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Portland District

Bonneville Lock and Dam
Columbia River Basin, Washington - Oregon

Hydraulic Evaluation of Lower Columbia River Adult Bypass Systems (HELCRABS)

Bradford Island A Branch Interim Evaluation Report

80% DRAFT



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Executive Summary

General

The purpose of the “Hydraulic Evaluation of The Lower Columbia River Adult Bypass Systems” (HELCRABS) study program is to assess the performance of each lower Columbia River adult passage system with respect to adult fisheries criteria. Specifically the HELCRABS study program encompasses the eight fishways that bypass upstream migrating salmonid adults around Bonneville dam, the Dalles dam, and John Day dam. The HELCRABS program was created in response to questions and directives regarding fishways in the National Marine Fisheries Service (NMFS) Biological Opinion for the Columbia River (BiOp). In the BiOp Operations Division of the Portland District (CENWP-OP) is to furnish NMFS evaluation reports for each fishway by the end of 2003. Each report shall contain (a) an assessment of the existing performance of a fishway with respect to hydraulic fisheries criteria, (b) recommended operational changes to optimize the fishway performance, and (c) recommendations for a need for structural changes if adequate performance is unattainable with the existing fishway system. CENWP-OP has tasked the Hydraulic Design Section (EC-HD) to conduct this hydraulic study in coordination with the three projects. The HELCRABS program is scoped to proceed in three phases: (1) the evaluation reports for CENWP-OP, (2) the field data verification and correction/refinement of the numerical models used to conduct the evaluations, and (3) linking the models to fishway control systems so that operations can be set in the project control rooms. This report describes the results of the evaluation of the Bonneville A Branch Fishway.

The Bradford Island A Branch Fishway is one of four ladder systems at the Bonneville Dam complex that provide bypass routes for upstream migrating adults past the dam. This ladder is located at the first powerhouse and on the south shore of the Columbia River and collects fish swimming up the first powerhouse tailrace channel (See Plate 1).

HELCRABS Computer Model

This fishway evaluation uses the HELCRABS numerical computer model created to simulate the hydraulic conditions in the A Branch Fishway. The model was developed by Northwest Hydraulic Consultants (NHC) in 1995-1997 and was calibrated from limited prototype field data. A verification of this model was warranted by concerns due to the limited calibration data and issues revealed in prior detailed model evaluations from earlier HELCRABS studies. Prior to using the model for fishway evaluation, EC-HD first embarked on a plan to verify/correct the model by performing prototype flow measurements and reviewing the internal program. The model evaluations identified a number of shortfalls, and therefore a portion of the Phase 2 scope (field measurements and model corrections) had to be completed in order to conduct the Phase 1 (fishway evaluation) portion. For this particular model, a special Excel Macro was created to counteract a critical problem in the hydraulic computations of the model. The most pertinent geometry corrections and calibrations to the model were made so that EC-HD could proceed with the fishway evaluation. However, a high tailwater flow measurement

test (tailrace > 25 feet), along with the possible model adjustments must be completed before the evaluation and report can be finalized. The remaining deficiencies are not serious and may be corrected in a later phase of the HELCRABS study.

Fisheries Criteria

The adult fish passage criteria are the following:

- Elevation entrance weir crest or sluice opening invert ≥ 8 feet below tailrace level (or entrance submergence ≥ 8 feet);
- Head difference across entrances should be between 1 – 2 feet, 1.5 feet optimum;
- Channel velocities should be between 1.5 - 4 ft/s, 2 ft/s optimum;
- Ladder head should be 1.0 ft (± 0.1 ft) for non-shad passage season (Aug 16-May 14) and 1.2 ft (± 0.1 ft) for shad passage season (May 15-Aug 15).
- Diffuser efflux velocities ≤ 0.5 ft/s.
- The exit control section hydraulic drop per pool shall range from 0.5 to 1.0 feet

Evaluation of Existing Operation

The evaluation of the current operation of the existing A Branch Fishway revealed the following cases where fishway criteria are not met:

- When tailrace levels < 10 ft (approximately 9% of the time during the main fish passage season, 1 March through 30 November); the entrance submergence is less than 8 feet;
- Low channel velocities (<1.5 ft/s, 1.0 ft/s in several cases) persist in the north and middle sections of the powerhouse channel.
- The diffuser velocity criteria (0.5 ft/s max) are currently exceeded mainly at diffuser FG3-4 in the north conduit, which runs typically at about 0.7 ft/s, and as high as 0.9 ft/s in the worst case.
- The average head drop in the exit section between 0.20 feet at low forebay (71.5 feet) and 0.46 feet at high forebay (76.5 feet) is lower than criteria.
- The ladder head at weir 54, on the upstream side of the Junction pool, is about 0.1-0.3 ft below ladder head criteria.

The first criteria conflict is caused by the physical limitations of the system (minimum invert for the both entrance locations is elevation 2 ft). The Bonneville tailwater falls below the 10-foot level threshold about 9% of the time. This can only be corrected by an expensive structural modification or by imposing a major limitation in project operation.

The second problem (channel velocities) is caused by the fact that the north and south entrance share the powerhouse channel. The north entrance removes a large portion of the flow from the channel leaving little flow to continue past the junction to the remainder of the powerhouse channel. Continuing downstream in the powerhouse channel, the flow rates and velocities will gradually increase to acceptable levels with the added diffuser flows along the way. However there is a section just downstream of the north entrance junction that is chronically slow and below criteria about 90% of the time.

Also when tailwater levels are less than 25 feet (about 90% of the time), the distance for which the channel velocities are below criteria (1.5 ft/s) levels will extend all the way down to powerhouse telescoping gate 34, about midway down the channel to the south entrance.

The third problem (diffuser velocities) results from the current operation of AWS control valve FV3-7 and the diffuser schedule along the north conduit. A higher volume of flow tends to go through diffuser FG3-4 than adjacent diffusers with velocities as high as 0.9 ft/s through the diffuser grating. Diffuser velocities through the remaining diffusers along the north AWS conduit are maintained at approximately 0.5 ft/s and are less than 0.3 ft/s through diffusers fed by the south conduit.

The fourth problem—low head in the exit section—is due to a change in design criteria since the section was constructed 30 years ago. Project biologists have not observed problems with fish passage in the exit section.

The low head at ladder weir 54 (and to a lesser degree at weir 55) is caused by a longer overflow crest length. The crest length at weir 54 is 57 ft, compared a length of 42 ft at the ladder control station weir 67. Thus the head at weir 54 will be 0.2 ft and 0.3 ft lower than control weir 67 at ladder controls head of 1.0 ft and 1.2 ft respectively.

A significant factor in the slow powerhouse channel velocity problem is the inconsistent and unpredictable operation of the south entrance weirs (WG-2 or WG-1) with respect to tailrace level. The current programmable logic control (PLC) mandates the minimum 8 feet submergence but does not regulate a maximum submergence level. Instead the PLC adjusts the south weirs according to entrance head limits and the weir crest elevation is not confined to any particular level between the required minimum 8 feet submergence and the bottom weir position. At the same time, the fish valve FV1-1, for the south AWS conduit, is also operated within specific entrance head limits. The settings for the south entrance weir and FV1-1 are interdependent and neither is specifically tied to the tailrace level. Consequently for an equivalent tailwater level on different days, the level of the south entrance weir will not be the same but instead will vary as a function of the history of tailwater levels leading to the present. For an equivalent tailwater level, the range of potential positions in weir crest or submergence can be between 5 to 8 feet. This uncertainty and variability in the operation of the south entrance weir will lead to inconsistency in the velocities in the powerhouse channel for equal tailwater levels.

The sonic velocity meter, located at the north end of the powerhouse channel, is set at too low in the channel (elevation 1.0 ft) to provide a reasonable estimate of the average channel velocity. With the sensor velocities averaging about 20% - 50% lower than the actual cross-sectional average velocity, the sensor provides misleading information on the systems performance with respect to criteria. Also the data readings are highly variable and should be averaged over a set time increment.

Recommended Changes to the Operation

Operational changes can improve--but not fully solve--the problem with respect channel velocity criteria for most tailrace levels. Proposed operational changes include:

- Change the PLC to tie the south entrance weirs (WG1 or WG-2) directly to the level of tailwater.
- In revising the PLC, set the south entrance weirs (WG1 or WG-2) to operate at maximum levels of submergence that will be allowed by the system without exceeding other hydraulic or operational criteria.
- Relax the diffuser velocity criteria to operate less than 1.0 ft/s.
- Stack the open diffusers (FG2-17 – 22) on the north side of the powerhouse channel by opening diffusers FG2-17 & 18 and closing diffusers FG 2- 4, 8, & 12.
- As an emergency precaution, reinstate Programmable Logic control (PLC) feature that incrementally closes fish valve FV1-1 if the pressure difference between South AWS conduit and powerhouse channel exceeds 10 pounds per square inch (psi).

The recommended operation of the entrance weir gates and diffusers is displayed in tabular form in Plate 13 for tailwater levels between 7 and 35 feet. For comparison, the existing operation schedule is shown in Plate 12.

Revising the PLC will guarantee a consistent and more optimum fishway performance for each tailwater level. Operating the south entrance weirs at deeper submergence will draw more flow and raise velocities in the powerhouse channel. The bulking of the open diffusers to the north side of the powerhouse channel will increase the average velocity along the powerhouse channel. The PLC close command for FV1-1 was a structural protection feature that was deleted when the AWS pressure transducer in the south conduit became unreliable. The transducer has since been recalibrated and the PLC feature should be reinstated. With the proposed operational changes, the channel velocity criteria will be met at most locations along the powerhouse channel, and more often at the sonic sensor location at the north end (by about an additional 30% of the time). Even though the criteria will not be met 60% of the time at the north end, the velocities will still be improved about 10-50% in this area. The revised plan will need to be field tested by the Project before incorporation into the Corps Fish Passage Plan.

Potential Structural Improvements

Recommended potential alternatives for structural changes include:

- Raise diffuser gratings to match original invert (elev. 0.0).
 - This would improve flow efficiency in the powerhouse channel and from the diffuser, raise average powerhouse channels velocities up to 20-25% at minimum tailwater levels, and increase diffuser grating areas so that they are less susceptible to being lifted off when plugged.

- Add non-overflow weir crests to weirs 54 and 55 so that the lengths of the overflow sections are equal to those of weirs 56-67.
 - The weir heads vary between weirs 67 and 54, as overflow weir crests are wider at weirs 54 and 55 than the rest. The addition of non-overflow weir sections at these two weirs would guarantee uniformity in overflow weir lengths and ladder heads throughout the section.
- Raise location of north powerhouse channel sonic velocity meter to elevation 5.5 feet.
 - Setting the meter at a higher level will provide data that is more representative of the powerhouse channel velocity at north end. Add time averaging feature to reduce the high variability in output.
- Either narrow north entrance openings or add vertical slot to upstream side of each north entrance bay.
 - A greater volume of flow can be induced down the powerhouse channel (to improve velocities) by either reducing the flow to the north entrances or by enlarging the south entrance opening. Reduction of flow to the north entrances could be accomplished by either narrowing the north entrance openings or by adding a vertical slot to the upstream face of each north entrance bay.
- Replace modulating south entrance gates with wider, shaped, fixed weir.
 - Increasing flow to the south entrance could be accomplished by replacing the south entrance weirs with a wider fixed shaped weir (the widths of the entrance channel bays are 9.67 ft, wider than the 8 to 8.25 feet weir slots).

Other more substantial and costly structural alternatives include (a) the lowering of the powerhouse channel invert and entrance openings to at least –1 feet elevation and (b) remove the number of vertical slot baffles in the exit section channel. The lowered invert and minimum entrance crest will allow the fishway system to meet the 8 feet minimum submergence for the full range of project tailrace levels. If the head criteria violations in the exit section are deemed unacceptable, the section would need to be overhauled by essentially reducing the number of pools by half.

Recommendations for Future Model Improvements

In addition, EC-HD recommends that work proceed on Phase 2 and Phase 3 of the HELCRABS study program for this fishway. (For A Branch Fishway, a new model is recommended for Phase 2 so that it may be run on windows 2000 computers and to provide greater flexibility and accuracy than the revised current model; Phase 3 includes model enhancements, such as better graphical output and model results linked to the project control system.) This will ensure greater model accuracy and allow the project personnel to make greater use of the model to monitor the fishway performance. Since a portion of the Phase 2 work was required to complete Phase 1, it is also recommended that the scopes of work for the remaining fishway systems be merged in to two phases rather than three described earlier. Phase 1 would conduct the fishway evaluations with

the necessary corrections to the model and Phase 2 would comprise final corrections, refinements and enhancements to the model.

1.0 Introduction

The Bonneville Project is located on the Columbia River, 42 miles east of Portland, Oregon on river mile 146. The Bradford Island Adult Fishway consists of two branches; the A Branch that serves the first powerhouse channel and the B Branch that serves the spillway channel. The A and B Branches share a common counting station and exit section. The A Branch located on Bradford Island and runs along the downstream face of the first powerhouse. This fishway was put into service concurrently with the first powerhouse in 1938. Over the next four decades, modifications were made to the entrances, auxiliary water supply (AWS) system, diffusers, fish valves, exit section, and forebay ladder control system.

The Hydraulic Evaluation of Lower Columbia River Adult Bypass Systems (HELCRABS) is a program developed to respond to the National Marine Fisheries Service (NMFS) Biological Opinion (BiOp). The BiOp in Section 9.6.1.6.3 Adult Fishway Operating Criteria states “The Corps annual fish passage plan stipulates operating criteria for the Federal Columbia River Powers System (FCRPS) hydro project adult fishways. Where these criteria are not satisfied, incremental adverse effects to adult migrants (such as delay) may occur. Actions to enhance compliance with fishway criteria include auxiliary water system assessments and upgrades. Other actions address the issue of inadequate fishway entrance weir submergence during low tailwater elevations”.

The BiOp also states under Reasonable and Prudent Action (RPA) 120: “The Corps shall develop improved conditions for adult fishway main entrances at FCRPS dams so that the best possible attraction conditions are provided for adult migrants, both at the Columbia River hydro projects and the four lower Snake hydro projects (where reservoir elevations are held near minimum operating pool (MOP). The Corps shall report the findings of fishway entrance flow-balancing investigations in a report to National Marine Fisheries Service (NMFS) by the end of 2001¹ and shall continue to work through the Fish Passage Operations and Maintenance (FPOM) group to evaluate and implement, as warranted, structural changes to satisfy fish passage plan fishway entrance criteria”.

Under previous scopes of work in the HELCRABS Program, the Portland District (CENWP) contracted Northwest Hydraulic Consultants (NHC) to develop computerized numerical models to analyze the hydraulics for adult fishways at NWP Columbia River Dams. Computer models have been developed for Bonneville Dam Fishways – A and B Branches, Cascades Island, Bonneville Second Powerhouse, John Day Dam Fishways – North and South, The Dalles Dam Fishways – North and East. During operation and further review of the model, a number of deficiencies or limitations were identified.

The HELCRABS program scope is currently planned to progress in three phases. This evaluation report is the product of Phase 1. Phase 2 includes field verification measurements and corrections and refinements to the model. Phase 3 will introduce

¹ The HELCRABS reports are being prepared for this purpose.

possible long-term plans integrating the model with the project control system. Portions of Phase 2 were completed to ensure an accurate evaluation for Phase 1.

This report documents the evaluation of the Bradford Island A Branch Fishway using the numerical model. Most importantly, recommendations are presented for revised fishway operations that will satisfy fish passage criteria under most conditions. Some structural alternatives to further improve fishway performance are presented as well. An evaluation of the numerical model is also provided in the report (Section 3.2, Appendix A & B) including the field verification measurements, the findings on model limitations, the corrections made to the model to conduct the evaluation, and recommendations for future corrections and refinements to the model (See Appendix A and B for more detail).

2.0 Fishway System Features

2.1 Fishway History

As stated earlier in Section 1, the A Branch Fishway originally came on line in 1938. The original general layout of the A Branch Fishway differs from the present layout only in the length of the powerhouse collection system and the location of the counting station. The original entrances were comprised of six to each powerhouse unit, two at the north end, and three at the south end of the first powerhouse. Three of the six entrances in each powerhouse unit were operative; the others closed with timber barriers. The collection channel connected the fish ladder at the north end of the powerhouse with the entrances to the fish lock to the south end of the powerhouse.

Operating criteria for the fishway required an upstream head of approximately 12 –15 inches on each weir of the fish ladder, an average channel velocity of 1 to 2 fps in the flooded portions of the fish ladders and in the powerhouse collection channel. For river flows greater than 178,000 cfs, a minimum depth of 6 ft with an average velocity of 4 ft/s over entrance gates was required.

The conventional pool-type fish ladders have been the primary means of passing fish over Bonneville Dam. The fixed weirs (weir 67 and downstream) have always been operated with two submerged orifices in each weir. Above the fixed weirs, the adjustable or stop-log weirs 69-79 were operated by placing or removing the stop logs that formed the crest of the adjustable weirs to absorb seasonal variations in pool elevations. The stop logs were placed to maintain a 1-ft differential between weirs, and sufficient water was introduced over the head gates at weir 82 to provide the desired head of 12 to 15 inches on the weirs. As designed and operated until 1950, flow from the forebay into the ladders was regulated by adjusting the overflow over the three pairs of mechanized head gates in conjunction with the columns of steel segmental gates at weirs 80 to 82.

Studies between 1976-1978 indicated entrances at the ends of the collection channel near the shoreline were the favored points of entry and fish passage could be improved with weir-type entrances. The study also found that the main unit gated orifice entrances were used infrequently by fish and actually were points where fish fell out of the collection channel back into the tailrace. Hence, the number of operational gates was reduced from twenty to five: leaving only powerhouse telescoping and orifice gates 9, 21, 34, 58 and 62 operational. The remaining orifice gates, operators, and automatic controls were removed and the openings were blocked with concrete stoplogs to minimize future maintenance requirements.

Changes have also been made to the diffusers in the A Branch ladder. Original wood diffusers were replaced by metal grating placed directly over the openings upon concrete supports below the invert. The wood diffusers matched the channel invert, whereas the channel floor levels at the diffuser openings are now 2 feet lower than the rest of the

channel. There is also an increased risk of blowing out the diffuser covers with the higher upward velocities through the grating due to the reduced cross-sectional flow area.

The modifications for peaking were implemented in the late 1970's and early 1980's to create more Project capacity for peaking power. The maximum operational limits of the Project forebay were raised from 75.5 feet to 77 feet. During these modifications, several major changes were made throughout the Bradford Island fishway system to accommodate the project changes and improve fish passage efficiency.

- A new exit section with a counting station and ladder makeup water supply system was installed,
- The crest lengths and elevations for the ladder weirs were altered in several places.
- The orifices were originally arranged in pairs that alternated sides between adjacent weirs. The inner, or middle, orifices were blocked and new orifices were cut into the opposite sides of the channel to produce the existing symmetrical design.
- The powerhouse telescoping sluice gate entrances were upgraded to the current configuration.
- Telescoping weirs were constructed in entrances 1 and 65 for high tailwater at the north and south entrances
- Sluice gates for underflow would be operated in entrances 2 and 64 at low tailwater at the north and south entrances.
- The orifice sizes of the diffuser gates in the south AWS conduit were reduced at all diffusers but the north end.
- Cut two additional diffuser gate orifices (FG2-22a & FG2-22b) to discharge into the same diffusion chamber for FG2-22. The result is one diffusion chamber is fed from three diffuser orifice gates: FG2-22, FG2-22a & FG2-22b.
- The main drop intake to diffuser FG3-3 was blocked and a smaller orifice was cut into the AWS conduit floor to reduce the inflow rate into this diffuser.
- The diffuser gate FG3-6 is held open at 1.5 feet, when otherwise closed. This is to provide the balance of flow (about 60 cfs) to maintain ladder heads for weir 22 and below. The lower weirs have longer overflow crests than the upstream ones.
- An accelerator wall was installed at downstream end of the junction of the north entrance and powerhouse channel to increase the local velocities into the north powerhouse channel.

The entrances were modified again in 1995. Before the changes, the openings at entrances WG-2 and WG-64 were controlled by sluice gates that closed from the top. They were replaced by weirs that telescope from minimum level 2 feet to provide greater submergence and operate under the low to medium tailrace levels. An extra weir leaf was also added to entrance WG-1 to allow a greater range of motion.

Between the 1980's and 2002, the number of operating powerhouse telescoping and orifice gates was five: # 9, 21, 34, 58, & 62. At the beginning the 2003 fish passage season, the powerhouse telescoping gates were permanently closed. This decision was

coordinated through the regional agencies. The weir entrances WG-1, WG-2, WG-64, & WG-65 are the sole remaining entrance openings.

2.1 Existing Fishway

The A Branch fishway is located on the north side of Bradford Island and continues along the face of the first powerhouse (See Plate 1). The ladder is approximately 1225 ft long and ranges from 30 ft to 40 ft wide. The slope is 1 on 16. The A and B Branch Fishways join at the Junction Pool to share a common exit section. The common exit is approximately 480 ft long and 40 ft wide (See Figure 1 for a photo of the North powerhouse with north entrances, A branch Ladder and the common exit section).

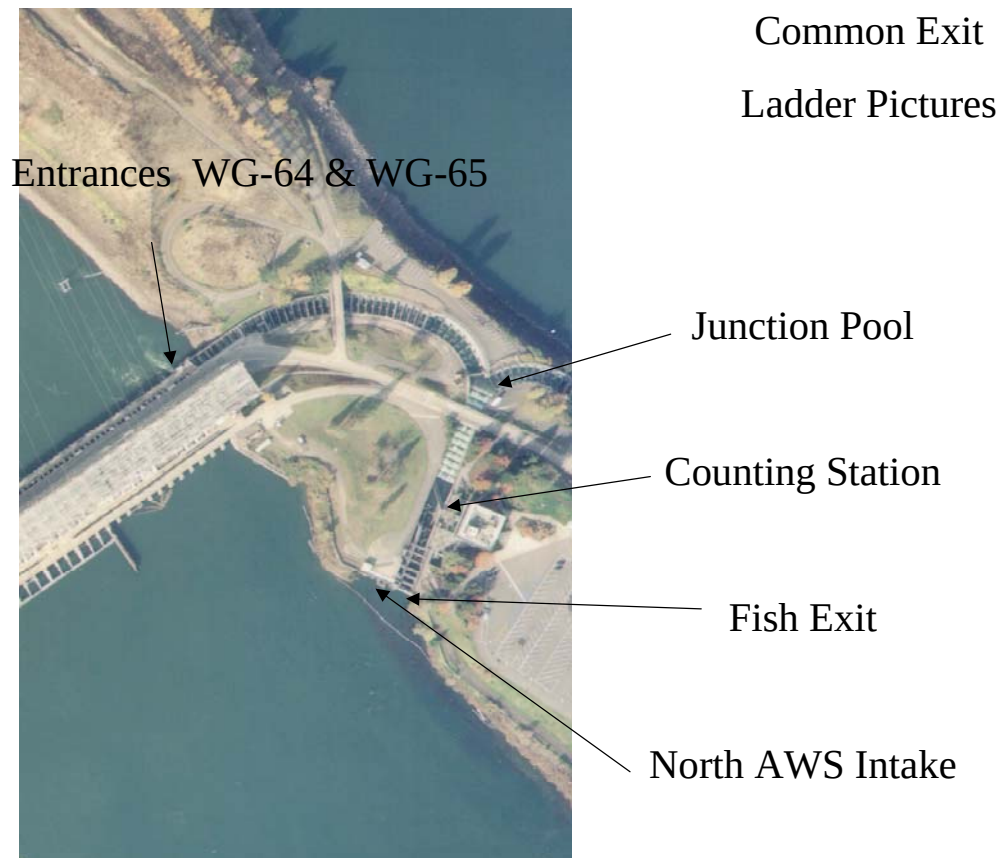


Figure 1: Aerial Photo of A Branch Ladder, North Entrance, and Bradford Island Exit Section

2.1.1 Entrances

Fish access to the ladder is through four main fishway entrances: two at each end of the first powerhouse collection channel. The entrances are labeled Weir Gate (WG) -1 (weir gate) and WG-2² at the south end of the powerhouse and WG-64 and WG-65 at the north

² In the 2003 Fish Passage Plan, weir gates WG-2 & WG-64 are actually labeled SG-2 & SG-64 (SG for sluice gate). This designation is passed down from an earlier era when they were actually sluice gates. In this report, these gates will be denoted as WG-2 & WG-64 to maintain logical consistency with the labels of the other entrance weir gates.

end. At each entrance location, only one weir gate is operated at a time, the gate selection being a function of tailwater level. Entrance locations are shown in Plate 2. Plan views of the north entrance location is shown in Plate 3 and the south entrance location is shown in Plate 4. Figure 2 shows a photo of north entrance weir gate WG-64.



Figure 2: Photo of North Entrance Weir Gate WG-64

The weir gates, WG-2 and WG-64 are both 8 ft wide and operate at the low to medium tailrace levels (<26 feet). Both weir gates have a minimum crest elevation of 2 ft. WG-2 can be raised to elevation 11 feet and WG-64 can be raised to 18 feet. The weirs, WG-1 and WG-65 are both 8.25 ft wide and are adjustable to from elevation 8.5 ft to 26 ft. The Weirs 2 & 64 are operated below a maximum tailwater level of 26 feet, and weirs 1 & 65 are operated above a minimum tailwater level of 23 feet. The dead-band is the 3-foot difference between tailwater levels for rising and falling tailwater conditions. Plate 5 shows the details of WG-1 and WG-65, the high tailwater weirs. (The configurations of WG-2 and WG-64 are similar, but with different minimum and maximum weir crest elevations).

The operation of the entrance weir gates is specific to each entrance weir gate as shown in Table 1. Each weir gate is specified in the first column. The second column lists a limit condition (usually entrance head) for which the PLC will activate the weir to move it position. This action is shown in the adjacent cell (col. 3) to the limit condition (col. 2). Adjacent to the action cell (fourth column) are the constraints upon the PLC action. The fifth, or rightmost, column shows the references sensor locations, which provide the pertinent data to the PLC program. For an example PLC action at WG-1 (top row):

when the entrance head falls below 1 foot, the PLC will command the weir to be raised as long as it does not go above the minimum 8 feet submergence or the maximum weir elevation 26 feet. The tailwater and channel sensors at the south end of the powerhouse provide the data that will activate and guide this PLC operation.

Table 1: Programmable Logic Control Program for Operation of A Branch Entrance Weir Gates

Entrance Weir Gate	Condition	Action	Constraints	Reference Sensor Locations
WG-1: (South-high: TW>23 ft. falling TW)	<1 ft. differential	Raise (close):	Min. 8 ft. submergence or Max. Weir Elev. 26.0 ft.	South TW and Channel
	>1.5 ft. differential	Lower (open):	Min. Crest Elev. 8.5 ft.	South TW and Channel
WG-2: (South-low: TW <26.0 ft. rising TW)	<1.2 ft. differential	Raise (close):	Min. 8 ft. submergence or Max. Weir Elev. 11.0 ft.	South TW and Channel
	>=1.5 ft. differential	Lower (open):	Min. Crest Elev. 2.0 ft.	South TW and Channel
WG-64: (North - low: (TW <26.0 ft. rising TW)	<1.4 ft. differential OR >8.6 ft. submergence	Raise (close):	Min. 8 ft. submergence or Max. Weir Elev. 18.0 ft.	North TW and Channel
	>=1.6 foot differential OR <8.0 foot submergence	Lower (open):	Min. Crest Elev. 2.0 ft.	North TW and Channel
	TW < 10 feet	switch to differential control:		
	TW >13.7 feet	switch to submergence control		
WG-65: (North-high: TW >23 ft. falling TW)	>8.8 ft. submergence	Raise (close):	Min. 8 ft. submergence or Max. Weir Elev. 26.0 ft.	North TW and Channel
	<8.0 ft. submergence	Lower (open):	Min. Crest Elev. 8.5 ft.	North TW and Channel

The chief difference between the north entrance and south entrance gates is the weir submergence control operation. The north gates operate with maximum submergence levels (8.6 feet for WG-64 and 8.8 feet for WG-65); whereas the south weir gates are not constrained by a maximum submergence level other than imposed by the minimum crest elevations. All gates are held to a minimum 8 feet of submergence, however the south gates may drift to deeper levels of submergence depending on antecedent tailwater levels. As the tailwater fluctuates, the south entrance weirs (WG1 or WG2) will adjust before South AWS conduit fish valve FV1-1 moves since the bandwidth of entrance heads that activate the weirs is narrower than that of FV1-1—which only adjusts if either the active weir gate runs up against physical constraints (maximum or minimum weir elevation) or minimum 8 feet submergence. If the tailwater fluctuates wildly, the FV1-1 will be forced to move, which means the active south entrance weir will probably not return to the same position that it held when it was at the same tailwater level before.

With the operational limits of WG-2 being between elevation 2 feet and 11 feet, the weir setting is known when the tailwater is less than 10 feet. At tailwater 19 or higher, the weir may be at 11 feet or less. As the tailwater rises above 19, the weir will eventually rise to the upper limit 11 feet, but it is not known at precisely what tailwater this will occur, and it might be different if valve FV1-1 has a different opening between one case and the next. This means for WG-2, the level of the weir is uncertain for tailwater levels between tailrace 10 – 26 feet. Likewise, the operational limits of WG-1 are between 8.5 and 26 feet. With the lowest operating tailwater being 23 feet, the weir could be anywhere between 8.5 and 15 feet for that tailwater. This holds true of any tailwater above 23 feet, even above 34 feet where the weir will stop rising to meet 8 feet of submergence—as it may be lagging at a far deeper level than required by the minimum submergence. Thus the level of the south entrance weir is uncertain for all tailwater levels above 10 feet.

2.1.1.1 Powerhouse Telescoping & Sluice Gates 9, 21, 34, 58, & 62

There are a total of 63 bulkhead slots (typically 6 per turbine unit) that form the west sidewall between the powerhouse collection channel and the tailrace. Starting from WG-2 at the south entrance, these slots are numbered from 3 to 63 from south to north, ending at WG-64. Up through 2002 fish passage season, five slots were equipped with special bulkhead assemblies with telescoping and sluice entrance gates at slots 9, 21, 34, 58, and 62.

Plate 6 shows a detailed drawing of a typical powerhouse telescoping and sluice gate. Each of these bulkheads assemblies has two orifice gates: one high and one low. Only one orifice is open at a time at each slot during operation. The flow openings for both high and low gates are 6 feet high by 2 feet wide orifices--considerably smaller than those at the main entrances. The bottom of the low orifice opening is elevation 4 feet and 10 feet for the upper opening (operated when tailwater > 16 feet).

Starting in 2003 fish passage season, these last five powerhouse gates were permanently closed off with bulkheads.

2.1.2 Powerhouse Collection Channel

The powerhouse Collection Channel runs along the downstream (west) face of the First Powerhouse (See Plate 2). This channel conveys fish from the south entrances to the north entrances and ultimately to the fish ladder over the dam. The powerhouse channel is 896 feet long and 17.58 feet wide. The design invert is elevation 0.0 feet. However floor diffusers take up most of the channel floor. Originally, the floor diffuser openings were covered by wooden gratings that were flush with the 0 invert. The wood grating panels were later replaced by metal grating panels, which rest on the concrete baffle beams two feet below. Consequently most of the channel invert is actually at elevation – 2 feet. If the diffuser gratings were raised to match the original invert, the hydraulic efficiency would improve and the average powerhouse channel velocities would increase, particularly at low tailrace levels.

2.1.2.1 Accelerator wall

An accelerator wall was installed in the north end of the powerhouse channel during the early 1980's. (Plate 3 shows a plan & cross-section of the accelerator wall.) The wall was installed to force higher local velocities from the junction into the powerhouse channel during lower tailwater condition. The wall is located in a bulkhead slot at the south end of the junction for the north entrance and at the south (downstream) end of diffuser FG2-22. The wall blocks a six-foot wide section of the west side of the channel. The wall extends from the invert up to elevation 13 feet. The benefit is strictly local to the wall opening location and the wall does not contribute to improved velocities immediately downstream in the powerhouse channel—in fact the flow into the powerhouse channel may be slightly retarded by the impedance of the wall, up to 30% of the channel cross-section at low tailwater levels. However, the wall may provide a potential secondary benefit of a biological nature: the wall, being on the west side of the channel, will push the passing fish more to the east side of the channel and away from the entrance bays for WG-64 and WG-65. Consequently, the fish may be less likely to fall back through the north entrances.

2.1.3 Auxiliary Water Conduits

An Auxiliary Water Supply (AWS) is used to furnish most of the attraction flow for the entrance openings and augments flow in the collection channel and lower submerged ladder section. The AWS flow is supplied through conduits from the forebay and is released through diffusion chambers located under the floors of the collection channel and certain lower ladder pools. There are two forebay intakes for the A Branch AWS. Plate 7 shows a detailed plan view of the AWS conduits. Plate 8 shows a schematic of the AWS for nodes and links that are simulated in the Kentucky Pipes program of the HELCRABS model. Plate 9 shows a typical diffuser layout (from B Branch) and Plate 10 shows all of the fish valves, FV1-1, FV3-7 and FV3-8.

2.1.3.1 South AWS conduit and Fish Valve 1-1

Fish Valve 1-1 (FV1-1) feeds the south end of the A Branch system and the powerhouse collection channel. It is located on the north side of the old navigation lock and supplies auxiliary water to the powerhouse collection channel through diffusers Fish Gate 2-1 (FG2-4) through FG2-22B. (Fish Gates are slide gates used for opening diffusers and are designated with 'FG' numbers). Originally all the diffusers for the south conduit had 4-foot square orifices. During the modification for peaking in the 1970's, smaller orifice plates were installed at most the of the FG2 diffusers to induce a higher proportion of discharge from the diffusers at the north end (FG2-22) of the conduit. All FG2 diffusers are left in manual mode and the same diffusers are open regardless of tailrace or forebay levels.

FV 1-1 is operated by a programmable logic control (PLC) that receives pressure transducer data from the tailrace, powerhouse collection channel and AWS conduit at 3 locations: the south end, north end and middle of the powerhouse channel. The valve is operated to maintain an average entrance head between 1.0 and 1.9 feet. As noted previously in the description of the fish entrance operations, FV1-1 rarely adjusts compared to entrance gates WG1 or WG2, since the FV1-1 controlling bandwidth for

entrance head differential is greater than those of the weir gates. The valve only adjusts when the weir gates either encounter physical constraints or minimum 8 feet submergence. Valve FV1-1 is typically about 3 feet open.

In previous years, pressure constraints had been imposed in the control program to limit pressure differences between the AWS and the collection channel to 10 psi. However, this control program feature was dropped when the pressure gages became inaccurate. During the 2003 in-water work season, the AWS gage was recalibrated. It is recommended the maximum pressure control logic feature be reinstated to protect the internal structure of the AWS conduit.

Table 2 lists the diffuser numbers, revised orifice dimensions and the operation of the diffuser gates. In addition to the variable orifice sizes, a unique feature of the system is the three orifice gates (FG2-22, 22a, & 22b) that discharge into a single diffusion chamber. This chamber is located at the north end of the powerhouse channel opposite the north entrance bays.

Table 2: Orifice Dimensions and Gate Settings for FG2-1 through FG2-22b

ORIFICE DIMENSIONS OF FG2-1 -22b			
Diffuser Gate Number FG2-	Original Opening (ft)	Revised Opening (ft. , in.)	Normal Operation
1	4	4'	manual closed
2	4	4'	manual closed
3	4	4'	manual closed
4	4	2' 6"	manual open
5	4	2' 7"	manual closed
6	4	2' 8"	manual closed
7	4	2' 8"	manual closed
8	4	2' 9"	manual open
9	4	2' 10"	manual closed
10	4	2' 11"	manual closed
11	4	2' 11"	manual closed
12	4	3'	manual open
13	4	3'	manual closed
14	4	3'	manual closed
15	4	3' 1"	manual closed
16	4	3' 1"	manual closed
17	4	3' 1"	manual closed
18	4	3' 1"	manual closed
19	4	3' 1"	manual open
20	4	3' 1"	manual open
21	4	3' 1"	manual open
22	4	4'	manual open
22-a	4	4'	manual open
22-b	4	4'	manual open

2.1.3.2 North AWS conduit and Fish Valve 3-7

Fish Valve 3-7 (FV3-7) feeds the north end of the A Branch. It is located upstream of the Bradford Island Counting Station near the fish ladder exit (see Plate 2 and Plate 11). It supplies additional water to the lower ladder pools through diffusers FG3-9 through FG3-3. FV3-7 is operated by the PLC according to the level of the forebay and the tailrace. Tailwater elevation is divided into ranges, within each specific tailwater range, valve position is determined by forebay elevations, in accordance with printed control curves. Table 3 shows the FV3-7 valve opening as a function of the tailwater and forebay levels (reference: Control Curves for Tainter Valve FV3-7, provided by Bonneville Project operators). There is a 0.5-foot dead band³ between each band (or range) of tailwater levels.

