic design analysis for a Mud Mountain Dam (MMD) fish trap and barrier replacement.

General Description. The existing MMD fish trap and haul is located on the left bank at river mile (RM) 24.3, near the town of Buckley. The trap and haul facility is co-located at a diversion dam constructed and owned by Puget Sound Energy (PSE). The dam diverts water to Lake Tapps as part of the PSE's White River Diversion Project (WRDP). The Muckleshoot Tribal Hatchery is situated at the WRDP on the right bank and has fish release features integrated into the diversion dam. The existing diversion dam built in 1940 and modified in 2002 consists of two removable steel sections, one 20 feet in length the other 14 feet in length, and 318 feet of wooden flash boards. The new fish barrier will replace the existing WRDP diversion dam.

River Characteristics. The White River is a glacial fed river with headwaters starting on the northwest slope of Mount Rainer. The channel slope ranges from 20 to 50 feet per mile. For the most part, the river consists of a single channel with a few areas where braiding has occurred. Situated at RM 29.6 is MMD with 400 square miles of contributing drainage basin area. River levels at the fish trap are regulated by MMD. MMD has a maximum release from the outlet works of 24,000 cfs and the maximum PMF release from MMD is 245,000 cfs. The MMD fish trap and haul facility is located at RM 24.3 and has 11 square miles of drainage between MMD and the fish trap.

Formulated Alternatives. Two preferred alternatives were brought to a 35% level of design. The first alternative is the federal preferred alternative (FPA), which meets the Corps objective of providing for upstream fish passage. The FPA consists of a 16-foot radial gate and 300-foot (150 foot for bedload sluice design option) long ogee weir. Based on additional evaluation the federally preferred plan will also likely require a 35' radial gate (bedload sluice design option). This feature has been incorporated into project costs, but is not reflected in design sheets. The second alternative is the locally preferred alternative (LPA) which provides for diversion to Lake Tapps as well as providing upstream fish passage. The LPA is a design developed by Puget Sound Energy (PSE) and sponsored by Pierce County, WA. This design consists of a 16-foot radial gate, a 35-foot radial gate, two 50-foot inflatable rubber weirs, and 114 feet of fixed crest removable panels. Both alternatives are sited at the existing trap and haul facility.

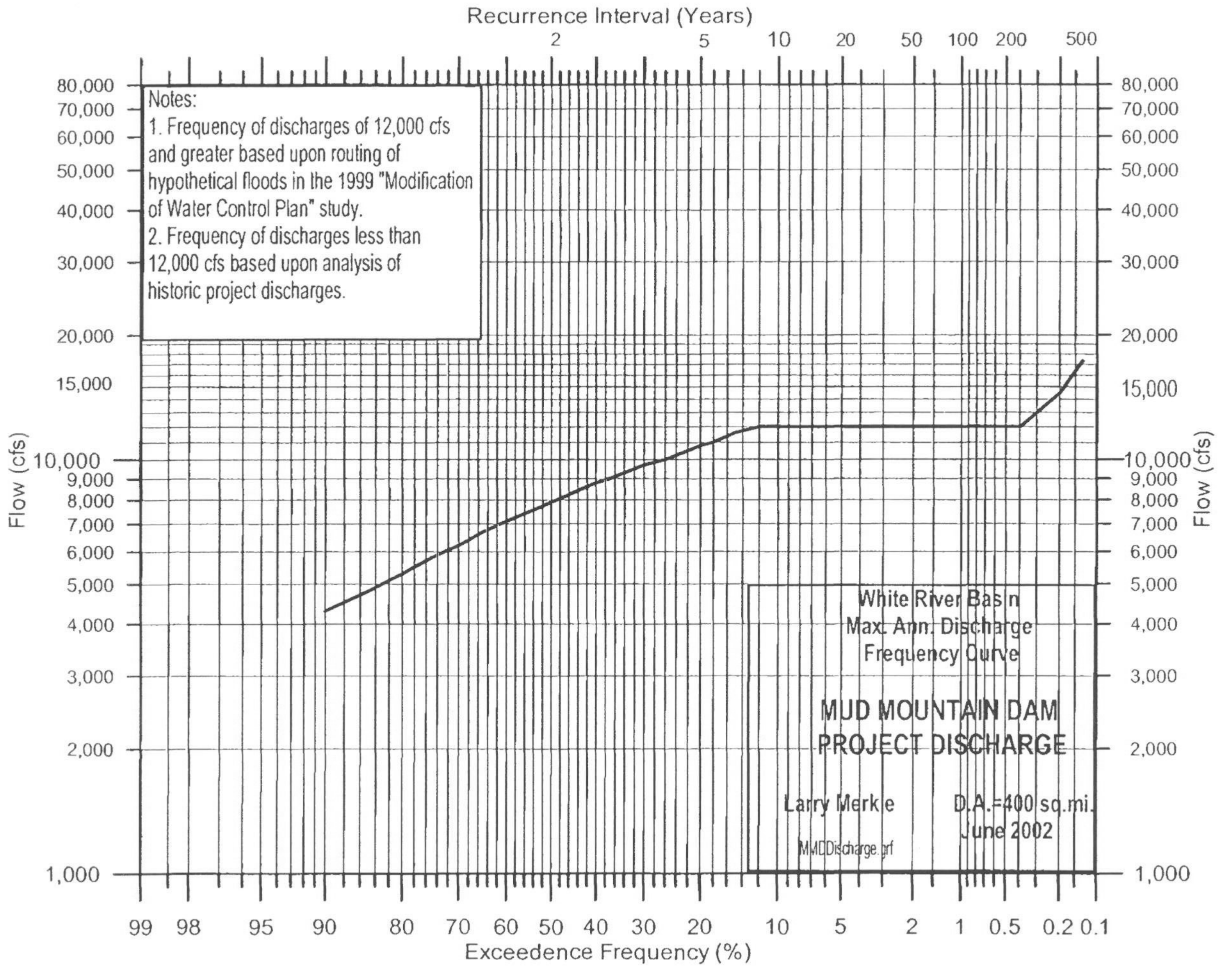
Basis for Design

FPA. The FPA is based on providing the minimum requirements to meet fish trap requirements. This design allows for fish passage and does not include project features to divert water to Lake Tapps. Auxiliary water supply for the Muckleshoot Tribal fish hatchery is included.

LPA. The design objective of the LPA is to meet fish trap requirements, exclude as much sediment load as possible from water diverted to Lake Tapps, and provide auxiliary water supply for the Muckleshoot Tribal fish hatchery. PSE through Northwest Hydraulics performed a physical model study in 1990-91 to perfect this design.

Hydrology

Flow Frequency. River flow at the project is heavily influenced by the regulation of MMD. Assessment of hydrologic frequency is based on the outflow frequency curve for MMD dated 2002.



Operation Flow Limit. The upper flow design criterion is 4,000 cfs for normal operation of the fish trap. This flow has a 92 percent chance of exceedance annually.

Flood Protection Flow. For design of flood proofing, a flow of 12,000 cfs was used as a design criteria. The chance of occurrence for this flow is 12% and the chance of exceedance is only 0.5%.

Dam Stability Flow. Dam stability calculations used 24,800 cfs, the maximum outlet channel capacity for MMD. This flow has a less than .1 percent chance of exceedance annually.

Hydraulics

Field Surveys. Field surveys were performed by Tetra Tech, Inc. around the Buckley Diversion Dam and from RM 16 to RM 23. The Corps surveyed cross-sections from RM 23.3 at the Tacoma pipeline crossing to RM 27.7 just below the USGS gage near Buckley. The control for these surveys was NAD27, Washington State Plane North. Existing levee data for the Muckleshoot Tribal Hatchery was obtained from the 12/24/1996 survey performed by Hammond, Collier & Wade -- Livingstone Associates, Inc. All survey points were ingested into ARCGIS then converted to a TIN surface for HEC-RAS cross-section development. The survey data was compared against the LTDD site plans for quality control. The two right bank concrete monuments were identical to survey values.

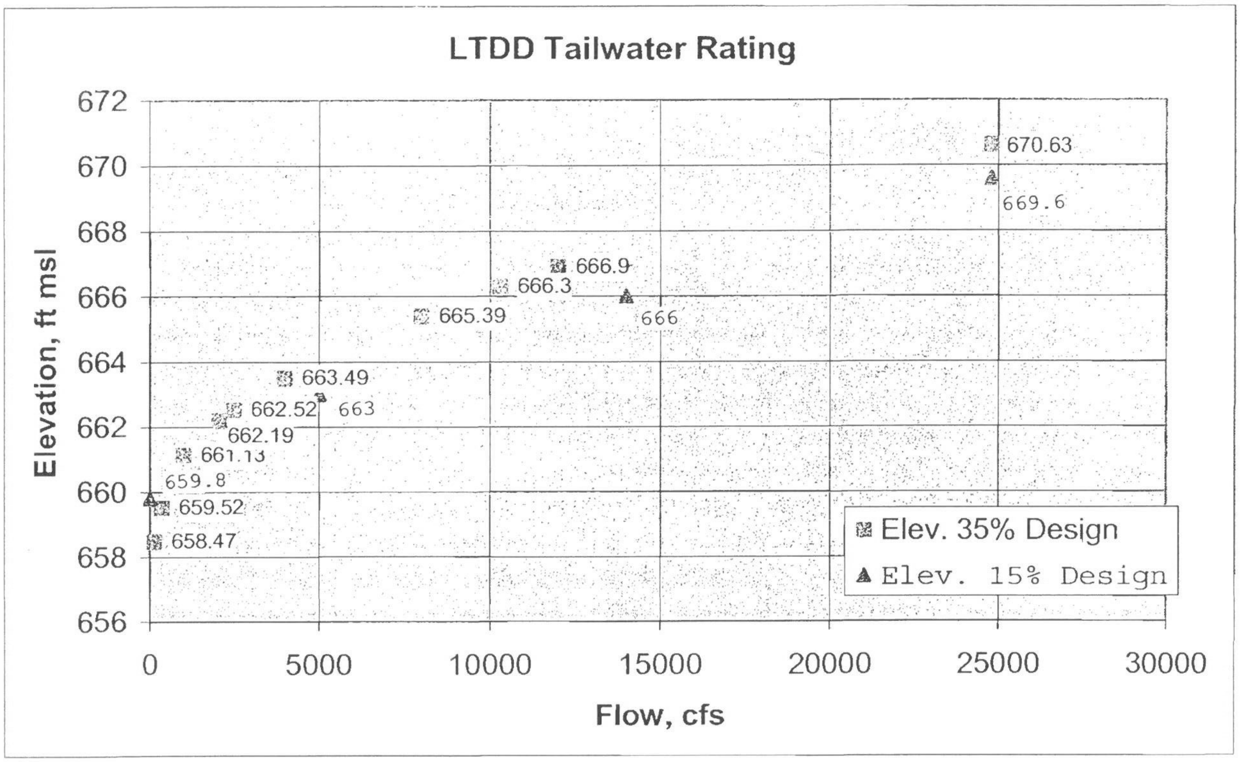
Backwater Modeling. Three conditions were modeled, a baseline condition with the existing Lake Tapps Diversion Dam (LTDD), the federally preferred alternative (FPA), and the locally preferred alternative (LPA). The FPA is alternative 1 from the MMD Fish Passage Investigation Alternatives Evaluation

Submittal dated February 2003. The LPA is Puget Sound Energy (PSE) proposed LTDD replacement design.

Baseline Condition. Cross-sections of the river were surveyed from river mile 23.3 at the City of Tacoma pipeline crossing to just below the USGS gage near Buckley at river mile 27.8. This information was assembled into a HEC-RAS model. Geometry for the existing LTDD was taken from the PSE design, Technical Memorandum No. 10, Hydraulic Model Studies. The LTDD was modeled as cross-sections in HEC-RAS not as an in-line structure. The model was calibrated to the February 6, 1974, high water marks from the Jordan/Avent backwater study which had a flow regime of 10,300 cfs. The model generally calibrated in the project reach with a water surface within 0.5 feet of observed data using an in-stream roughness coefficient of 0.028 and over-bank roughness coefficient of 0.08. The reach between RM 24.18 and the LTDD calibrated within a foot of observed 1974 values. This can be attributed to channel geometry changes from 1974 to present caused by bedload mobilization from large flood events such as the 1996 flood event. The White River is a mixed regime hydraulic problem with both supercritical and subcritical flows. Reach boundary conditions were set to critical depth at river mile 23.3 and 27.7. Upstream supercritical flows from RM 24.7 transition to subcritical flows below RM 24.34 as the water nears the LTDD impoundment at RM 24.3. Backwater conditions at LTDD are controlled by the cross-section at RM 24.18. The flow regime between RM 24.18 and LTDD is subcritical. A cross-section location map is displayed in Figure 1, Aerial With Cross Section Location. Water surface profiles, channel velocities, and Froude numbers are presented in Figure 2, Figure , and Figure on pages 13.

Existing Muckleshoot Tribal Hatchery Flood Protection. The baseline conditions modeled the levee top and wet toe from RM 24.3 to RM 24.5611 which is at levee station 12+70. Interpolated cross-sections were used from RM 24.5611 to RM 24.7. The levee crest elevations and crest widths are presented in Plate 13 Locally Preferred Alternative, Levee and River Bank Plan Profile and Section in the main report. There is no levee below levee station 7+80. All widths below this station are labeled as bank, s.g. for sand bag, or w.w. for wing wall. As modeled, the existing levee for the baseline condition will contain a steady-state flow of 12,000 cfs. During the 1996 event with a flow of 13,200 cfs, the fish hatchery experienced minor flooding near the diversion dam. The modeled water surface profiles are also presented in Figure 2 Baseline Channel Velocity

Tailwater Conditions. Various profiles at river mile 24.29 were assembled into a rating curve. This curve represents the tail water rating for the project. The baseline condition rating was within 0.02 feet of the FPA and the LPA design. The tailwater condition at the project site, RM 24.3, is controlled by the downstream cross-section at river mile 24.18.



City of Tacoma Pipeline Removal Effects. There has been some concern that the replacement of the Tacoma Pipeline crossing at river mile 23.3 would cause head cutting, which could lower the tail water conditions at LTDD. Replacement of the crossing includes the removal of a 5-ft drop structure that protected the old crossing. The channel slope in the vicinity of the crossing is steep and variable. Downstream of the crossing the slope is approximately 30 ft per mile. The slope increases to over 60 feet per mile upstream of the pipeline crossing, between RM 23.3 and RM 23.7, and then flattens to about 30 ft per mile from RM 23.7 upstream to the LTDD at RM 24.3.

The Corps' HEC-6 sediment transport model was used to evaluate the potential for channel degradation following the removal of the pipeline drop structure. The Meyer-Peter and Muller formula was used to calculate bedload transport. The model covered the river from RM 23.1 to 24.16 (just downstream of the LTDD). Channel geometry and channel roughness values were obtained from the HEC-RAS model prepared for this GRR. The number of interpolated cross-sections used in the HEC-RAS model was greatly reduced in the HEC-6 model to lessen the sensitivity of the bedload transport calculations. Bed material gradation data was taken from Dunn's 1986 geomorphic study. To evaluate potential scour from the removal of the drop structure, the river was modeled with and without the structure. A simplified hydrograph for the high flow season, limited to a maximum discharge of 6,000 cfs, was repeated four times to simulate a four year time period.

The modeling results indicate that bedload transport in this reach of the White River is supply limited. About 10 percent more gravel was discharged from the reach than entered. Figures 5-7 show that the scour was spread throughout the reach and that most of the channel degradation occurred during the first two years of the simulation. The channel degraded as the model eroded all available fine and medium gravel from the bed. Those size classes only made up 0-3 percent of the initial bed material. Coarse and very coarse gravel were the dominant size classes of bedload transport and also made up 30-50 percent of the initial bed material. The generally small cobbles only became mobile at 6,000 cfs, which became a limiting factor in the amount of scour that could occur in the models. The trend of channel degradation computed by the model is consistent with the degradation trend observed by Dunne (1986) near RM 27, but modeled rates of around 0.5-1 ft per year are much higher than the 0.025 ft per year observed by Dunne.

The bedload transport and scour amounts were very similar for the with and without drop structure conditions, except for the reach from RM 23.2 to RM 23.7 (Figure 6). Removal of the drop structure at RM 23.3 caused additional upstream scour that ranged from about 2 ft at RM 23.4 to near zero at RM 23.7. The increase in upstream scour was limited by nearly 3 ft of deposition downstream of RM 23.3. The deposition was reduced to near zero at RM 23.2. The upstream boundary of increased erosion (RM 23.7) corresponds to a natural break in slope where the channel slope changes from over 60 ft per mile to about 30 ft per mile. Both the with- and without-drop structure models produced significant erosion between RM 23.5 and RM 23.9, suggesting this was possibly an unstable reach before the drop structure was removed. Based on the results of the bedload transport modeling, it seems reasonable to expect the LTDD tailwater elevations to drop about a 1 ft over the next several years.

The HEC-6 bedload transport modeling was a condensed effort that has several limitations related to both transport processes and available data. The White River has a steep, high-energy channel that pushes the limits of the Meyer-Peter and Muller bedload transport formula. There were no bedload transport measurements and only a few bed material samples that could be used to refine the calculations. The steep channel slope required closely spaced cross-sections to facilitate hydraulic calculations. The closely spaced cross-sections and narrow channel combined to produce bed material storage volumes that were relatively small compared to the bedload transport rates, causing model to be very sensitive to localized changes in transport rates. In the model, the maximum discharge had to be restricted to 6,000 cfs, because higher flows caused the model to become unstable. The instability was most often caused by the filling of the channel at cross-sections where the transport rates dropped.

FPA

Feature Description

16-foot Radial Gate. A 16-foot radial gate near the left bank provides fish attraction water as well as sediment sluicing capabilities. The maximum opening for the radial gate is 15 feet and the trunion is 18 feet above a gate invert of 657 feet msl. Exit velocities for uncontrolled flow range from 10 to 20 fps depending on the upstream head. With these velocities, an apron can be used with no stilling basin. Downstream control can be achieved with riprap.

35-foot Radial Gate. Adjacent to the 16-foot radial gate, a second 35-foot radial gate was added in conjunction with a shortened ogee weir as a bedload passage design option. The gate has a maximum opening of 15 feet and the trunion is 18 feet above a gate invert of 657 feet msl. As noted earlier, this feature is not included in design plates, but is included in project costs.

Gate Sill. Currently there is no raised sill in the design for either radial gate. There has been some concern about the geometry of the gate sill for both radial gates and reliability of gate operation given the aggressive bedload on the White River. This issue will be addressed in the next design iteration if the FPA is brought forward to the next level of design.

Ogee Weir. A 300-foot long ogee weir is located on the right bank of the dam. The crest elevation is 672.5 feet msl and the invert of the stilling basin is 663.3 feet msl. To better handle bedload passage, a shorter ogee weir length of 150 feet is included as a design option. Refer to the sediment transport section for a bedload passage design rational.

Water Surface Profiles

Backwater Modeling. Two FPA configurations were modeled. The first consisted of the original FPA and the second modified to better handle bedload passage. The baseline HECRAS model was modified for each configuration by adding an inline structure with the necessary gates and ogee weir. Gate settings were selected in accordance with the operation schedule.

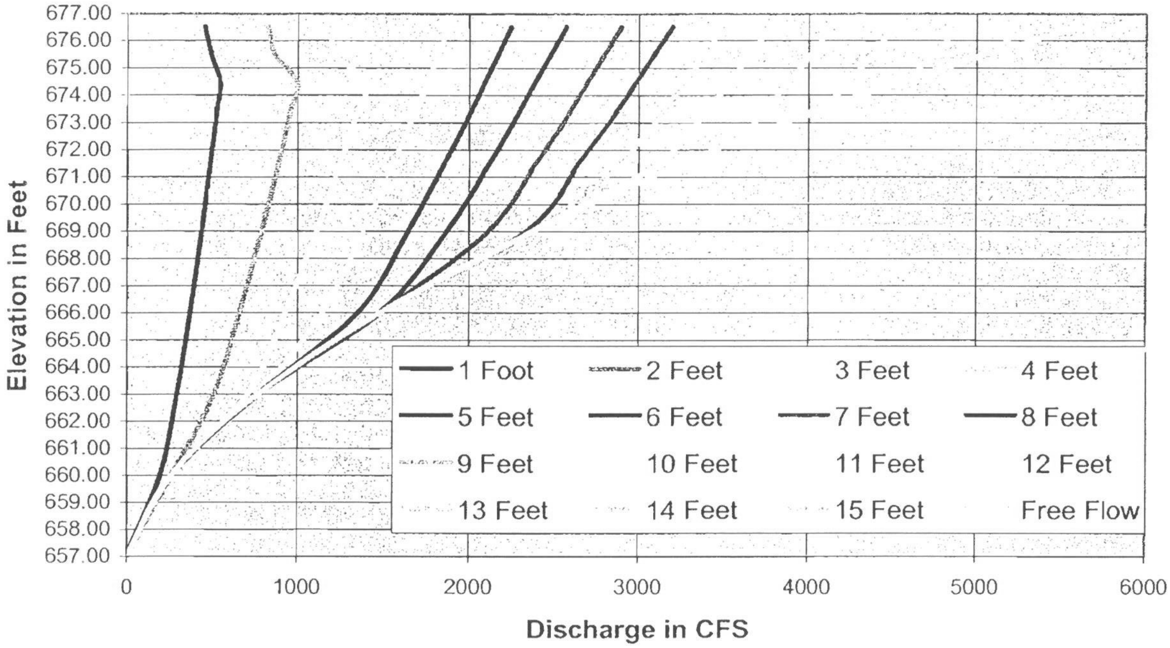
Original Configuration. The FPA was modeled as an in-line structure in HEC-RAS. The 16 ft. radial gate and the auxiliary water supply gates were set to meet the rules specified in the Flow Control Operational Schedule on the Alternative 1 Plan, Plate 3, MMD Fish Passage Investigation Alternatives Evaluation Submittal. Water surface profiles and channel velocities are presented in Figure 3 Baseline Channel Velocity on page 14.