³ A dead band is the amount of overlap allowed between controlling levels to prevent excessive and unnecessary valve movement. For example under a rising tailwater (TW) condition where the

Table 3: FV3-7 Valve Opening Schedule Versus Tailwater and Forebay Elevations

FV3-7 Valve Openings in Feet					
Band of Tailwater Levels		Forebay Elevations (feet)			
Min. TW	Max. TW	72	74	76	78
8.0	14.0	1.4	1.3	1.1	
13.5	17.0	2.3	2.1	2.0	1.8
16.5	20.0	3.6	3.5	3.1	3.0
19.5	25.0	4.7	4.2	4.0	3.6
24.5	28.0	5.9	5.4	5.0	4.7
27.5	31.0	6.9	6.4	5.9	5.5
30.5	> 31	7.5	7.0	6.5	6.2

Diffusers FG3-13 through FG3-10 have been permanently closed. Thus, the highest diffuser is now FG3-9 at weir 31. The dimensions for the orifices are 3 feet square. Diffuser FG3-6 is continuously held open at 1.5 feet to provide approximately 60 cfs to augment a pool section where the ladder is widened. During the Modifications for Peaking, the downwell opening for FG3-3 was plugged and a smaller floor intake (5.5 ft by 1.33 ft) was cut into the AWS floor. Table 4 lists the diffuser numbers and the operation of the diffuser gates.

Table 4: Diffuser Gate Operation for FG3-3 Through FG3-9

Diffuser Gate Number FG3-X	Gate is Open at Nominal Tailrace Levels
3	> 8'
4	> 13.5'
5	> 16.5'
6*	> 19.5'
7	> 25'
8	> 28'
9	> 31'

* FG3-6 is held open at 18-inches when closed

TW < 31 ft, the valve will not change until the TW > 31 ft. Conversely in a falling TW condition where the TW > 31 ft, the valve will not change position until the TW < 30.5 ft.

2.1.3.3 Fish Valve 3-8

The two AWS conduits meet at Fish Valve 3-8 (FV3-8), which was designed to maintain a 4.16-6.0 psi head differential between the AWS conduit and fish ladder, but is currently left in a closed position. When it was used in the past, there were problems with transients or sloshing between the north and south AWS conduits. This blocks the hydraulic connection between the north and south AWS conduits.

2.1.4 Overflow Ladder Weirs

The overflow ladder connects the north end of the powerhouse collection channel to the junction pool and exit section. The ladder is approximately 1225 ft long and ranges from 30 ft to 40 ft wide. The slope is 1 on 16. The source of ladder flow comes from Bradford Island exit section, the flow is evenly split between A and B Branch at the junction pool.

The width of weir channel is 30 feet between weirs 10 and 18, tapers to 40 feet between weirs 18 to 20, and 40 feet for the remaining weirs from 20 to 53 at the junction pool. Several of the weirs are notched at two sides to provide a limited overflow crest. There are a total of two orifice openings in each weir. The orifice openings are 2-feet square and are symmetrically oriented near each side of the channel.

The system of weirs in A Branch is complicated. The ladder systems is comprised of the following distinct segments:

- Weirs 10-15
- Weirs 16-53
- Junction pool
- Weirs 54-67

2.1.4.1 Weirs 10-15

Unlike all other weirs in the Bonneville system, the overflow crest elevations for these weirs do not match the weir numbers. Another difference is that the head difference between adjacent weir crests is 1.25 feet, instead of 1.0 foot as with all the rest. These weirs are not notched. The respective combination of weir numbers and weir elevations are provided in Table 5 below.

Table 5: Weir Dimensions for A Branch Weirs 10-15

Weir Number	Crest elevation (feet)	Channel width (feet)	Crest Length (feet)	Non-overflow Length (ft)	Non-overflow crest (ft)
10	8.5	30	30	0	NA
11	11.75	30	30	0	NA
12	11.0	30	30	0	NA
13	12.25	30	30	0	NA
14	13.5	30	30	0	NA
15	14.75	30	30	0	NA

2.1.4.2 Weirs 16-53

In this section, the crest elevations are equal to the weir numbers. The ladder goes through several transitions in this section. At the lower end, the weirs are 30 feet wide with no notches; at the upper end the weirs are 40 feet wide with 5.2-foot wide notches on each side. Table 6 provides all the pertinent geometry information for this section.

Table 6: Weir Dimensions for A Branch Weirs 16-53

Weir Number	Crest elevation (feet)	Channel width (feet)	Overflow Length (feet)	Non-overflow Length (ft)	Non-overflow crest (ft)
16	16	30	30	0	18
17	17	30	30	0	19
18	18	30	30	0	20
19	19	33.2	30	3.2	21
20	20	40	30.2	9.8	22
21	21	40	30.2	9.8	23
22	22	40	30.3	9.7	24
23	23	40	10.4	29.6	25
24	24	40	10.4	29.6	26
Same pattern and widths for weirs between Weirs 24 and 53					
53	53	40	10.4	29.6	55

2.1.4.3 Junction Pool

The A Branch and B Branch ladder merge at the junction pool. Weirs 54-67, the counting station and the exit section for Bradford Island are upstream of the junction pool. The water flow from the exit section is split evenly between equivalent weirs 53 for each branch. There is a permanently closed diffuser (FG3-13) in the floor of the Junction pool. Figure 3 shows a photo of the junction pool.

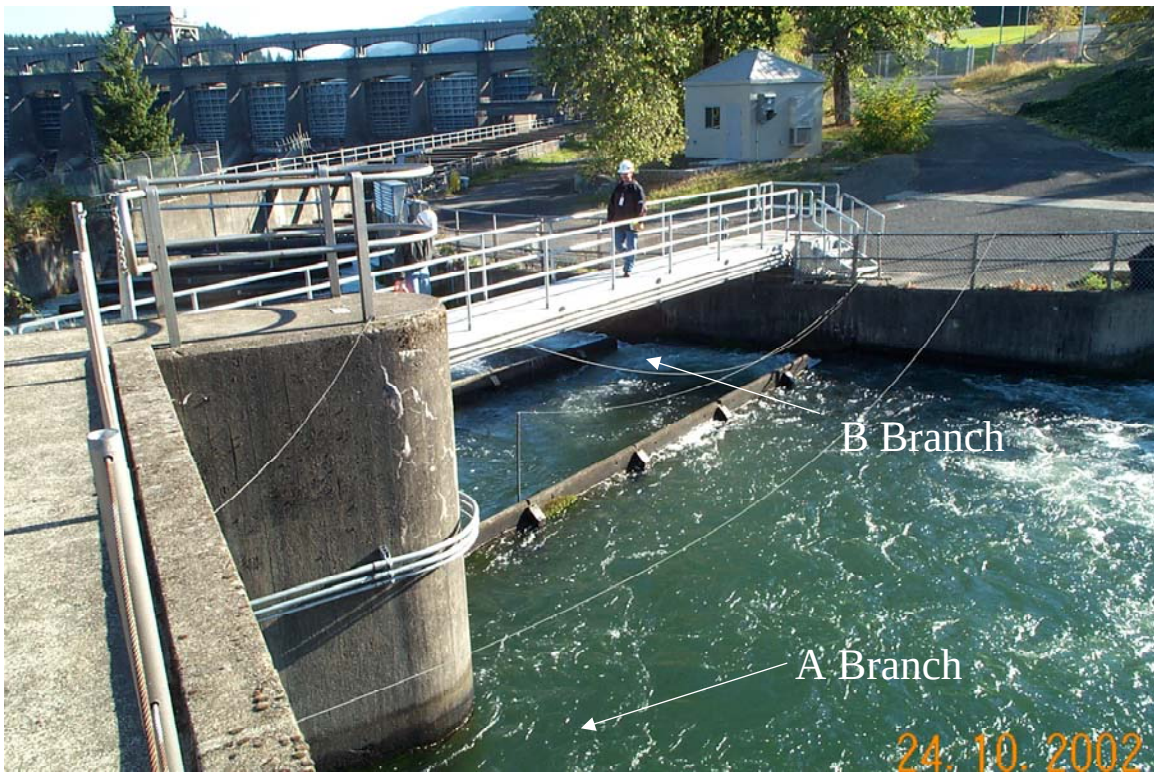


Figure 3: Photo of Junction Pool

2.1.4.4 Weirs 54-67

This series of weirs extend upstream from the junction pool to counting station and exit section. The weirs are not notched and the weir lengths are widest at the downstream end of the section. Like most other weirs, the elevation difference between weir crests is 1 foot and each weir comes with two 2-foot square orifices. Table 7 displays the weir dimensional data for this section.

Table 7: Weir Dimensions for Exit Section Weirs 54-67

Weir Number	Crest elevation (feet)	Channel width (feet)	Overflow Length (feet)	Non-overflow Length (ft)	Non-overflow crest (ft)
54	54	57	57	0	NA
55	55	47	47	0	NA
56	56	42	42	0	NA
Same pattern and widths for weirs between Weirs 56 and 67					
67	67	42	42	0	NA

At weir 67, the head above the crest is monitored for ladder control. The ladder head criteria are 1.0 foot in non-shad season (fall and early spring), and 1.2 feet in shad season (spring and summer). If the ladder head deviates beyond ± 0.1 feet from the preset target head, FV3-9 will automatically adjust to keep the ladder in criteria.

Weirs 54 & 55, the bottom two weirs in this section, have longer overflow crests than the rest of the section. This results in lower heads at these weirs that are often out of ladder head criteria. This issue is discussed in greater detail in section 4.3.1.

2.1.5 Exit Section

The exit section is the common passage for fish from both branches (Bradford Island) to the forebay on the north side of the first powerhouse. The exit section is basically divided into the following parts: the counting station, the exit channel, and the make-up water supply channel with FV3-9. Plate 11 shows a plan view of the exit section including the location of the counting station, exit channel, FV3-7, FV3-9, and the fish exit.

In the 1970's, the Bradford Island exit section was renovated when the operational limits of the forebay were raised with the modifications for peaking from a maximum level 75.5 feet to 77 feet. The modifications included new fixed vertical baffles and slots, a new fish valve FV3-9, and new fish counting station.

2.1.5.1 Counting Station and Picket lead

The fish counting station includes an approach pool with the picket lead, counting slot, exit pool, counting slot bypass, and counting room. The approach pool is just above weir 67 and has a picket lead that both guides the fish towards the counting slot and passes make-up water from the upstream FV3-9. The counting slot is a narrow section that runs adjacent to the counting room with a viewing window. The slot is 20 feet long and 3 feet wide. There is a mechanical crowder that can reduce the slot width to improve viewing access or change velocities. Design velocities are 2 – 6 ft/s in the slot, much higher than through the picket lead.

A field measurement was recorded at both ends of the slot in October 2002. With a forebay level of about 75.7 feet and a control ladder head of 1.3 feet, the velocities were measured to be 3.1 ft/s at the upstream end and 5.0 ft/s at the downstream end, both velocities well within design criteria.

A counting slot bypass is used to control the rate of flow and velocity in the counting slot and is adjacent to counting slot on the opposite side from the counting window. The picketed lead extends across the downstream opening to the slot to prevent fish entry. Inside the slot, there is a system of manually adjustable louvers that are used to regulate the flow through the slot bypass and counting slot. Figure 4 shows the counting station with the slot bypass and upstream exit pools (upper right).

2.1.5.2 Exit Channel

The exit channel consists of 17 pools separated by a labyrinth system of baffles and vertical slot openings. This channel goes from the exit pool (just upstream of the counting slot) to the fish exit to the forebay. The invert to the channel is 63 feet. The slot widths vary between 1 ft 10 inches at the upstream end to 3 ft 9 inches at the downstream end. The width of the fish exit is 2 feet 3 1/8 inches.

There are seven rectangular screened orifice openings in the west sidewall of the exit channel. The purpose of these openings is to exchange water between the exit channel and the adjacent makeup water channel. The upstream five orifices remove excess water from the exit channel. The down-stream two offices are 'add-in water' orifices.

The average head drop in the exit section was designed to range from 0.20 feet for low normal forebay 71.5 ft and 0.46 feet for high normal forebay 76.5 ft. The head drop criteria is now 0.5-1.0 feet, essentially doubled since the exit channel was designed in the 1970's. The fact that the head drops in the exit channel are below criteria does not appear to cause any delay problems according to project biologists.



Figure 4: Counting Station, Counting Bypass Slot and Exit Channel

The head drops were roughly measured between the pools with a sounding tape in October 2002 at a forebay level of about 75.7 feet. The head drops ranged between 0.3 to 0.8 feet, for an average of about 0.45 feet per pool over the whole section. The two head extremes were located in adjacent pools, which could be a result of a single erroneous head measurement. Otherwise it could be a point of concern. Elsewhere, the head drops were found to be uniform through the exit channel and the system appears to be operating as designed.

2.1.5.3 Makeup water supply system and channel

The makeup water supply system and channel augments the flow through the exit channel so that ladder head criteria are met at weir 67. The makeup water supply channel runs adjacent to the exit channel on the west side. This water is (adult) fish free--screened from at both ends. Fish valve FV3-9 regulates the flow and adjusts to maintain ladder head criteria as the forebay changes.

3.0 Numerical Model

The Bonneville A Branch numerical model was first developed by Northwest Hydraulic Consultants (NHC) under the HELCRABS program in 1995. In 1998, NHC upgraded it to incorporate the change at the entrance gates in 1996, when the two sluice gate entrances SG-2 & SG-64 were replaced with modulating weirs, WG-2 and WG-64. The numerical HELCRABS model for the A Branch Fishway produces a simulation of the hydraulic conditions within the lower and middle portions of the ladder system. The results are used to evaluate the fishway performance with respect to fisheries criteria and develop operational plans for a full range of boundary conditions (tailrace and forebay levels). The program simulates conditions at the entrances, collection channel, diffusers, and overflow ladder system up to the picket lead, where the upstream ladder head is controlled by the forebay exit and head control system (the forebay exit and ladder head control systems are not included in the simulations). The program requires the following input parameters from the user:

- Forebay level
- Tailrace level
- Open entrances (weirs and sluice gates), operated as opened or closed
- Open diffusers, operated as opened or closed
- Fish valve settings
- Head above weir crest at upstream picket lead

The program then produces the following output information:

- Entrance head and flow rates from each entrance opening
- Channel velocities and water levels in the Powerhouse collection and ladder channels
- Diffuser discharge rates and velocities
- Head, flow rates and velocities across overflow ladder weirs and orifices
- If output defaults are changed before a run; the output from the pressurized system can be obtained. This includes flow rates, velocities, and hydraulic grade line throughout the AWS conduits and diffuser branches.

3.1 Model Operation

The A Branch model is run in a DOS command prompt by entering the following in the command line:

BONNA [INPUT] [OUTPUT]

The [INPUT] file name has to be consistent for the two required input files the [INPUT].in and the [INPUT].inp file. The [OUTPUT] file can be any name except FISH,

which is an intermediate file name generated by the program. Once the BONNA command and file names are entered the program is executed and an input screen appears that allows for changing diffuser, tainter valve, entrance settings, and other values relevant to the model operations.

Once the desired settings are set in the input screen the program is set to iterate to find a solution. The program operates two main subprograms to produce a final solution. Subprograms, 'FISHBONN' and 'KPIPE', are alternately run to iterate towards a convergence in flow rates between open channel and closed conduit systems. FISHBONN simulates the open channel portion of the system including ladders, collection channel and entrances. KPIPE operates the closed conduit portion of the system (AWS), including fish valves, conduits, gates and diffusers. At completion, FISHBONN provides water levels at each diffuser to KPIPE. Conversely, KPIPE runs to return diffuser discharge rates to FISHBONN. This iterative procedure continues until the differences in flow rates between the two program routines are brought within specified tolerances.

There are three geometry files that are read by the program to conduct the simulation. A user knowledgeable of the program can modify these files (without actually modifying the model code) and change the results of the computer simulations:

- INP File - file created from the Graphical Users Interface (GUI) interface by the user; user inputs forebay & tailrace levels, open entrances, and fish valve settings.
- FDR file - file contains unchanging geometry information and pertinent head loss coefficients for the open channel portions of the system and the fish valves including the entrances, collection channel, ladder weirs, and fish valves.
- IN file - file contains unchanging geometry information and head loss coefficients (friction and minor loss) for the pressurized AWS systems including the conduits, diffuser gates, and diffusers. This is also the location the GUI imports diffuser gate status, either open or closed.

After a successful simulation, the open channel flow output are written to [OUTPUT].prn and AWS pressurized flow results are written to [OUTPUT].txt, both of which can be viewed in any text editor or printed. The files [OUTPUT].in and [OUTPUT].inp are also generated so that the model run can be repeated without having to spend time reentering information into the input screen of the program.

3.2 Numerical Model Evaluation

EC-HD evaluated the A Branch model by comparing the model outputs to our analytical expectations and prototype data collected. Through use of the model and a more detailed review of the model functions as part of this study, the following concerns have been identified:

- The program does not run on computers that have NT or WIN2000 operating systems.

- Only head data (without flow measurements) was collected in the field to calibrate the model.
- There is possible inaccurate simulation of entrance heads, particularly at low tailrace levels
- Open channel flow energy losses caused by upward flow from the diffusers were not accounted for (i.e. spatially varied flow must use force + momentum balance equations to properly compute results) in the open channel (powerhouse channel) water surface profiles.
- The model uses a sub-program called Kentucky Pipes to simulate the hydraulics in the AWS conduits. This program works off two basic assumptions which are fully or partly incorrect:
 - i. All conduits are circular and
 - ii. All flow is pressurized in the AWS conduits.
- Other deficiencies maybe discovered upon closer inspection of the program and geometry files.

As part of this study the A Branch model was evaluated to identify and correct these deficiencies so that the model could be best applied for accurate evaluation of the ladder system operation. Many of the most essential corrections were made in the geometry file so that the program could be used for this evaluation. However, a special model adjustment Excel Macro had to be developed to ensure reasonably accurate simulation of AWS flow rates and system pressures. A complete description of the evaluation, findings, and corrections to the model is presented in the following sections.

3.3 Evaluation Procedures

The evaluation process took a two-pronged strategy. The first phase was the collection of field data (including flow rates) that could be used to test the validity of the model over a range of tailwater and valve settings. The second phase was an examination of the program code and the geometry files. The results of both were used to revise the model for more accurate simulations of prototype hydraulic conditions. The following two subsections describe each process.

3.3.1 Field Measurements

Two data collection trips were conducted to provide data sets for model validation. The data collection trips were conducted on August 15 2002, October 10 2002, and July 2 2003. The third test was worked into the same day as a primary B Branch measurement and provided the highest quality measurements. These trips included flow measurements at the Ladder Augmentation Flow Channel intake, the fish exit, the North AWS bulkhead slots, the south AWS intake, and one location in the powerhouse channel. It is preferable to measure all entrances and exits in order to check continuity of flow, but it hasn't been possible to obtain direct measurements at the entrances. This problem was compounded during the August 2002 measurement, which also had 5 open telescoping gates along the powerhouse channel. (The powerhouse channel gates were closed during the Oct 2002 and July 2003 tests.) With the number that were open and the fact that the powerhouse channel runs under the powerhouse tailrace deck and is largely inaccessible makes

measurement unfeasible. The only location providing sufficient access is a portion of the channel downstream of powerhouse sluice gate #9 at FG2-3. No sources or sinks of water lie between this location and the entrance weir and therefore this measurement is representative of water exiting through the south entrance weirs. In addition to the flow measurements, the ladder settings (i.e., entrance sluice gate, diffuser, and tainter valve settings) and the water surface measurements were recorded for comparison to model output. (Project forebay was provided from the control room as well as directly measured from the powerhouse deck, while the local tailwater elevation and the powerhouse channel water surface level were taken from the first powerhouse 55 deck). The forebay, tailwater, and other water level measurements are accurate to the nearest 0.1 feet. The trip reports were prepared to provide detailed accounts of each data collection trip; which include data collection worksheets, collection conditions, data limitations and figures showing the specific locations of data collection. The trip reports are located in Appendix B.

A certain amount of error will inevitably occur in field measurements. In the case of flow measurements, the introduced error is largely a function of the location where the data is being collected. The price meter measures flow by counting the rotation of propeller cups placed into the flow. The rotation count is then converted to a velocity required to move the propeller at that speed. With fewer rotations come lower count numbers and therefore greater percent error is introduced into the measurement. Given the same count duration, locations with lower velocities, such as the AWS intakes produce higher errors. For the AWS intakes errors of 10% to 15 % are expected. (However, the pygmy meter was often applied to the low velocity conditions to significantly reduce the percent error.) For the higher velocity locations the envelope of measurement error is approximately 5%. A number of other factors can affect the accuracy of measurements such as channel geometry, lateral or vertical flow components, and sampling locations along the transect or cross-section of flow area. These were minimized by the choice of location of the transects and sampling points within the transect.

In the July 2002 test, the measuring methodology was improved for the North AWS intake. An Acoustic Doppler Velocimeter (ADV) was inserted through a price meter lead fish weight. A hinged metal rod was also attached to the weight so the ADV meter could be oriented perpendicular to the measurement cross-section. The measurements captured the velocity components normal to the cross-section, thus providing an accurate flow measurement through the intake. In addition, the total velocity magnitude could be derived from the 3-dimensional ADV data. This magnitude is the same as what would be measured by a price meter, which is unrestrained in the horizontal direction and will line up with the direction of flow. The price meter was found to often deviate from the direction normal to the cross-section. A comparison showed the average total velocity was 17% higher than the average normal velocity component that is used to compute the flow rate. This factor was used to correct the North AWS intake data from the previous data collection tests (Aug 2002 & Oct 2002), which were obtained using a price meter.

A data collection trip still needs to be conducted at a high tailwater level (> 25 feet) with entrance weirs 1 and 65 open. These higher weirs are set in different locations with respect to the obliquely oriented entrance openings from the passing powerhouse channel. The contraction coefficients of the entrance weirs will be a function of the proximity from the upstream corner of the opening to the powerhouse channel, the angle between the entrance opening and the powerhouse channel, and the general proportion of lateral flow component to the entrance flow. These values must be empirically obtained from flow measurements, such as the ones completed for the low entrance weirs 2 & 64. The model will be then calibrated for entrance weirs 1 & 65 based on the data from the high tailwater tests. This tailwater level will not occur till next spring or early summer. Until then, the A branch evaluation report cannot be finalized.

3.3.2 Evaluation of Program Code and Geometry Files

The results of a detailed evaluation of program code and geometry files are presented in the EC-HD memorandum: *Evaluation of HELCRABS Simulation Program for Bonneville "A" Branch Fish Ladder*, prepared by B. C. Cook Consulting, 2/18/2003. This memo is located in **Appendix A** of this report and is also located in the project directory under the electronic file name of 'A_Br_Model_Eval_MEMO'. [Link to File](#).

There is also an attached Errata memorandum in Appendix A that was developed after the Cook memo was completed because new information became available regarding the geometry and operation of the system. The new information came from a combination of Project operator sources, discovery of pertinent & relevant calculations from the Modification for Peaking era, and most significantly, the improved flow measurement testing results. The result of this new information was that the minor loss coefficients for the diffusers and fish valves have to be recalibrated.

In general, the following problems, listed in order of significance to the model accuracy were found in the code and geometry files:

1. The model assumes pressurized flow throughout the AWS conduits including the fish valves that control the inflow. Only at very high tailwater levels (>30 ft) would this be true.
2. Cross sectional area of the pipes do not represent equivalent cross sectional area they represent equivalent hydraulic diameters.
3. Entrance coefficients overestimate entrance heads
4. Missing or inappropriate head loss coefficients in geometry files for the closed conduit or AWS systems.
5. The program cannot be operated on any computers with Windows versions later than 1998 because the main Fortran program uses an external program, Kentucky Pipes, for closed conduit computations. A critical linking software (Phantom) fails to work with later versions of Windows. Phantom is used to transfer information between Kentucky pipes and the main Fortran program.
6. Equations for the entrance weir coefficients need to be revised to more adequately fit theoretical curves.

7. No accounting for energy losses from upward diffuser flow in open channel analyses in powerhouse channel.
8. In computing the channel velocities, the invert for the powerhouse channel is hard-wired into the program code; the current level (-2 feet) is correct but the program prevents future modifications.
9. Output does not reiterate all of the input data, which makes for an incomplete document upon future review. Other I/O corrections would improve the ease of user operation.

Item 1—the inclusion of the Fish Valves in the Kentucky Pipe Program—is a significant shortfall in the A Branch computer model. Kentucky Pipes run on the assumption that the all components are under pressurized flow conditions. The AWS flow is indeed pressurized in the lower portions of the AWS conduit (the proportion depends on tailrace level and AWS flow rate). However, the fish valves are physically located at levels that will usually be higher than the hydraulic gradeline (HGL) in the AWS conduits (The inverts at FV1-1 and FV3-7 are 48.6 feet and 58.0 feet, respectively). This means the valves normally discharge to atmosphere into steep conduits that run open channel down to a lower ‘reservoir’ in the AWS system. The fish valves control the inflow from the forebay into both branches of the AWS conduit. So the flow from the fish valves are normally a function of the gate opening and the head difference based on the forebay and valve invert.

The problem is that Kentucky pipe program treats the valves as operating under pressure-ignoring the physical constraints of the high inverts of the valves. Essentially the program uses the head difference between the forebay and the lower reservoirs in the AWS to determine the head drops across the fish valves and compute the valve discharges. The head drops across the fish valves are vastly overestimated and thus the AWS inflow rates are overestimated. The alternative result is that the flow rates are approximately right but pressure gradelines in the lower conduits are overestimated, thus exaggerating the pressure differences between the AWS conduits and the ladder. So when the Kentucky Pipes runs with the fish valves in the file, pressurized flow is assumed and one of two things happens:

- The fish valve flow is overestimated by an inflated head difference caused by an AWS HGL downstream of the valve being lower than the valve invert; or
- If the flow rates are about right for a normal tailwater run, then the HGL or pressures in the AWS are likely overestimated.

The above problem is addressed by a special model adjustment Excel macro which is described in the following section 3.3.2.1.

The second problem—the use of the hydraulic diameter in the IN files for Kentucky Pipes—places greater importance in head losses due to friction than minor losses. In actuality most of the system head losses are generated by minor losses, particularly at diffusers. The minor losses are a function of pipe velocity, which requires an accurate cross-sectional flow area. Thus an ‘equivalent area diameter’ (the diameter of a circle with equal cross-sectional area to the rectangular conduit) should be used instead of the

‘hydraulic diameter’. Simultaneously, the effect of the rectangular shape upon the friction losses can be factored in with an adjustment to the roughness dimension for the pipes. All of these adjustments are explained and documented in the Cook Memorandum and Errata sheet in Appendix A.

Most of the problems with items 2, 3 and 4 above have been corrected with extensive adjustments to the geometry (INI & IN) files. Specifically, the revised A Branch model incorporates revisions to cross sectional flow areas, minor loss coefficients, and entrance weir coefficients that better fit theoretical values and measured flow data. More details on the revised A Branch computer model are provided in Appendix A.

Items 1, 5 - 9 above cannot be fully corrected without either revisions to the program code or a development of a new model, both of which are beyond the scope of this phase of the study.

With the completed model revisions, the model has been made sufficiently accurate to proceed confidently with an evaluation of the fishway operations. The process of running the revised model is inconvenient since the model can only be used on Windows 98 computers, and require the added steps of the Excel macro program that must be run before starting the HELCRABS model.

3.3.2.1 Model Pre-Adjustment Macro

A special model pre-adjustment or “pre-calculation” Excel macro has been created to compensate for the improper assumption applied with the models use of Kentucky Pipes. The objective of the macro is to make sure the HELCRABS model produces the correct fish valve discharge (based on the invert elevation or HGL elevation) and provide an accurate level of the hydraulic gradeline within the AWS conduits so that system pressures may be more accurately estimated. The macro accomplishes this by adjusting certain pipe coefficients that artificially reduce the amount of energy downstream of the tainter valves and ensure the model computes the correct discharge from the valves. The first step of the macro is to compute what the flow rates should be from the fish valves as a function of forebay and gate opening. The next step inserts the valve flow rate into another sheet that computes the flows and head losses through the diffusers and AWS conduit to determine the HGL level below the fish valve. The program then back-calculates the artificial, or ‘corrective’, minor loss coefficients in each conduit for substitution into the K-pipes data file so that it produces the correct flow rates and HGL’s in the AWS. It is cumbersome to operate and maintain. Additionally, it is not following proper hydraulic theory. The model user is essentially “tricking” a pressurized system model to produce the correct valve discharges and hydraulic gradelines below the valves.

Under high tailrace conditions where HGL can submerge a valve invert level, the macro program compensates by replacing the invert with the computed HGL level to revise the head difference for the valve flow computation and iterates with the macro until the flow rate and head losses are hydraulically balanced.

The basic inputs, steps and outputs of the macro are listed below.

MACRO INPUTS:

- Forebay (FB) level (ft)
- Tailwater (TW) level (ft)
- Entrance Head Estimate (usually 1-1.5 ft)
- Head on Weirs (usually 1-1.2 ft)
- FV1-1 Opening
- FV3-7 Opening (automatically calculated from lookup table)
- Entrance weirs WG-65, WG-64, WG-2, WG-1 settings. If closed, make higher than TW (40 ft works well)
- Diffuser settings, either open or closed. They automatically highlight if they should be on per Fish Passage Plan (FPP).
- Choose if FG3-6 is partially open or fully open.

MACRO PROGRAM STEPS:

1. Establish the water surface elevation or hydraulic gradeline (HGL) from the input data to determine the open channel boundary conditions for each AWS diffuser:
2. Establish initial guess for the HGL with the AWS conduit immediately downstream of each fish valve. The initial HGL is set to the valve invert (Z) elevation. This is just a seed value to start the calculations.
3. Compute the flows rates through each fish valve.
4. Route computed fish valve flows through AWS conduits and diffusers
5. If the new target HGL_v (from the last step) is greater than the valve invert (Z) and does not match the last HGL_v (from step 3 used to compute the valve discharge rates), a solution must be obtained through additional iterations between the valve computations (Step 3) and the AWS computations (Step 4).
6. Upon solution, compute the phony minor loss coefficients downstream of each fish valve to be applied to the program data files.
7. The final step in the macro is to create new HELCRABS input or data file sheets.

MACRO OUTPUTS:

- The ‘corrective’ minor loss coefficients for pipes 3 and 60.
- The required diameter for diffuser FG3-6 depending on whether it is partially or fully open.

These values are entered into the IN file and saved as RUN.IN and the HELCRABS model is now prepared to be run.

This macro is documented in detail in the EC-HD memorandum: *Pre-Adjustment Macro for HELCRABS A Branch Model* by Sean Askelson, located in Appendix A.

3.3.3 Comparison with Field Measurements

The model simulations were run with the same boundary conditions (tailrace & forebay levels) and operational settings (entrances openings, diffuser openings, fish valve settings, and head on control weir 67) recorded during the collection of field data. The following tables show detailed comparisons between the field measurement and model, both original and revised.

3.3.3.1 Original Model Data Comparison

Table 8 shows part 1 of the comparison with the original model, which covers system inflows and powerhouse channel velocities. The biggest problem areas are the discharge rates through FV3-7 (> 30% high) and the velocities at the north end of the powerhouse (more than 30% underestimated with errors > 0.5 feet per second). Overall the model underestimates the total inflow by about 10%.

Table 9 shows the second part of comparison with the original model, covering the entrance head and discharge rates. Here larger problems are uncovered.

1. The change in water levels from the north end to the south end of the powerhouse are overestimated by an average of 0.8 feet. This was caused by an unrealistically high Manning's roughness values given for the powerhouse channel: 0.125 for tailrace below 21.7 feet and 0.08 for tailraces > 21.7 feet.
2. The entrance heads are greatly overestimated (on the order of 60-110 %, or magnitudes up to 2.5 feet in error with most differences greater than 1 foot). The differences were made somewhat worse with the correction of the entrance invert and weir width geometry, compounded by a problematic equation for the entrance weir coefficients. (See notes at bottom of table).

Another factor shown in the tables were AWS pressures. Pressures were not available in the North AWS conduit, but the HGL was available in the South conduit for one of the data collection tests (July 2, 03). The HGL in the south conduit was reported from the control room to be 17.5 feet near the south entrance. The reading was based on a recently recalibrated pressure transducer in the conduit. By contrast, the HGL computed by the model for the same boundary conditions is 33.8 feet, double the level of the HGL. This exaggerates the pressure difference between the AWS conduit and powerhouse channel: instead of 0.6 psi differential as in the prototype, the model produces a pressure difference of 7.7 psi. With the system is designed for more than 1300 cfs with a maximum allowable pressure difference of 10 psi (for structural reasons), the 7.7 psi certainly cannot be happening when the FV1-1 flow rate is less than 700 cfs.

In summary the chief problems with the original model in comparison with the measurement data are the following:

- Overestimates FV3-7inflow
- Underestimates the velocities at the north end of the powerhouse channel
- Overestimates water level change along powerhouse channel

- Overestimates entrances heads at both locations, worst is at north entrance.
- Overestimates the pressures in the south AWS conduit.