Bedload Passage Configuration. Backwater calculations were conducted on a revised configuration for bedload passage. This revised configuration has a water surface elevation at the dam of 671.9 feet msl for a design flow of 12,000 cfs. A gate opening of 15.5 feet was used for the 16-foot and 35-foot radial gates in order to pass the structural stability flow of 24,800 cfs without overtopping these gates. A design head of 8 feet was used for the ogee spillway. For a flow of 24,800 cfs, the water surface at the dam was 673.9 feet msl.

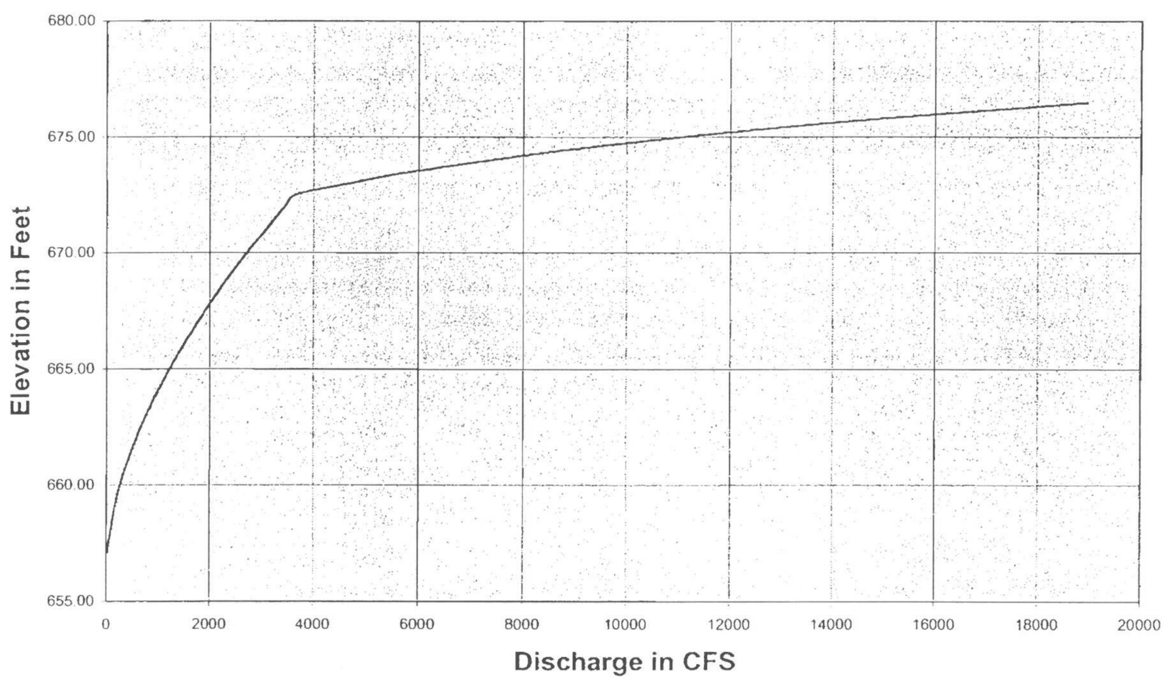
Impoundment Behind Dam. At a normal pool of 671.5 ft. msl, 16 ac-ft of water is impounded with a depth of 9.5 ft. at the dam. The impoundment volume was calculated by summing the cross-section volumes from RM 24.4252 to RM 24.3.

Muckleshoot Fish Hatchery Cutoff Levee. It is intended that the FPA levee design will provide the same level of protection as the existing levee including freeboard. A levee extension was modeled as a vertical line in HECRAS. The cross-sections from RM 23.3 to RM 24.4557 were extended to contain the design flow. The extensions ranged up to 3 feet. The channel width for the extended cross-sections ranges from 400 to 600 feet.

Gate Rating Curve. A gate rating was constructed for the FPA, no sediment sluicing option. The procedures in EM1110-2-1605 and HDC-320 Tainter Gates in Open Channels, sheets 4 though 8, were used. The bend above elevation 675 feet for 1 through 4-foot curves is due to uncontrolled ogee flow backwater effects.



Project Maximum Release. The following plot presents the maximum release for the project outlet features, one 16-foot radial gate and a 300-foot ogee weir.



Operation Schedule. An operation schedule was developed for the FPA. This schedule minimizes the upstream water surface.

Flow	Elevation	Fishway Water Supply	Bypass Ramp Gate	16 ' Radial			300' Ogee Weir
				GO	Flow	Vel.	Flow
(cfs)	(ft)	(cfs)	(cfs)	(ft)	(cfs)	(fps)	(cfs)
180	671.5	130	50	0	0	0	0
430	671.5	130	300	0	0	0	0
550	671.5	130	20	0.8	400	31	0
1080	671.5	130	20	2.1	930	28	0
2040	671.5	130	20	5.1	1890	25	0
2500	671.5	130	20	6.8	2350	26	0
4075	672.66	0	0	15.5	3700	29	375
7990	674.19	0	0	15.5	4400	29	3590
10490	674.88	0	0	15.5	4720	30	5770
12010	675.36	0	0	15.5	4900	30	7110
24830	679.04	0	0	15.5	5970	31	18860

Ogee Geometry. A design head of 8 feet was selected for the 300-foot ogee. Ogee geometry should follow the standard shape defined in HDC 111 Sheets 1 and 2.

Scour Protection. The scour protection design for the FPA was based on the physical model study performed by Northwest Hydraulic Consultants in 1991 and is presented in detail in Montgomery Watson TM - 2. The model study indicates the maximum scour depth of 23 feet will occur downstream of the 35-foot radial gate apron roller bucket. At the end of the apron, the scour depth is less at 8 feet. For this reason the toe of the cutoff wall was set at 645 feet for both radial gates and rubber weirs. In addition, a 4-foot sheet pile cutoff wall for both radial gates and partial extension into the first rubber weir. Riprap sizing was designed to withstand 25 fps for both radial gates, 20 fps for the rubber weirs, and 15 fps for the fixed crest weirs. Estimates indicate a riprap size in excess of 6 feet will be required for streambank stabilization.

LPA

Background. Northwest Hydraulic Consultants (NHC) conducted a physical model study of the proposed White River Diversion Dam in 1991 and 1992. The purpose of this study was to perfect the hydraulic structural features of the project especially for exclusion and passage of bedload and for downstream scour. The resulting design was referred to as the PSE reference design in the 15% design submittal. With the sponsorship of Pierce County, this design became the LPA. This design was based on an inflow design flood of 18,400 cfs.

Feature Description

16-foot Radial Gate. A 16-foot radial gate near the left bank provides fish attraction water as well as sediment sluicing capabilities. The maximum opening for the radial gate is 15 feet and the trunion is 18 feet above a gate invert of 657 feet msl. The approach apron is at a 4% slope while the discharge apron is flat with no end sill or baffles.

35-foot Radial Gate. Adjacent to the 16-foot radial gate is a 35-foot radial gate. The gate has a maximum opening of 15 feet and the trunion is 18 feet above a gate invert of 657 feet msl. A roller bucket is included at the end of the afterbay apron to enhance fish attraction conditions at the fishway entrance while reducing downstream scour.

Gate Sill. The LPA will use replaceable gate lips for both radial gates. No gate sill is used in this design.

Flow Directing Walls. A 109-foot exclusion wall varying from 7 to 9.4 feet in height runs between the forebays of the 16-foot and 35-foot radial gates. A 100-foot flow direction wall varying from 15 and 17 feet in height separates the approach to the 35-foot radial gate and the first rubber weir.

Inflatable Weirs. Two 50-foot inflatable weirs are situated adjacent to the 35-foot radial gate. Inflated, the weir has an invert of 672.5 feet msl and, deflated, the weir has an invert of 663 feet msl.

Fixed Crest Panels. Six removable fixed crest panels are situated on the right bank. The elevation of the crest is 672.75 feet msl with a length of approximately 19 feet per panel.

Diversion Intake. The diversion intake on the left bank consists of 16 7-foot by 12.5-foot bays with an invert of 662 feet msl.

Water Surface Profiles

Backwater Modeling. Two geometry sets were developed for the in-line dam structure, one with the rubber weirs inflated, and the other for high flows with the rubber weirs deflated. All gates in conjunction with low/high flow geometry were set in accordance with operational rules specified in Section VIII, Addendum to TM-3, White River Project, Diversion Dam Rebuild, Final Design Criteria. The lake Tapps diversion was modeled as in-stream flow changes linearly prorated over the cross-sections within the 100 ft. lateral weir. For a discharge of 12,000 cfs, the maximum water surface at the dam was 671.5 feet with a tailwater elevation of 666.9 feet. For a discharge of 24,800 cfs, the water surface at the dam was 672.5 feet with a tailwater elevation of 670.63 feet.

Impoundment Behind Dam. At a normal pool of 671.5 ft. msl, 29 ac-ft of water is impounded at a depth of 14.5 ft. at the dam. The impoundment volume was calculated by summing the cross-section volumes from RM 24.4252 to RM 24.3.

Muckleshoot Fish Hatchery Cutoff Levee. At the dam, the water surface is 2.7 feet below existing protection. From levee station 220 to 770, difference between existing protection and water surface ranges from 0.5 feet to 2.5 feet. Above station 770, the difference between existing protection and the water surface is greater than 2.5 feet.

Operation Schedule. Due to significant backwater effects, individual gate ratings are not practical. A total project rating was developed based on a sequenced operation of controlled hydraulic features.