Inferences from the comparison results with the original model:

- *Develop macro to address the fish valve problem with Kentucky pipes*
- *Revise entrance weir coefficients.*
- *Correct geometry of AWS conduits and diffusers to match flow areas.*
- *To better simulate flows and pressures in the AWS system, the conduit/diffuser loss coefficients need to be increased.*
- *Reduce the Manning's roughness for the powerhouse channel.*

Table 8: Comparison of Original Model with Measured Data, Part 1 (System Inflows and Channel Velocities)

A BRANCH SUMMARY COMPARISON OF RUNS FROM ORIGINAL MODEL WITH FIELD DATA							
PART 1: SYSTEM INFLOWS & CHANNEL VELOCITIES							
Average Project Forebay Conditions (ft)					*Shaded cells indicate estimated values.		
Test Date	8/15/02	10/10/02	7/2/03				
Forebay	75.16	75.76	75.43				
A. A Branch Ladder Flow (cfs)						Good simulation of Ladder flow	
Test Date	8/15/02	10/10/02	7/2/03		Average		
Ladder Head	1.3	1.0	1.2				
Measured	130	106	122		119		
Model	132	96	119		116		
% Diff	1%	-9%	-2%		-3%		
B. Discharge through Fish Valve 1-1 (South AWS)						Good FV1-1 flow estimates (but excessive AWS pressures)	
Test Date	8/15/02	10/10/02	7/2/03		Average		
Valve Setting	3.70	3.0	2.9				
Measured	808	874	678		786		
Model	857	776	718		784		
% Diff	6%	-11%	6%		0%		
C. Discharge through Fish Valve 3-7 (North AWS)						Model overestimates FV3-7 flow by more than 30%	
Test Date	8/15/02	10/10/02	7/2/03		Average		
Valve Setting	1.25	1.3	2.85				
Measured	310	261	536		369		
Model	372	395	689		486		
% Diff	20%	52%	29%		32%		
D. Total System Inflow (cfs)						Model overestimates total system inflow by about 10%	
Test Date	8/15/02	10/10/02	7/2/03		Average		
Measured	1117	1135	1214		1155		
Model	1230	1172	1407		1269		
% Diff	10%	3%	16%		10%		
E. Powerhouse Channel Velocities							Good simulation of south PH velocities, poor at the north end (max error > 0.5 ft/s)
	Test Date	8/15/02	10/10/02	7/2/03		Average	
Project Tailrace		13.8	10.0	14.8			
South End Near FG2-3	Measured	1.4	2.2	2.1		1.9	
	Model	1.4	2.0	2.1		1.8	
	% Diff	3%	-10%	-3%		-4%	
North End Sonic Meter Near FG2-20	Measured	1.0	0.9	1.3		1.1	
	Model	1.0	0.4	0.8		0.7	
	% Diff	-6%	-58%	-41%		-35%	

Good simulation of Ladder flow

Good FV1-1 flow estimates (but excessive AWS pressures)

Model overestimates FV3-7 flow by more than 30%

Model overestimates total system inflow by about 10%

Good simulation of south PH velocities, poor at the north end (max error > 0.5 ft/s)

Table 9: Comparison of Original Model with Measured Data, Part 2 (Entrance Heads and System Discharges)

PART 2: ENTRANCE HEADS & SYSTEM DISCHARGES					
Average Project Tailrace Conditions (ft)					
Test Date	8/15/02	10/10/02	7/2/03		
Tailrace	13.75	10.00	14.88		
*Shaded cells indicate estimated values.					
F. Change in Powerhouse Channel Levels (No > So)					
	Change in Water level from North to South PH Channel (ft)				
Test Date	8/15/02	10/10/02	7/2/03		Average
Measured	0.0	0.1	0.1		0.1
Model	0.7	1.0	0.8		0.9
Diff	0.72	0.91	0.76		0.80
G. South Entrance Head					
Test Date	8/15/02	10/10/02	7/2/03		Average
Measured	1.4	1.4	1.4		1.4
Model	1.3	3.0	2.5		2.2
% Diff	-7%	111%	80%		61%
H. North Entrance Head					
Test Date	8/15/02	10/10/02	7/2/03		Average
Measured	1.4	1.5	1.5		1.5
Model	2.0	4.0	3.3		3.1
% Diff	44%	165%	127%		114%
I. Powerhouse Gates (9, 21, 34, 58, 62) Discharges					
Test Date	8/15/02	10/10/02	7/2/03		Average
Measured	350	0	0		350
Model	409	0	0		409
% Diff	17%	NA	NA		17%
J. South Entrance Discharge					
Test Date	8/15/02	10/10/02	7/2/03		Average
Measured	413	509	674		532
Model	422	524	701		549
% Diff	2%	3%	4%		3%
K. North Entrance Discharge					
Test Date	8/15/02	10/10/02	7/2/03		Average
Measured	505	667	582		585
Model	538	743	825		702
% Diff	7%	11%	42%		20%
L. Total System Outflows (cfs)					
Test Date	8/15/02	10/10/02	7/2/03		Average
Measured	1268	1176	1256		1233
Model	1369	1268	1525		1387
% Diff	8%	8%	21%		12%
¹ Note comparison made with corrected 8.25' weir crest (WG # 1, 65) ² Note comparisons made with corrected inverts 0.0 at North entrance and 1.99 at South entrance					

Model greatly overestimates change in water level from north end to south end of PH Channel. (max error >0.9 feet)

Model greatly overestimates entrance heads at both locations (60 -110 %); worst on north entrance (max error> 2.5 feet)

Comparison not made since flow values were estimated.

Good simulation of south entrance flow rates.

Comparison not made since flow values were estimated.

Model overestimates total system discharge

3.3.3.2 Revised Model Data Comparison

The next set of tables display the revised model comparisons with the measurement data. Table 10 shows part 1 of the comparison with the revised model, which covers system inflows and powerhouse channel velocities. All problem areas are significantly improved. All average comparisons are brought within 5%. The accuracy of the flow rate at FV1-1 is diminished by about 1% compared to the original model, but this was a calculated tradeoff to improve overall results. The improved simulations of flow rates at FV3-7 are a result of the special pre-adjustment Excel macro added to the revised model.

Table 11 shows the second part of comparison with the revised model, covering the entrance head and discharge rates. Again all the main problems are significantly improved.

1. The change in water levels from the north end to the south end of the powerhouse channel averages the same as the prototype data, with a maximum difference of 0.05 feet. This was corrected by replacing the high Manning's roughness values with a value of 0.035 in the powerhouse channel.
2. The entrance heads are greatly improved—within 5% on the average at both locations. The maximum deviation is 0.23 feet and the median deviation is about 0.15 feet. The improvements resulted from adjusted entrance weir coefficients described in the Cook Memorandum and Errata sheet in Appendix A.

The pressures in the south conduit are more accurate with the revised model. The HGL in the south conduit was reported from the control room to be 17.5 feet near the south entrance. By contrast, the HGL computed by the model for the same boundary conditions is 18.3 feet, about 0.8 feet higher than the prototype HGL. The model pressure difference between the AWS conduit and powerhouse channel is 0.95 psi compared to 0.6 psi pressured differential in the prototype and 7.7psi from the original model.

Also, while data was not available, the pressure differences between the north AWS conduit and A branch ladder are of interest in both models. For July 2, 2003 boundary conditions, the original model produces a pressure difference of 4 psi and the revised model produces a difference of 6.3 psi. In either case, the HGL will be well below the FV3-7 invert—which helps explain why the original model overestimates the FV3-7 discharge by about 30%.

As stated earlier the expected error from field measurements can be looked at, at a minimum, as a function of the flows being measured. Thus the model was considered accurate as long as the model results were within the sampling error of the particular flow location (i.e., 5% for the entrances and ladder, and 15% for the AWS intakes).

Table 10: Comparison of Revised Model with Measured Data, Part 1 (System Inflows and Channel Velocities)

A BRANCH SUMMARY COMPARISON OF REVISED MODEL WITH FIELD DATA						
PART 1: SYSTEM INFLOWS & CHANNEL VELOCITIES						
Average Project Forebay Conditions (ft)					<i>*Shaded cells indicate estimated values.</i>	
Test Date	8/15/02	10/10/02	7/2/03			
Forebay	75.16	75.76	75.43			
A. A Branch Ladder Flow (cfs)						
Test Date	8/15/02	10/10/02	7/2/03		Average	
Ladder Head	1.2	1.0	1.2			
Measured	130	106	122		119	
Model	119	96	119		112	
% Diff	-8%	-9%	-2%		-7%	
B. Discharge through Fish Valve 1-1 (South AWS)						
Test Date	8/15/02	10/10/02	7/2/03		Average	
Valve Setting	3.70	3.0	2.9			
Measured	808	874	678		786	
Model	876	739	711		775	
% Diff	8%	-15%	5%		-1%	
C. Discharge through Fish Valve 3-7 (North AWS)						
Test Date	8/15/02	10/10/02	7/2/03		Average	
Valve Setting	1.25	1.3	2.85			
Measured	310	261	536		369	
Model	259	271	542		358	
% Diff	-16%	4%	1%		-3%	
D. Total System Inflow (cfs)						
Test Date	8/15/02	10/10/02	7/2/03		Average	
Measured	1117	1135	1214		1155	
Model	1135	1011	1253		1133	
% Diff	2%	-11%	3%		-2%	
E. Powerhouse Channel Velocities						
	Test Date	8/15/02	10/10/02	7/2/03		Average
Project Tailrace		13.8	10.0	14.8		
South End Near FG2-3	Measured	1.4	2.2	2.1		1.9
	Model	1.3	2.1	2.3		1.9
	% Diff	-5%	-5%	10%		1%
North End Sonic Meter Near FG2-20	Measured	0.9	0.8	1.3		1.0
	Model	0.9	0.6	1.3		0.9
	% Diff	1%	-21%	2%		-4%
Summary Notes:						
					No change from original model	
					Good FV1-1 flow estimates--within 5% (much improved AWS pressures)	
					Good FV3-7 flow estimates; much improved (within 5%)	
					Better simulation of total inflow (within 5%)	
					Improved simulation of PH cha. velocities at both ends (max error < 0.2 ft/s)	

No change from original model

Good FV1-1 flow estimates--within 5% (much improved AWS pressures)

Good FV3-7 flow estimates; much improved (within 5%)

Better simulation of total inflow (within 5%)

Improved simulation of PH cha. velocities at both ends (max error < 0.2 ft/s)

Table 11: Comparison of Revised Model with Measured Data, Part 2 (Entrance Heads and System Discharges)

PART 2: ENTRANCE HEADS & SYSTEM DISCHARGES					
Average Project Tailrace Conditions (ft)					
Test Date	8/15/02	10/10/02	7/2/03		
Tailrace	13.75	10.00	14.88		
F. Change in Powerhouse Channel Levels (No > So)					
	Change in Water level from North to South PH Channel (ft)				
Test Date	8/15/02	10/10/02	7/2/03		Average
Measured	0.00	0.10	0.09		0.06
Model	0.03	0.06	0.08		0.06
Diff	0.03	-0.04	-0.01		-0.01
G. South Entrance Head					
Test Date	8/15/02	10/10/02	7/2/03		Average
Measured	1.4	1.4	1.4		1.39
Model	1.4	1.3	1.6		1.43
% Diff	-3%	-7%	20%		3%
H. North Entrance Head					
Test Date	8/15/02	10/10/02	7/2/03		Average
Measured	1.4	1.5	1.5		1.45
Model	1.4	1.4	1.7		1.49
% Diff	-1%	-9%	18%		3%
I. Powerhouse Gates (9, 21, 34, 58, 62) Discharges					
Test Date	8/15/02	10/10/02	7/2/03		Average
Measured	350	0	0		350
Model	367	0	0		367
% Diff	5%	NA	NA		5%
J. South Entrance Discharge					
Test Date	8/15/02	10/10/02	7/2/03		Average
Measured	413	509	674		532
Model	392	487	756		545
% Diff	-5%	-4%	12%		2%
K. North Entrance Discharge					
Test Date	8/15/02	10/10/02	7/2/03		Average
Measured	505	667	582		585
Model	495	620	616		577
% Diff	-2%	-7%	6%		-1%
L. Total System Outflows (cfs)					
Test Date	8/15/02	10/10/02	7/2/03		Average
Measured	1268	1176	1256		1233
Model	1255	1106	1373		1245
% Diff	-1%	-6%	9%		1%

*Shaded cells indicate estimated values.

Much improved simulation of change in water level from north end to south end of PH Channel. (Max error < 0.05 ')

Much improved simulations of entrance heads at both locations. (averages within 5%; Max error < 0.25 feet)

No change from original model since flow values were estimated.

Good simulation of south entrance flow rates.

Comparison not made since flow values were estimated.

Improved simulation of total system discharge

¹Note comparison made with corrected 8.25' weir crest (WG # 1, 65)

²Note comparisons made with corrected inverts 0.0 at North entrance and 1.99 at South entrance

3.4 Model Evaluation Conclusions

There were several deficiencies discovered in both the geometry files and the program code. The general items of concern are listed in Paragraph 3.3.2 (See Cook Consulting memo in Appendix A for a detailed report of the changes made to the geometry files and recommended program code corrections).

The geometry files have been corrected or adjusted so that the program will provide reasonably accurate simulations. With this, EC-HD was able to proceed with an effective evaluation of the system performance with respect to fish criteria. The program code was written with considerable flexibility by making geometry files available for user access, and as such, the most important changes could be made through the geometry files. However, there remain minor deficiencies in the program code that, when corrected, will provide clearer output and greater simulation accuracy.

4.0 Fishway Evaluations

After calibrating and making minor modifications to the numerical model as described in Section 3 the model was used to conduct an evaluation of the A Branch Fishway. The purpose of the evaluation is to determine whether current operational procedures are adequate to meet fish passage requirements throughout the ladder (excluding the exit control section portion which is not included in the A Branch Model and is reported to perform excellently according to project biologists). If model simulations showed the current operating scheme failed to meet hydraulic criteria, an alternate operating scheme was developed using the modified model. The following section describes the operational criteria used to evaluate the ladder, an evaluation of the ladder as it is currently operated, and an explanation of an alternate operating plan developed to improve performance of the ladder with respect to the operational criteria.

4.1 Operational Criteria

The Corps of Engineers Fish Passage Plan (FPP), the document of Corps operational policy pertaining to the fish passage systems on the Columbia, lists a number of hydraulic criteria agreed by regional agencies to be beneficial to the passage of fish through the projects. These criteria, though still being researched, are used in this evaluation. The primary hydraulic characteristics desired in the ladder are as follow:

- Head drop across ladder entrance – 1.0 ft to 2.0 ft with 1.5 ft optimum
- Minimum entrance weir submergence – 8 ft
- Head over overflow ladder weirs:
 - 1.0 ft $\pm$ 0.1 ft during non-shad season (Aug 16- May 14) and
 - 1.2 ft $\pm$ 0.1 ft during shad passage season (May 15 – Aug 15)
- Exit section head criteria – 0.5 ft to 1.0 ft between pools
- Channel velocities – 1.5 to 4 ft/s with 2ft/s optimum
- Diffuser velocities –0.5 ft/s maximum

In addition to the criteria listed above, it is noted in Bonneville Dam Design Memorandum (DM) No.1: Modification for Peaking (2) that the AWS system is to be operated to allow no more than 5 psi of pressure differential across the system. It is stated in the DM that by maintaining the AWS with a pressure differential of no greater than 5 psi, juvenile migrants inadvertently entering the system from the forebay can pass through the trash racks, conduits, and diffusion gratings without sustaining significant injury. The current operations specify the AWS pressure differentials be maintained below 6 psi. Therefore the 6-psi maximum criterion is applied to this fishway evaluation in addition to the above bulleted items.

The current operational plan for the fishway is provided in the form of a figure listing diffuser valve openings for a given tailwater elevation for all of the ladders at Bonneville (BDF-9-6-OAO/1). Fishway operations are also provided in the FPP for the Columbia

River. Plate 12 provides a summary of the diffuser, entrance weir, and entrance sluice gate settings for ladder operations consistent with both the Fishway Operation diagram and the FPP. The only deviation from this operation plan in the current ladder operations is that the powerhouse telescoping and sluice gates are now closed.

4.2 Evaluation Procedures

In order to evaluate the current fishway, the model was used to simulate hydraulic conditions for a number of project forebay and tailrace elevation combinations. The numerical model was first used to evaluate the current operations by checking the resultant hydraulic conditions from those operations. Specifically, model runs were conducted at a forebay of 74.5 ft and eight tailwater elevations between 8 and 35 ft NGVD. The hydraulic conditions in the ladder were compared to the fisheries criteria described above.

As discussed in section 2.1.1 (and analyzed in greater detail in section 4.3.1 b), the level of the south entrance weir is uncertain for tailwater levels above 10 feet and the valve opening for FV1-1 is also uncertain at any tailrace. This makes the simulation of the existing system difficult. To simulate the existing operation in those tailwater ranges, the basic plan described below was followed:

- Set FV3-7 according to tailwater and forebay curves (See Table 3).
- Depending on the tailwater level, select between weir pairs 2 & 64 or 1 & 65.
 - If the low set of weirs then:
 - Set north entrance weir WG-64 at 8.3 feet submergence (average between 8-8.6 ft. limits). Make sure the head differential stays between 1.4 and 1.6 feet.
 - Find the range of the south entrance weir crest elevations (WG-2) that can produce an entrance head of 1.35 feet (average between limits 1.2 –1.5 feet) with no less than 8 ft. of submergence and can be adequately supplied by FV1-1. Assume the median weir elevation between the minimum and maximum levels. Also make sure there is a gradual change in FV1-1 between different tailwater levels.
 - If the high set of weirs then:
 - Set south entrance weir WG-65 at 8.4 feet submergence (average between 8-8.8 ft. limits). *There are no operational head limits on this one.*
 - Find the range of the south entrance weir elevations (WG-1) that can produce an entrance head of 1.25 feet (average between limits 1.0 –1.5 feet) with no less than 8 ft. of submergence and can be adequately supplied by FV1-1. Also make sure there is a gradual change in FV1-1 between different tailwater levels.

Results and conclusions from this evaluation are provided in Section 4.3.1.

The evaluation then focused on operating the A Branch Fishway to optimize performance with respect to the operational criteria. This portion of the evaluation was done by generating model simulations for the same eight tailwater elevations ranging from 8 ft to 35 ft NGVD and a forebay level of 74.5 ft. Only one of the criteria violations can actually be addressed by changing the operation: low powerhouse channel velocities. (The other criteria violations are caused by geometry limitations and would require structural modifications to correct them.). Thus the operational optimization centered on improving the powerhouse channel velocities, without sacrificing on other criteria. However, some relaxation on the diffuser velocity criteria was permitted as long as the diffuser velocities staid below 0.8 ft/s. Another concern was AWS conduit pressures. There are no operational constraints placed on the Fish Valve operations that will regulate pressures, however at other fishway systems the pressures between the conduit and fishway channels are held below 6 psi for fish passage concerns and 10 psi for structural concerns.

4.3 Fishway Evaluation Conclusions

4.3.1 Current Operations Plan

The current operation has undergone recent change with the closure of the powerhouse telescoping gates (9, 21, 34, 58 and 62) last year. No other changes were made to the operation. While the use of the diffusers FG2-4, 8, and 12 along the powerhouse channel were designed to make up for water lost to the channel from previously opened powerhouse gates 9, 21, & 34 at the middle and south end of the channel, these diffusers settings remain open. The current operation is outlined in a matrix for incremental tailwater levels between 8 and 35 feet in Plate 12 of this report. The normal weir crest elevations are listed for the entrance weirs. (Note: the ranges of possible weir levels are shown under the columns for south entrance weirs WG1 & WG-2 for each tailrace level.)

The operations and geometry of the north and south entrance weirs are different. The physical difference was designed into the 1996 installation of the low entrance weirs to assure that more flow would be pulled down the powerhouse channel by the south entrance. The maximum crest elevation for the low north entrance weir (WG-64) is 18 feet and only 11 feet at the low south entrance weir (WG-2). The other key difference between north and south entrance weirs is operational. Unlike the north entrance weirs, in which the submergence levels are tightly regulated between 8 – 8.8 feet, the south entrance weirs are unconstrained by any maximum submergence level except when the weirs bottom out. This leads to uncertainty regarding the elevation of the weir crest at the south entrance for a given tailrace level—it can be much deeper than the minimum 8 feet submergence.

4.3.1.1 Performance with Respect to Criteria

Table 12 shows the model simulation results for the existing fishway operation for a range of tailwater conditions between 8 feet and 35⁴ feet. For these simulations, the south weirs were assumed to be at the median level of the potential range of operation that the system is capable of meeting the PLC criteria for each given tailwater condition. (The median is also about the same as the median line from the 2003 fisheries inspection data.) The tailwater levels for the simulation are listed at the top of each column. Below tailwater row, the table lists information in basically four sections. The first section provides the settings for the fish valves FV1-1 and FV3-7, the ladder head, and crests elevations for the operating entrance weirs (closed if shaded gray). The next section provides the computed discharge rates through the same components and the total system discharges. The third section lists the water levels, and pressure data including: water levels for the tailrace, north and south entrance locations, the hydraulic gradeline in both AWS conduits, and pressure differences between conduit and fishway. The AWS hydraulic gradeline levels and pressure differences are located at the pressure transducer location at FG2-2 for the south conduit and (estimated) at FG3-5 for the north conduit.

Multiple simulations are shown for Tailrace 18 to illustrate the potential range of performance depending on the level of south entrance weir. Tailrace designated '18A' represents a condition where the south entrance weir, WG-2, matches the minimum 8 feet of submergence according to the PLC operation and fisheries criteria. '18B' shows the median weir level and submergence like the other entries in the table. 18C represents the minimum possible weir level and maximum weir submergence for tailwater 18. These three columns illuminate the considerable differences between channel velocities depending on the level of the south entrance weir. Obviously operating the south entrance weir near 8 feet of submergence will produce much lower velocities in the channel compared to the median level or maximum submergence of operation. This further points to the need to establish consistency in the operation of the south weirs.

Powerhouse Channel Velocities. According to model simulations, the current A Branch operations fails to produce sufficient velocities to meet the velocity criteria (1.5 – 4 ft/s) along the powerhouse channel at the north end. The worst cases appear to occur at minimum tailwater levels (below elevation 15 feet). The system will not meet the velocity criteria until the tailwater rises above about 24 feet. This means the system does not meet the velocity criteria at the north end about 90% of the time during the fish passage season. If the south entrance weir is operated at or near 8 feet of submergence, the velocity criteria will also not be met at the south end of the powerhouse channel under higher tailwater conditions (above 18 feet).

⁴ Simulations for tailwater levels above 26 feet will need to be revisited in the final report submittal, since all results for WG-1 and WG-65 are based on uncalibrated estimates for weir coefficients. The study team intends to collect flow data during a high tailrace condition (>26 ft) next spring so that the model may be calibrated for these entrance weirs.

Table 12: Existing Operation of A Branch Fishway: Model Simulation Results for Tailwater Levels Between 8 and 35 Feet Based on Fish Passage Plan and Current Programmable Logic control Commands

Existing Operation Table in Accordance with Fish Passage Plan and Operational Sheet BDF-9-6-0A0/1										
TAILWATER ELEVATION (ft)	8	10	15	18A	18B	18C	22	26*	30*	35*
SETTINGS:										
Inflow: (valve openings, ft)										
South AWS (FV1-1 opening) (ft)	1.9	3.3	2.4	0.1	1.4	3.0	1.3	2.2	1.9	2.2
North AWS (FV3-7 opening) (ft)	1.3	1.3	2.1	3.6	3.6	3.6	4.3	5.5	6.5	7.1
AWS conduit regulator FV3-8 (ft)	0	0	0	0	0	0	0	0	0	0
Weir 67 Ladder Head (ft)	1.0	1.0	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Outflow: (weir elevations, ft)										
South Entrance WG-1	40	40	40	40	40	40	40	8.5	10	12
South Entrance WG-2	2.0	2.0	4.5	10.0	6.0	2.0	7.5	40.0	40.0	40.0
PH gates 9, 21, 34, 58, & 62	closed	closed	closed	closed	closed	closed	closed	closed	closed	closed
North Entrance WG-64	2.0	2.0	6.7	10.0	9.7	9.7	13.7	40.0	40.0	40.0
North Entrance WG-65	40	40	40	40	40	40	40	17.6	21.6	26
DISCHARGE:										
Inflow: (cfs)										
South AWS (FV1-1)	466	774	591	14	346	720	334	535	466	536
North AWS (FV3-7)	259	261	409	645	644	644	748	953	1152	1288
AWS conduit regulator FV3-8 (ft)	0	0	0	0	0	0	0	0	0	0
Weir 67 Ladder Flow (ft)	192	192	239	239	239	239	239	239	239	239
Outflow: (cfs)						0.0				
South Entrance WG-1	0	0	0	0	0	0	0	1182	1322	1501
South Entrance WG-2	378	496	634	350	651	995	757	0	0	0
PH gates 9, 21, 34, 58, & 62	0	0	0	0	0	0	0	0	0	0
North Entrance WG-64	442	633	486	428	460	488	444	0	0	0
North Entrance WG-65	0	0	0	0	0	0	0	425	416	442
Total System Discharge (cfs)	916	1225	1239	897	1230	1602	1320	1726	1857	2062
WATER LEVEL, HGL, AND PRESSURE DATA										
Tailwater (ft)	8	10	15	18	18	18	22	26	30	35
Water Level at Pool 19 (FG3-5)	20.0	20.0	20.0	21.8	21.9	21.9	24.6	28.4	32.3	37.1
North PH Channel Water Level (ft)	9.4	11.5	16.4	19.4	19.4	19.6	23.4	27.5	31.4	36.4
South PH Channel Water Level (ft)	9.3	11.3	16.3	19.3	19.3	19.3	23.3	27.3	31.3	36.3
HGL North AWS (at FG3-5) (ft)	30.8	31.0	28.4	31.9	32.0	32.0	34.8	38.7	42.3	45.9
HGL South AWS (at FG2-2) (ft)	10.2	13.6	17.7	19.3	19.8	21.8	23.8	28.5	32.2	37.5
Δ North AWS (psi) @FG3-5	4.7	4.8	3.6	4.4	4.4	4.4	4.4	4.4	4.3	3.8
Δ South AWS (psi) @ FG2-2	0.4	1.0	0.6	0.0	0.2	1.1	0.2	0.5	0.4	0.5
FISH PASSAGE CRITERIA:										
Tailwater (ft)	8	10	15	18A	18B	18C	22	26	30	35
North Entrance Head (ft)	1.4	1.4	1.4	1.3	1.4	1.6	1.4	1.5	1.4	1.4
South Entrance Head (ft)	1.3	1.4	1.3	1.3	1.4	1.4	1.4	1.4	1.3	1.4
North Entr. Weir Submergence (ft)	6.0	8.0	8.3	8.0	8.3	8.3	8.3	8.4	8.4	9.0
South Entr. Weir Submergence (ft)	6.0	8.0	10.5	8.0	12.0	16.0	14.5	17.5	20.0	23.0
North PH Channel Velocities (ft/s)	0.8	0.6	1.1	0.9	1.3	1.8	1.3	1.8	1.9	1.9
South PH Channel Velocities (ft/s)	1.9	2.1	2.0	0.9	1.7	2.7	1.7	2.3	2.3	2.2
Max AWS Diffuser Velocities (ft/s)	0.6	0.6	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7

*Model has not been calibrated for high tailwater conditions and entrance weirs WG-1 & WG-65; Flow tests pending next spring.

One unforeseen consequence of the 2003 shutdown of the powerhouse telescoping and sluice gates may be the overall reduction in flow to the powerhouse channel. The powerhouse sluice gates discharged over 350 cfs during the Aug 2002 data collection trip. While the overall total system discharge was less than 100 cfs compared to latter data with closed gates, there will be potentially higher system discharge capacity with the

powerhouse & telescoping & sluice gates left open, with the extra flow entering the powerhouse channel.

The velocities are low in the powerhouse channel because the north entrance removes too much of the flow from the A Branch ladder and diffusers FG2-22, 22a & 22b, leaving little remaining flow to pass on down the powerhouse channel. A major cause of this problem is the design of the system with both entrances drawing from a single channel. (Note that the Bonneville second powerhouse fishway, designed 40 years later, has separate channels for each entrance.) Another contributing geometrical factor is the different angles of the entrance outlet channels with respect to the powerhouse channel alignment: about 30 degrees at the north entrance and about 120 degrees at the south entrance. There will be less flow efficiency at the entrance that has the larger turning angle. A third geometrical factor concerns the more frequently used low entrance weirs (WG-2 and WG-64): WG-64 is located farther downstream of the upstream corner of the entrance outlet channel and powerhouse channel. This means the flow has a less radical turn out of the powerhouse channel into WG-64 compared to WG-2. Both of these factors make the north entrance more efficient hydraulically and are reflected in the contraction coefficients in the entrance computations (0.05 for the WG-64 versus 0.25 for WG-2). All things being equal, WG-64 will discharge about 20% more flow than WG-2. Finally there is the tendency for the north entrance to experience higher entrance heads than the south entrance since the water levels at the north end of the powerhouse channel are usually higher than the south end due to energy losses generated along the channel.

The 1996 entrance modifications and the current PLC operation were clearly designed to counteract the tendency of the north entrance to pass more discharge than the south entrance. But this plan may have been partly reversed by shutdown of the powerhouse telescoping gates, causing an overall reduction in total inflow into the powerhouse channel from the north end.

Diffuser Velocities. The 0.5 ft/s criteria diffuser velocity may be being violated at the lower diffusers in the north AWS conduit. The highest diffuser velocities are estimated to be typically around 0.7 ft/s at diffuser FG3-4. At tailrace 28 feet, the model computations report the FG3-4 velocity going as high as 0.9 ft/s. The diffuser velocities in the south conduit stay well below 0.5 ft/s under all operations. Discussions with biologists indicate this violation may be less of a concern than the low channel velocities. The concern rises considerably if the velocities begin to exceed 1 ft/s. The fish may be disturbed or falsely attracted to the bottom diffusers. More importantly, the risk is increases for diffuser gratings to be blown off by a combination of debris plugging and higher differential heads resulting from the blockage.

Criteria Violations due to Structural Limitations. There are three criteria violations that cannot be solved by changing the ladder operation: minimum entrance submergence at low tailwater elevations and low head drops between pools in the exit section.

The minimum weir crest for both entrances is elevation 2 feet, so when the tailwater drops below 10 feet (about 9% of the time during a normal fish passage season), the

minimum 8 feet of weir submergence cannot be met. The consequence of this is less attraction flow from the entrance into the tailrace. The lower the submergence and flow rate, the less the entrance jet will project out into the tailrace.

Weirs 54 and 55 do not operate in ladder head criteria; 1.0 ft (± 0.1 ft) for non-shad season and 1.2 ft (± 0.1 ft) for shad season. The head is lower at these weirs because overflow weir crests are longer than at control weir 67. Table 13 shows the different head levels depending on the head (in feet) at the control weir 67.

Table 13: Fish Ladder Head in Feet at tWeirs 54 and 55 Versus Control Weir 67 Head

Weir	Control weir 67	Weir 55	Weir 54
Crest Length (ft)	42 ft	47 ft	57 ft
Ladder head (non-shad)	1.0 ft	0.9 ft	0.8 ft
Ladder head (shad)	1.2 ft	1.1 ft	1.0 ft

The head variability can be corrected by adding non-overflow sections to these two weirs so that the net overflow lengths are 42 feet like the rest of the weirs in this section.

The range of head drops between pools are lower than criteria for the exit section. The average head drop in the exit section is between 0.20 feet at low forebay (71.5 feet) and 0.46 feet at high forebay (76.5 feet). The current criteria for the exit section are between 0.5 – 1.0 feet. Thus the head drops are less than half of the current criteria. The exit section was designed according to different criteria 30 years ago. No biological concerns have been reported from this condition.

4.3.1.2 Uncertainty of Weir Levels with Current PLC Operations

The nuances of the PLC operations for the South Entrance weirs (WG-2 or WG-1) and South AWS fish FV1-1 create inconsistent settings for equivalent tailwater levels. The movements of both WG-2 (and WG-1) and FV1-1 are tied to either entrance head or minimum submergence. The south entrance gate will usually move first since their ranges of entrance head limits are narrower than and encompassed by the limits for FV1-1. Under a falling tailrace condition, the entrance head will increase. If the head exceeds 1.5 ft, the south entrance weir drops. This will happen before the entrance head reaches 1.9 ft—which would force FV1-1 to start closing. If the weir bottoms out, then FV1-1 must then close by some increment. Likewise in a rising tailrace condition, the entrance weir will first experience a head differential of 1.2 ft—causing the weir to rise—before FV1-1 is forced to open (when the head reaches 1.0 ft). However the entrance weir must stop if it encounters the minimum 8 feet submergence threshold. Then the head may drop below 1.0 ft, causing FV1-1 to open. In general it appears FV1-1 does not move as often as the entrances. For the same tailwater level on different days, the particular weir setting at the south entrance could be different depending on the history of tailwater levels. This uncertainty has made the evaluation of the existing operation more difficult.

Analysis of fishway inspection data reveals the south entrance weirs are unpredictable. Tim Darland, Project Biologist, furnished valuable 2003 fishway inspection data between March 5 and July 27, 2003. (Data between March 13 and April 30 is flawed as the PLC did not function properly and the weir submergence for the north entrance weir did not operate within its strict submergence limits.) The analysis of the remaining unimpaired data verifies that the position of the south entrance weir will still vary with respect to tailwater level. Figure 5 shows the crest elevation of weir WG-2 with respect to tailwater level. At about tailwater 20 (for example), the weir has been as low as 4 feet and above 9 feet—which means there is a range of at least 5 feet that the position of the weir could be within when the tailwater is 20 feet. Figure 6 shows the tailwater submergence for WG-2 versus tailwater elevation. Like the previous chart, this shows the submergence can vary as much as 5 feet for a given tailwater elevation. Figure 7 displays the valve opening for fish valve FV1-1 versus tailwater elevation. At tailwater level 13, the setting for FV1-1 was less than 1 foot on one occasion and nearly 5 feet in another. The variability of FV1-1 data helps clarify the reason entrance weir WG-2 does not have consistency in operation with respect to tailwater level. The position of both FV1-1 and WG-2 are a complex and interdependent function of antecedent tailwater levels—with the corresponding systemic responses—leading up to the present. This problem leads to an inconsistent performance with respect to tailwater level where the fishway may be within criteria at one end of the potential spectrum of weir operation and out of criteria at the other end of it.

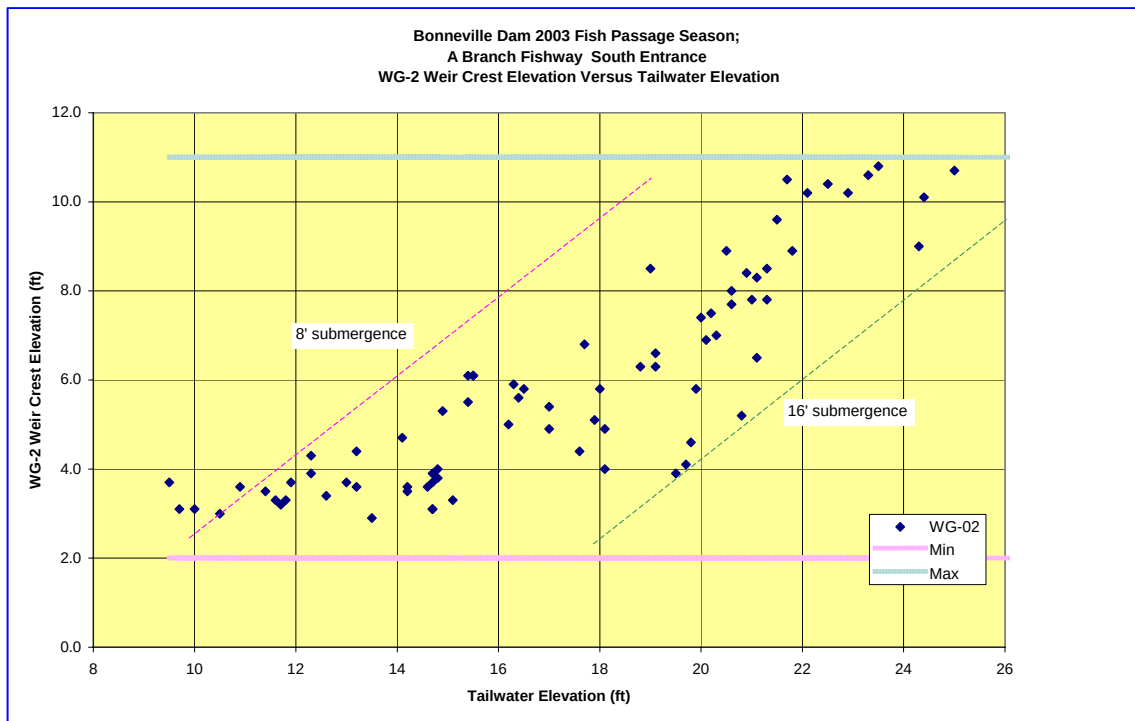


Figure 5: Crest Elevation of South Entrance Weir WG-2 Versus Tailwater Elevation (normal PLC operation)

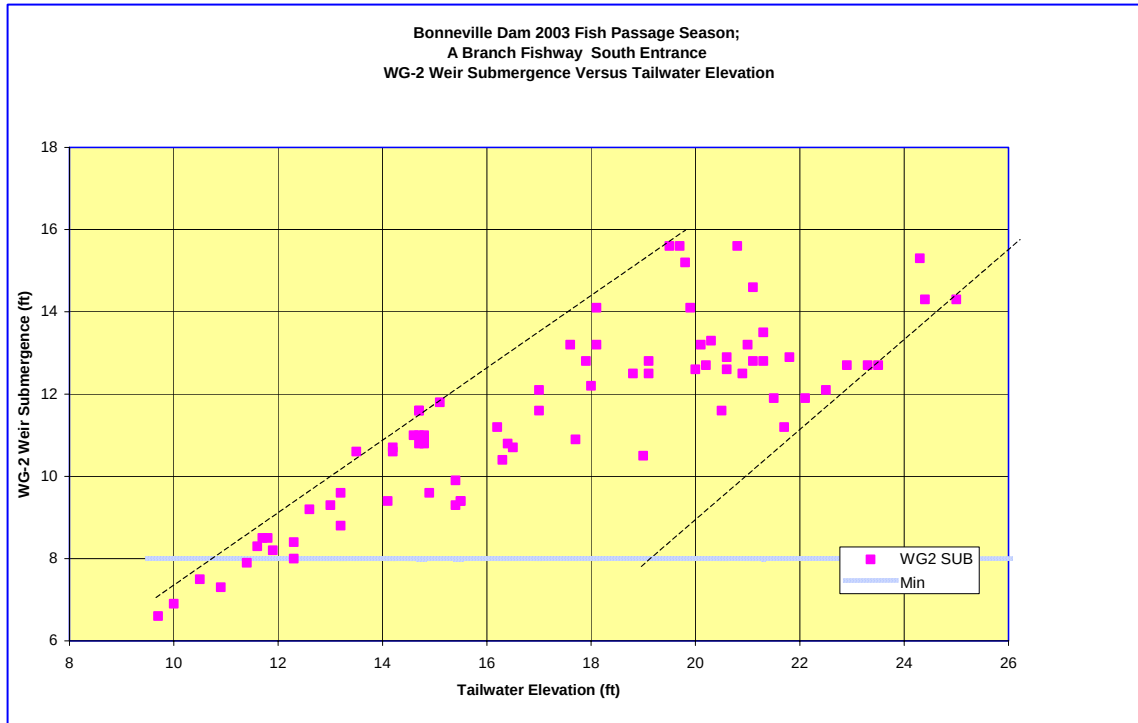


Figure 6: Submergence of South Entrance Weir WG-2 Versus Tailwater Elevation

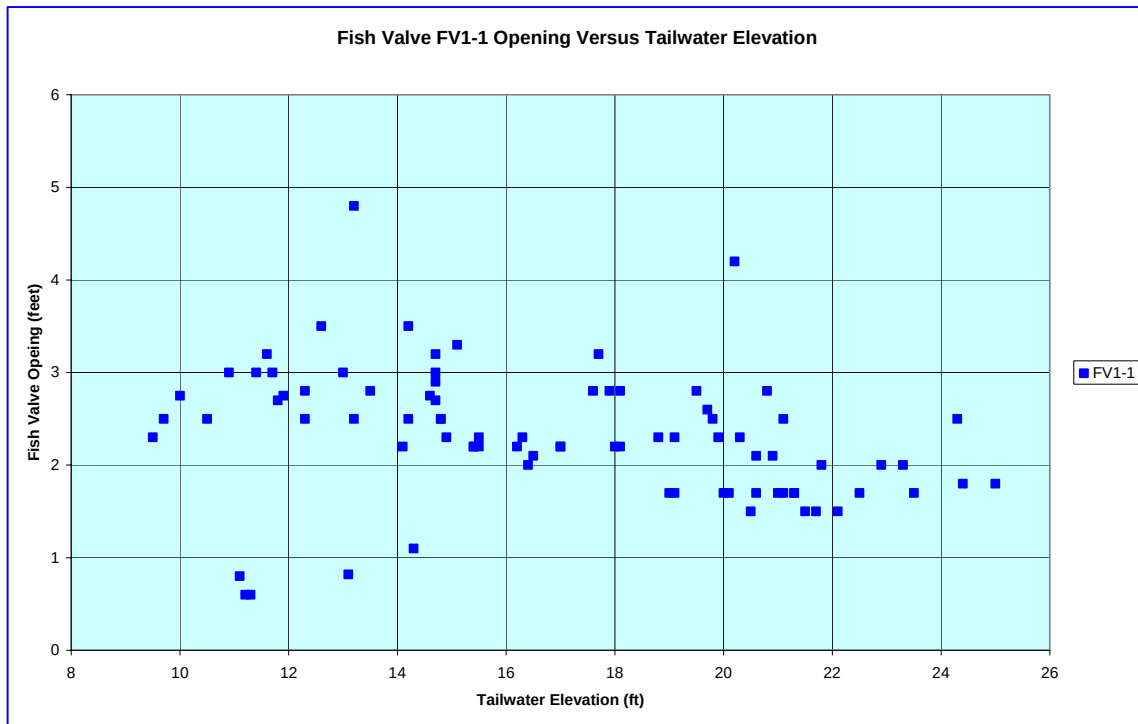


Figure 7: Valve Opening of FV1-1 Versus Tailwater Elevation (normal PLC operation)

By contrast, the operation of the north entrance weirs tracks closely with the tailwater level and the minimum 8 feet of submergence. This is evident in the following figures.

(Again the data for the period the PLC was malfunctioning is excluded.) Figure 8 provides the crest elevation of north entrance weir WG-64 versus tailwater elevation. Likewise, Figure 9 shows the weir WG-64 submergence with respect to the tailwater level. The PLC limits (8.0 – 8.6 feet) for weir submergence are indicated by the shaded lines; and the data shows the how well the weir submergence stays within these limits.

The impaired data--from the period the PLC was malfunctioning--also provides useful information. During this period, the north entrance weir operated more like the south entrance weir and was free to wander to deeper levels of submergence. The average WG-64 submergence was 8.4 feet when the PLC was operating properly and was 12.5 feet when it was malfunctioning. The consequence of the deeper submergence of the north entrance was lower velocities at the north end. For approximately equivalent tailrace levels, the velocity at the sonic meter in the north end of the powerhouse collection channel was 20% higher when the weir submergence was held near 8 feet compared to the period the weir submergence was deeper. This appears to be the intent of the designers of the PLC logic: to keep the north entrance weir tightly constrained and allow the south weir to go deeper to induce more flow down the powerhouse channel.

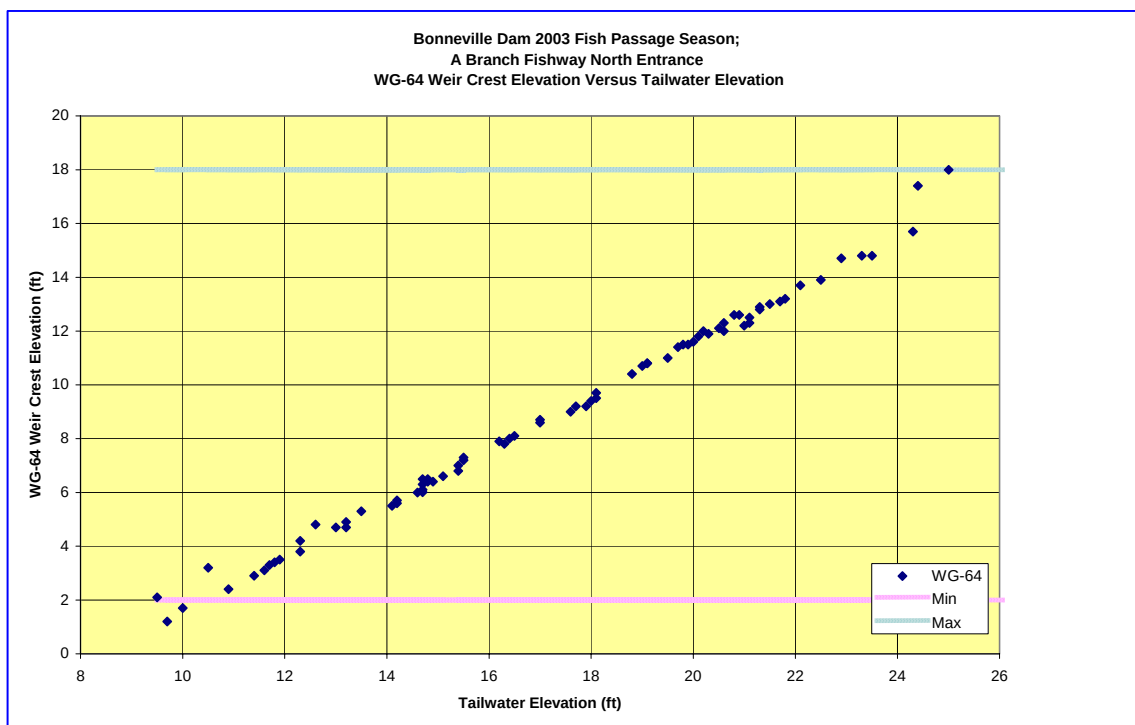


Figure 8: Crest Elevation of North Entrance Weir WG-64 Versus Tailwater Elevation (normal PLC operation)

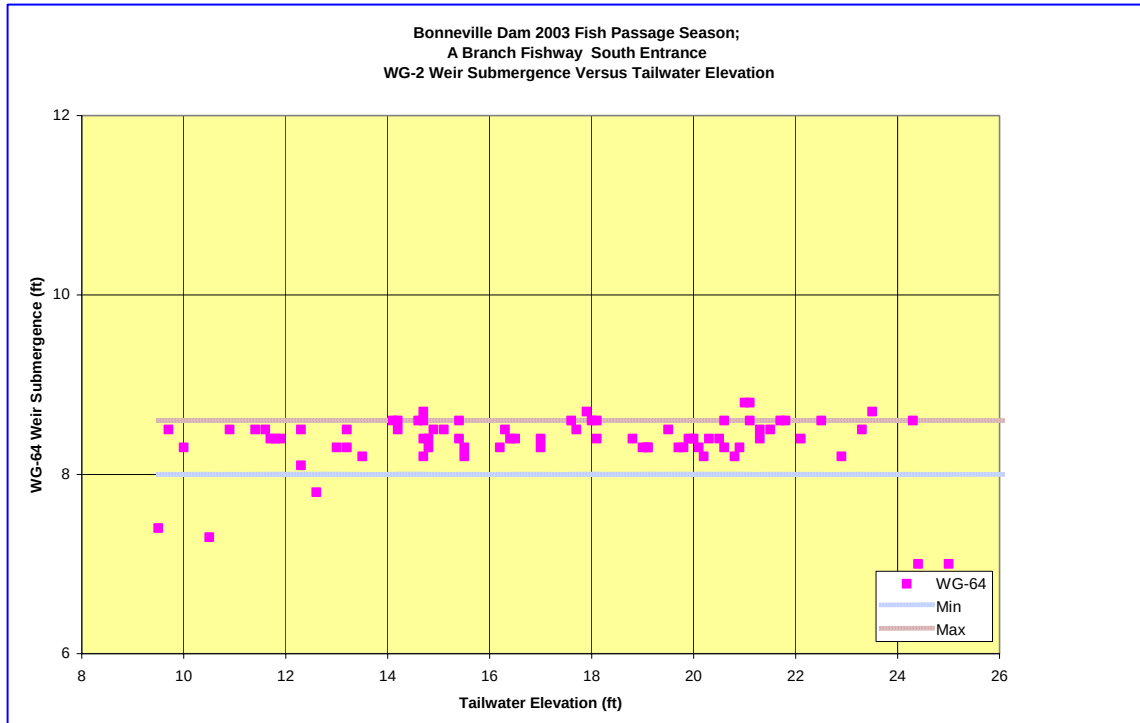


Figure 9: Submergence of North Entrance Weir WG-64 Versus Tailwater Elevation

5.0 Recommendations

There are a number of recommendations as a result of this model study. They primarily consist of operational or structural changes to improve performance of the A Branch ladder with respect to operational criteria but some pertain to the numerical model itself. Recommendations for the numerical model and fishway are also provided in the following paragraphs.

5.1 Numerical Model Modifications

While the most important corrections have been made to the geometry files, there remain several items that require direct revision to the program code to ensure greater accuracy and provide more useful output information. The following recommendations are listed for the future correction of the remaining program deficiencies:

1. Modify (recompile) program so that it can be operated on windows 2000 PCs.
2. Correct erroneous adjustments made in subroutines and equations for structural cross beams in entrance weir computations;
3. Change the entrance weir equations to better match theoretical curves and provide more accurate computation of the weir coefficients;
4. Include force + momentum balance analyses to properly account for energy losses from upward diffuser flow in open channel computations for the collection channel;
5. Provide user options to change output defaults to provide:
 - a. Expanded output to include all input data, including geometry (IN & FDR) file, which makes for an complete document upon future review, and
 - b. Include results from pressurized system (AWS) with the open channel output results;
6. Output should include magnitude and location of maximum pressure differentials between AWS conduit and adjacent ladder system; and
7. Forebay level should be shown in output.

In addition to addressing the remaining program deficiencies, there are potential enhancements that could empower the user to extract more visually descriptive output information while simultaneously requiring less effort upfront.

- GUI interface for the user so that graphical as well as tabular output may be provided.
- Graphical output: Output data file can be processed automatically and displayed graphically so that a large number of users with varied backgrounds can understand conditions in the ladder;

Color coded tables that display green when section of the ladder are in criteria and red when out.

Ultimately output could be sent to a drawing of ladder system so that when the user selects a location (diffuser, entrance opening, channel location, et al.), the flow rates, velocities and water levels would be displayed.

5.2 Fishway Operational Modifications

The recommended operation is outlined in a matrix for incremental tailwater levels between 8 and 35 feet in Plate 13 of this report. The current ladder fails to meet velocity criteria in the powerhouse channel for most tailwater levels seen at Bonneville and the level of the south entrance weir is not a consistent function of tailwater level.

Operational changes can improve, but not fully solve, the problem with respect channel velocity criteria for most tailrace levels. The velocity criteria will still not be fully met at tailwater levels below 17 feet (exceeded 38% of the time). However velocities will be improved on the order of 10 – 50% at the north end of the powerhouse channel.

Proposed operational changes include the following items:

1. Change the PLC to tie the south entrance weirs (WG1 or WG-2) directly to the tailwater level.
Revise the PLC so that the south entrance weir is set according to tailwater elevation. Revise the limits of the fish valve FV1-1 to regulate the entrance head at the south entrance between 1.2 - 1.5 feet—the current limits for the south entrance weir modulations. Set outer limits of FV1-1 to the current 1.0 –1.9 feet. The benefits of these changes will be a consistent and more predictable operation of the south entrance weirs with respect to tailwater elevation. This in turn will ensure more consistency in the powerhouse channel velocities. A side benefit will be less movement in the south entrance weirs and possibly FV1-1, thus potentially reducing maintenance stresses on them.
2. In revising the PLC, set the south entrance weirs (WG1 or WG-2) to operate at maximum levels of submergence that will be allowed by the system without exceeding other hydraulic or operational criteria. By doing this, the maximum potential flow will be drawn into the powerhouse channel and the powerhouse channel velocities will be raised.
3. Relax the diffuser velocity criteria to operate up to 1.0 ft/s maximum. The north AWS is already being operated such that the maximum velocity is about 0.9 ft/s. The system was originally designed according to 1 ft/s criteria. The velocities should be kept below this level to avoid the possibilities of blowing off the diffuser gratings.
4. Stack the open diffusers (FG2-17 – 22) on the north side of the powerhouse channel by opening diffusers FG2-17 & 18 and closing diffusers FG 2- 4, 8, & 12. The bulking of the open diffusers on the north side of the powerhouse channel will increase the average velocity along the powerhouse channel. The current layout of the open FG2 diffusers (along the powerhouse channel) were designed to provide makeup water from discharge removed from the channel by the five powerhouse

telescoping gates. These gates have been permanently closed this year and there is no need to hold to the current layout of open diffuser if there is room for improvement.

5. Reinstate PLC feature that incrementally closes fish valve FV1-1 if the pressure difference between South AWS conduit and powerhouse channel exceeds 10 psi. The close command for FV1-1 was previously included in the PLC program to protect the structural integrity of the walls. Anecdotal information states that the maximum allowable pressure between the AWS conduit and fish ladder channel should be 10 psi for structural purposes and 6 psi for biological purposes. The PLC protection feature was deleted when the AWS pressure transducer in the south conduit became unreliable. The transducer has since been recalibrated and the PLC feature should be reinstated.

The recommended operation is outlined in a matrix for incremental tailwater levels between 8 and 35 feet in Plate 13 of this report. EC-HD recommends a trial operation of the ladder entrances and AWS system in accordance with the proposed operation.

Table 14 and Table 15 show the results of the proposed operational changes. Table 14 shows the optimized results for the low/medium tailwater weirs WG-2 & WG-64, and likewise, Table 15 shows the results for high tailwater weirs WG-1⁵ & WG-65. The layout of the tables are the same as in Table 12 (existing operation) with the tailwater levels listed across the top row followed by the sections for settings, discharges, water level & pressure data, and performance with respect to fish passage criteria.

With the proposed operational changes, the channel velocity criteria will be met in most locations along the powerhouse channel, but not always at the sonic sensor location at the north end. However the threshold tailwater level below which criteria is violated will be reduced significantly from about 24 feet for existing operation to about 17 feet for the optimized operation. This means the percent of time that the system fails to meet criteria at the north end is reduced from 90% to 62%. Also, the velocities will be increased (from the existing operation) by about 10 % at low tailwater levels and about 50% at the upper limits of WG-2 or tailrace 26. The improvements are less (0-20%) at the high tailrace levels and WG-1, but velocities should be within criteria at these levels.

The maximum diffuser velocities will be unchanged from the current operation since the operation of the north conduit diffusers and FV3-7 will not change. Diffusers velocities in the south conduit will be higher, but will still meet the 0.5 ft/s criterion.

EC-HD recommends a trial operation of the ladder entrances and AWS system in accordance with the proposed operation. The trial operations should be accompanied by field verification tests for velocities and heads. If the tests prove successful and there is concurrence from the regional agencies, the recommended operational changes should be incorporated into the Corps Fish Passage Plan.

⁵ Simulations in the second table (tailwater levels above 24 feet) will need to be revised in the final report submittal, since all results for WG-1 and WG-65 are based on uncalibrated estimates for weir coefficients. The study team intends to collect high tailwater flow data next spring so that the model may be calibrated for these entrance weirs.

Table 14: Optimized Operation of A Branch Fishway Part 1: Low Tailwater Entrance Weirs WG-2 & WG--64 (Model Simulation Results for Tailwater Levels Between 8 and 35 Feet)

Optimized Operation Table for Entrances Weirs WG 2 & WG 64 (Low/Medium Tailwater Weirs)									
TAILWATER ELEVATION (ft)	8	10	12	14	16	18	20	22	24A
SETTINGS:									
Inflow: (valve openings)									
South AWS (FV1-1 opening) (ft)	2.0	3.4	3.6	3.1	3.7	3.0	3.0	4.5	4.5
North AWS (FV3-7 opening) (ft)	1.3	1.3	1.3	2.1	2.1	3.6	4.3	4.3	4.3
AWS conduit regulator FV3-8 (ft)	0	0	0	0	0	0	0	0	0
Weir 67 Ladder Head (ft)	1.0	1.0	1.0	1.2	1.2	1.2	1.2	1.2	1.2
Outflow: (weir elevations, ft)									
South Entrance WG-1	40	40	40	40	40	40	40	40	40
South Entrance WG-2	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	4.0
PH gates 9, 21, 34, 58, & 62	closed	closed	closed	closed	closed	closed	closed	closed	closed
North Entrance WG-64	2.0	2.0	3.7	5.7	7.7	9.7	11.7	13.7	15.7
North Entrance WG-65	40	40	40	40	40	40	40	40	40
DISCHARGE:									
Inflow: (cfs)									
South AWS (FV1-1)	489	804	836	731	845	720	720	859	842
North AWS (FV3-7)	259	261	262	410	409	644	747	747	750
AWS conduit regulator FV3-8 (ft)	0	0	0	0	0	0	0	0	0
Weir 67 Ladder Flow (ft)	192	192	192	239	239	239	239	239	239
Outflow: (cfs)									
South Entrance WG-1	0	0	0	0	0	0	0	0	0
South Entrance WG-2	384	502	620	739	869	995	1112	1251	1250
PH gates 9, 21, 34, 58, & 62	0	0	0	0	0	0	0	0	0
North Entrance WG-64	460	659	574	521	504	488	474	474	461
North Entrance WG-65	0	0	0	0	0	0	0	0	0
Total System Discharge (cfs)	940	1257	1290	1379	1492	1602	1706	1845	1831
WATER LEVEL, HGL, AND PRESSURE DATA									
Tailrace (ft)	8	10	12	14	16	18	20	22	24
Water Level at Pool 19 (FG3-5)	20.0	20.0	20.0	20.0	20.1	21.9	23.3	24.7	26.3
North PH Channel Water Level (ft)	9.5	11.6	13.6	15.5	17.6	19.6	21.5	23.6	25.5
South PH Channel Water Level (ft)	9.3	11.3	13.3	15.3	17.3	19.3	21.3	23.3	25.3
HGL North AWS (at FG3-5) (ft)	30.8	31.0	31.6	28.0	28.8	32.0	33.5	34.9	36.6
HGL South AWS (at FG2-2) (ft)	10.5	14.3	16.5	17.8	20.6	21.8	23.7	26.7	28.5
Δ North AWS (psi) @FG3-5	4.7	4.8	5.0	3.5	3.8	4.4	4.4	4.4	4.5
Δ South AWS (psi) @ FG2-2	0.5	1.3	1.4	1.1	1.4	1.1	1.1	1.5	1.4
FISH PASSAGE CRITERIA:									
Tailwater (ft)	8	10	12	14	16	18	20	22	24A
North Entrance Head (ft)	1.5	1.5	1.5	1.5	1.6	1.6	1.5	1.6	1.5
South Entrance Head (ft)	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
North Entr. Weir Submergence (ft)	6.0	8.0	8.3	8.3	8.3	8.3	8.3	8.3	8.3
South Entr. Weir Submergence (ft)	6.0	8.0	10.0	12.0	14.0	16.0	18.0	20.0	20.0
North PH Channel Velocities (ft/s)	0.9	0.7	1.0	1.4	1.5	1.8	1.9	2.0	1.8
South PH Channel Velocities (ft/s)	1.9	2.1	2.3	2.4	2.6	2.7	2.7	2.8	2.6
Max AWS Diffuser Velocities (ft/s)	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.7	0.7

Table 15: Optimized Operation of A Branch Fishway Part 2: High Tailwater Entrance Weirs WG-1 & WG--65 (Model Simulation Results for Tailwater Levels Between 8 and 35 Feet)

(High Tailwater Weirs*)							
TAILWATER ELEVATION (ft)	24B	26	28	30	32	34	35
SETTINGS:							
Inflow: (valve openings)							
South AWS (FV1-1 opening) (ft)	2.3	2.2	2.1	3.3	4.4	4.4	4.4
North AWS (FV3-7 opening) (ft)	4.3	5.5	6.5	6.5	7.1	7.1	7.1
AWS conduit regulator FV3-8 (ft)	0	0	0	0	0	0	0
Weir 67 Ladder Head (ft)	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Outflow: (weir elevations, ft)							
South Entrance WG-1	8.5	8.5	8.5	8.5	8.5	9.7	10.4
South Entrance WG-2	40	40	40	40	40	40	40
PH gates 9, 21, 34, 58, & 62	closed	closed	closed	closed	closed	closed	closed
North Entrance WG-64	40	40	40	40	40	40	40
North Entrance WG-65	15.6	17.6	19.6	21.6	23.6	25.6	26.6
DISCHARGE:							
Inflow: (cfs)							
South AWS (FV1-1)	568	535	512	704	767	749	739
North AWS (FV3-7)	750	953	1151	1151	1283	1286	1287
AWS conduit regulator FV3-8 (ft)	0	0	0	0	0	0	0
Weir 67 Ladder Flow (ft)	239	239	239	239	239	239	239
Outflow: (cfs)							
South Entrance WG-1	1009	1179	1358	1546	1741	1730	1722
South Entrance WG-2	0	0	0	0	0	0	0
PH gates 9, 21, 34, 58, & 62	0	0	0	0	0	0	0
North Entrance WG-64	0	0	0	0	0	0	0
North Entrance WG-65	429	427	426	428	428	423	423
Total System Discharge (cfs)	1557	1726	1903	2094	2288	2273	2265
WATER LEVEL, HGL, AND PRESSURE DATA							
Tailrace (ft)	24	26	28	30	32	34	35
Water Level at Pool 19 (FG3-5)	26.3	28.4	30.5	32.4	34.4	36.2	37.2
North PH Channel Water Level (ft)	25.5	27.5	29.5	31.5	33.5	35.5	36.5
South PH Channel Water Level (ft)	25.3	27.3	29.3	31.3	33.3	35.3	36.3
HGL North AWS (at FG3-5) (ft)	36.6	38.7	45.4	42.3	43.2	45.0	45.9
HGL South AWS (at FG2-2) (ft)	26.8	28.7	30.6	33.6	36.0	37.9	38.8
Δ North AWS (psi) @FG3-5	4.5	4.4	6.4	4.3	3.8	3.8	3.8
Δ South AWS (psi) @ FG2-2	0.7	0.6	0.6	1.0	1.2	1.1	1.1
FISH PASSAGE CRITERIA:							
Tailwater (ft)	24B	26	28	30	32	34	35
North Entrance Head (ft)	1.5	1.5	1.5	1.5	1.5	1.5	1.5
South Entrance Head (ft)	1.4	1.4	1.4	1.4	1.3	1.4	1.4
North Entr. Weir Submergence (ft)	8.4	8.4	8.4	8.4	8.4	8.4	8.4
South Entr. Weir Submergence (ft)	15.5	17.5	19.5	21.5	23.5	24.3	24.6
North PH Channel Velocities (ft/s)	1.6	1.8	2.1	2.1	2.3	2.1	2.1
South PH Channel Velocities (ft/s)	2.1	2.3	2.5	2.6	2.8	2.6	2.6
Max AWS Diffuser Velocities (ft/s)	0.7	0.7	0.9	0.7	0.7	0.7	0.7

*Model has not been calibrated for high tailwater conditions and entrance weirs WG-1 & WG-65; Flow tests pending next spring.

5.3 Fishway Structural Modifications

Not all criteria violations can be entirely met by modifying the operation. There are a number of potential structural modifications that could help the system better meet the criteria and generally improve the performance of the fishway.

The following list provides the potential structural recommendations:

1. Raise diffuser gratings to match the original invert (elev. 0.0).
This would raise the invert of the channel from elevation -2.0 to 0.0 and make for a relatively seamless channel bottom. This change would improve flow efficiency in the powerhouse channel and raise average powerhouse channel velocities up to 20-25% at minimum tailwater levels. Additionally important, the effective flow area of the diffuser grating would be significantly increased as the grating would no longer rest directly against the concrete bubbler beams. This effective increase in grating area would reduce the velocities through the grating, which in turn would reduce the likelihood of having the gratings blown off by high pressures and debris build up.
2. Add non-overflow weir crests to weirs 54 and 55 so that the lengths of the overflow sections are equal to those of weirs 56-67. The head over the ladder vary between weirs 67 and 54. The overflow weir crests are wider at weirs 54 and 55 than the rest in this section. Analyses shows that the heads at these weirs are up to 0.2 to 0.3 feet lower than the head at control weir 67. The length of the non-overflow sections should be 15 feet and 5 feet from weirs 45 and 55, respectively. The addition of non-overflow weir sections at these two weirs would guarantee uniformity in overflow weir lengths and ladder heads throughout the section.
3. Raise the sonic velocity sensor in the north powerhouse channel to a higher level in the channel or install a second sensor at a higher level. With the low elevation of the existing sensor (1 foot or 3 feet above the invert), the measurement does not represent the average velocity of the channel.
4. Either narrow the north entrance openings or add a second vertical slot to the upstream opening to the entrance bay. To improve powerhouse channel velocities, a greater volume of flow needs to be drawn down the powerhouse channel. This can be accomplished by reducing the flow to the north entrances. Either narrowing the north entrance openings or adding a vertical slot to the upstream face of the each north entrance bay. The accelerator wall would be removed.
5. Replace modulating south entrance gates with wider, shaped, fixed weir. Another way to increase the powerhouse channel velocities is to increase the flow through the south entrance. A fixed and shaped weir at the south entrance would assure a consistent performance and would allow for a higher width of flow at the lower tailwater levels. The widths of the entrance channels are wider 9.67 ft than the 8 - 8.25 feet weir slots. An additional benefit would be lower maintenance costs.

Other more substantial and costly structural alternatives include (a) the lowering of the powerhouse channel invert and entrance openings to at least –1 feet elevation and (b) reducing the number of baffles in the exit section. If the invert and minimum weir crest is lowered the Fishway can meet the 8 feet minimum submergence for the full range of project tailrace levels. If the head criteria violations in the exit section are deemed unacceptable, the section would need to be overhauled by reducing the number of pools by half. A similar modification was actually completed at the John Day South Fishway in 2002 to mitigate a fish jumping problem.

6.0 References

1. Brater, E. F., King, H. W., *Handbook of Hydraulics*, 1976.
2. Chow, V. T., *Open Channel Hydraulics*, (1959)
3. Corps of Engineers, Waterways Experiment Station, *Hydraulic Design Criteria*. Revised 1954
4. Corps of Engineers, Portland District. *Information Bulletin; Fish Passage Facilities Bonneville Dam, Columbia River, Oregon & Washington*. Report no. 66-1, Bonneville Hydraulic Laboratory. April 1958.
5. Corps of Engineers, Portland District. *Bonneville Dam, Design Memorandum No. 1, Modification for Peaking*. Revised September 1971.
6. Corps of Engineers, Division Hydraulic Laboratory. Technical Report No 141-1; *Modification of Fish Ladders, Bonneville Dam, Columbia River Oregon & Washington*; Hydraulic Model Investigations by L. Z. Perkins & P. M. Smith. December 1973.
7. Corps of Engineers, *Hydraulic Design of Reservoir Outlet works, EM 1110-2-1602*, 1980.
8. Corps of Engineers, Portland District. *Bonneville Dam, Design Memorandum 35, First Powerhouse Upstream Migrant Collection Modification*. Sept. 1980.
9. Corps of Engineers, Northwest division. *Fish Passage Plan*. 2003.
10. Corps of Engineers, Portland District 80% Draft *Bonneville Bradford Island & Cascade Island Adult Fishways Assessment Phase I Report*. 2003
11. Henderson, F.M., *Open Channel Flow*, (1966)
12. Jeppson, Roland W., *Open Channel Flow Utilizing Computers, Revised Draft*, Utah State University (1994)
13. Miller, D.S., *Internal Flow Systems*, (1978)
14. Northwest Hydraulics Consultants Inc. and Montgomery Watson Consulting Engineers Inc. Bonneville Dam, Route Juvenile Bypass System Excess Water Phase II and Modifications to the First Adult Powerhouse Fish Ladder Main Entrances. Prepared for Corps of Engineers, Portland District. September 1993.
15. Northwest Hydraulics Consultants Inc. Bonneville Dam, Hydraulic Evaluation of the First Adult Powerhouse Adult Bypass Systems. Prepared for Corps of Engineers, Portland District. December 1995; revised 1998.
16. Tullis, J. Paul, *Hydraulics of Pipelines*. 1989.

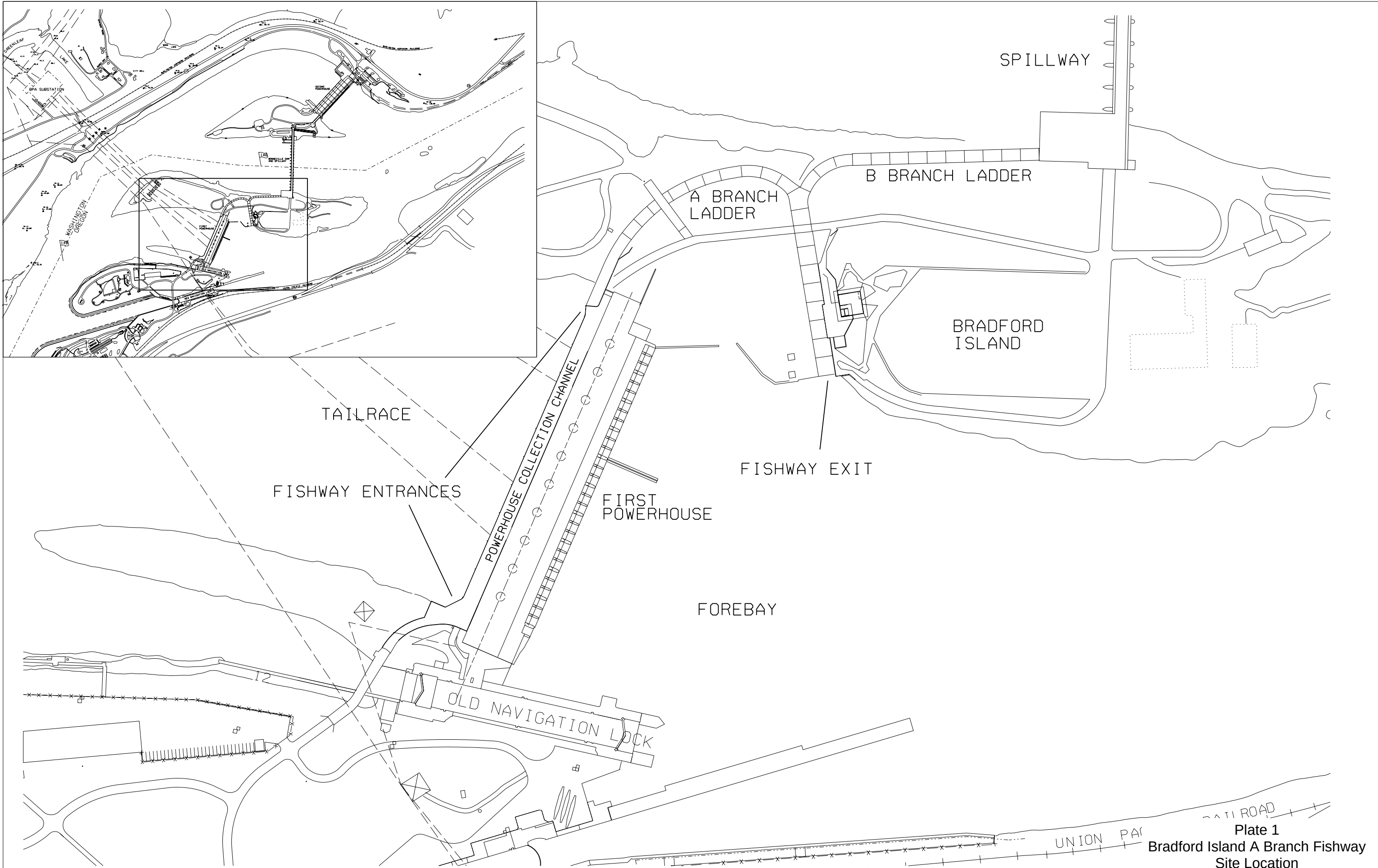


Plate 1
Bradford Island A Branch Fishway
Site Location

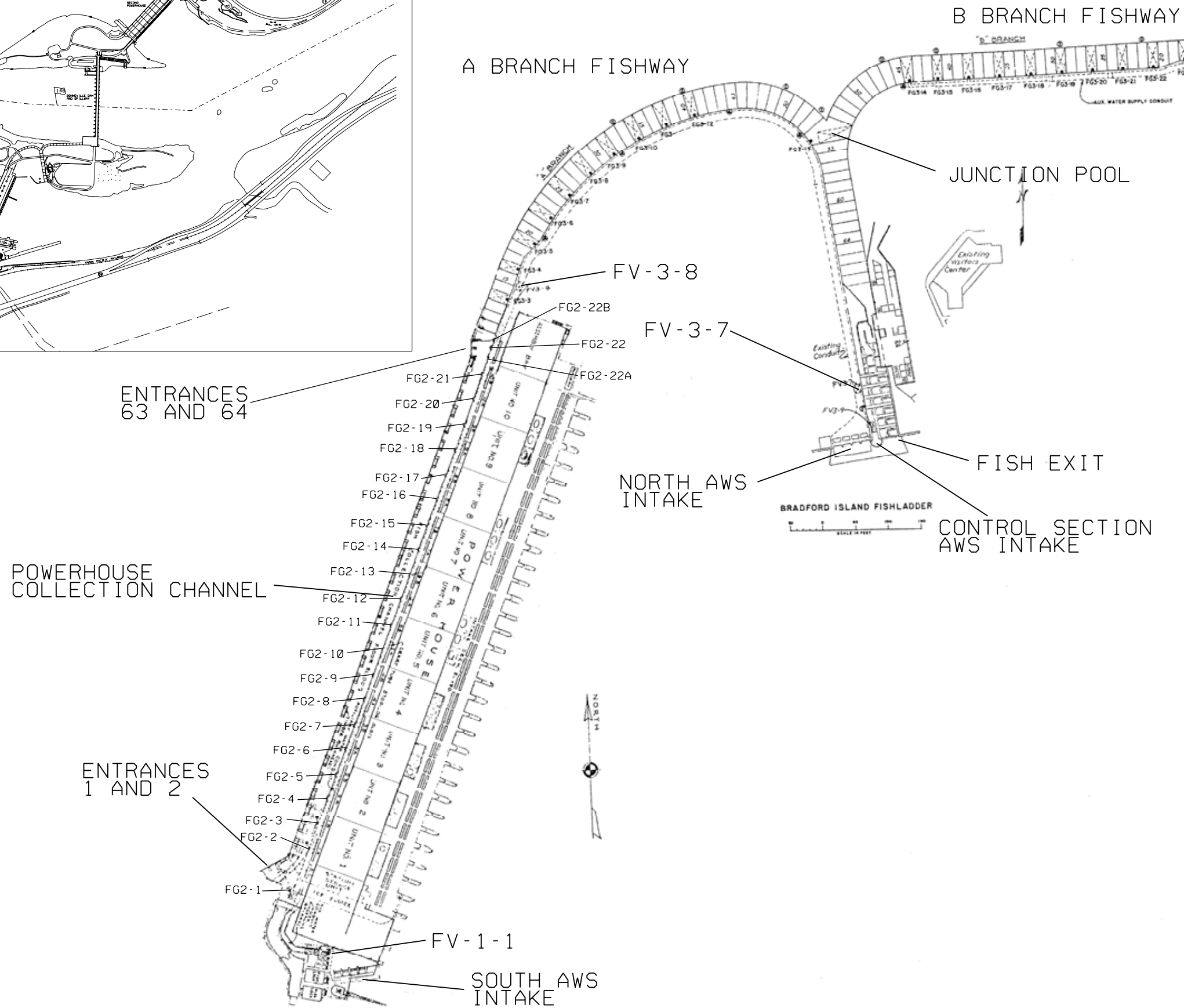
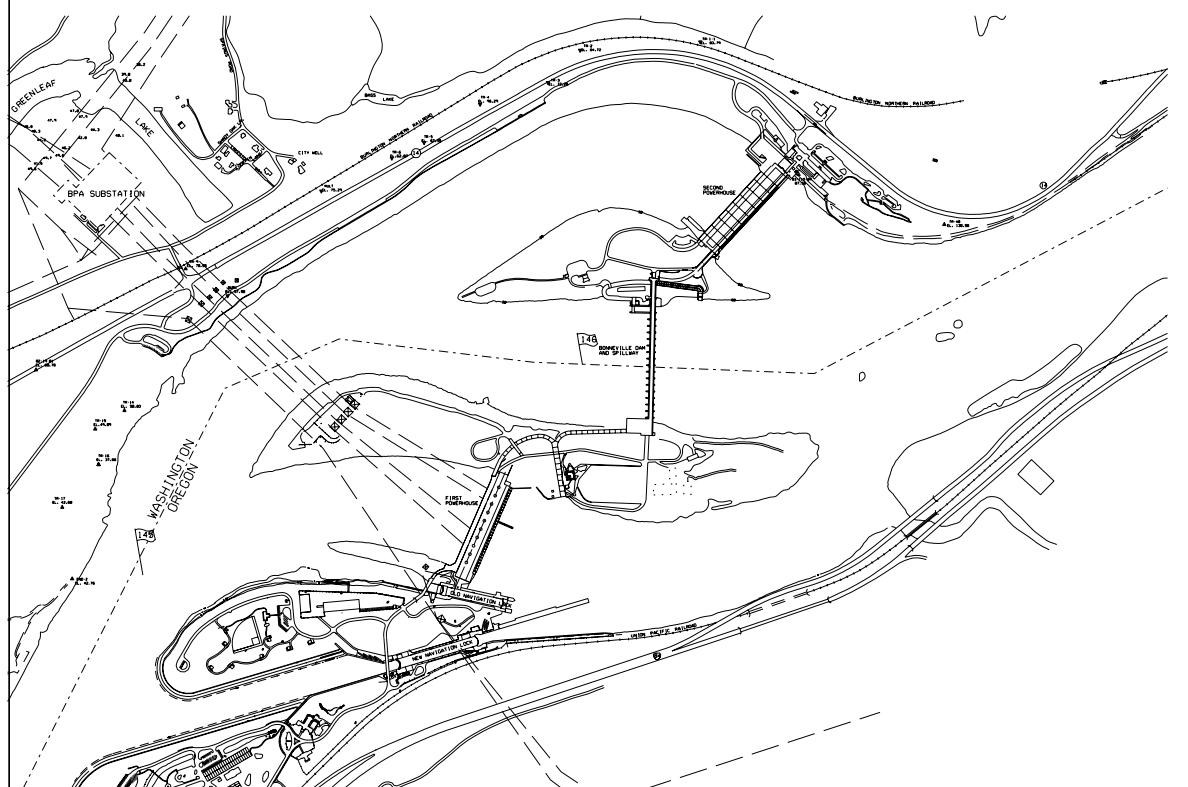