Flow	Elevation	Diversion	Fishway Water Supply	Bypass Ramp Gate	16 ' Radial			35' Radial			Rubber Weir #1	Rubber Weir #2
					GO	Flow	Vel	GO	Flow	Vel		
(cfs)	(ft)	(cfs)	(cfs)	(cfs)	(ft)	(cfs)	(fps)	(ft)	(cfs)	(fps)		
180	671.5	0	130	50	0	0		0	0		up	up
650	671.5	220	130	300	0	0		0	0		up	up
1418	671.5	870	130	20	0.8	398	31	0	0		up	up
3000	671.5	1920	130	20	0	0		0.8	930	33	up	up
4050	671.5	2000	130	20	0	0		1.6	1900	33	up	up
4540	671.5	2000	130	20	0	0		2	2390	33	up	up
6000	671.5	2000	0	0	0	0		3.4	4000	33	up	up
9300	671.5	2000	0	0	2	0	22	15.5	7300	29	up	up
12290	671.5	2000	0	0	9.1	2920	27	15.5	7370	30	up	up
12770	671.5	2000	0	0	15.5	3380	28	15.5	7390	30	up	up
20750	671.5	2000	0	0	15.5	3460	28	15.5	7570	30	down	down
24010	672.6	2000	0	0	15.5	3950	29	15.5	8630	31	down	down

Scour Protection. The scour protection for the LPA was based on the physical model study performed by Northwest Hydraulic Consultants in 1991 and is presented in detail in Montgomery Watson TM - 2. The model study indicates the maximum scour depth of 23 feet will occur downstream of the 35-foot radial gate apron roller bucket. At the end of the apron, the scour depth is less at 8 feet. For this reason the toe of the cutoff wall was set at 645 feet for both radial gates and rubber weirs. In addition, a 4-foot sheet pile cutoff wall for both radial gates and partial extension into the first rubber weir. Riprap sizing was designed to withstand 25 fps for both radial gates, 20 fps for the rubber weirs, and 15 fps for the fixed crest weirs. Estimates indicate a riprap size in excess of 6 feet will be required for streambank stabilization.

Exclusion Velocity. A design discrepancy was identified in the review comments for the 75% GRR of the Mud Mountain Fish Trap and Barrier concept design. Velocities through the 16-foot and 35-foot radial gate do not meet the exclusion velocity criteria of 24 fps. After further analysis, it was determined that fish exclusion can be accomplished operationally.

Sediment Transport

Sediment Characteristics. The White River annual suspended sediment load at the project site ranges from 100,000 tons per year to 1,000,000 tons per year with an average of 500,000 tons per year. The average annual bedload at the project site is 20,000 tons per year with a minimum of 6000 tons per year and a maximum of 56,000 tons per year (Dunn, 1986). The White River bed material consists of coarse material with particle sizes ranging up to 512 mm with larger material sourced from over-bank glacial till. The bedload particle size distribution depends on flow. For flows below 2500 cfs, the majority of particles are smaller than 1 mm with an average of .3 m.m. For flows above 6000 c.f.s. the distribution is bi-modal. The distribution of particles below 1 mm is the same as lower flows but a second mode of larger particles is apparent with particle sizes greater than 16 mm and an average of 64 mm. Mobilization of cobble size particles occurs between 7,000 cfs and 8,000 cfs (Northwest Hydraulic Consultants, 1992). WRDP diverts 200,000 tons of sediment per year. The majority of this sediment load is transported at flows above 1000 cfs. For higher White River flows when bedload is in motion, the flume is shut down so as not to plug it with cobbles and gravel. None of the current sediment transport analytical relationships such as Meyer-Peter are considered reliable for this site due to the hydraulic conditions and the large particle sizes.

Sediment Design Objective. The design objective for sediment management is to pass bedload sediment through the dam to prevent its accumulation in locations adverse to dam operation. Bedload sediment should also be excluded from the fish trap water supply intake, fishway entrance, and attraction water features.

Bedload Passage Design Discrepancy. From a discussion with the Seattle District sediment specialist, Karl Eriksen, some design characteristics in relation to the passage of bedload were identified which could adversely impact the performance the MMD fish trap. These characteristics are:

The flow width at and immediately upstream of the fish barrier is approximately 400 feet while the upstream natural channel width ranges from 50 to 100 feet.

Because of the excessive flow width near the barrier, bedload may form deposits outside the influence of the 16-foot radial gate, which could reroute water away from the fish trap water intake.

Bedload Passage Solution. As a solution to this bedload passage discrepancy, Karl Eriksen recommended adding an additional 35-foot radial gate and shortening the ogee width by 20 to 30 percent. A physical model will be required to advance the design to better handle bedload movement upstream of the project. The scale of the model would be in the range of 1:25 to 1:40. Such a model would likely cost between $200,000 and $300,000.

Sedimentation of Fish Trap Intake. Several design concepts related to reducing sedimentation within the fish trap water system were identified in further discussions with Karl Eriksen. One concept was to skim water from the top of the water column. Both the LPA and FPA draw water from the full vertical column of water. The top of the water column may have a significantly smaller sediment load. A physical model of the structure would be useful in determining the sedimentation trends at the water intake. The scale of the model would be in the range of 1:12 to 1:15. Such a model would likely cost between $200,000 and $300,000.

Conclusions. Of the two plans, the LPA has been furthered to a greater level of design. However, some redesign of the LPA will be required to meet exclusion velocity requirements. Also of concern is the lack of a gate sill and possible impacts on operation reliability and increased maintenance. These aspects will be evaluated in the next phase of design. If the FPA is brought to the next level of design, a physical model is recommended to better refine hydraulic features for bedload passage, scour protection, and fish attraction. An additional 35-foot gate along with a shorter ogee weir would likely be required for bedload passage. A physical model would better refine this solution.