Plate 2
Bradford Island A Branch Fishway
General Plan View

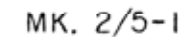
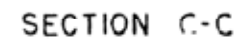
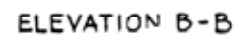
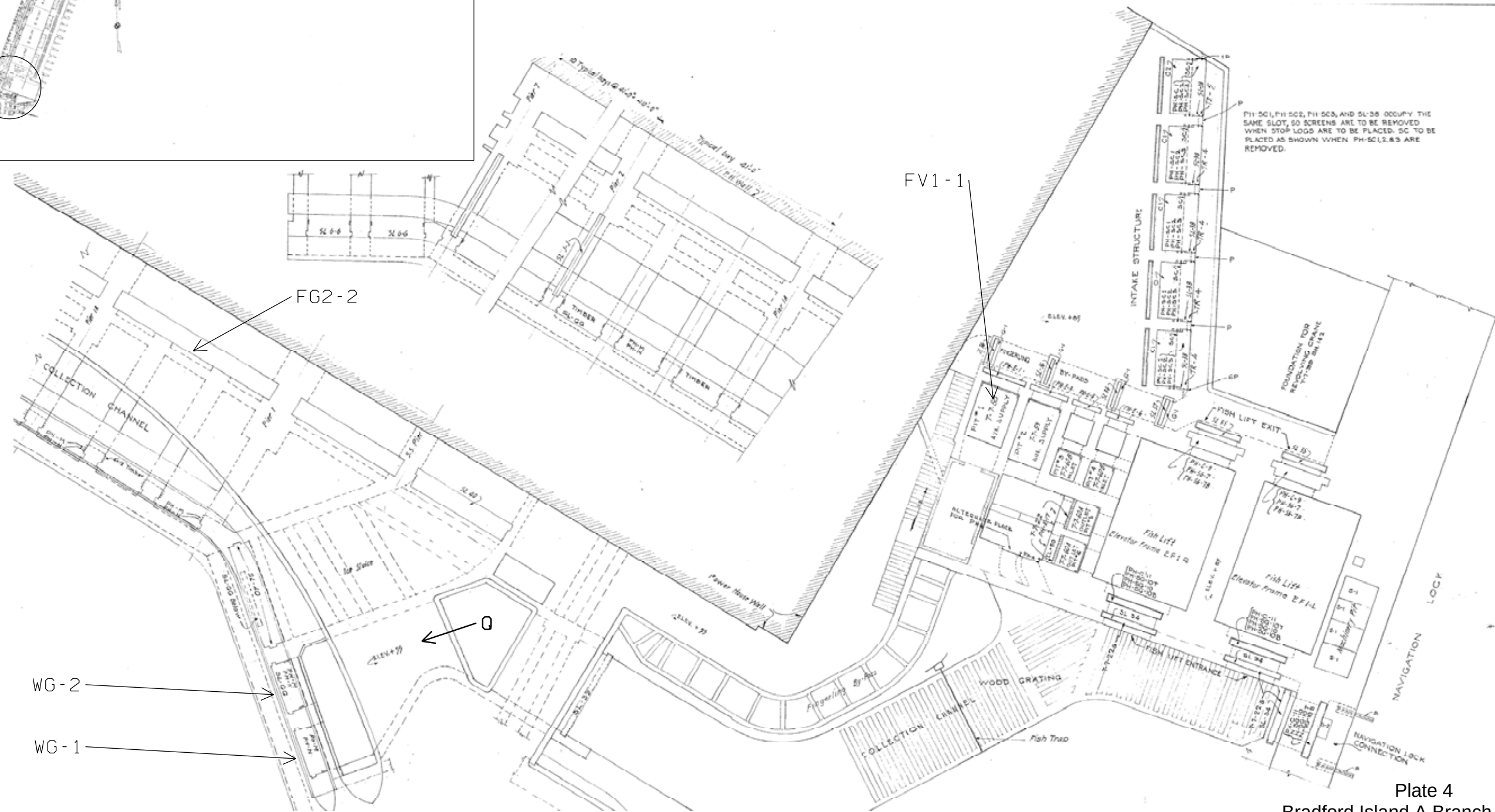
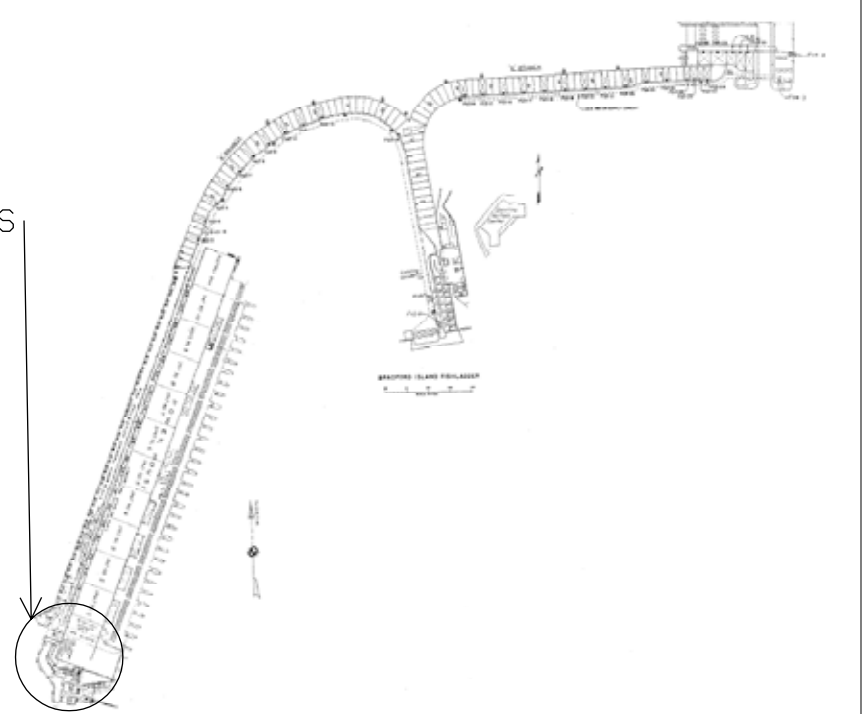


Plate 3
Bradford Island A Branch Fishway
North Entrance Plan with Accelerator Wall

SOUTH ENTRANCES
AND AWS INTAKE



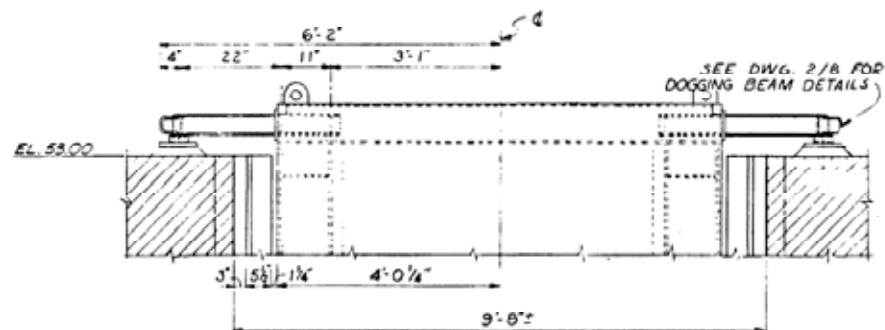
FG2-2

WG-2

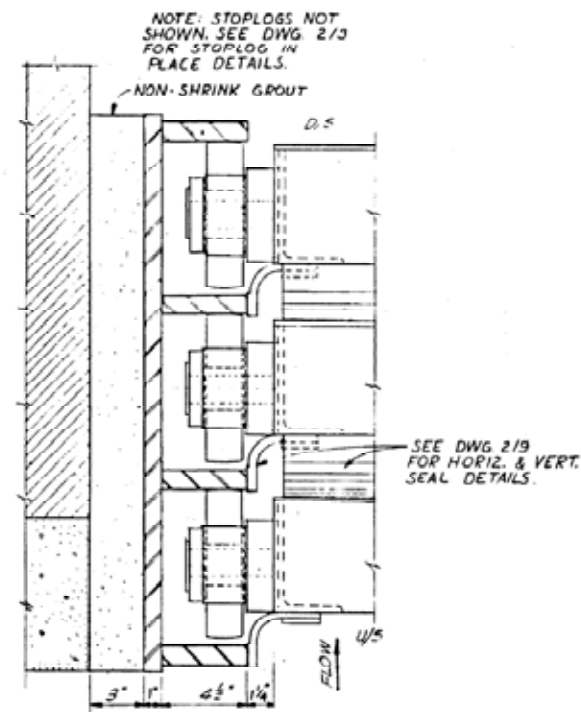
WG-1

FV1-1

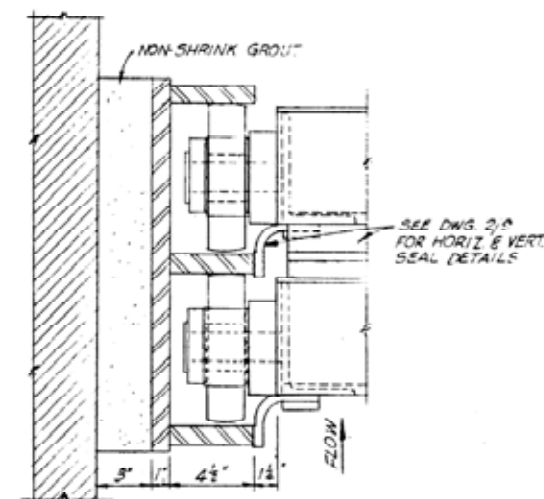
Plate 4
Bradford Island A Branch Fishway
South Entrance Plan



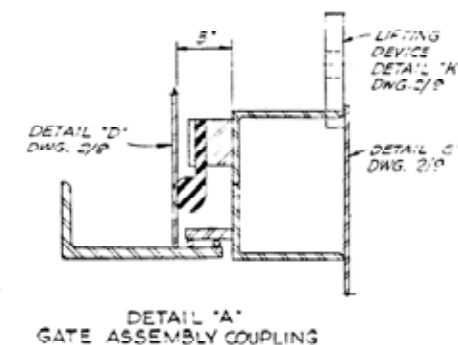
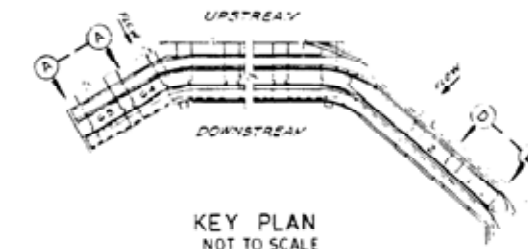
ELEVATION
DOGGING BEAMS EXTENDED



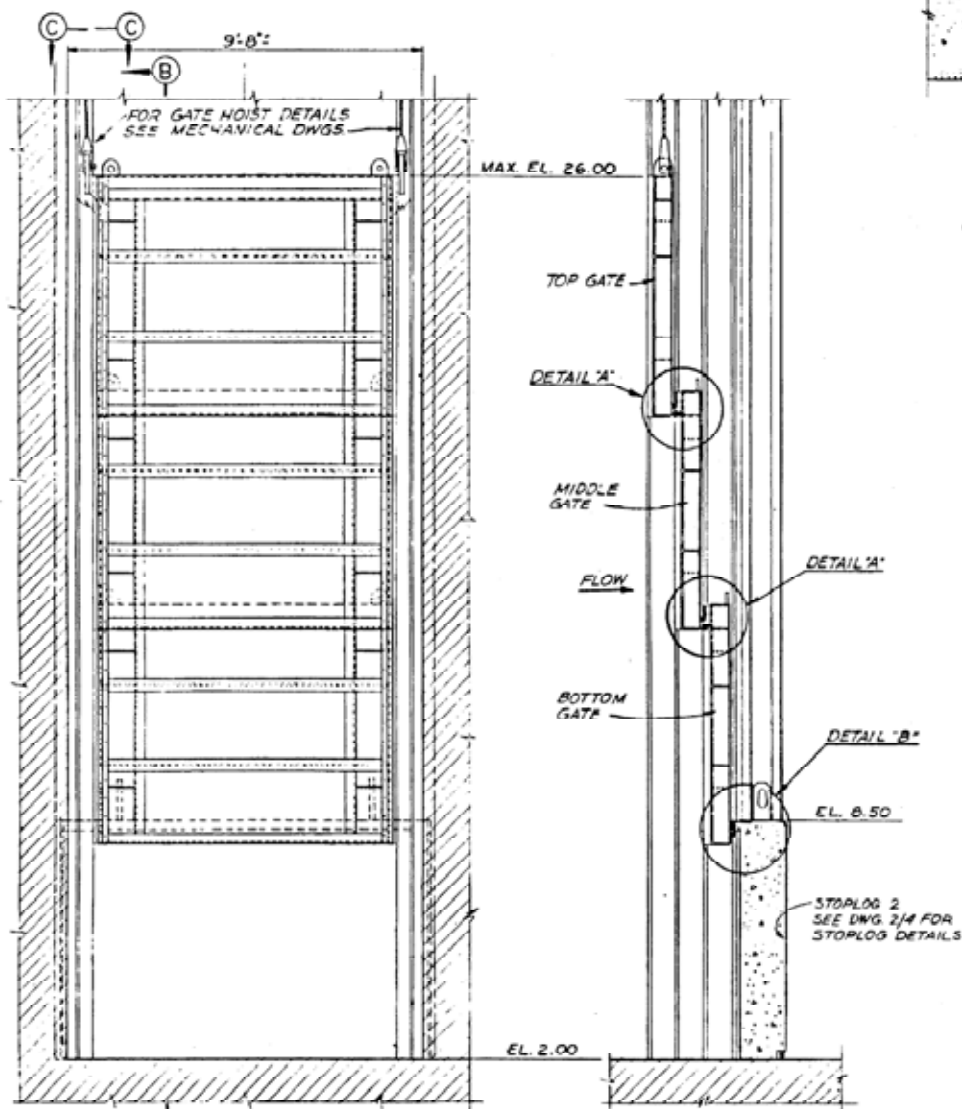
SECTION C-C
WHEEL & SEAL ARRANGEMENT



SECTION F-F
WHEEL & SEAL ARRANGEMENT



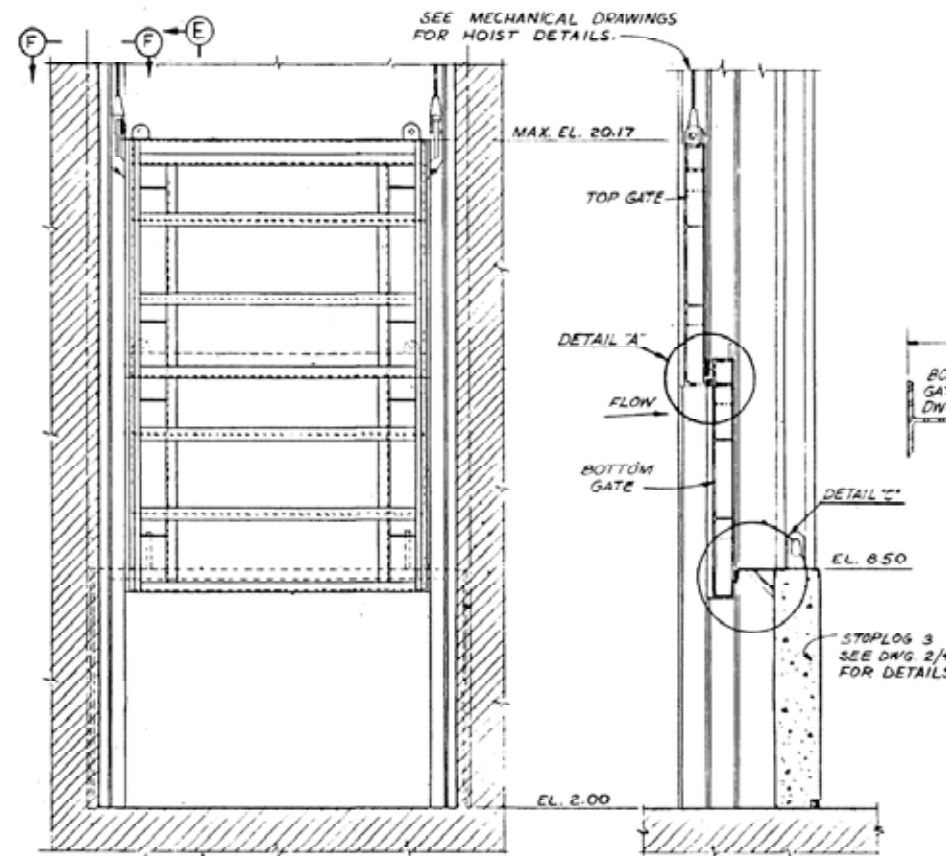
DETAIL "A"
GATE ASSEMBLY COUPLING



ELEVATION A-A

SECTION B-B

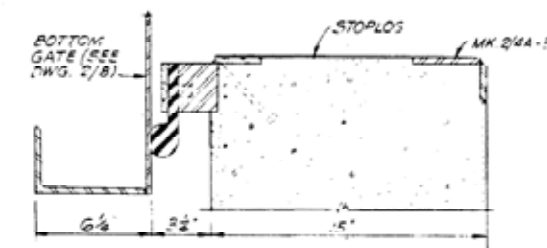
ENTRANCE 65 WEIR GATE ASSEMBLY



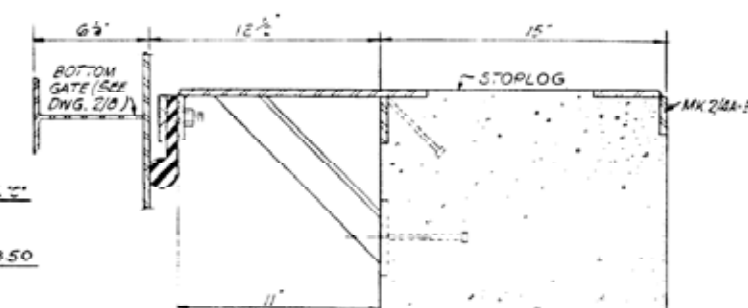
ELEVATION D-D

SECTION E-E

ENTRANCE 1 WEIR GATE ASSEMBLY

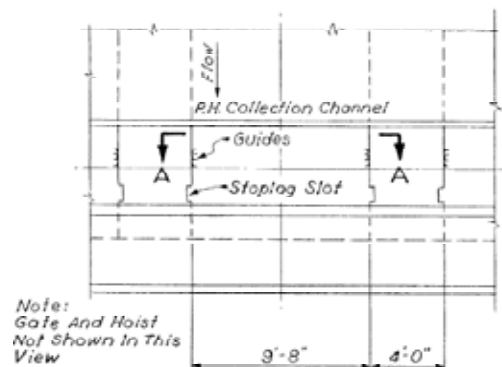


DETAIL "B"
WEIR GATE & STOPLOG SEAL ASSEMBLY ENTRANCE 65

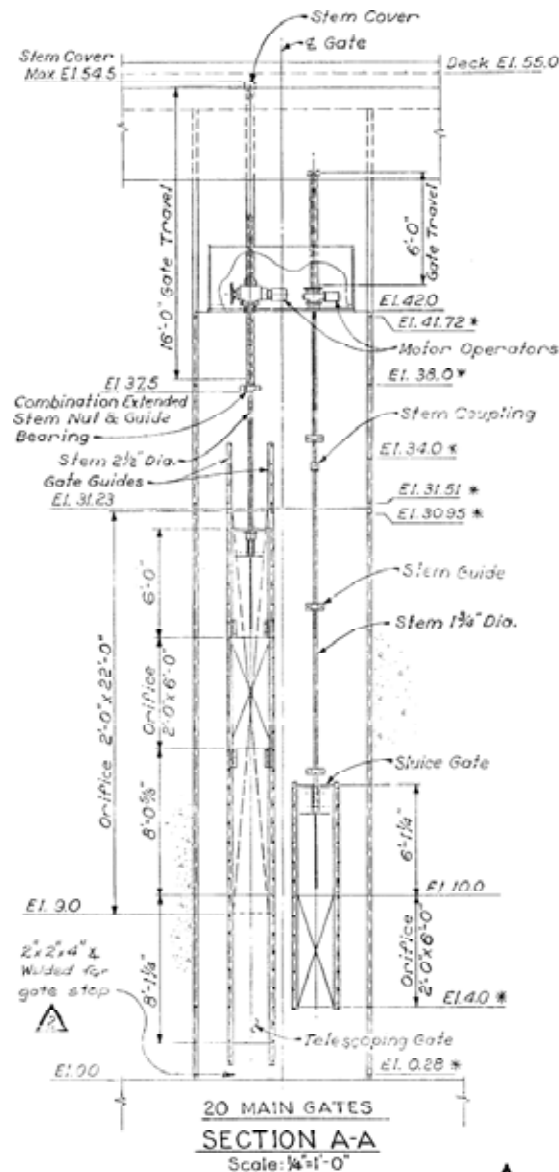


DETAIL "C"
WEIR GATE AND STOPLOG SEAL ASSEMBLY ENTRANCE 1

NOTES:
1. FOR GENERAL NOTES SEE DWG. BDP-1.5-0-0/2.



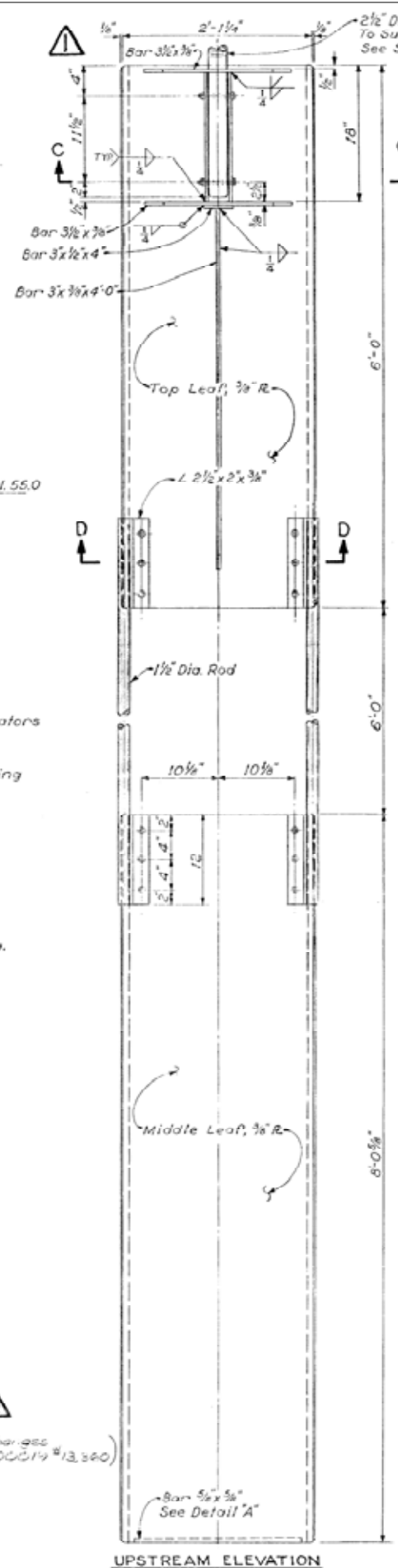
TYPICAL PLAN
Scale: 1/4"=1'-0"



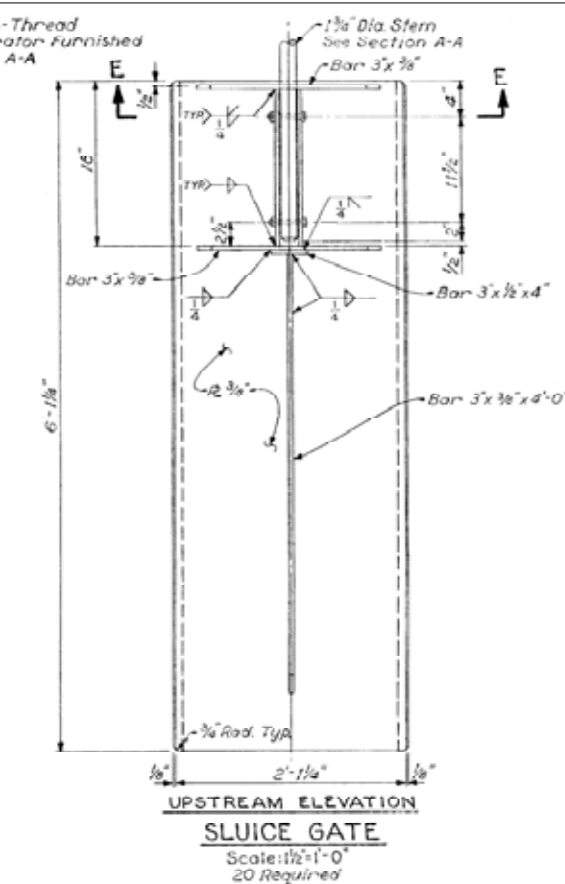
SECTION A-A
Scale: 1/4"=1'-0"

Note: * Indicates Location of 3/8" STIFF. R's. See Guide Reinforcement Detail Dwg. No. BDF-3-1/4

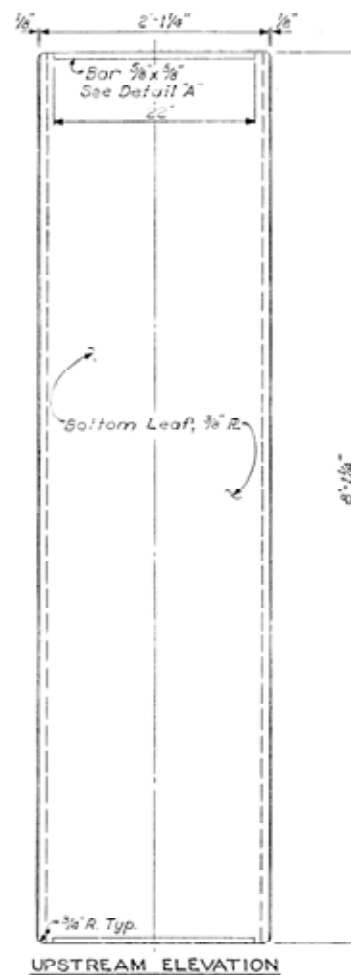
(For other charges See Mat. H-00011/13,360)



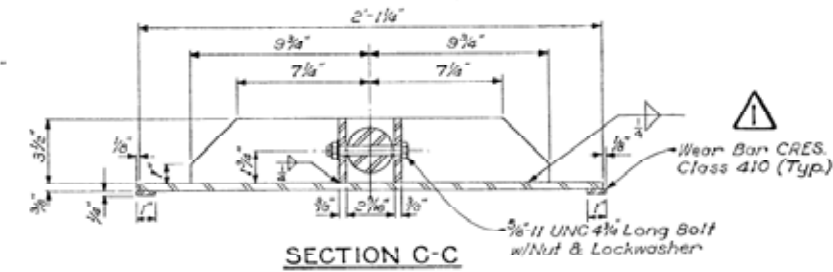
TELESCOPING GATE
Scale: 1/8"=1'-0"
20 Required



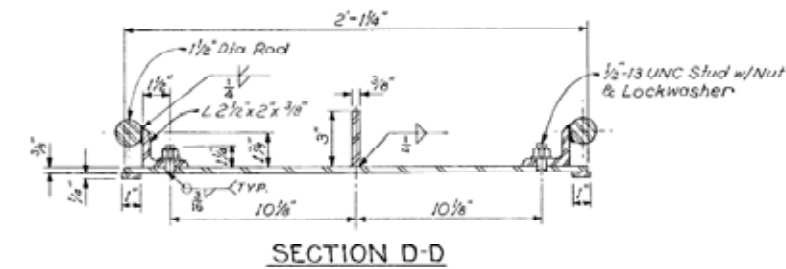
**UPSTREAM ELEVATION
SLUICE GATE**
Scale: 1/8"=1'-0"
20 Required



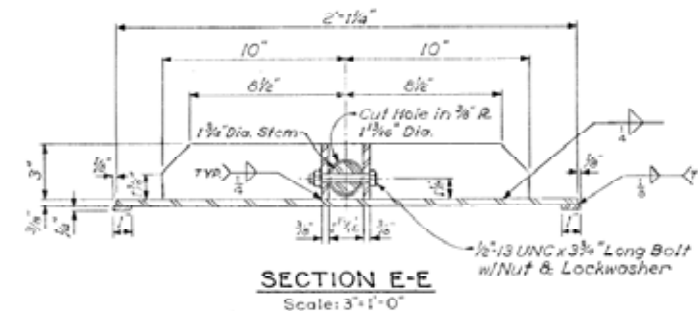
UPSTREAM ELEVATION



SECTION C-C



SECTION D-D

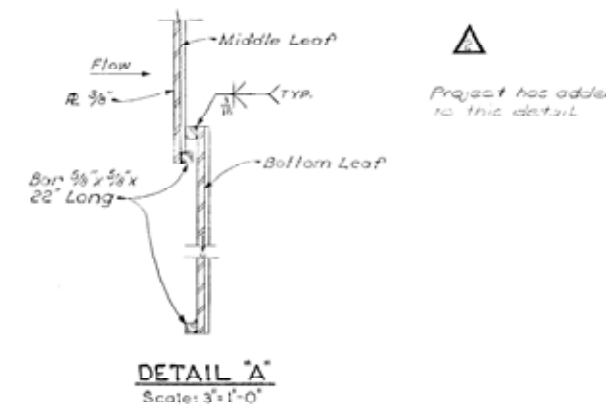


SECTION E-E
Scale: 3/8"=1'-0"

NOTES:
1. 20 Gates required. One each for Collection Channel Entrances 5, 9, 10, 15, 16, 21, 22, 27, 28, 33, 34, 39, 40, 45, 46, 51, 52, 57, 58 & 62.
2. Painting & Materials - See Dwg. No. BDF-3-1/3

REFERENCE DRAWINGS:
BDF-3-1/8 Main Gate & Details
BDF-3-1/11 Platform & Misc. Equipment
BDF-3-1/1 General Plan

(6) Collection System Equipment



DETAIL A-A
Scale: 3/8"=1'-0"