Figure 1, Aerial With Cross Section Locations

Figure 2, Baseline Water Surface Profile

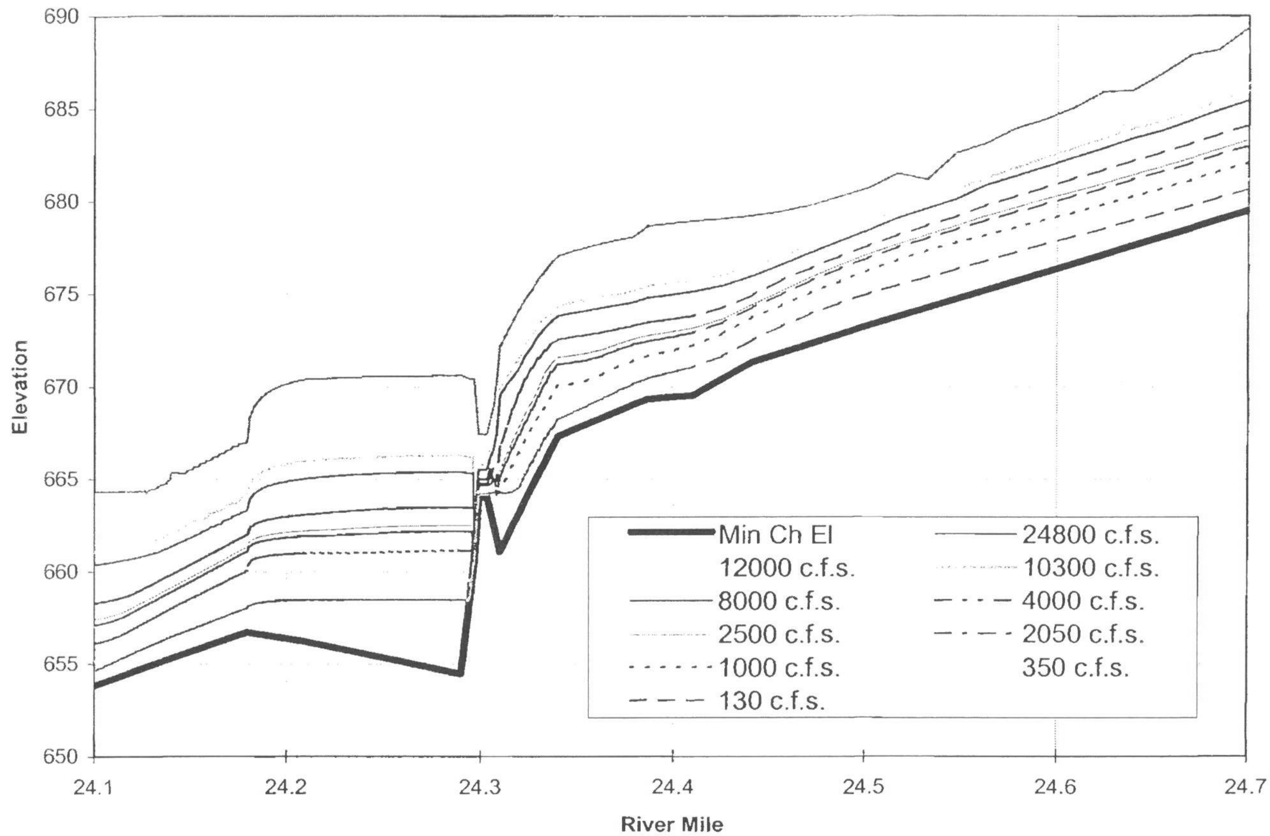


Figure 3, Baseline Channel Velocity

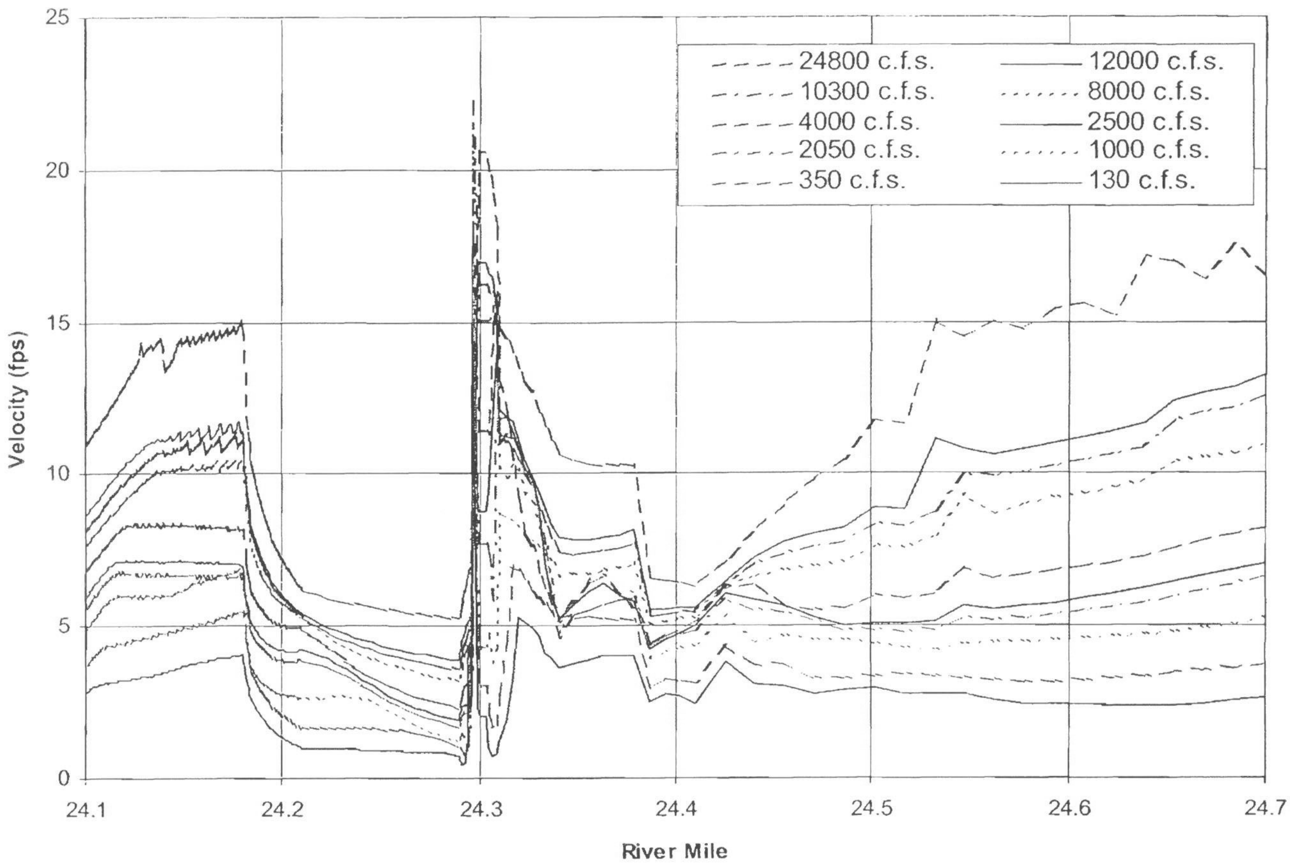


Figure 4, Baseline Froude Number

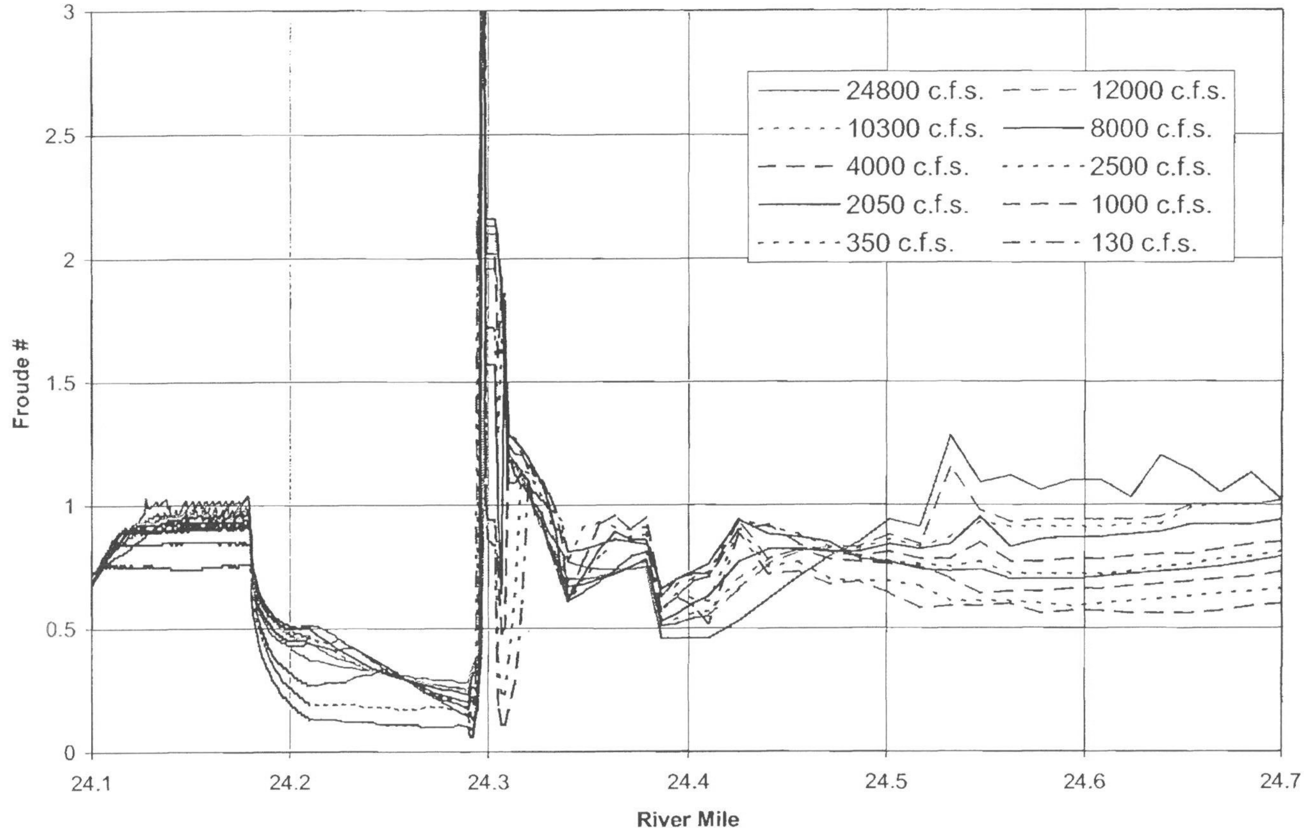


Figure 5, FPA Water Surface Profile

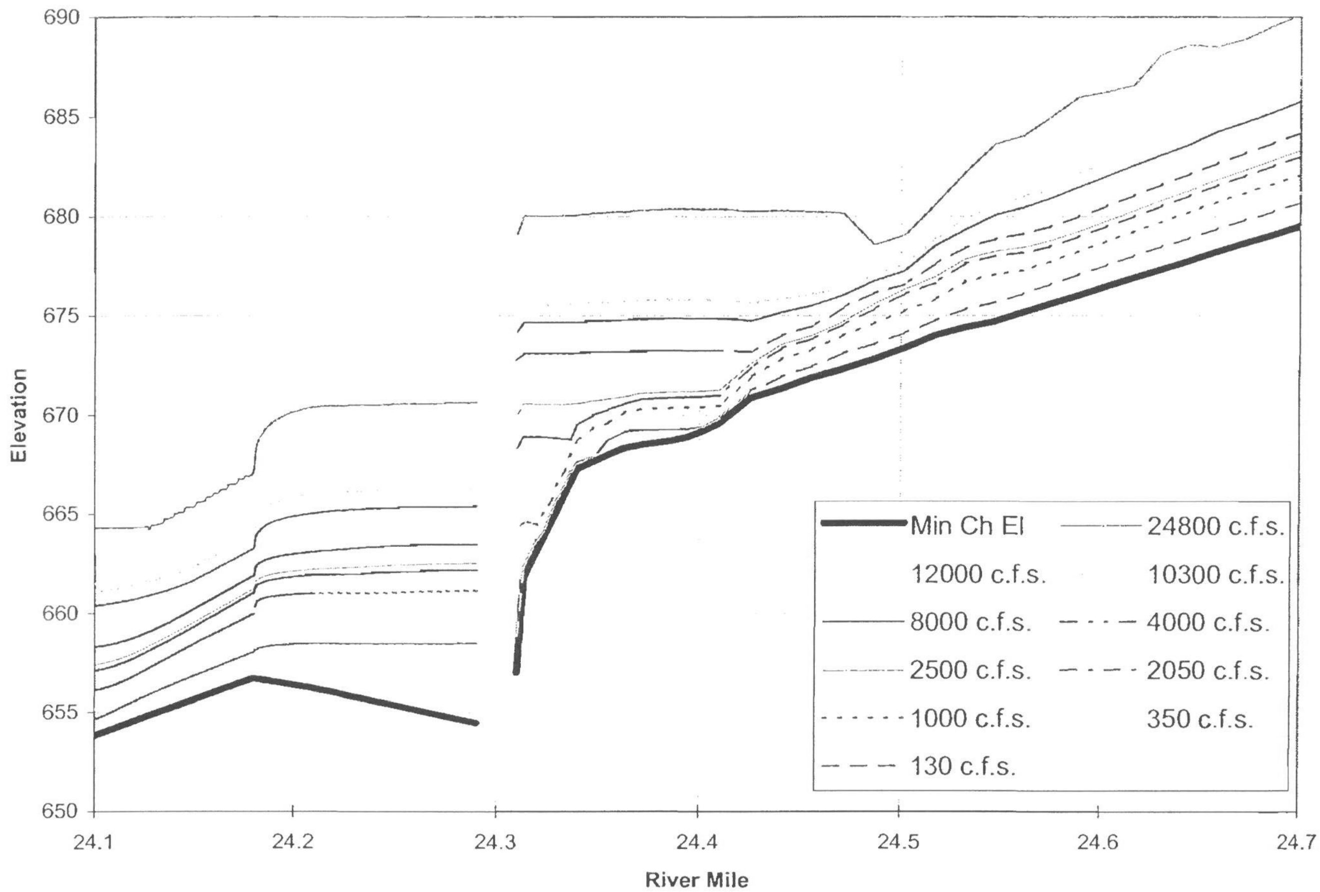


Figure 6, FPA Channel Velocity