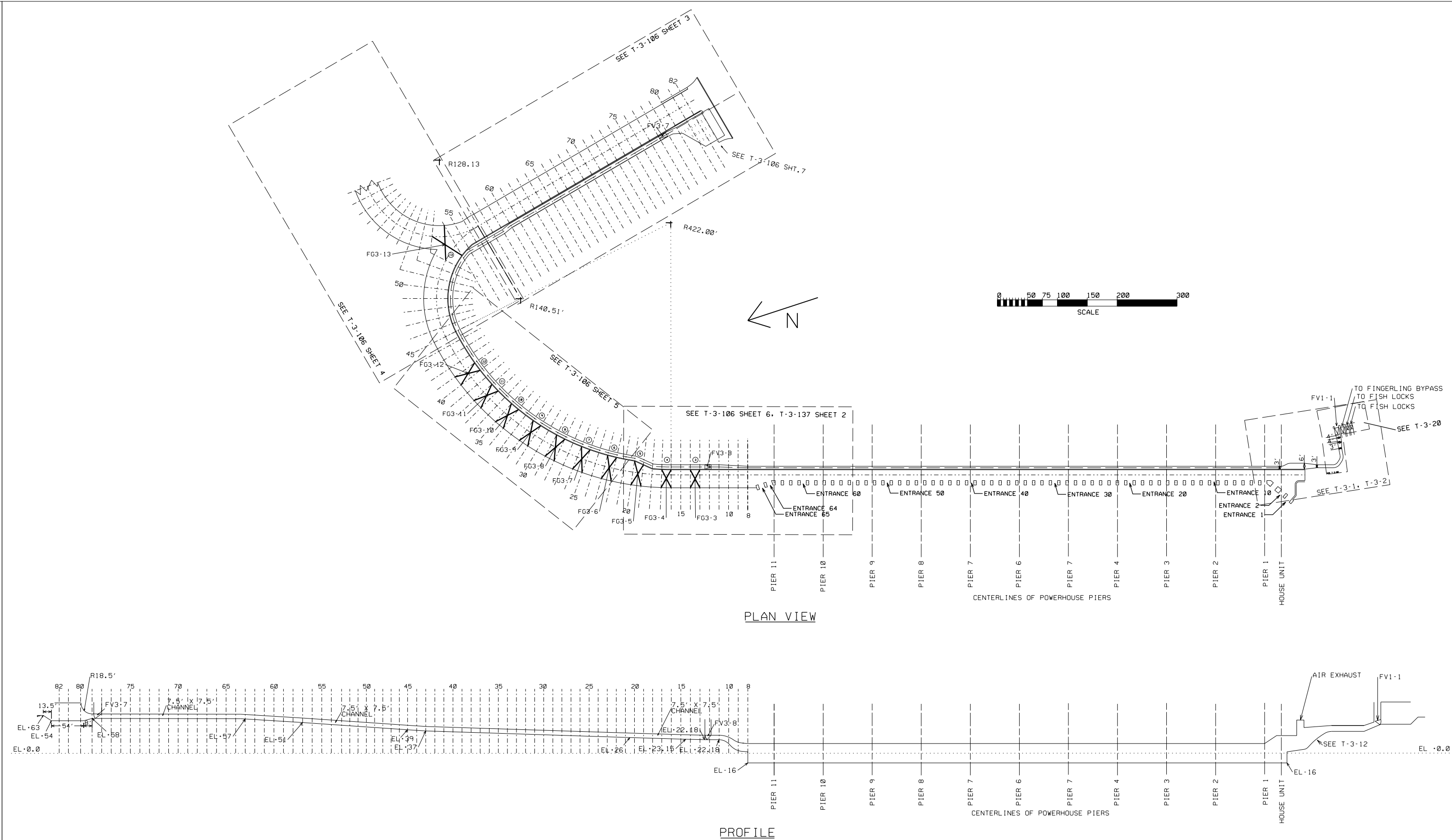
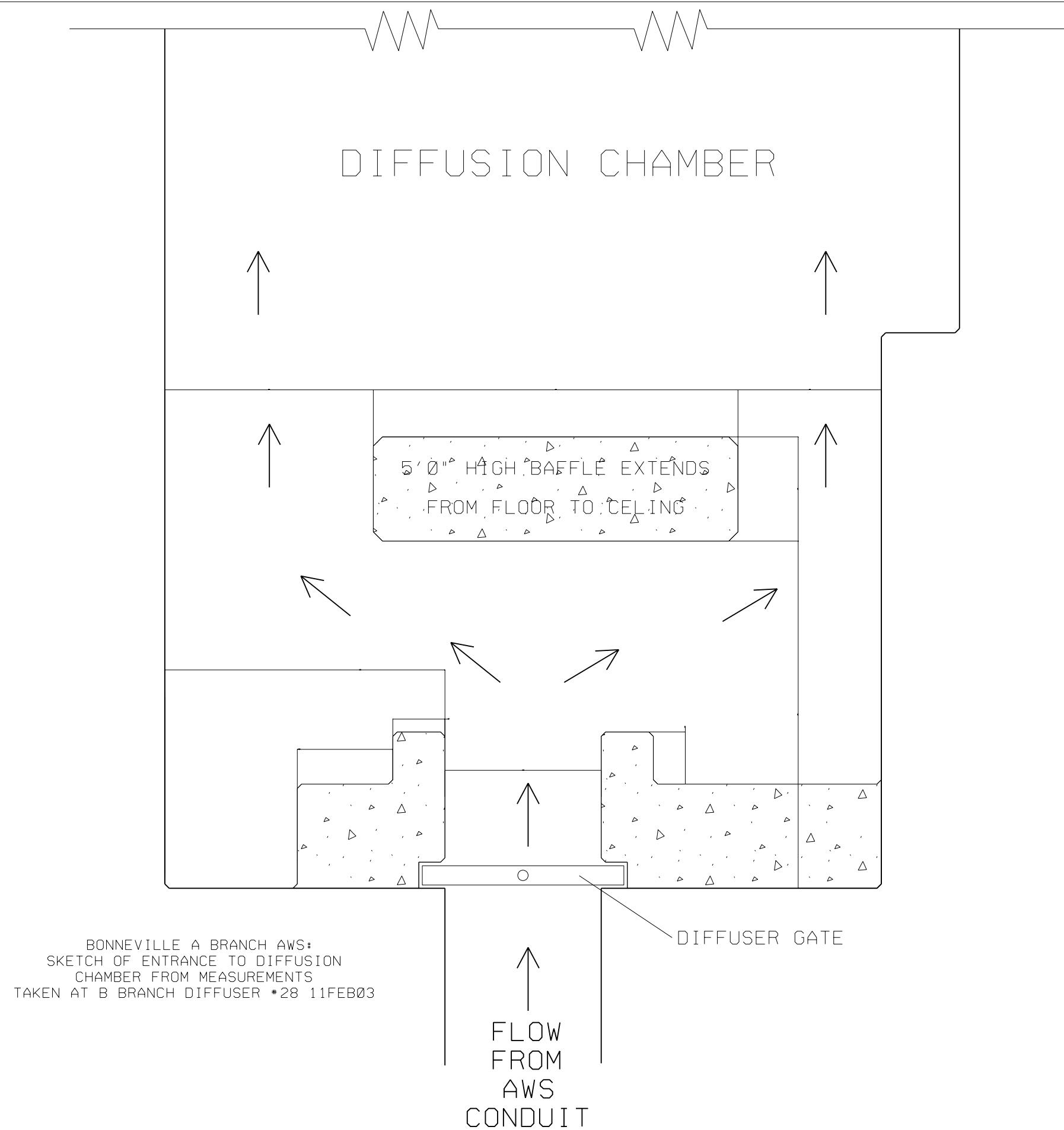
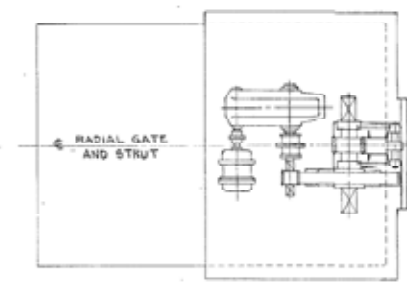
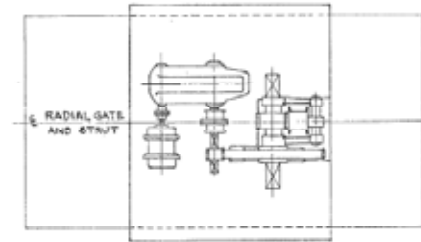


Plate 7
Bradford Island A Branch Fishway
AWS Conduits Plan & Profile

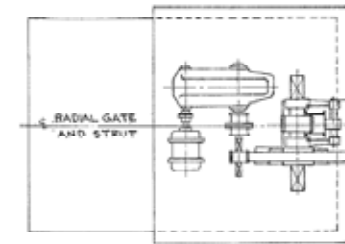




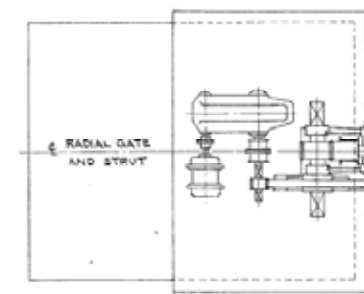
FV1-1



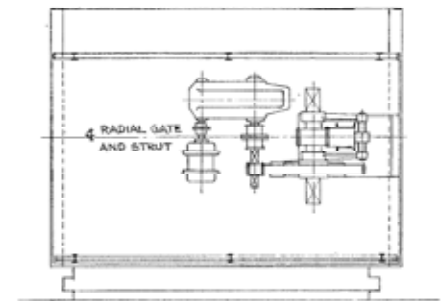
FISHLOCK



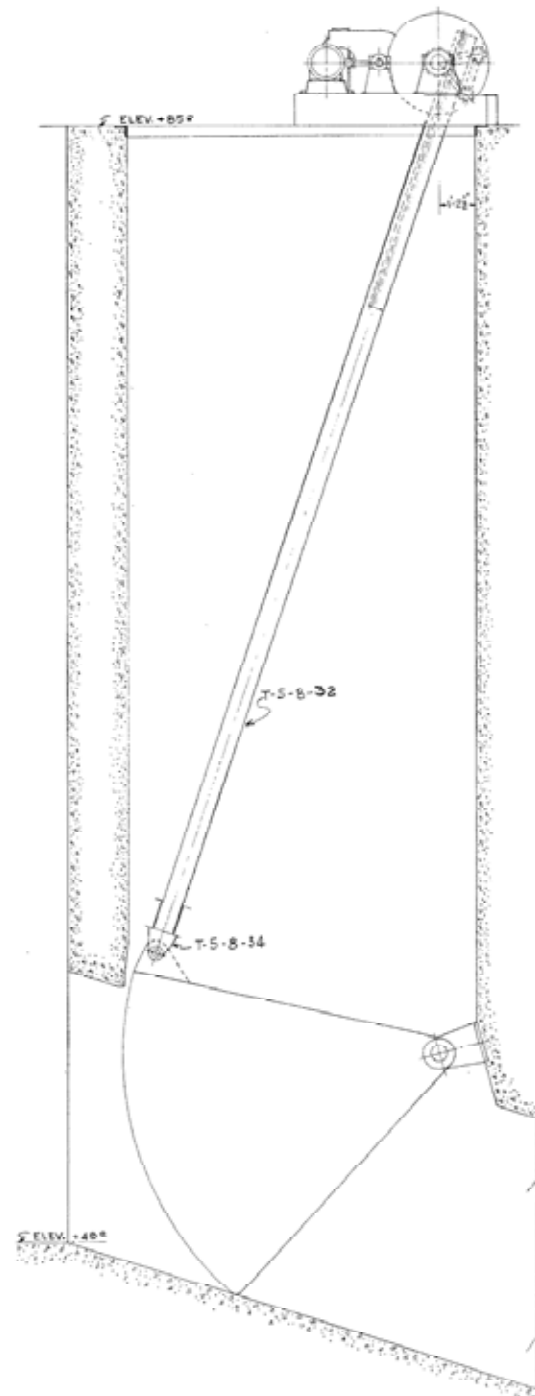
FV4-3, FV4-4, FV5-3, FV5-4
(B BRANCH AND CASCADES ISLAND)



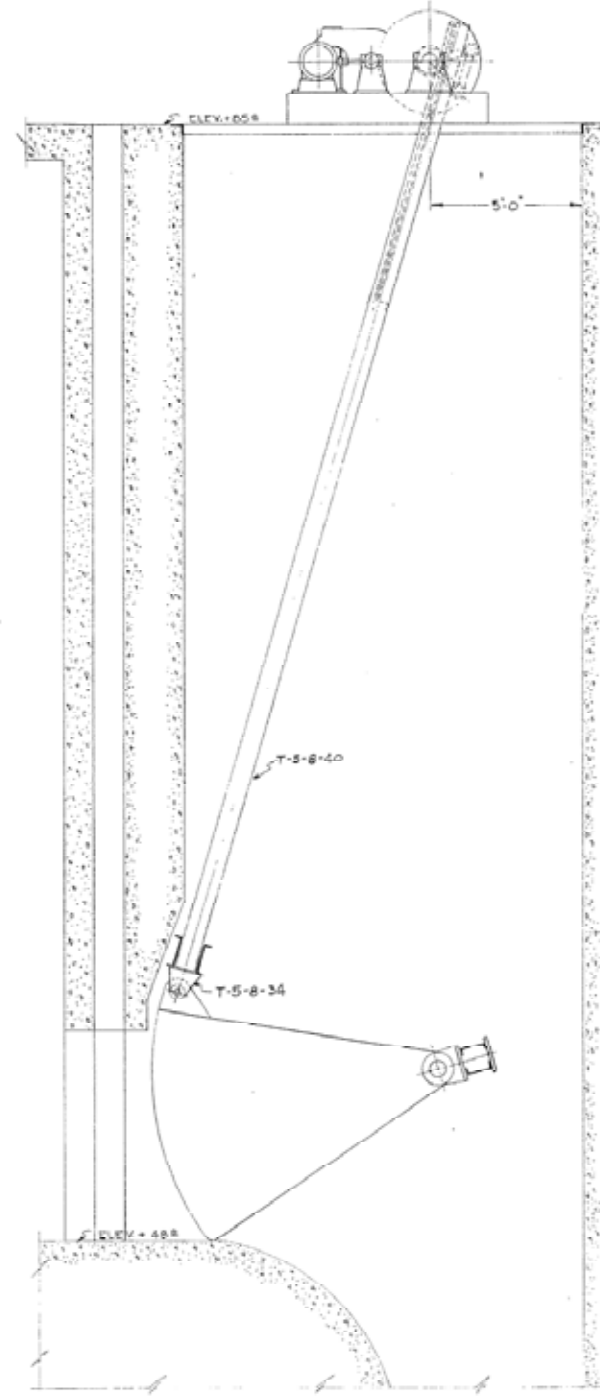
FV3-7



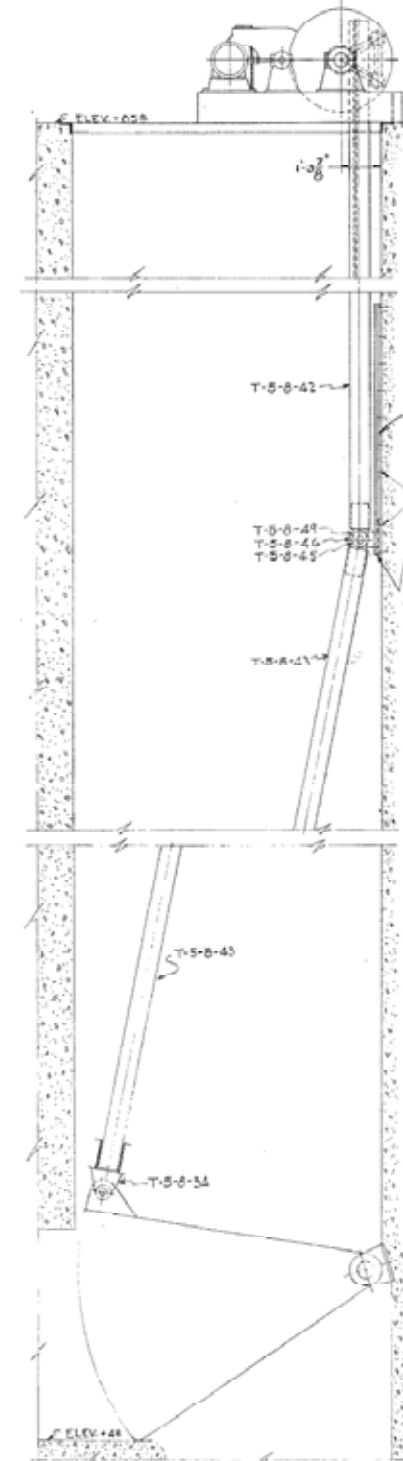
FV3-8



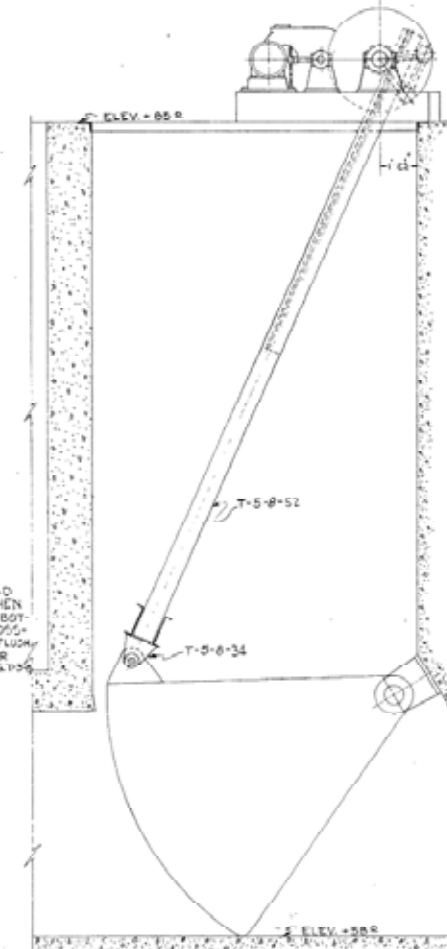
POWER HOUSE RADIAL GATE NO. 1



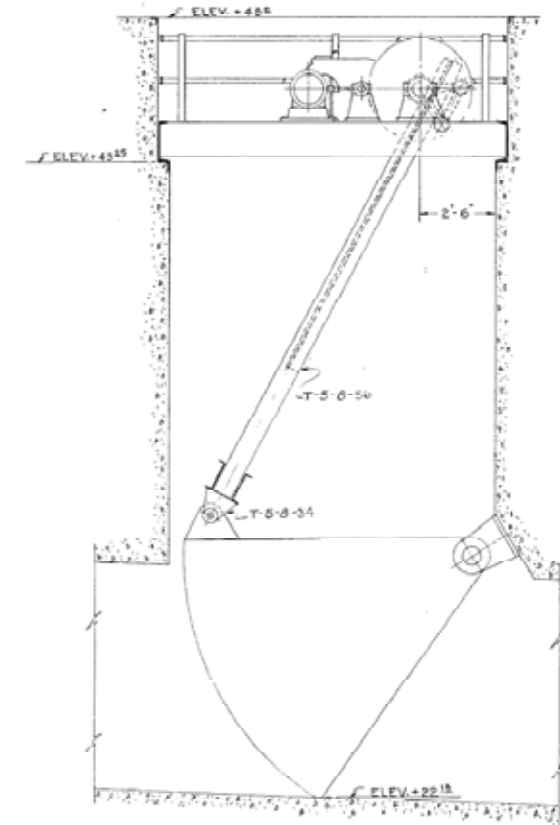
POWER HOUSE RADIAL GATE NO. 2



SPILLWAY DAM RADIAL GATES
TYPICAL FOR 4 GATES
2 GATES NO. 3
2 GATES NO. 4



INLET RADIAL GATE
BRADFORD ISLAND LADDER



REGULATING RADIAL GATE
BRADFORD ISLAND LADDER

NOTES:-
FOR GENERAL ASSEMBLY SEE DWG. T-5-B, SHEET 1.
FOR DETAILS SEE DWG. T-5-B, SHEETS 3 TO 11
INCLUSIVE.
FOR CINCH ANCHOR SPACING IN BASES SEE
DWG. T-5-B, SHEETS 1 & 2 INCLUSIVE.
ONLY DRAWINGS LISTED IN PAR. 108 OF THE SPECIFICATIONS
AND MARKED THIS (●) ON THIS DRAWING CONSTITUTE A PART OF
THIS CONTRACT. OTHER DRAWINGS LISTED HERE ARE FOR REFERENCE ONLY.

EXISTING OPERATION

Current Diffuser Gate Schedule for the Powerhouse Auxiliary Water Conduit

POWERHOUSE AND SOUTH AWS SYSTEM														
	Fish Valve	South AWS Diffusers (manual)												
TW	FV1-1	FG2-1	FG2-2	FG2-3	FG2-4	FG2-5	FG2-6	FG2-7	FG2-8	FG2-9	FG2-10	FG2-11	FG2-12	T/W
7	OPEN	CLOSED	CLOSED	CLOSED	OPEN	CLOSED	CLOSED	CLOSED	OPEN	CLOSED	CLOSED	CLOSED	OPEN	7
10	OPEN	CLOSED	CLOSED	CLOSED	OPEN	CLOSED	CLOSED	CLOSED	OPEN	CLOSED	CLOSED	CLOSED	OPEN	10
15	OPEN	CLOSED	CLOSED	CLOSED	OPEN	CLOSED	CLOSED	CLOSED	OPEN	CLOSED	CLOSED	CLOSED	OPEN	15
20	OPEN	CLOSED	CLOSED	CLOSED	OPEN	CLOSED	CLOSED	CLOSED	OPEN	CLOSED	CLOSED	CLOSED	OPEN	20
25	OPEN	CLOSED	CLOSED	CLOSED	OPEN	CLOSED	CLOSED	CLOSED	OPEN	CLOSED	CLOSED	CLOSED	OPEN	25
30	OPEN	CLOSED	CLOSED	CLOSED	OPEN	CLOSED	CLOSED	CLOSED	OPEN	CLOSED	CLOSED	CLOSED	OPEN	30
35	OPEN	CLOSED	CLOSED	CLOSED	OPEN	CLOSED	CLOSED	CLOSED	OPEN	CLOSED	CLOSED	CLOSED	OPEN	35
South AWS Diffusers (manual, continued)														
TW		FG2-13	FG2-14	FG2-15	FG2-16	FG2-17	FG2-18	FG2-19	FG2-20	FG2-21	FG2-22a	FG2-22	FG2-22b	T/W
7		CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	7
10		CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	10
15		CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	15
20		CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	20
25		CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	25
30		CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	30
35		CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	35

Current Diffuser Gate Schedule for North AWS Conduit and Entrance Weir Gate Settings

	Fish Valve	North AWS Diffusers							Entrance Weir Gate Crest Elevations (ft)				
TW	FV3-7 ¹	FG3-3	FG3-4	FG3-5	FG3-6	FG3-7	FG3-8	FG3-9	WG-1	WG-2	WG-64	WG-65	T/W
7	1.3	CLOSED	CLOSED	CLOSED	Half Open	CLOSED	CLOSED	CLOSED	CLOSED	2 - 3	2 - 3	CLOSED	7
8	1.3	OPEN	CLOSED	CLOSED	Half Open	CLOSED	CLOSED	CLOSED	CLOSED	2 - 3	2 - 3	CLOSED	8
9	1.3	OPEN	CLOSED	CLOSED	Half Open	CLOSED	CLOSED	CLOSED	CLOSED	2 - 3	2 - 3	CLOSED	9
10	1.3	OPEN	CLOSED	CLOSED	Half Open	CLOSED	CLOSED	CLOSED	CLOSED	2 - 3	2 - 3	CLOSED	10
11	1.3	OPEN	CLOSED	CLOSED	Half Open	CLOSED	CLOSED	CLOSED	CLOSED	2 - 3	2.7	CLOSED	11
12	1.3	OPEN	CLOSED	CLOSED	Half Open	CLOSED	CLOSED	CLOSED	CLOSED	2 - 4	3.7	CLOSED	12
13	1.3	OPEN	CLOSED	CLOSED	Half Open	CLOSED	CLOSED	CLOSED	CLOSED	2 - 5	4.7	CLOSED	13
14	2.1	OPEN	OPEN	CLOSED	Half Open	CLOSED	CLOSED	CLOSED	CLOSED	2 - 6	5.7	CLOSED	14
15	2.1	OPEN	OPEN	CLOSED	Half Open	CLOSED	CLOSED	CLOSED	CLOSED	2 - 7	6.7	CLOSED	15
16	2.1	OPEN	OPEN	CLOSED	Half Open	CLOSED	CLOSED	CLOSED	CLOSED	2 - 8	7.7	CLOSED	16
17	3.5	OPEN	OPEN	OPEN	Half Open	CLOSED	CLOSED	CLOSED	CLOSED	2 - 9	8.7	CLOSED	17
18	3.5	OPEN	OPEN	OPEN	Half Open	CLOSED	CLOSED	CLOSED	CLOSED	2 - 10	9.7	CLOSED	18
19	3.5	OPEN	OPEN	OPEN	Half Open	CLOSED	CLOSED	CLOSED	CLOSED	2 - 11	10.7	CLOSED	19
20	4.2	OPEN	OPEN	OPEN	OPEN	CLOSED	CLOSED	CLOSED	CLOSED	2 - 11	11.7	CLOSED	20
21	4.2	OPEN	OPEN	OPEN	OPEN	CLOSED	CLOSED	CLOSED	CLOSED	2 - 11	12.7	CLOSED	21
22	4.2	OPEN	OPEN	OPEN	OPEN	CLOSED	CLOSED	CLOSED	CLOSED	2 - 11	13.7	CLOSED	22
23	4.2	OPEN	OPEN	OPEN	OPEN	CLOSED	CLOSED	CLOSED	8.5 - 15	2 - 11	14.7	CLOSED	23 ²
24	4.2	OPEN	OPEN	OPEN	OPEN	CLOSED	CLOSED	CLOSED	8.5 - 16	2 - 11	15.7	CLOSED	24
25	5.4	OPEN	OPEN	OPEN	OPEN	CLOSED	CLOSED	CLOSED	8.5 - 17	2 - 11	16.7	16.6	25
26	5.4	OPEN	OPEN	OPEN	OPEN	OPEN	CLOSED	CLOSED	8.5 - 18	2 - 11	17.7	17.6	26 ³
27	5.4	OPEN	OPEN	OPEN	OPEN	OPEN	CLOSED	CLOSED	8.5 - 19	CLOSED	CLOSED	18.6	27
28	6.4	OPEN	OPEN	OPEN	OPEN	OPEN	CLOSED	CLOSED	8.5 - 20	CLOSED	CLOSED	19.6	28
29	6.4	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	CLOSED	8.5 - 21	CLOSED	CLOSED	20.6	29
30	6.4	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	CLOSED	8.5 - 22	CLOSED	CLOSED	21.6	30
31	7.0	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	8.5 - 23	CLOSED	CLOSED	22.6	31
32	7.0	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	8.5 - 24	CLOSED	CLOSED	23.6	32
33	7.0	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	8.5 - 25	CLOSED	CLOSED	24.6	33
34	7.0	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	8.5 - 26	CLOSED	CLOSED	25.6	34
35	7.0	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	8.5 - 27	CLOSED	CLOSED	26.6	35

1. Forebay level of 74 feet assumed for FV3-7 Valve settings
2. If the Tailrace is falling from above elevation 26 feet, WG-1 & WG-65 are open down to TW23 feet.
3. If the Tailrace is rising from below elevation 23 feet, WG-2 & WG-64 are open up to TW 26 feet.

OPTIMIZED OPERATION

Proposed Diffuser Gate Schedule for the Powerhouse Auxiliary Water Conduit

POWERHOUSE AND SOUTH AWS SYSTEM													
TW	Fish Valve FV1-1	South AWS Diffusers (manual)											
		FG2-1	FG2-2	FG2-3	FG2-4	FG2-5	FG2-6	FG2-7	FG2-8	FG2-9	FG2-10	FG2-11	FG2-12
8	OPEN	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED
10	OPEN	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED
15	OPEN	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED
20	OPEN	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED
25	OPEN	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED
30	OPEN	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED
35	OPEN	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED
South AWS Diffusers (manual, continued)													
TW	FG2-13	FG2-14	FG2-15	FG2-16	FG2-17	FG2-18	FG2-19	FG2-20	FG2-21	FG2-22a	FG2-22	FG2-22b	T/W
8	CLOSED	CLOSED	CLOSED	CLOSED	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	8
10	CLOSED	CLOSED	CLOSED	CLOSED	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	10
15	CLOSED	CLOSED	CLOSED	CLOSED	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	15
20	CLOSED	CLOSED	CLOSED	CLOSED	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	20
25	CLOSED	CLOSED	CLOSED	CLOSED	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	25
30	CLOSED	CLOSED	CLOSED	CLOSED	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	30
35	CLOSED	CLOSED	CLOSED	CLOSED	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	35

Proposed Diffuser Gate Schedule for North AWS Conduit and Entrance Weir Gate Settings

TW	Fish Valve FV3-7	North AWS Diffusers							Weir Gate Entrances				T/W
		FG3-3	FG3-4	FG3-5	FG3-6	FG3-7	FG3-8	FG3-9	WG-1	WG-2	WG-64	WG-65	
7	1.3	CLOSED	CLOSED	CLOSED	Half Open	CLOSED	CLOSED	CLOSED	CLOSED	2	2	CLOSED	7
8	1.3	OPEN	CLOSED	CLOSED	Half Open	CLOSED	CLOSED	CLOSED	CLOSED	2	2	CLOSED	8
9	1.3	OPEN	CLOSED	CLOSED	Half Open	CLOSED	CLOSED	CLOSED	CLOSED	2	2	CLOSED	9
10	1.3	OPEN	CLOSED	CLOSED	Half Open	CLOSED	CLOSED	CLOSED	CLOSED	2	2	CLOSED	10
11	1.3	OPEN	CLOSED	CLOSED	Half Open	CLOSED	CLOSED	CLOSED	CLOSED	2	2.7	CLOSED	11
12	1.3	OPEN	CLOSED	CLOSED	Half Open	CLOSED	CLOSED	CLOSED	CLOSED	2	3.7	CLOSED	12
13	1.3	OPEN	CLOSED	CLOSED	Half Open	CLOSED	CLOSED	CLOSED	CLOSED	2	4.7	CLOSED	13
14	2.1	OPEN	OPEN	CLOSED	Half Open	CLOSED	CLOSED	CLOSED	CLOSED	2	5.7	CLOSED	14
15	2.1	OPEN	OPEN	CLOSED	Half Open	CLOSED	CLOSED	CLOSED	CLOSED	2	6.7	CLOSED	15
16	2.1	OPEN	OPEN	CLOSED	Half Open	CLOSED	CLOSED	CLOSED	CLOSED	2	7.7	CLOSED	16
17	3.5	OPEN	OPEN	OPEN	Half Open	CLOSED	CLOSED	CLOSED	CLOSED	2	8.7	CLOSED	17
18	3.5	OPEN	OPEN	OPEN	Half Open	CLOSED	CLOSED	CLOSED	CLOSED	2	9.7	CLOSED	18
19	3.5	OPEN	OPEN	OPEN	Half Open	CLOSED	CLOSED	CLOSED	CLOSED	2	10.7	CLOSED	19
20	4.2	OPEN	OPEN	OPEN	OPEN	CLOSED	CLOSED	CLOSED	CLOSED	2	11.7	CLOSED	20
21	4.2	OPEN	OPEN	OPEN	OPEN	CLOSED	CLOSED	CLOSED	CLOSED	2	12.7	CLOSED	21
22	4.2	OPEN	OPEN	OPEN	OPEN	CLOSED	CLOSED	CLOSED	CLOSED	3	13.7	CLOSED	22
23	4.2	OPEN	OPEN	OPEN	OPEN	CLOSED	CLOSED	CLOSED	8.5	4	14.7	16.6	23
24	4.2	OPEN	OPEN	OPEN	OPEN	CLOSED	CLOSED	CLOSED	8.5	5	15.7	17.6	24
25	5.4	OPEN	OPEN	OPEN	OPEN	CLOSED	CLOSED	CLOSED	8.5	6	16.7	18.6	25
26	5.4	OPEN	OPEN	OPEN	OPEN	OPEN	CLOSED	CLOSED	8.5	7	17.7	19.6	26
27	5.4	OPEN	OPEN	OPEN	OPEN	OPEN	CLOSED	CLOSED	8.5	CLOSED	CLOSED	20.6	27
28	6.4	OPEN	OPEN	OPEN	OPEN	OPEN	CLOSED	CLOSED	8.5	CLOSED	CLOSED	21.6	28
29	6.4	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	CLOSED	8.5	CLOSED	CLOSED	22.6	29
30	6.4	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	CLOSED	8.5	CLOSED	CLOSED	23.6	30
31	7.0	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	8.5	CLOSED	CLOSED	24.6	31
32	7.0	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	8.5	CLOSED	CLOSED	25.6	32
33	7.0	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	9.1	CLOSED	CLOSED	26.6	33
34	7.0	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	9.7	CLOSED	CLOSED	27.6	34
35	7.0	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	10.4	CLOSED	CLOSED	28.6	35

MEMORANDUM FOR RECORD

12 February 2003

From: B. C. Cook, Cook Consulting

Subject: Evaluation of HELCRABS Simulation Program for Bonneville "A" Branch Fish Ladder

Objectives:

1. Review program simulation methodology; equations and assumptions
2. Review program code.
3. Review program output; check results with separate calculations
4. Identify deficiencies and quantify errors

1.0 HELCRABS "A" Branch Methodology, Assumptions, Description etc.**1.1 "A" Branch Ladder Components and Description**

The "A" Branch consists of the following hydraulic components:

1. The Control Section common to both the "A" and "B" Branches (series of pools controlling water inflow and fish leaving the ladder)
2. The ladder section ("A" and "B" Branch common to weir #53)
3. Ladder section connecting to Powerhouse Collection Channel
4. The North Auxiliary Water Supply (AWS) System
5. The South AWS System
6. The Powerhouse Collection Channel (PCC) System

1.2 General Computational Path**1.2.1 General Model Algorithm**

The HELCRABS simulation model of the Bonneville "A" Branch fish ladder system is a significant undertaking involving the use of steady state one-dimensional hydraulics and mathematics to simulate the prototype system. The Northwest Hydraulic Consultants (NHC) model involves several input and output files and the model has been developed to present the easiest way of running the model to the user. This allows simple input, but there is also a down side, in that making changes to the geometry and coefficient files is difficult. This type of flexibility is needed to model different alternatives and conditions. Weirs and control structures are constantly being modified to comply with species of fish and fisheries criteria. To make this type of change to the model geometry would be very difficult for a user at the Bonneville Project. The model reads the input files and proceeds with Kentucky Pipes (K-PIPES) to simulate the pressure hydraulics of the system. A main program iterates between the pressure flow routine that simulates the AWS System and the open channel program that simulates the PCC and ladder until water surface elevations and the flow calculations are hydraulically balanced.

1.2.2 AWS Simulation (aka Auxiliary Water Conduit – Dwg. T-8-16)

The purpose of the AWS is to inject supplemental water through the diffusers into the Powerhouse Collection Channel (PCC) and fish ladder at locations along the length of the facility to keep the flow and velocity at sufficient levels to attract the adult salmon into

the ladder system. The PCC has hydraulic outflow at the North and South entrance weirs and also has outflow at the fish entrance orifices along the face of the powerhouse. The function of the AWS is to make up for this outflow and maintain two feet per second velocity required by the fishery criteria. The source of this supplemental water is the forebay. The tainter gates (FV1-1) and (FV3.7) control the inflow and steep rectangular conduits of varying widths delivers this water to the AWS conduits. Sluice gates allow the diffuser water to enter the PCC and the ladder by dispensing it underneath the channel through closely placed members.

NHC chose to simulate the North and South AWS systems as a network of pipes under pressure. There are several commercial programs available to analyze the losses in water distribution systems (i.e. EPANET, K-PIPES, HAESTED METHODS, etc. etc.). All of these programs assume that the network is made up of circular pipes, valves, reservoirs and other fittings that are included as minor losses. These programs solve the pipe systems in one of two ways.

1. Using the principles of Hardy Cross, iterating the change in flow in each loop until the change is negligible.
2. Solving a system of simultaneous equations that equates the loss around a loop to zero.

Reservoirs are simulated as fixed grade nodes (FGN) and this is explained in the NHC users manual. The output from these programs is flow in each pipe in the network and the elevation of the hydraulic grade line (HGL) at each node. The assumption is made that the pipes are flowing under pressure or in some cases a slight negative pressure, but never less than the vapor pressure of water. The decision by NHC to use the K-Pipes commits the user to acceptance of these assumptions. Modifications to the geometry were necessary to use this commercial program. The rectangular geometry of the AWS system was converted to circular geometry by equating the hydraulic radii. This is a standard technique widely used and recognized in hydraulic texts and literature. This methodology however, under estimates the velocity and consequently the loss in systems where the major losses are the “minor losses”. In the case of “A” Branch, the bulk of the losses are bends, gate coefficients, orifices and other flow constrictors built into the system. NHC recognized this in a later report on The Dalles East Fishway Model. A better simulation of the losses in the system would result if the “equivalent area” were used to convert rectangular conduits to circular conduits for the K-Pipes program.

For this reason, EC-HD has started replacing the hydraulic diameters with equivalent diameters in the AWS geometry files. They are also adjusting the minor loss coefficients based on a combination of theory and prototype data. While friction losses are minor cause of system headlosses, the following adjustment are being made for the roughness “e” to account for the larger perimeters in the rectangular conduits:

k_s = Darcy Roughness adjusted for square conduit
based on true roughness e and neglecting Reynolds numbers:

$$k_s := \left(4.2 \sqrt{B \cdot H} \right) \cdot \left[\frac{e}{\left(\frac{7.4 \cdot B \cdot H}{B + H} \right)} \right] \left[\left[\frac{\pi \cdot B \cdot H}{(B + H)^2} \right]^{0.25} \right]$$

in which,

k_s = Darcy roughness adjusted for rectangular conduit (turbulent flows)

e = actual Darcy Weisbach roughness for the conduit material (0.004 feet in model);

B = width of rectangular conduit

H = height of rectangular conduit

(Abstracted from Stephen Schlenker comments on Draft Memo dated December, 2002)

Therefore, the methodology for converting the rectangular geometry to circular is being modified as follows:

Equating Hydraulic Radii (present NHC method)

$$D = \frac{\pi B H}{2(B + H)}$$

Equating Areas:(modification in progress)

$$D = \sqrt{\frac{4 B H}{\pi}}$$

1.2.3 PCC Simulation (aka Fish Collection Channel – Dwg. T-8-16)

This open channel across the face of the Bonneville First Power House is a very complex but important component of the system that is vital to adult passage up the “A” Branch portion of the ladder. The inflow to this component is the bifurcated ladder flow entering from the north end of the channel and diffuser flow entering the channel through regularly spaced orifices connected to the South AWS. The outflow occurs through the fish entrances orifices that are connected to the tailwater, and the South Entrance Weirs #’s 1 and #2 and North Entrance Weirs #’s 64 and 65. The North and the South Entrance Weirs maintain the water surface in the channel approximately one to two feet higher than the tailwater. The resulting volume and velocity of outflow attracts the salmon into the PCC to begin the first leg of surmounting the obstacle of Bonneville Dam. The operation of this component of the system is delicately balanced by competing biological and hydraulic criteria.

NHC combines the friction and turbulence losses by modifying Manning’s frictional loss coefficient. The contraction losses for the open channel flow are applied at the entrance weirs and gates. The losses were determined by data taken during visits to the site. The friction/turbulence loss was also determined from these tests. This factor representing the frictional/turbulence loss is assumed to be a straight line function of the tailwater and varies from 0.125 at elevation 7.805 MSL, to 0.08 at elevation 21.7 MSL. This result is

applied in Mannings' equation as an adjusted roughness parameter. The straight line expression for this assumption of frictional/turbulence losses is:

$$n = 0.1503 - 0.003239 \cdot (T_w \text{ elev})$$

The program applies a contraction loss to the fishway entrance weirs. The values of these contraction loss (C_L) coefficients are given on p. 10 of the 1996 NHC users manual. The application of this loss is taken as a reduced efficiency in the weir equations.

1.2.4 Critique of PCC Simulation

In analyzing this complex series of inflows and outflows to the channel, the flow regime must be classified as Spatially Varied Flow (SVF). NHC attempts to treat this as Gradually Varied Flow (GVF) and by combining turbulence and frictional loss together as a modified Manning's roughness coefficient, they consistently over estimates the slope of the water surface. By the time the calculations reach the north end of the PCC, the calculated GVF water surface is considerably higher than the physical measurements. This inflated depth at the north end of the channel and consequently over estimates the flow out of Entrance Weir #65 or Entrance Gate #64. Hydraulic Design (EC-HD) has reduced the high "n" value (.125) in the program and has simulated the PCC water surface very closely for both the August and the October data without complete theoretical purity of using SVF.

1.2.5 Comparison of SVF and GVF

The main difference between the two methodologies is the SVF assumes a control volume centered on a diffuser or a fish entrance orifice. Using linear momentum principles the unknown depth of the control volume will either be elevated or depressed when compared to the known downstream depth, and this rise or fall in the depth depends on whether the change of flow is either inflow or outflow. Using GVF principles with a Manning's roughness coefficient modified to include both turbulence losses as well as frictional losses, the water surface rises throughout the length of the channel. A comparison of SVF and GVF profiles will be graphically presented in the next section as well as comparisons with physical measurements along the axis of the channel.

2.0 Review and Comparison of Program Output with Measured Data:

During the period of August through October of 2002, the personnel of EC-HD measured the simultaneous flow and the boundary conditions on the "A" Branch on two separate occasions. The dates and significant boundary conditions are given in the table above.

**Bonneville "A" Branch
Data Measurement Boundary Conditions**

Date of Data Measurements	Forebay Elev.	Tailwater Elev.	Tainter Gate Hts.		EW #2 Crest Elev.	EW # 64 Crest Elev.
			FV1-1	FV3-7		
18 Aug. 2002	75.3	13.5	3.70	1.25	5.90	5.50
10 Oct. 2002	75.75	10.15	3.00	1.30	2.00	2.00

Access to this "raw" data is through link([\\cadd5.nwp.usace.army.gov](http://cadd5.nwp.usace.army.gov)).

This data consists of inflow measurements near the AWS entrances; heads in the pools of the ladder; elevations of the water surfaces in the PCC; Forebay and Tailwater elevations.

2.1.0 Measured Data Compared to HELCRABS Simulation

The measured data taken on 15 Aug. and 10 Oct. 2002 was input to the HELCRABS program. Some of the comparisons of the measured data and the simulation are given below in the Summary of Results Table. This table compares the differences between the measured and the simulated and also the percentage of difference. Before the final run of the measured data the model was tested and the geometry files were examined, and modified where it was thought necessary to simulated the operation on the days the measured data was taken. Some of the changes for the initial simulations were:

- Length of Entrance Weirs #1 and #65 were set to 8.25 ft.
- Length of Entrance Weirs #2 and #64 set to 8.0 ft.
- Dia. Of Pipe #39 reduced to 0.5 inches

(to simulate the closed tainter gate FV3-8, between the North and South AWS)

After these changes were made, the data was simulated in the HELCRABS model and electronic copies of these runs are available on link

(\Cadd5\Columbia\HELCRABS\Fishway_Computer_Programs\Field_Data\Bradford_Island_A_Branch\A_Branch_Current_Model_Runs). The initial simulations of the PCC water surfaces was taken from this data.

2.2.0 Discussion of Summary Comparison Table

Shown below is a series of tables that compares the simulated HELCRABS data with the measurements taken on the 15 August and the 10 October. The HELCRABS data was runs that used the initial geometry and parameter files provided by NHC.

2.2.1 Table A Ladder Flow

The difference between the HELCRABS simulated values and the measured values is minimal. The ladder was set for the upstream migration of Shad on the 15 Aug. measurements, and for Salmon on the 10 Oct. measurements.

SUMMARY COMPARISON OF RUNS FROM ORIGINAL MODEL WITH FIELD DATA					
A. Ladder Flow					
	15-Aug		10-Oct		
Test	Head on Picketed Lead	Total Ladder flow (cfs)	Head on Picketed Lead	Total Ladder flow (cfs)	Average
Measured	1.3	259	1	191	225
Model	1.3	264	1	192	228
% Diff		2%		1%	1%
<i>*Italics indicate measured values were either questionable or estimated.</i> Good Simulation of Ladder (1%).					
B. Discharge through FV1-1 (South AWS)					
Test No.	Valve Coefficients				
	15-Aug	10-Oct	Spring-03	Average	
Forebay	75.1	75.1			
Valve Setting	1.2	1.3			
Measured	870	816		843	
Model	886	799		843	
% Diff	1.8%	-2.1%		-0.1%	
C. Discharge through FV3-7 (North AWS)					
Test No.	Valve Coefficients				
	15-Aug	10-Oct	Spring-03	Average	
Forebay	75.2	75.5			
Valve Setting	3.7	3.0			
Measured	369	323		346	
Model	278	284		281	
% Diff	-25%	-12%		-19%	
D. PCC Near South Entrance					
Test	South Power House Velocities (ft/s)				
	15-Aug	10-Oct	Spring-03	Average	
Tailrace	13.3	10.1			
Measured	1.4	2.2		2	
Model	1.1	2.1		2	
% Diff	-21%	-5%		-11%	
E. South Entrance Discharge Weir # 2					
Test No.	Total Entrance Flow Rates (cfs)				
	15-Aug	10-Oct	Spring-03	Average	
Tailrace	13.7	10.1			
Measured	413	533		473	
Model	388	496		442	
% Diff	-6%	-7%		-7%	
Model slightly underestimates South entrance flow rates (5-10%), however was significantly increased when the invert geometry was corrected.					

Continuation of Summary Comparison Tables.

F. North Entrance Discharge Weir # 64				
Test No.	Entrance Head (ft)			
	15-Aug	10-Oct	Spring-03	Average
Tailrace	14	10		
Measured	--	--		
Model	492	682		587
% Diff	NA	NA		

G. South Entrance Head Weir # 2				
Test No.	Entrance Head (ft)			
	15-Aug	10-Oct	Spring-03	Average
Tailrace	13.7	10.1		
Crest Elev.	5.5	2.0		
Measured	1.4	1.3		1.4
Model	1.2	1.6		1.4
% Diff	-14%	23%		3.7%

H. North Entrance Head Weir # 64				
Test No.	Entrance Head (ft)			
	15-Aug	10-Oct	Spring-03	Average
Tailrace	13.7	10.1		
Crest Elev.	5.5	2.0		
Measured	1.4	1.3		1.4
Model	1.9	2.8		2.4
% Diff	36%	115%		74%

Entrance heads are significantly higher in model.

***Note #1: comparison made with corrected 8.25" fixed weir crest (weirs # 1, 65)**

***Note #2: Invert Elev. For Entrance Weir Sills were not correct in the Initial Geometry File**

2.2.2 North and South AWS Disch. (Table B. and C.)

The south AWS is controlled by the FV1-1 valve and the north AWS is controlled by FV3-7. The measured and the simulated data compare well for FV1-1, showing a percent of difference of 1.8% for the 15 Aug. data, and -2.1% for the 10 October data. The discharge through FV3-7 (Table C) does not show good comparison. The percentage of differences indicates that the model underestimated the flow on both days. The percentage for 15 Aug. was a -25% and the 10 Oct. was -12%. (There is some question on this measured data).

2.2.3 Table D – Velocities in the PCC Near the South Entrance Weir

These velocities were measured in the PCC just upstream of the South Entrance. The percentage of difference between the measured and the simulated were -21% for the 15 Aug. data, and -5% for the 10 Oct. data.

2.2.4 Table E – Discharge South Entrance Weir

The model consistently underestimated the discharge by a –6% and –7% on each of the respective testing days.

2.2.4 Table F – Discharge of North Entrance Weir

Since the instrumentation could not reach the water surface to measure the discharge, no comparison can be expressed. However, it is expected that the model discharge would be greater than the actual due to the fact that the GVF computations with the inflated “n” value consistently over estimates the elevation of the water surface in the north end of the PCC.

2.2.5 Table G – Heads on the South Entrance Weir

The percentage of difference varies greatly on the days of the measurement. The 15 Aug. data shows a difference of –14% and the 10 Oct. data shows a 23% difference.

2.2.6 Table H – Heads on the North Entrance Weirs

This data exhibits a wide percentage of difference which is again due to the NHC “n” value that attempts to combine friction loss with turbulence losses.

2.2.7 The Analysis of Entrance Weirs (Abstracted from EC-HD Comments on Draft Memo, dated 12/10/02)

The geometry provided by NHC had the approach elevations to the entrance weirs at –2 feet. This incorrect according to the drawings. The invert of the approach entrance weirs (#64,#65) is 0.0 feet. The invert of the approach to the South entrance weirs (#1,#2) is a +2.0 feet. When this corrected geometry is applied to the model, the simulated outflows are considerably off. The model calculations with these corrected approach invert elevations and compared with the measured quantities are:

approach channel invert elevation ((North Entrance) = 0 ft										
approach channel invert elevation ((southEntrance) = 1.95 ft										
NHC HELCRABS model for same tailrace and entrance head (for direct comparison)										
Date	TR	WSus	Entrance Head	Zweir	H/W	Cd	Cc	HELCRABS Model	Measured	% difference
Entrance 2										
15-Aug	13.5	15.1	1.6	5.5	2.7	0.79	0.05	553	413	34%
10-Oct	10.1	11.4	1.3	2.0	1E+13	0.60	0.05	378	509	-26%
Entrance 64										
15-Aug	13.5	15.1	1.6	5.9	1.6	0.74	0.19	417		
10-Oct	10	11.4	1.4	2.0	4.7	0.71	0.19	394		

The above table shows that with the equivalent head and corrected geometry, the model is off by approximately 30% in each case.

The cause for the errors in the model are two fold:

1. The methodology for the Weir coefficient (Cw) in the model is flawed. (Refer Cascade Island Memo)

Cw=Weir discharge coefficient (2 equations)

- If $H1/P$ (upstream weir head over weir height) < 2.5 , the well established Rehbach equation is used. (however, the actual upper limit is $H1/P = 5$. The variable in the code for this upper limit is x-val(2,2).
 $C_w = 0.6 * (0.08 * H1/P)$
- If $H1/P > 2.5$, a second unreferenced equation is applied:
 $C_w = X + Y/(H1/P)$ where ($X=0.611$), $Y=0.5275$ in the input file)

The $H1/P$ limit and the second equation are both problematic since they will overestimate the entrance head given a specific flow rate. There is no theoretical basis for this equation. Discharge coefficients from the theoretical equations for $H1/P > 2.5$ will be about 20-30% higher than those produced by the second equation. That much more flow may be required to produce equivalent entrance heads, the only parameter that is gauged daily in operation.

The following figure shows a comparison of the above equations used in the HELCRABS model, theoretical curves based on Rehbach, Rouse and Henderson, and the following suggested revision to the model using the model subroutines:

C_w = Weir discharge coefficient (2 equations)

- If $H1/P$ (upstream weir head over weir height) < 5 , Rehbach equation is used :
 $C_w = 0.6 * (0.08 * H1/P)$
- If $H1/P > 5$, a second unreferenced equation is applied:
 $C_w = 1.011$ (constant C_w for $H1/P > 5$ to approximate the theoretical curves)

2. The contraction coefficients need to be slightly modified to obtain final agreement with prototype data. The south entrance ones should be higher than those at the north entrance because the bend u/s of the south entrance is greater than 90 degrees and it is less than 90 degrees at the north entrance.

To match the data we proposed the following contraction coefficients:

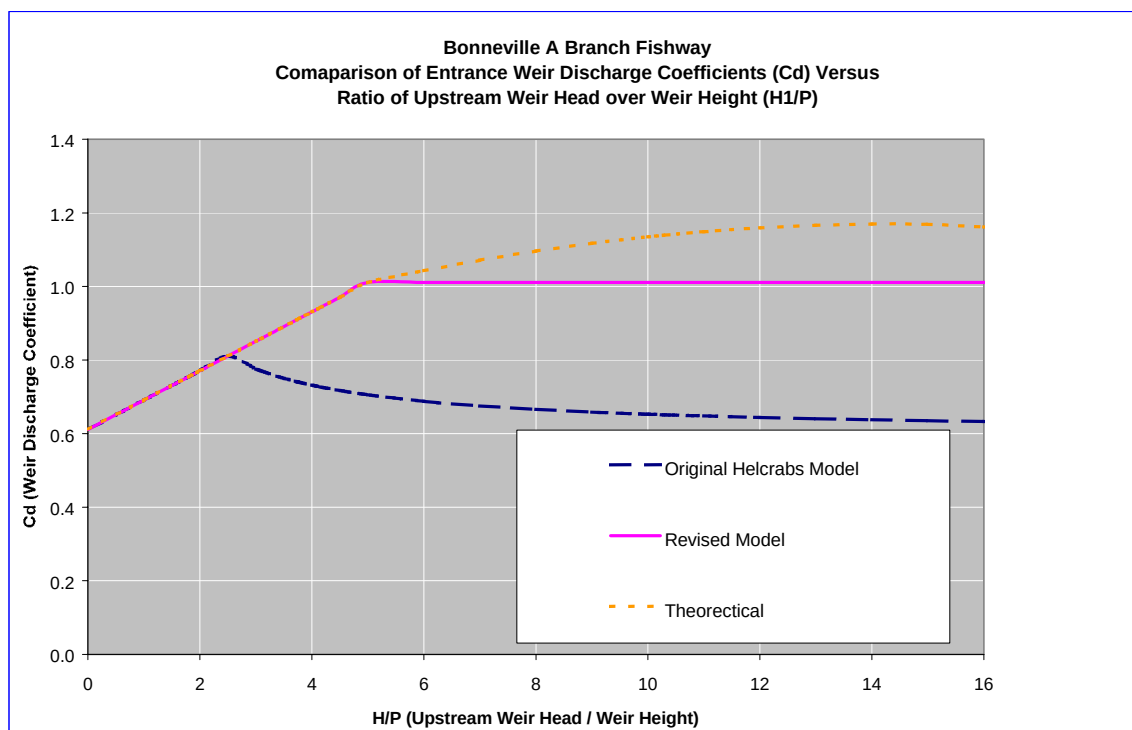
weir 1 = 0.07

weir 2 = 0.25

weir 64 = 0.03

weir 65 = 0.14

These have been applied to the model plus the above adjustments to provide a far better comparative result with the prototype data shown in the table below.



These changes in the geometry and parameter files have been applied to the HELCRABSL model and the results provide a far better comparison with the prototype data taken in August and October of 2002.

approach channel invert elevation ((North Entrance) = 0 ft										
approach channel invert elevation ((southEntrance) = 1.95 ft										
0 0 ft										
REVISED HELCRABS at Equiv Tailrace & head as tests										
Date	TR	WSus	Entrance Head	Zweir	H/W	Cd	Cc	HELCRABS Model	Measured	% difference
Entrance		2								
15-Aug	13.7	15.1	1.4	5.5	2.7	0.83	0.25	434	413	5%
10-Oct	10	11.4	1.4	2.0	188	1.01	0.25	517	509	2%
Entrance		64								
15-Aug	13.7	15.1	1.4	5.9	1.6	0.74	0.03	475		
10-Oct	10	11.4	1.4	2.0	4.7	0.99	0.03	653		

3.0 Suggested Program Modifications:

3.1.0 Powerhouse Collection Channel Water Surface Profile Computations Using NHC original Geometry and Parameters

The HELCRABS program starts the PCC calculations at the south entrance and solves continuity at each inlet/outlet. It then calculates the frictional loss to the next inlet/outlet to determine the next upstream water surface elevation. Manning's roughness is calculated as a straight line function of the tailwater as indicated above. This methodology fails to account for the loss/gain in momentum as each of these inflow/outflow devices is encountered. As a result, the present program over estimates

the water surface elevation at the north end of the PCC and this in turn over estimates the amount of flow across the north entrance weirs. The program using these parameters also over estimates the outflow from the fish entrance orifices and under estimates the inflow from the diffusers.

3.1.1 Powerhouse Collection Channel Water Surface Profile Using Pipe Diameters based on Equivalent Areas.

The Hydraulic Design Section (EC-HD) has given considerable time to studying the geometry and methodology to simulating the South PCC and The North and South AWS. The changes to the geometry and parameter file in HELCRABS have been cataloged in the following spread sheets.

CATALOGUE OF DIAMETER & LOSS CHANGES to HELCRABS GEOMETRY & COEFFICIENT FILES

IN File Location: [PIPES] Changes to File Geometry						
Link	Valve or diffuser	Length (ft)		Pipe Dia. (in)		Reason
		From	To	From	To	
1		80.0		116.0		A
2	FV3-7	200.0		90.0	101.6	A
3		200.0		3.0	101.6	A
4		5.0		60.8	70.3	A
5	FG3-13	1.5		36.0	40.6	A
6		200.0		90.0	101.6	A
7		6.0		60.8	70.3	A
8	FG3-12	1.5		36.0	40.6	A
9		45.0		90.0	101.6	A
10		7.0		60.8	70.3	A
11	FG3-11	1.5		36.0	40.6	A
12		45.0		90.0	101.6	A
13		8.0		60.8	70.3	A
14	FG3-10	1.5		36.0	40.6	A
15		45.0		90.0	101.6	A
16		9.0		60.8	70.3	A
17	FG3-9	1.5		36.0	40.6	A
18		45.0		90.0	101.6	A
19		10.0		60.8	70.3	A
20	FG3-8	1.5		36.0	40.6	A
21		45.0		90.0	101.6	A
22		12.0		60.8	70.3	A
23	FG3-7	1.5		36.0	40.6	A
24		45.0		90.0	101.6	A
25		13.0		60.8	70.3	A
26	FG3-6	1.5		36.0	23.5	A
27		45.0		90.0	101.6	A
28		19.0		60.8	70.3	A
29	FG3-5	1.5		36.0	40.6	A
30		45.0		90.0	101.6	A

IN File Location: [PIPES] Loss Coefficient Changes						
Link	Diffuser	Roughness e (0.001 ft)		Minor Loss coef		Reason
		From	To	From	To	
1		4		0.6	2.0	A, B, D
2	FV3-7	4	5.1	xxxx		A, B
3		4	5.1	0		A, B
4		4	5.2	0		A, B
5	FG3-13	4	4.8	2.5	1000.0	A, B, D
6		4	5.1	0.1		A, B
7		4	5.2	0		A, B
8	FG3-12	4	4.8	2.5	1000.0	A, B, D
9		4	5.1	0.1		A, B
10		4	5.2	0		A, B
11	FG3-11	4	4.8	2.5	1000.0	A, B, D
12		4	5.1	0.1		A, B
13		4	5.2	0		A, B
14	FG3-10	4	4.8	2.5	1000.0	A, B, D
15		4	5.1	0.1		A, B
16		4	5.2	0		A, B
17	FG3-9	4	4.8	2.5	1.9	A, B, C
18		4	5.1	0.1		A, B
19		4	5.2	0		A, B
20	FG3-8	4	4.8	2.5	1.9	A, B, C
21		4	5.1	0.1		A, B
22		4	5.2	0		A, B
23	FG3-7	4	4.8	2.5	1.9	A, B, C
24		4	5.1	0.1		A, B
25		4	5.2	0		A, B
26	FG3-6	4	4.8	2.5	1.5	A, B, C
27		4	5.1	0.1		A, B
28		4	5.2	0		A, B
29	FG3-5	4	4.8	2.5	2.0	A, B, C
30		4	5.1	0.1		A, B

Cont'd. EC-HD changes to HELCRABS geometry and coefficient files

IN File Location: [PIPES]			Changes to File Geometry			
Link	Valve or diffuser	File Changes				Reason
		Length (ft)		Pipe Dia. (in)		
		From	To	From	To	
31		21.0		60.8	70.3	A
32	FG3-4	1.5		36.0	40.6	A
33		3.0		90.0	101.6	A
34		8.0		90.0	101.6	A
35		1.5	1.0	25.6	70.3	A
36		40.0	19.0	98.8	70.3	A
37		8.0	1.0	60.8	70.3	A
38	FG3-3	1.5		36.0	40.6	A
39	FV3-8	300.0		90.0		A, B
40		25.0		90.0	101.6	A
41	FG-22-c	1.5		48.0	54.2	A
42		15.0		104.8	176.5	A
43	FG-22-b	1.5		48.0	54.2	A
44		15.0		104.8	176.5	A
45	FG-22-a	1.5		48.0	54.2	A
46		30.0		104.8	176.5	A
47	FG2-21	1.5		28.0	41.8	A
48		40.0		104.8	176.5	A
49	FG2-20	1.5		28.0	41.8	A
50		45.0		104.8	176.5	A
51	FG2-17	1.5		27.0	41.8	A
52		40.0		104.8	176.5	A
53	FG2-12	1.5		26.0	40.6	A
54		45.0		104.8	176.5	A
55	FG2-7	1.5		25.0	36.1	A
56		40.0		104.8	176.5	A
57	FG2-4	1.5		24.0	33.9	A
58		40.0		104.8	176.5	A
59		115.0		140.4	106.5	A,B
60		40.0		96.0	106.5	A
61	FV1-1	40.0		96.0	106.5	A,B
62		20.0		96.0	106.5	A
63	FG2-6	1.5		32.0	36.1	A
64		45.0		104.8	176.5	A
65	FG2-5	1.5		31.0	35.0	A
66		40.0		104.8	176.5	A
67	FG2-11	1.5		35.0	39.5	A
68		40.0		104.8	176.5	A
69	FG2-10	1.5		35.0	39.5	A
70		45.0		104.8	176.5	A
71	FG2-9	1.5		34.0	38.4	A
72		40.0		104.8	176.5	A
73	FG2-8	1.5		33.0	37.2	A
74		45.0		104.8	176.5	A
75	FG2-16	1.5		37.0	41.8	A
76		45.0		104.8	176.5	A
77	FG2-15	1.5		37.0	41.8	A
78		45.0		104.8	176.5	A
79	FG2-14	1.5		37.0	40.6	A
80		45.0		104.8	176.5	A
81	FG2-13	1.5		37.0	40.6	A
82		45.0		104.8	176.5	A
83	FG2-19	1.5		37.0	41.8	A
84		45.0		104.8	176.5	A
85	FG2-18	1.5		37.0	41.8	A
86		40.0		104.8	176.5	A
87		40.0		104.8	176.5	A
88	FG2-3	1.5		29.0	54.2	A
89		40.0		104.8	176.5	A
90	FG2-2	1.5		28.0	54.2	A
91	FG2-1	1.5		27.0	54.2	A
92		100.0		104.8	176.5	A

A. Geometry changed to diameter of equivalent flow area

B. Correction to geometry

IN File Location: [PIPES]			Loss Coefficient Changes			
Link	Diffuser	File Changes				Reason
		Roughness e (0.001 ft)		Minor Loss coef		
		From	To	From	To	
31		4	5.2	0		A, B
32	FG3-4	4	4.8	2.5	2.6	A, B, C
33		4	5.1	0.1		A, B
34		4	5.1	0		A, B
35		4	5.2	1.77		A, B
36		4	5.2	1.2		A, B
37		4	5.2	1.55		A, B, C
38	FG3-3	4	4.8	2.5	2.6	A, B
39	FV3-8	4	5.1	0		A, B
40		4	5.1	0.4		A, B
41	FG-22-c	4	4.9	2.5	17.6	A, B, C
42		4	11.0	0.1		A, B
43	FG-22-b	4	4.9	2.5	17.6	A, B, C
44		4	11.0	0.1		A, B
45	FG-22-a	4	4.9	2.5	17.6	A, B, C
46		4	11.0	0.1		A, B
47	FG2-21	4	4.8	2.5	7.4	A, B, C
48		4	11.0	0.1		A, B
49	FG2-20	4	4.8	2.5	7.4	A, B, C
50		4	11.0	0.1		A, B
51	FG2-17	4	4.8	2.5	7.4	A, B, C
52		4	11.0	0.1		A, B
53	FG2-12	4	4.8	2.5	6.8	A, B, C
54		4	11.0	0.1		A, B
55	FG2-7	4	4.8	2.5	4.8	A, B, C
56		4	11.0	0.1		A, B
57	FG2-4	4	4.8	2.5	4.1	A, B, C
58		4	11.0	0.1		A, B
59		4	5.2	0.4	10.0	A, B
60		4	5.2	0		A, B
61	FV1-1	4	5.2	xxxx		A, B
62		4	5.2	3	0.3	A, B, D
63	FG2-6	4	4.8	2.5	4.8	A, B, C
64		4	11.0	0.1		A, B
65	FG2-5	4	4.8	2.5	4.5	A, B, C
66		4	11.0	0.1		A, B
67	FG2-11	4	4.8	2.5	6.3	A, B, C
68		4	11.0	0.1		A, B
69	FG2-10	4	4.8	2.5	6.3	A, B, C
70		4	11.0	0.1		A, B
71	FG2-9	4	4.8	2.5	5.7	A, B, C
72		4	11.0	0.1		A, B
73	FG2-8	4	4.8	2.5	5.3	A, B, C
74		4	11.0	0.1		A, B
75	FG2-16	4	4.8	2.5	7.4	A, B, C
76		4	11.0	0.1		A, B
77	FG2-15	4	4.8	2.5	7.4	A, B, C
78		4	11.0	0.1		A, B
79	FG2-14	4	4.8	2.5	6.8	A, B, C
80		4	11.0	0.1		A, B
81	FG2-13	4	4.8	2.5	6.8	A, B, C
82		4	11.0	0.1		A, B
83	FG2-19	4	4.8	2.5	7.4	A, B, C
84		4	11.0	0.1		A, B
85	FG2-18	4	4.8	2.5	7.4	A, B, C
86		4	11.0	0.1		A, B
87		4	11.0	0.1		A, B
88	FG2-3	4	4.9	2.5	18.0	A, B, C
89		4	11.0	0.1		A, B
90	FG2-2	4	4.9	2.5	18.0	A, B, C
91	FG2-1	4	4.9	2.5	18.0	A, B, C
92		4	11.0	0		A, B

A. Geometry changed to diameter of equivalent flow area causes changes

B. Roughness (e) increased for rectangular conduits due to larger wetted

C. Minor loss coefficients (K) for diffusers calibrated from prototype data

D. Minor Loss corrected from Geometry

APPENDIX A- Item 1

AREA of CONCERN: ENTRANCE WEIR 2 (South Entrance, north slot)						line 1starts at weir no (2)		
						CHANGES to File		
Page No.	Line no.	Item No.	Variable	Program Function	Variable name in Function	From	To	Purpose of Change
3	2	1	contr. Coeff	Slot_ Discharge	ContCoef	0.19	0.25	Accounts for flow contraction; increased because u/s bend > 90 deg.
3	3	2	Weir Width	"	Width	8.25	8.0	Corrected per mods shown in drawing 6 in NHC report for Mods to 1st PH entrances (1993)
3	3	1	entrance invert	"	Invert	-2.0	2.0	Corrected per asbuilt drawings, I.E = +2 at So entrance
3	3	2	h1/p eqn barrier	"	Klimit	2.5	5	More accurate Cw for H1/p > 2.5; Cw is higher at H1/p > 2.5
3	5	1	c1 high	"	c1 HI	0.6	1.011	Adjust Cw for H1/P > 5 to approach theory and prototype data.
3	5	2	c2 high Kr	"	c2 HI	0.5275	0	Assumes constant Cw for H1/P > 5
3	8	1	Min weir elev	Ent Q	ent min	6.5	2	Corrected per mods shown in drawing 7 in NHC report for Mods to 1st PH entrances (1993)
3	8	2	Max weir elev	Ent Q	ent max	36.5	18	Corrected per mods shown in drawing 7 in NHC report (1993)
AREA of CONCERN: ENTRANCE WEIR 1 (South Entrance, south slot)						line 1starts at weir no (1)		
						CHANGES to File		
Page No.	Line no.	Item No.	Variable	Program Function	Variable name in Function	From	To	Purpose of Change
3	3	1	contr. Coeff	Slot_ Discharge	ContCoef	0.19	0.07	Accounts for flow contraction; NHC HELCRABS Report had 0.05 instead of 0.19; increased from 0.05 because u/s bend > 90 deg.
3	4	1	entrance invert	"	Invert	-2.0	2.0	Corrected per asbuilt drawings, I.E = +2 at So entrance
3	4	2	h1/p eqn barrier	"	Klimit	2.5	5	More accurate Cw for H1/p > 2.5; Cw is higher at H1/p > 2.5
3	7	1	c1 high	"	c1 HI	0.6	1.011	Adjust Cw for H1/P > 5 to closer to theoretical and data measurements. Assumes flat curve for H1/P >5
3	7	2	c2 high Kr	"	c2 HI	0.5275	0	"
3	8	2	Max weir elev	Ent Q	ent max	23.5	26	Corrected per mods shown in drawing 7 in NHC report (1993)

AREA of CONCERN: POWERHOUSE CHANNEL ORIFICE GATES # 62, 58, 34, 21, 9						Line 1 starts at gate number		
						CHANGES to File		
2	4	2	h1/p eqn barrier	"	Klimit	2.5	5	More accurate Cw for H1/p > 2.5; Cw is higher at H1/p > 2.5
								Adjust Cw for H1/P > 5 to closer to theoretical and data measurements. Assumes flat curve for H1/P > 5
2	7	1	c1 high	"	c1 HI	0.6	1.011	
2	7	2	c2 high Kr	"	c2 HI	0.5275	0	"

Cont'd. of Weir Coefficient Changes.

AREA of CONCERN: ENTRANCE WEIR 65 (North Entrance, north slot) line 1 starts at weir no (65)								
						CHANGES to File		
Page No.	Line no.	Item No.	Variable	Program Function	Variable name in Function	From	To	Purpose of Change
2	2	1	contr. Coeff	Slot_ Discharge	ContCoef	0.19	0.14	Accounts for flow contraction; reduced because u/s bend < 90 deg.
2	3	1	entrance invert	"	Invert	-2.0	0.0	Corrected per asbuilt drawings, I.E = 0 at North entrance
2	3	2	h1/p eqn barrier	"	Klimit	2.5	5	More accurate Cw for H1/p > 2.5; Cw is higher at H1/p > 2.5
2	5	1	c1 high	"	c1 HI	0.6	1.011	Adjust Cw for H1/P > 5 to approach theory and prototype data.
2	5	2	c2 high Kr	"	c2 HI	0.5275	0	Assumes constant Cw for H1/P > 5
AREA of CONCERN: ENTRANCE WEIR 64 (North Entrance, south slot) line 1 starts at weir no (64)								
						CHANGES to File		
Page No.	Line no.	Item No.	Variable	Program Function	Variable name in Function	From	To	Purpose of Change
2	2	1	contr. Coeff	Slot_ Discharge	ContCoef	0.19	0.03	Accounts for flow contraction; NHC HELCRABS Report had 0.05 instead of 0.19; reduced further because u/s bend < 90 deg.
2	2	2	Weir Width	"	Width	8.25	8.0	Corrected per mods shown in drawing 4 in NHC report for Mods to 1st PH entrances (1993)
2	3	1	entrance invert	"	Invert	-2.0	0.0	Corrected per asbuilt drawings, I.E = 0 at North entrance
2	3	2	h1/p eqn barrier	"	Klimit	2.5	5	More accurate Cw for H1/p > 2.5; Cw is higher at H1/p > 2.5
2	5	1	c1 high	"	c1 HI	0.6	1.011	Adjust Cw for H1/P > 5 to closer to theoretical and data measurements. Assumes flat curve for H1/P > 5
2	5	2	c2 high Kr	"	c2 HI	0.5275	0	"
2	8	2	Max weir elev	Ent Q	ent max	23	18	Corrected per mods shown in drawing 5 in NHC report for Mods to 1st PH entrances (1993)

The results in the output of the model are shown in the graphical plots of the water surface profiles.

3.2 Graphical Comparisons

A graphical representation of this is shown on the included plots of the PCC water surfaces. The boundary conditions for the comparison of these three water surfaces are those of the measured conditions on the 15 August 2002 and the 10 October, 2002. The four water surfaces profiles shown are:

1. The HELCRABS using NHC geometry and parameters
2. The SVF (bcc) calculation, in the spreadsheets
3. The measured data. This data was interpolated between the end and mid points on actual water surfaces.
4. HELCRABS using EC-HD adjusted parameters and geometry

In analyzing this complex series of inflows and outflows to the channel, the flow regime must be classified as Spatially Varied Flow (SVF) and analyzed as such. NHC attempts to treat this as Gradually Varied Flow (GVF) and by combining turbulence and frictional

loss together as a modified Manning's roughness coefficient, they consistently over estimates the slope of the water surface. By the time the calculations reach the north end of the PCC (over 1000 ft.), the calculated GVF water surface is considerably higher than the physical measurements. This inflated depth at the north end of the channel and consequently over estimates the flow out of Entrance Weir #65 or Entrance Gate #64.

Comparing the four water surfaces, it is plain that the initial geometry and parameters developed by NHC for the "A" Branch computation is continually rising and outstrips both the SVF calculations and the measured data by 0.7 of a foot or more. Both sets of initial data exhibited this characteristic. The SVF computations and the measured data are within a tenth of foot of each other, and generally follow similar trends. The EC-HD modified set of geometry and hydraulic parameters also produced a water surface profile very close to both sets of measured data.