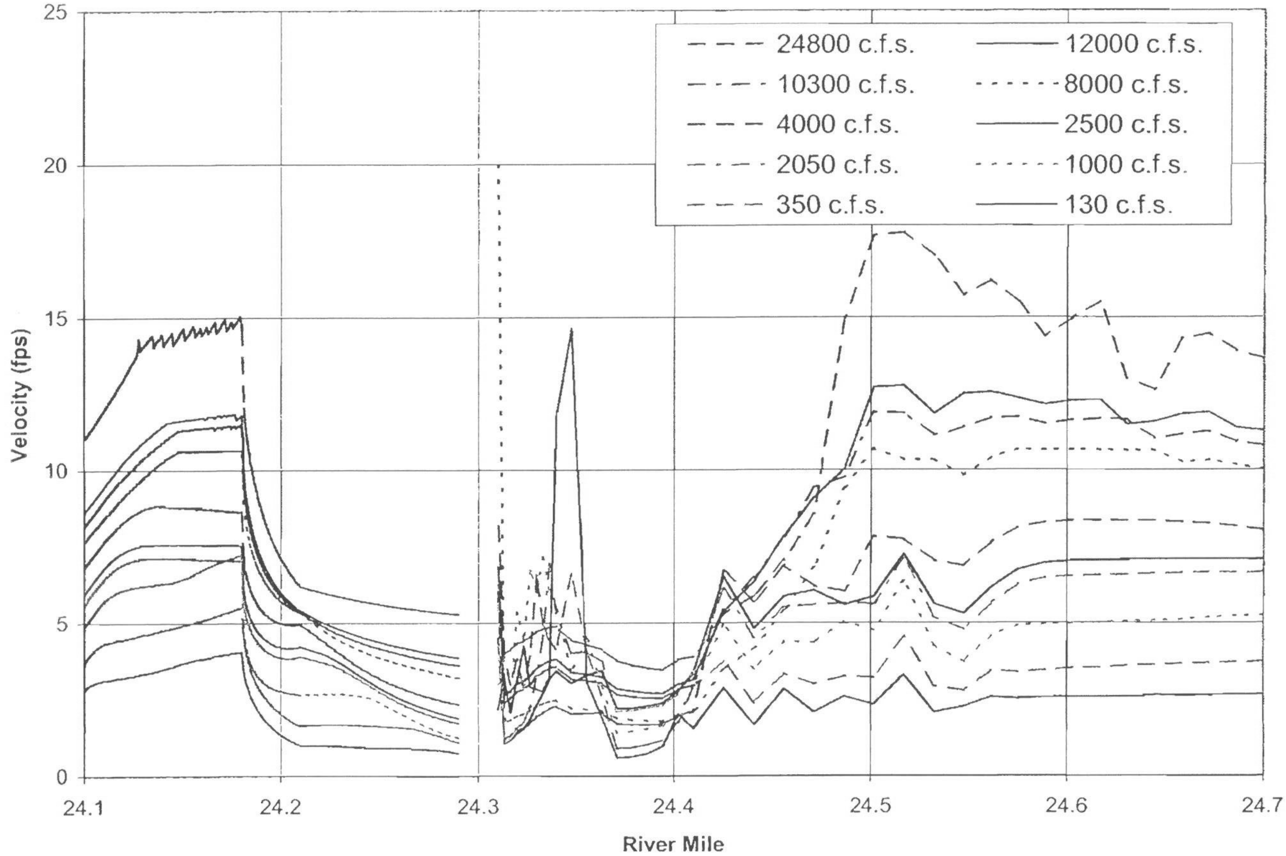


Figure 7, FPA Froude Number

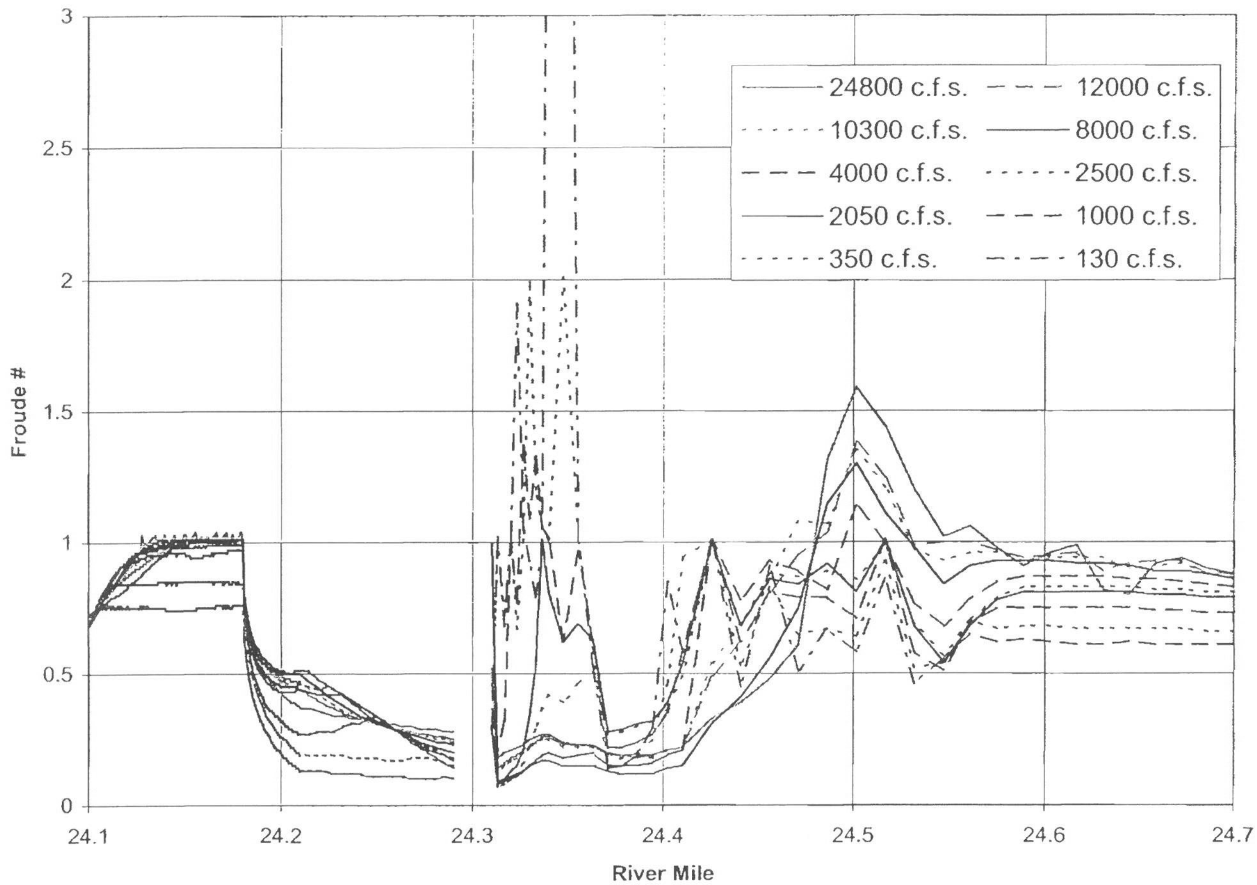


Figure 8, LPA Water Surface Profile

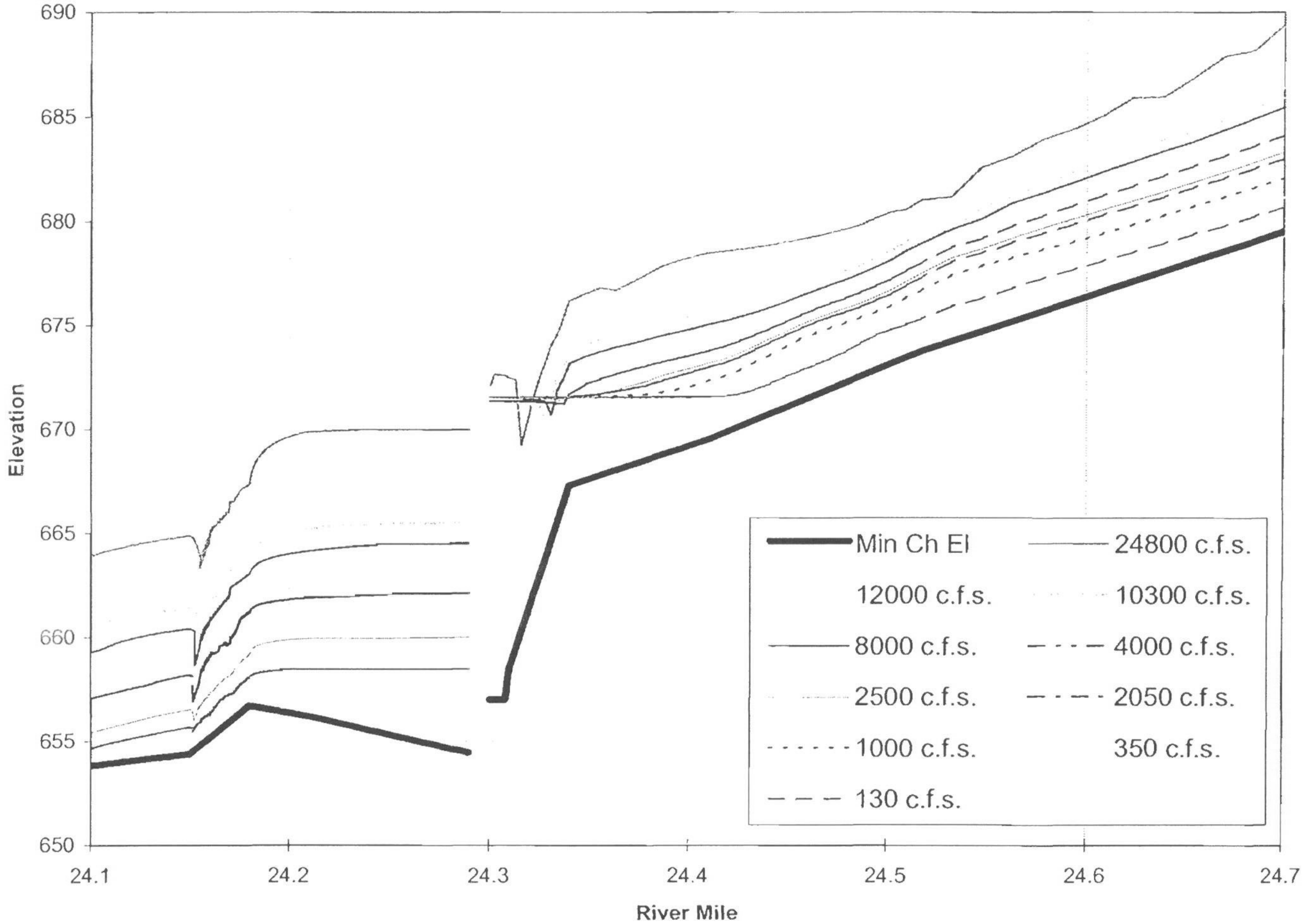


Figure 9, LPA Channel Velocity

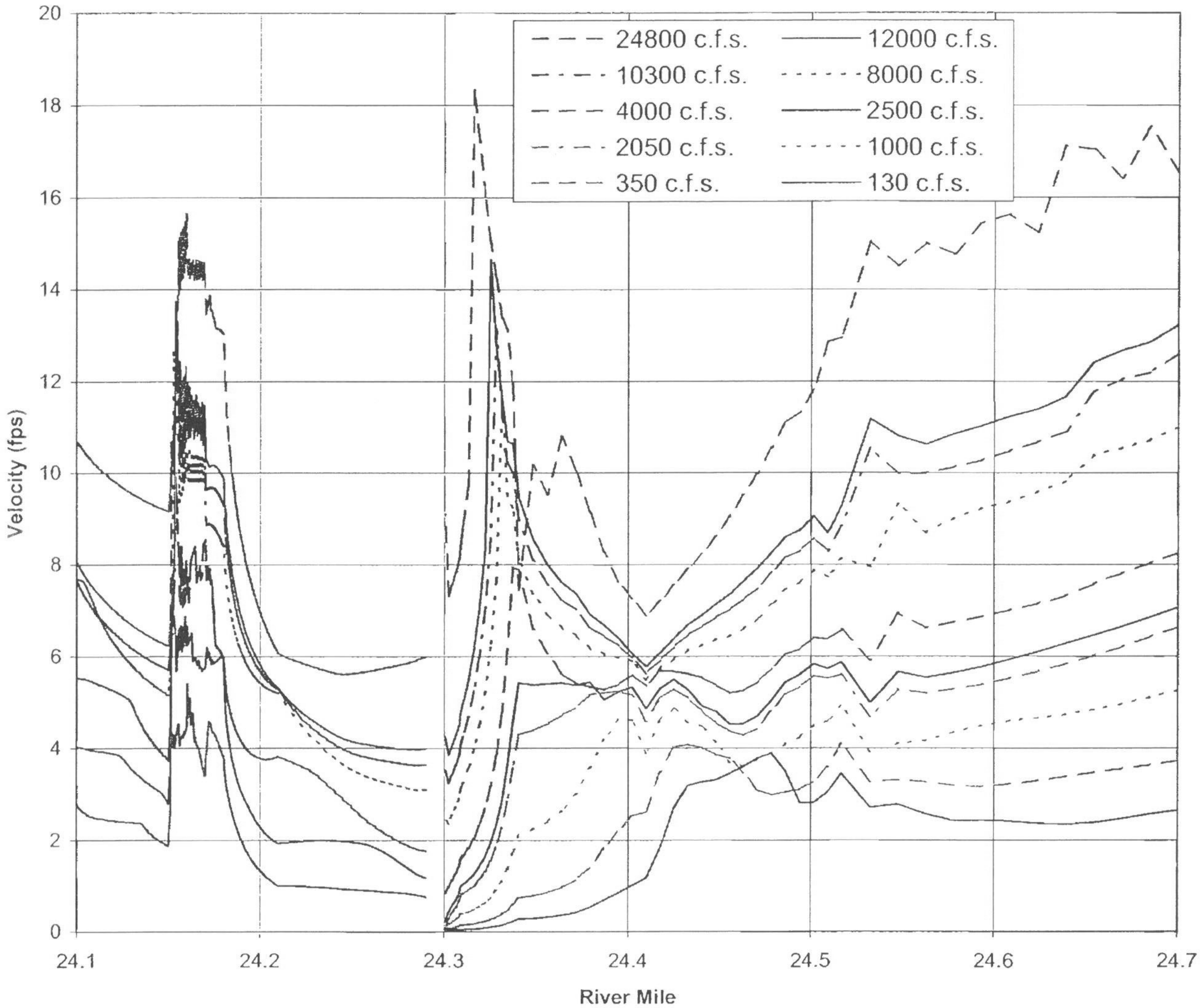
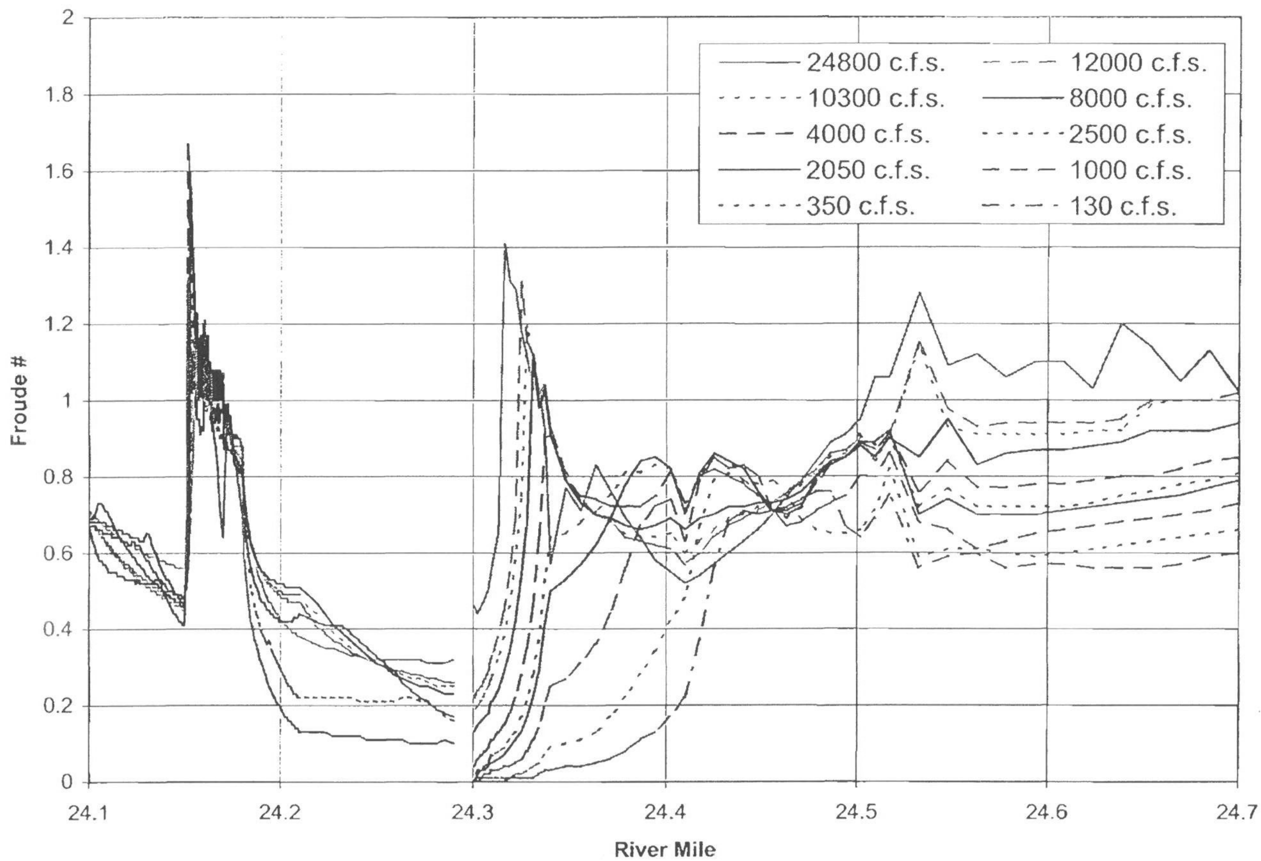


Figure 10, LPA Froude Number



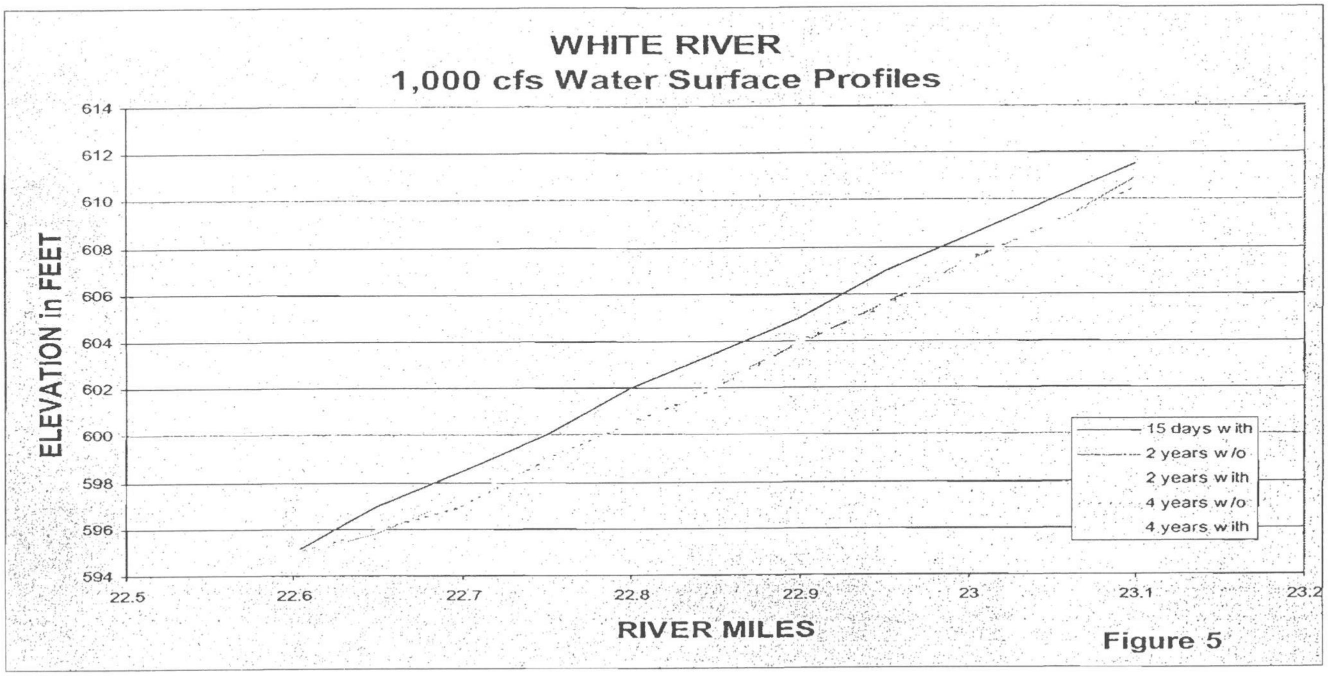


Figure 5. With and without drop structure water surface profiles for 1,000 cfs. The 1,000 cfs water surface profiles are used here to represent the overall changes to the river bed.

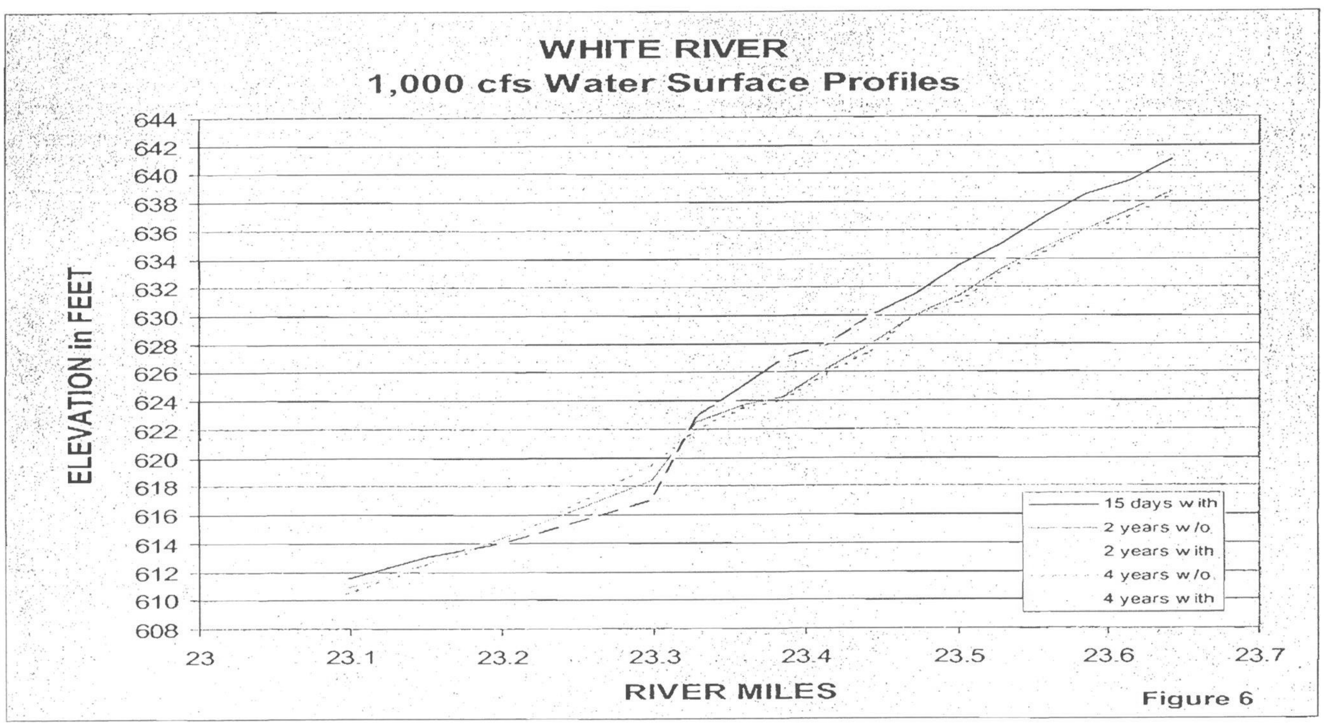


Figure 6. With and without drop structure water surface profiles for 1,000 cfs. The 1,000 cfs water surface profiles are used here to represent the overall changes to the river bed.

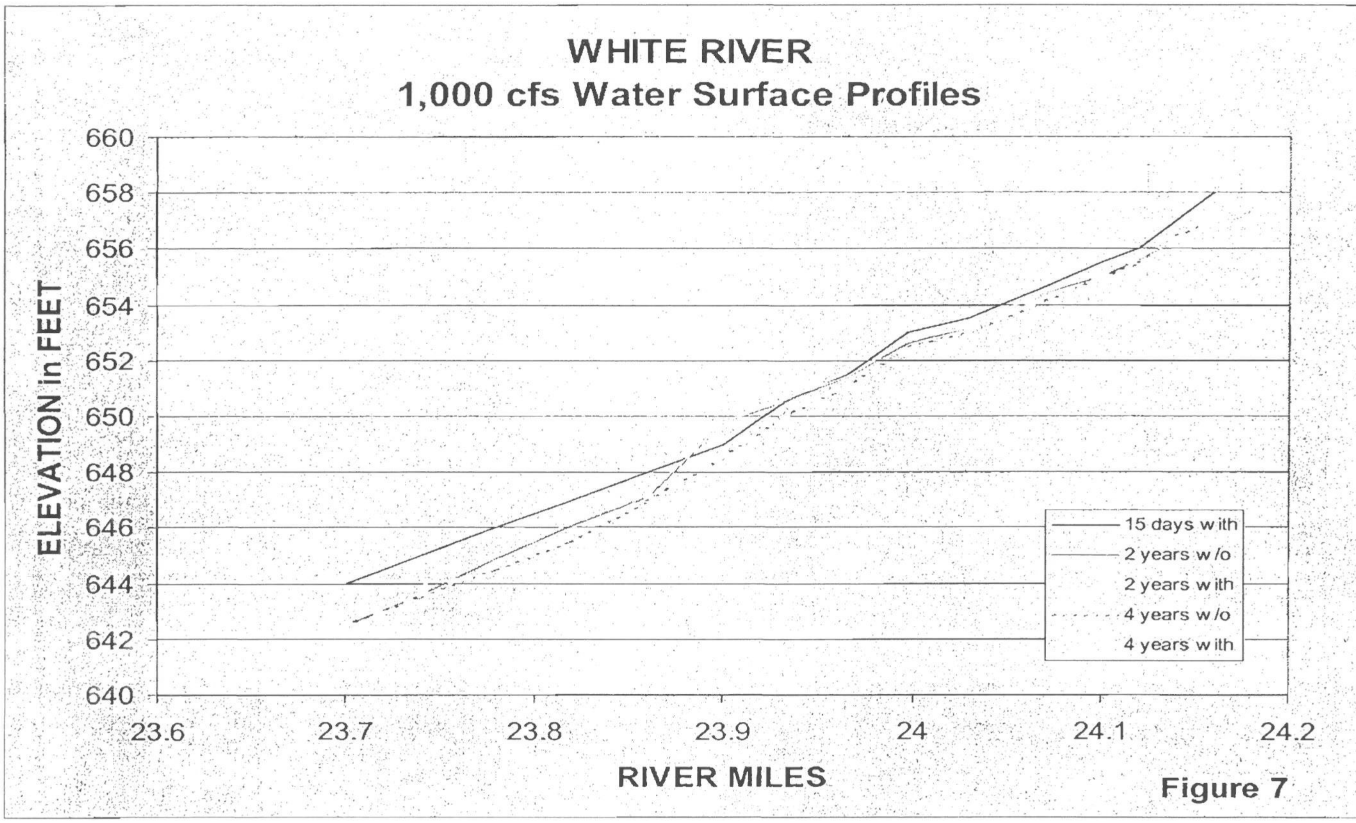


Figure 7. With and without drop structure water surface profiles for 1,000 cfs. The 1,000 cfs water surface profiles are used here to represent the overall changes to the river bed.

Table 1, White River Profile

Existing Conditions								Federal Preferred Plan (Original)		Federal Preferred Plan (w/ 35' radial)		Locally Preferred Plan	
Mile	Station (ft)	Levee Station (ft)	Crest Elev. (ft msl)	Width (ft)	Flow (cfs)	Vel. (fps)	WS Elev. (ft msl)	WS Elev. (ft)	Vel. (fps)	WS Elev. (ft)	Vel. (fps)	WS Elev. (ft)	Vel. (fps)
24.7000	131138		689.78		12000	11.2	687.00	686.98	11.3	687	11.29	687.00	11.2
24.6861	131050		690.00		12000	11.3	686.52	686.49	11.4	686.52	11.39	686.52	11.3
24.6722	130963	2300.0	690.00		12000	11.9	685.84	685.83	11.9	685.85	11.88	685.84	11.9
24.6583	130876	2171.3	690.00		12000	11.8	685.37	685.37	11.8	685.36	11.82	685.37	11.8
24.6444	130789	2042.5	690.00		12000	11.5	684.98	684.95	11.6	684.94	11.57	684.98	11.5
24.6305	130701	1913.8	688.00		12000	11.7	684.40	684.51	11.5	684.49	11.47	684.40	11.7
24.6166	130614	1785.0	687.00		12000	12.1	683.77	683.66	12.3	683.68	12.32	683.77	12.1
24.6027	130527	1656.3	686.00		12000	12.3	683.12	683.11	12.3	683.16	12.34	683.12	12.3
24.5888	130439	1527.5	685.50		12000	12.3	682.60	682.57	12.3	682.71	12.33	682.60	12.3
24.5749	130352	1398.8	685.00		12000	12.3	682.05	682.02	12.3	682.04	12.34	682.05	12.3
24.5611	130265	1270.0	684.50	10	12000	12.6	681.35	681.46	12.3	681.35	12.29	681.35	12.6
24.5473	130178	1180.0	683.80	10	12000	12.6	680.76	680.89	12.2	680.77	12.24	680.76	12.6
24.5321	130082	1080.0	683.20	5	12000	12.0	680.28	680.37	11.7	680.27	11.73	680.28	12.0
24.5168	129986	980.0	682.60	6	12000	12.6	679.13	679.65	10.8	679.13	10.81	679.13	12.6
24.5015	129889	880.0	680.70	50	12000	12.7	677.78	678.40	10.2	677.79	10.22	677.78	12.7
24.4863	129793	780.0	679.00	bank	12000	9.7	677.46	677.51	9.4	677.41	9.49	677.46	9.7
24.4710	129697	680.0	677.50	bank	12000	9.1	676.76	676.99	8.4	676.86	8.37	676.76	9.1
24.4557	129601	580.0	677.00	bank	12000	8.5	676.16	676.82	6.7	676.24	6.72	676.16	8.5
24.4405	129505	480.0	675.90	bank	12000	7.6	675.67	676.73	5.4	675.74	5.37	675.67	7.6
24.4252	129409	380.0	675.00	bank	12000	8.9	674.58	676.67	4.5	674.7	4.53	674.58	8.9

24.4100	129313	280.0	674.10	bank	12000	5.0	674.00	676.75	2.8	674.24	2.83	674.00	5.0
24.4022	129268	272.9	674.10	bank	12000	4.7	673.97	676.74	2.7	674.21	2.72	673.97	4.7
24.3944	129222	265.9	674.00	bank	12000	4.3	673.95	676.74	2.6	674.21	2.56	673.95	4.3
24.3866	129177	258.8	673.90	bank	12000	4.3	673.90	676.73	2.6	674.17	2.58	673.90	4.3
24.3788	129131	251.7	673.80	bank	12000	4.4	673.84	676.71	2.6	674.12	2.64	673.84	4.4
24.3711	129085	244.6	673.80	bank	12000	4.5	673.76	676.69	2.7	674.06	2.72	673.76	4.5
24.3633	129040	237.6	673.80	bank	12000	5.7	673.49	676.65	3.1	673.85	3.07	673.49	5.7
24.3555	128994	230.5	673.70	bank	12000	5.9	673.34	676.63	3.1	673.75	3.14	673.34	5.9
24.3477	128949	223.4	673.60	bank	12000	6.1	673.16	676.60	3.2	673.63	3.21	673.17	6.1
24.3400	128903	216.4	673.60	s.b.	12000	8.2	672.46	676.54	3.6	673.3	3.60	672.48	8.2
24.3366	128856	193.6	673.60	s.b.	12000	9.3	671.87	676.53	3.6	673.2	3.56	671.84	9.4
24.3333	128810	170.8	673.60	s.b.	12000	10.1	671.29	676.52	3.4	673.15	3.45	671.33	10.0
24.3300	128763	148.1	673.60	s.b.	12000	11.0	670.55	676.52	3.3	673.13	3.33	671.17	9.2
24.3266	128717	125.3	674.06	s.b.	12000	14.3	668.61	676.52	3.1	673.14	3.14	671.29	7.5
24.3233	128670	102.5	674.20	s.b.	12000	15.0	667.51	676.52	3.0	673.15	2.98	671.34	6.5
24.3200	128623	79.8	674.20	w.w.	12000	12.7	667.58	676.52	2.9	673.15	2.88	671.36	5.9
24.3166	128577	57.0	674.20	w.w.	12000	8.1	668.47	676.52	2.7	673.17	2.69	671.42	5.0
24.3133	128530	34.2	674.20	w.w.	12000	6.8	668.58	676.53	2.5	673.18	2.55	671.45	4.5
24.3100	128483	11.5	674.74	w.w.	12000	5.8	668.66	675.74	7.2	671.92	7.22	671.48	4.0
24.3000	128469	0.0	674.00		12000	9.8	667.47						