The main difference between the two methodologies is the SVF assumes a control volume centered on a diffuser or a fish entrance orifice. Using linear momentum principles the unknown depth of the control volume will either be elevated or depressed when compared to the known downstream depth, and this rise or fall in the depth depends on whether the change of flow is either inflow or outflow. The water surface between these control volumes is computed with Mannings' equation. The value of this roughness coefficient is 0.02, which is assumed without knowledge of the condition of the PCC surface, but is within the range of common hydraulic practice, *given that the age of this concrete is some 60+ years*. Using the initial NHC geometry and parameters, the GVF principles with a Manning's roughness coefficient modified to include both turbulence losses as well as frictional losses, the HELCRABS water surface rises throughout the length of the channel. Only when the Manning's roughness is reduced to a more traditional value, does the HELCRABS calculation of the water surface become acceptably close to the measured data. This GVF treatment is not theoretical "pure", but it gives acceptable results for the PCC water surface calculations.

3.3 SVF Spreadsheet PCC Calculations

Spread sheets that applies the SVF methodology to both data sets is attached for comparison. The graph of the water surfaces showing the results of the SVF and the initial GVF calculations and compared with the physical measurements indicates the relative precision of each method. Using the control volume concept, the water surface computed at the north entrance weirs is practically the same as the starting water surface elevation at the south entrance weirs. This is significant because there are almost equal amounts of inflow and outflow coming into the PCC from the diffusers and the fish entrance orifices. It is intuitive that if the water surface rises across a control volume when there is additional flow being added to the channel, the upstream water surface will be less when there is flow being withdrawn from the channel. Furthermore, physical measurement in the form of the "Bonneville Project Sheet" dated 8/15/02 at 8:30 am indicated that the elevation of the water surface at the south entrance was 15.1 ft. and 15.2 ft. at the north entrance of the PCC. This compares to the HELCRABS calculation of 15.07 ft. at the south entrance and 15.77 ft. at the north entrance. As mentioned before

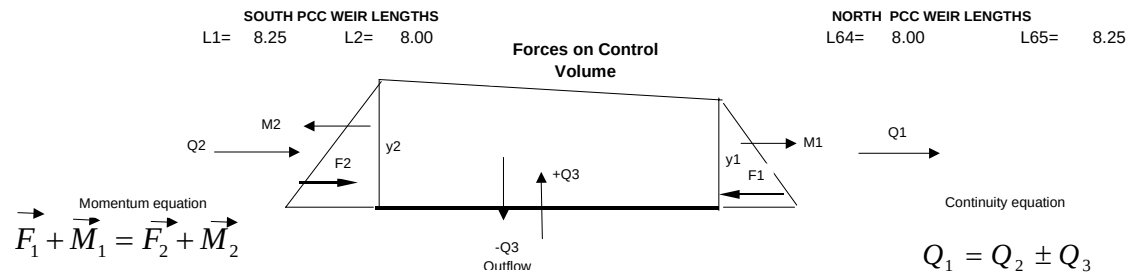
this inflates the north entrance weir flow and also has an effect on the calculation of the diffuser inflow and the fish entrance orifice outflow along the PCC.

A comparison of the SVF methodology and the GVF model calculations using the modified set of the geometry and coefficient file is not so plain. Although theoretical purity is not observed, the results are acceptable, in so far as the water surface calculations for the PCC are concerned.

BONNEVILLE "A" BRANCH POWERHOUSE COLLECTION CHANNEL
SPATIALLY VARIED FLOW WATER SURFACE CALCULATION --- (15 AUG DATA)

	El. TW	El Crest	El. Invert	P	H2	Delta H	H1	Villimonte	H1/P	Weir Coef.	Ht. X Beam	Weir Disch.
South EW	13.50	5.9	2	3.90	7.60	1.57	9.12	0.58	2.34	0.59	0	403.57
North EW	13.50	5.5	2	3.50	8.00	1.55	9.55	0.57	2.73	0.60	0	434.39
	Manning's Rough	0.02		Coef. Disch.=	0.70							

Gate/Diff Number	Approx. Station	U/S Q2	D/S Q1	In/Out Q3 flow	D/S depth	Channel Width	Goalseek for U/S depth	U/S depth	Area	Hyd. Rad.	Enrg. Grad	GoalSeek u/s depth
	0	0	0	0	15.0	17.58	0.00E+00	15.0	264.10	5.55	0.00E+00	0.00E+00
#2 Entrance Weir	80	404	0	-404	15.0	17.58	-1.28E-04	14.9	264.10	5.55	4.30E-05	1.70E-06
Fish Entrance # 9	147.5	485	404	-81	14.9	17.58	-1.37E-04	14.9	262.29	5.53	6.32E-05	2.72E-06
Diff. # 4	205	420	485	64	14.9	17.58	-1.25E-04	14.9	262.82	5.54	4.73E-05	1.72E-06
Fish Entrance # 21	312.5	502	420	-81	15.0	17.58	-1.33E-04	14.9	262.31	5.53	6.76E-05	2.79E-06
Diff. # 8	345	388	502	114	14.9	17.58	-1.10E-04	15.0	263.16	5.54	4.02E-05	1.20E-06
Fish Entrance # 34	485	470	388	-82	15.0	17.58	-1.20E-04	14.9	262.70	5.53	5.91E-05	2.10E-06
Diff. # 12	510	403	470	66	14.9	17.58	-1.04E-04	15.0	263.19	5.54	4.34E-05	1.04E-06
Diff. # 19	787.5	281	403	122	15.0	17.58	-4.75E-05	15.0	264.06	5.55	2.09E-05	2.55E-07
Fish Entrance # 58	808.5	364	281	-83	15.0	17.58	-7.32E-05	15.0	263.64	5.54	3.52E-05	6.74E-07
Diff. # 20	852	295	364	69	15.0	17.58	-4.70E-05	15.0	264.03	5.55	2.30E-05	2.83E-07
Diff. # 21	860	226	295	69	15.0	17.58	-2.06E-05	15.0	264.32	5.55	1.35E-05	6.64E-08
Fish Entrance # 62	884	310	226	-83	15.0	17.58	-5.03E-05	15.0	263.97	5.54	2.54E-05	3.37E-07
Diff. # 221	890	109	310	201	15.0	17.58	3.00E-05	15.1	264.64	5.55	3.11E-06	2.48E-08
# 64 Entrance Weir	898	543	109	-434	15.1	17.58	-1.25E-04	14.9	262.39	5.53	7.93E-05	4.94E-06
Diff. #222	905	342	543	201	14.9	17.58	-1.46E-04	15.0	263.82	5.54	3.10E-05	1.61E-06
Diff. #223	912	142	342	201	15.0	17.58	-8.20E-05	15.0	264.58	5.55	5.28E-06	



BONNEVILLE "A" BRANCH POWERHOUSE COLLECTION CHANNEL
SPATIALLY VARIED FLOW WATER SURFACE CALCULATION --- (10 Oct. 02 DATA)

	El. TW	El Crest	El. Invert	P	H2	Delta H	H1	Villimonte	H1/P	Weir Coef.	Ht. X Beam	Weir Disch.
South EW #2	10.00	2	0	2.00	8.00	1.60	9.60	0.58	4.80	0.66	0	499
North EW #64	10.00	2	0	2.00	8.00	1.66	9.66	0.58	4.83	0.66	0	511
Manning's Rough		0.02		Coef. Disch	0.70							

Gate/Diff Number	Approx. Station	U/S Q2	D/S Q1	In/Out Q3 flow	D/S depth	Channel Width	Goalseek for U/S depth	U/S depth	Area	Hyd. Rad.	Enrg. Grad	GoalSeek u/s depth
	0	0	0	0	11.6	17.58	1.09E-05	11.6	203.96	5.00	0.00E+00	0.00E+00
#2 Entrance Weir	80	499	0	-499	11.6	17.58	5.18E-05	11.4	203.96	5.00	1.27E-04	2.56E-06
Fish Entrance # 9	147.5	499	499	0	11.4	17.58	5.00E-05	11.4	200.76	4.97	1.32E-04	2.46E-06
Diff. # 4	205	443	499	56	11.4	17.58	4.24E-05	11.5	201.62	4.98	1.03E-04	1.55E-06
Fish Entrance # 21	312.5	443	443	0	11.5	17.58	3.94E-05	11.5	201.82	4.98	1.03E-04	1.51E-06
Diff. # 8	345	347	443	96	11.5	17.58	2.80E-05	11.5	202.91	4.99	6.21E-05	5.77E-07
Fish Entrance # 34	485	347	347	0	11.5	17.58	2.47E-05	11.5	203.06	4.99	6.20E-05	5.62E-07
Diff. # 12	510	347	347	0	11.6	17.58	2.41E-05	11.6	203.09	4.99	6.19E-05	3.94E-07
Diff. # 19	787.5	253	347	94	11.6	17.58	6.31E-06	11.6	204.15	5.00	3.25E-05	7.06E-08
Fish Entrance # 58	808.5	253	253	0	11.6	17.58	5.90E-06	11.6	204.16	5.00	3.25E-05	-9.72E-04
Diff. # 20	852	200	253	53	11.6	17.58	-6.02E-06	11.6	204.52	5.01	2.03E-05	4.59E-08
Diff. # 21	860	149	200	52	11.6	17.58	-1.17E-05	11.6	204.76	5.01	1.11E-05	4.97E-08
Fish Entrance # 62	884	149	149	0	11.6	17.58	-1.20E-05	11.6	204.76	5.01	1.11E-05	5.00E-08
Diff. # 221	890	-2	149	150	11.6	17.58	-2.67E-05	11.7	205.05	5.01	1.32E-09	1.36E-11
# 64 Entrance Weir	898	509	-2	-511	11.7	17.58	-6.20E-05	11.5	201.58	4.98	1.36E-04	7.15E-06
Diff. #222	905	359	509	150	11.5	17.58	-8.64E-05	11.6	203.36	4.99	6.61E-05	3.46E-06
Diff. #223	912	210	359	149	11.6	17.58	-8.30E-05	11.6	204.49	5.01	2.23E-05	

L1= 8.25 L2= 8.00 L64= 8.00 L65= 8.25

Note: All entrance gates closed and Diffusers 4,8,19,20,21,221,222,223 are open

Sum of Diffuser Inflow= 799.60
Sum of Ent. Weir Outflow= 1009.93

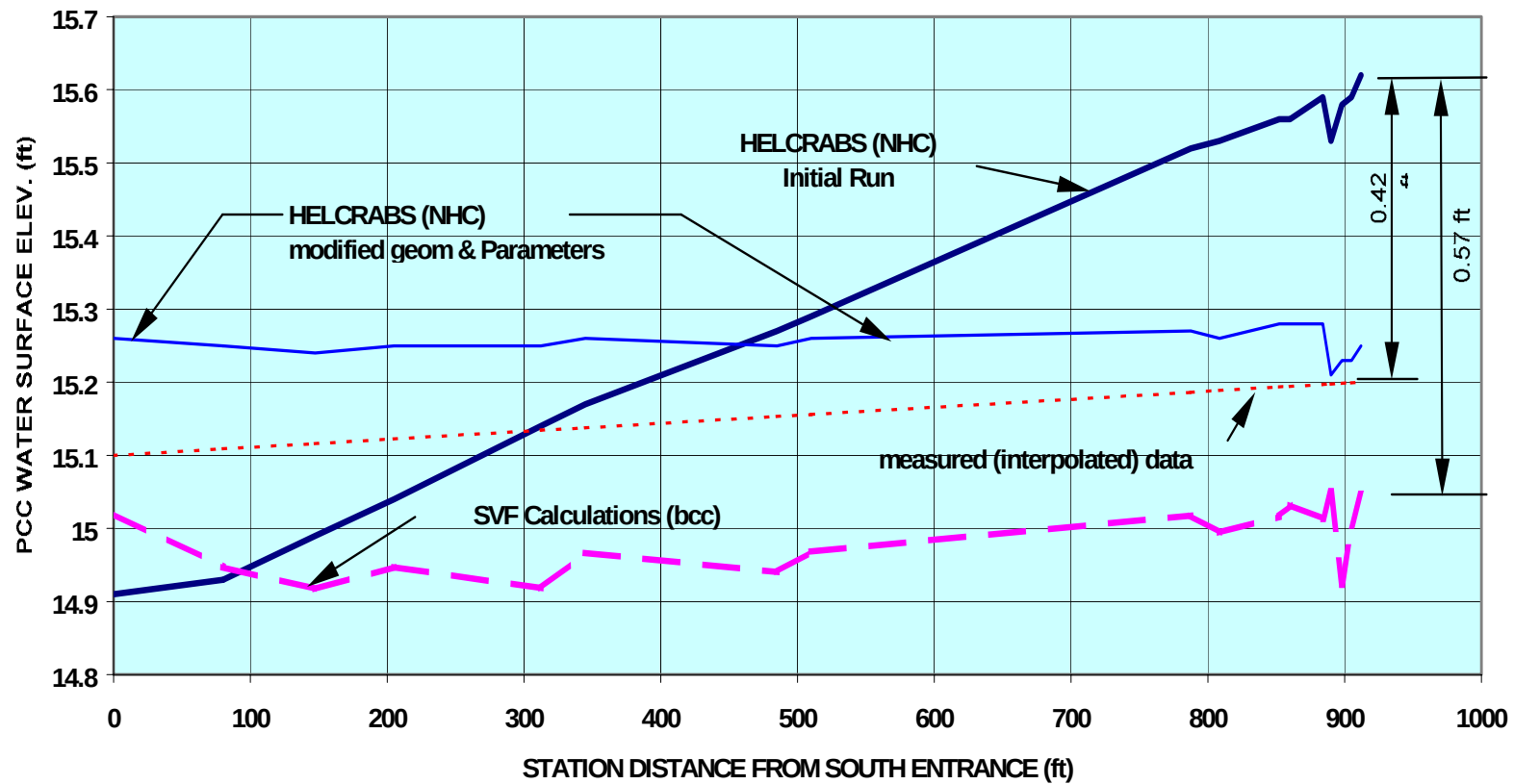
SOUTH PCC WEIR LENGTHS
L1= 8.25 L2= 8.00

NORTH PCC WEIR LENGTHS
L64= 8.00 L65= 8.25

APPENDIX A

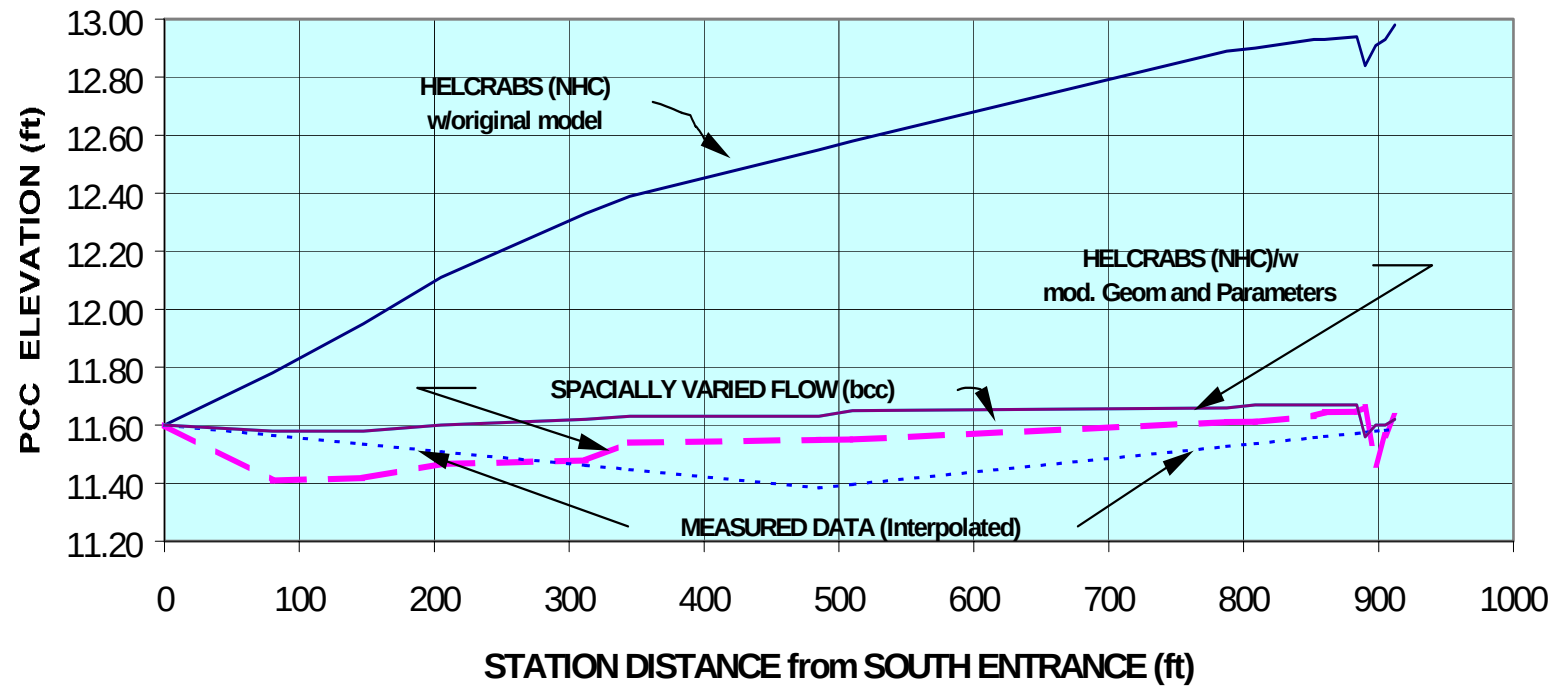
BONNEVILLE "A" BRANCH
COMPARISON OF WATER SURFACE
PROFILES IN PCC

15 August 2002 Data



BONNEVILLE "A" BRANCH COMPARISON OF WATER SURFACE PROFILES IN PCC

October 10, 2002 — Data



3.0 Critique of Pressure Flow Assumptions in the South AWS Simulation

The Hydraulic Schematic of the “A” Branch South Water Supply Conduit shows an indication of the difficulty of simulating the head loss in this steep plunging cascade as a series of circular pipes with individual minor loss coefficients in the K-Pipes program. The large uncontrollable variable affecting the amount of head loss that must be dissipated between FV1-1 and the AWS is the elevation of the tailwater. This boundary condition can vary from elevation 7 feet to 35 feet above MSL. The forebay is much more restricted by operational and geometrical constraints. On the average, there is usually 35-50 feet of potential energy that needs to be dissipated in this system. In the prototype this is accomplished with a hydraulic jump and turbulence. In the HELCRABS model this is accomplished as friction and minor losses through a series of pipes. The inclusion of the tainter valves in the K-Pipes simulation ignores the hydraulic disconnect of the pressurized diffusers and the open channel atmospheric flow downstream of the fish valve. The only head loss variable in the series of pipes simulating this part of the system is the programs ability to modify the tainter gate coefficient of discharge. The remaining minor loss coefficients are constants. This has been recognized by EC-HD as a major impediment to simulating the reality of the hydraulics in the upper reach of the “A” Branch AWS. This was the causal factor for in considering a precursor algorithm to be run prior to any simulation submitted to the HELCRABS model. This precursor routine would determine the value of a minor loss “K” value to compute the energy loss in the series of pipes that simulates the South Water Supply Conduit.

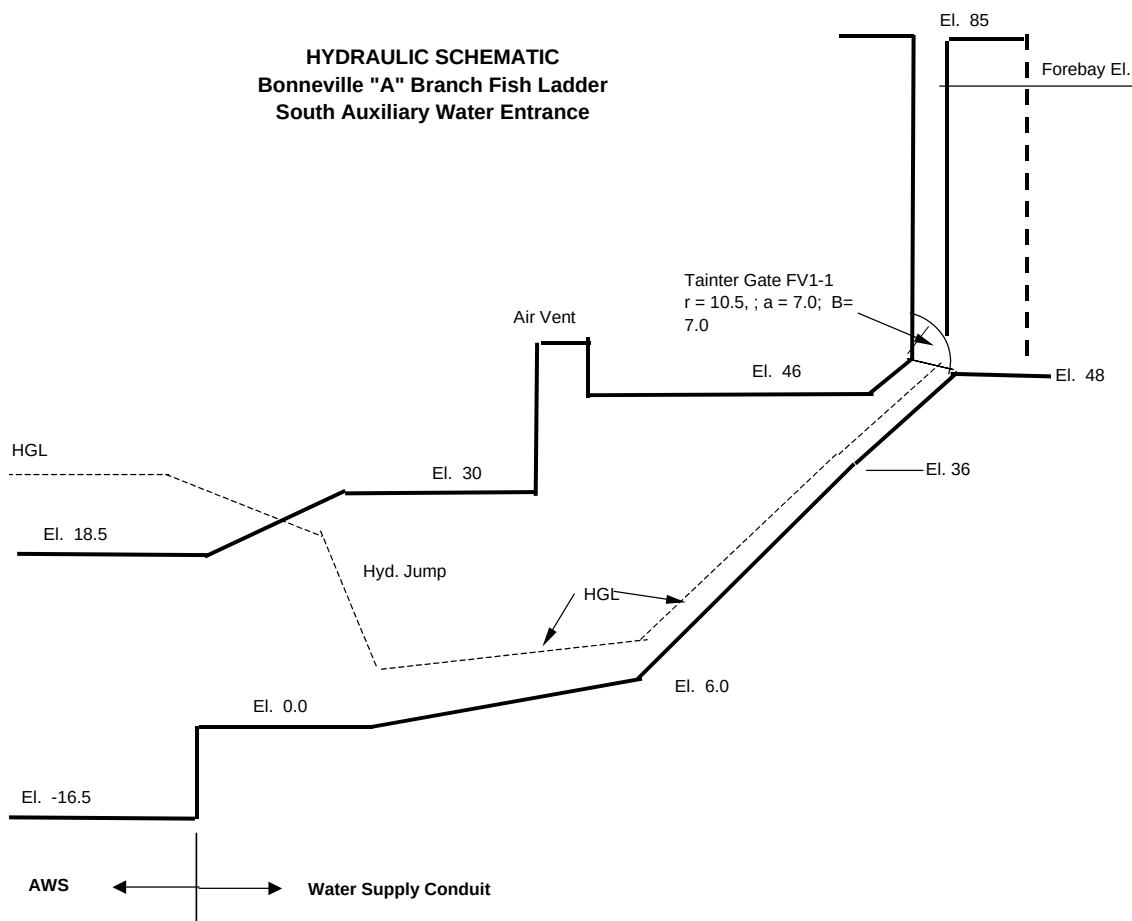
4.0 Critique of Pressure Flow Assumptions in the South AWS Simulations

The hydraulic schematic of the “A” Branch South Water Supply Conduit shows an indication of the difficulty of simulating the head loss in this steep plunging cascade as a series of circular pipes with individual minor loss coefficients in the K-Pipes program. The large uncontrollable variable affecting the amount of head loss that must be dissipated between FV1-1 and the AWS is the elevation of the tailwater. This parameter can vary from approximately 7 feet to 35 feet (MSL). The forebay is much more restricted by operational and geometrical constraints. On the average, approximately 35-50 feet of potential energy needs to be dissipated in this system. In the prototype this is accomplished with a hydraulic jump and a great deal of turbulence. In the HELCRABS model this is accomplished as friction and minor loss through a series of pipes. The inclusion of the tainter valves in the K-Pipes simulation ignores the hydraulic disconnect of the pressurized diffusers and the open channel atmospheric flow downstream of the fish valve. The only head loss variable in the series of pipes simulating this part of the system is the programs ability to modify the tainter gate coefficient. The remaining minor loss coefficients are constants. This has been recognized by EC-HD as a major impediment to simulating reality in the upper reaches of “A” Branch AWS. This was the causal factor in considering a precursor algorithm to be run prior to running the HELCRABS model to determine a minor loss “K” value to compute the energy loss of the system.

Operations has specified that the operating criteria for this system will be from 4-6 psi of differential head between the water surface of the PCC and the HGL in the AWS. This ensures under most circumstances that the AWS will operate under positive pressure. Operations should check this criteria. Under certain low tailwater conditions with minimal head on the entrance weirs, the HGL in the AWS could be below the soffit of the conduit. The following would always ensure pressure flow:

$$Y_{PCC} + \Delta h \geq 18.5$$

This requires that the elevation of the water surface in the PCC plus the differential head between the PCC water surface and the HGL in the AWS should be greater than the elevation of the soffit of the AWS. Operations can specify the left hand side of the above equation and that then locates the elevation of the HGL at the beginning of the AWS. This then sets the amount of energy that must be dissipated in the model in the series of pipes simulating the Water Supply Conduit. This means that the person using HELCRABS to simulate a set of boundary *conditions must be able* to specify at least one of the minor loss coefficients to correctly simulate the prototype head loss as the model is not configured. EC_HD has proposed a precursor algorithm that would compute this coefficient before attempting to run the model. This decision involves evaluating a couple of competing alternatives, and has not yet been completed.

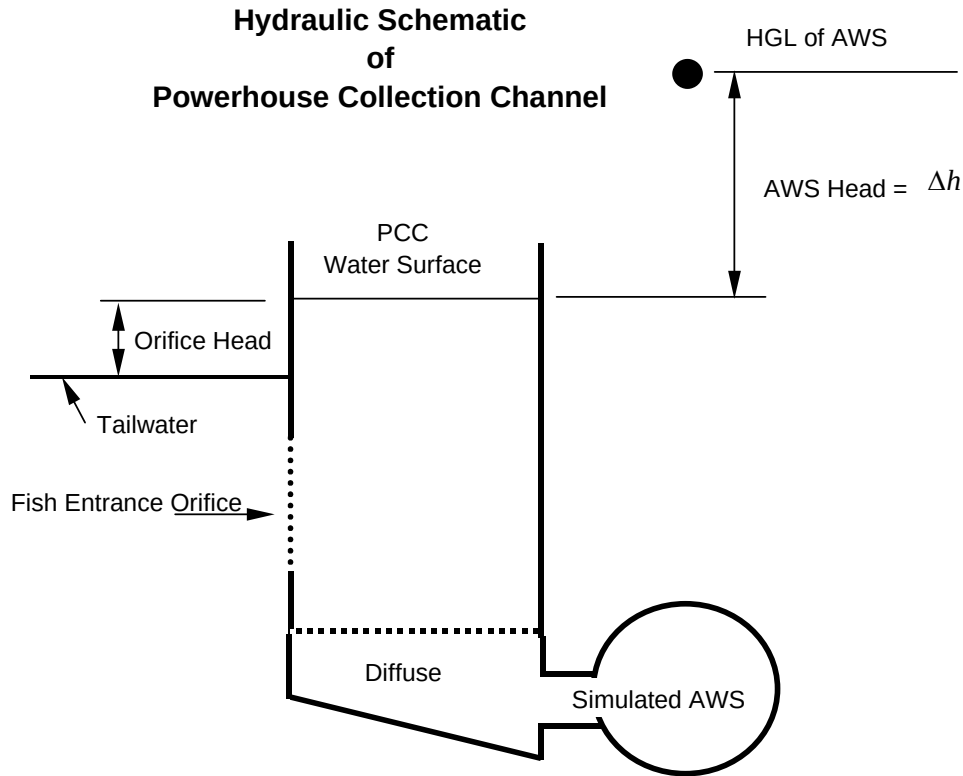


4.1 Sample Calculation of Diffuser flow into AWS

The Hydraulic Sketch below shows the way the model simulates the hydraulic connection between the PCC and the AWS. The PCC in the model is a Fixed Grade Node (FGN). This means that K-Pipes considers it a tank or a reservoir. The parallel pipe along side of the PCC is the simulated pressure pipe system (AWS) that K-Pipes solves. The prototype PCC and the AWS are connected hydraulically by a sluice gated orifice. The model simulates this as a short pipe with a rather large minor loss coefficient (K) to accommodate all the losses between the AWS and the PCC (i.e. bend, orifice, grating, etc.). The following example demonstrate the models computation of the diffuser flow from the AWS to the PCC.

Example Calculation: (10 Oct. data w/modified geom. and parameter files):

Taking the data from diffuser #8 near the south end of the PCC, the following calculation demonstrates the algorithm the model uses to compute the diffuser inflow to the PCC.



Given model data: Diffuser Flow (Q) = 85.4 cfs
 Elev. PCC water surface = 11.60 ft.
 Minor loss Coeff. (K) = 4.1
 Elev. HGL in AWS = 22.37 ft.
 Dia. of simulated pipe = 33.9 inches

$$\Delta h = K \frac{Q^2}{2gA^2}$$

$$\Delta h = 4.1 \frac{85.4^2}{64.4(6.27)^2}$$

$$\Delta h = 11.81 \text{ ft.}$$

$$\Delta h = 5.12 \text{ psi}$$

The elevation of the measured HGL in the AWS on 10/10/02 was approximately elevation 25.0 ft. The above calculation of delta h and the elevation of the PCC, combines to give the model simulation of the HGL as 23.41 ft. The 5.12 psi is almost exactly in the middle of the operational criteria of 4-6 psi of differential head. The use of the modified geometry and parameter files was able to produce acceptable results for the boundary conditions existing on the day the sample data was taken. Further proof of the

ability of the program to simulate conditions with a high tailwater will be tested in the spring of 2003.

5.0 Suggested Program Modifications

5.1 Operating System

Present running of the program is cumbersome because the program can only be run using WINDOWS 95. It is suggested that the program be recompiled and modified so that other hardware within the EC-HD section may run the program using a later version of WINDOWS.

5.2 PCC Water Surface Computations

The rather large difference between the measured water surface profiles seems to justify consideration of using Spatially Varied Flow analysis of computing the water surface in the PCC. Since changing the code of the model is not an option at this time, Hydraulic Design (EC-HD) has taken the practical step of greatly reducing the models “n” value(0.125) by approximately a value of ten with the result of bringing the model computed water surface in the PCC down to the measured results. If modifying the code becomes a future alternative, adding a subroutine that would perform the necessary hydraulic calculations should be considered at that time.

5.3 Suggested Program Algorithm Change

The input parameters that determine the flow in FV1-1 and Fv3-7 is the elevation of the forebay and the gate heights. Then it is an iterative process for the user to run the model and see if his/her gate height selection produces the quantity of flow in the AWS to meet the biological and operational criteria. If a particular selection of input parameters does not give a simulation that meets these criteria, some of the parameters must be changed and the model rerun to meet all of the criteria. Some suggested changes in the model algorithm are:

1. Allow the user to select the differential head across the PCC/AWS.
2. Allow the user to select the differential head across the south entrance weir.
3. The other input variables would be the same.
4. Allow the model to solve the PCC/AWS continuity and this would yield the required flows from FV1-1 and FV3-7. The gate height could be determined from this.

These input parameters would allow the user to go directly to the criteria and the model would simulate the operation of the system accordingly.

If these suggested modifications cannot be implemented, it would be prudent to consider developing a new “A” Branch model.

5.3 Entrance Weir Coefficients

The entrance weirs function as submerged weirs. This type of weir requires an empirical modifier to accurately predict the flow across these units. Biological requirements give a range of one to two feet of head drop across these structures, and also requires a

submergence of the weir crest of eight feet. This produces enough flow into the tailwater to attract fish and also enough distance to the weir crest to prevent injury. There is no issue with NHC on the use of the Villemonte coefficient. The main area of difference is the issue of the elevation of the approach sill and piece-wise function that NHC uses for computing the weir coefficient (C_w). The hydraulic design section (EC-HD), has investigated this algorithm and found no theoretical or empirical data to support the “third leg” of the NHC function. This is explained very thoroughly in section 3.1 and 3.2. The solution, if this program is to continue as a tool to plan and guide operations, is to modify the code so that the piece-wise function will accurately reflect the efficiency of the weir.

5.4 Channel Velocities (PCC)

The invert of the PCC is -2 ft. (MSL). This elevation is at the present “hard-wired” into the code and is correct, but there is no way to change this if the diffusers are returned to their former configuration. This is another instance of being denied access to the code to make changes that conform to changes in the geometry and operational criteria.

Memorandum for the Record

Sept. 29 2003

From: Stephen Schlenker, EC-HD

Subject: **ERRATA Sheet** *for*

Memorandum for the Record prepared by Cook Consulting, "Evaluation of HELCRABS Simulation of Program for Bonneville 'A' Branch Fish Ladder". (Feb. 2003)

1. New Information

New information was obtained after submittal of the above memorandum. This new information resulted in an adjustment to some of the data from the first two data collection trips (8-15-02 & 10-10-02) and a change in the coefficients for the diffusers and Fish valves. Revised tables were developed to replace the two tables that document the HELCRABS model data file changes in the Cook Memorandum. These replacement tables are found in the Appendix under Table 10, Table 11 and Table 12 (at the end of this memorandum).

The following paragraphs outline the new information and the effects the to the computer model:

1.1. The head difference between the south AWS conduit and powerhouse channel is lower than previously estimated.

- During the 3rd trip, the control room provided the hydraulic gradeline elevation (el. 17.'3) in the south conduit from a pressure transducer located near the south entrance.
- This reading compared differently than the measurement taken behind FG3-8 the same day, which was about the same (el. 25') as the previous measurement trips, regardless of different tailwater levels.
- The pressure transducer reading is more credible since it was recalibrated last winter and the analyses shows the diffuser coefficients to be more plausible.

1.2. The estimated flow rates in the North AWS computed from measurements from the first two data collection trips were approximately 17% too high.

- During the 3rd trip, an improved means (ADV meter rigidly constrained from lateral rotation) of measuring the flow rate at the FV3-7 intake was used
- Data analyses revealed that the improved means of measurement was 17% lower than the methods (price meter) used in the previous two data collection trips.

1.3. The diffuser gate FG3-6 is held open at 1.5 feet instead of 0.5 feet, as reported from a project biologist.

- Calculations¹ for Modifications for Peaking shows that the size of the orifice should be half the area of a fully open orifice. This translates to an orifice half open or 1.5 feet.
 - While no drawings have been located to verify which dimension is correct, the 1.5' opening the calculations matches hydraulic expectations far better than the 0.5 feet, particularly when both sources stated that the goal of the half open position at FG3-6 was to provide an extra 60 – 65 cfs to the ladder to hydraulically balance the change in crest width from 10.4feet to over 30 feet at pool 22.
- 1.4. The diffuser FG3-3 has a modified intake that constricts the flow into the downshaft by means of a 5.5' x 1.4' orifice opening in the conduit floor.
- Modification for peaking change from original construction drawing T3-106.
 - This was verified in drawing BDF 2-1/3 (book BD-30) and observed during field inspection of the North Conduit, Feb 2003.
 - Also documented in previously referenced calculations¹ is the determination of the orifice size for FG3-3.

Table 1 List of Drawings for Diffuser Configurations.

Ref Drawings:	Book	Sheets
Diffuser chambers	BD -22	T-3-83, sheets 1, 2, 5, & 6
Diff FG-3-3 intake orifice	BD -30	BDF 2-1/3
PH AWS (FG2-n) orifice openings	BD -33	BDF 3-1/12
FG2-22, 2 new gates	BD -33	BDF 3-1/13

- 1.5. A potential concern is diffuser FG3-4 which according the reference calculations¹ would be resized from 3 ft square to 2.75 ft square opening for Modifications for Peaking.
- No drawing could be found showing this change in the As Builts for Modifications for Peaking; whereas those drawings do show the changes at FG3-3 and all the of the resized orifices along the powerhouse channel.
 - However also not able to locate drawing for change at FG3-6.
 - Will field verify (if or if not) during inspection of the diffusers during the dewatered field inspection for RPA 126 study scheduled to commence during winter 2003-04
2. List of items to be verified in the field during the dewatered fishway inspection of A branch to complete the Bonneville Cascade/Bradford Island Fishway Assessment (RPA 126) study.

¹ *Bonneville Dam, Fish Facilities Modifications Powerhouse Entrances—powerhouse Collection System, Book 4* (1970). Calculations are shown under tab labeled “A” Branch orifice sizes. Booklet is located at reference location’ 01c 06’ in the EC-HD library with additional description *Bonneville Dam, Fish Facilities Modifications #--Sizing of A Branch Diffusers, Control of FV3-8*

- 2.1. FG3-6 valve stop height
- 2.2. FG3-4 orifice size
3. Revision of coefficients for diffusers, fish valves and entrances:
 - 3.1. One additional and improved data set to incorporate into calibration.
 - One more data set with permanently closed powerhouse telescoping & sluice gates condition.
 - 3.2. Recalibrate diffuser coefficients for south conduit based on pressure transducer data taken during the 3rd test.
 - Test the results on the previous two tests for plausible results.
 - 3.3. With the revised flow rates at FV3-7, the total system inflow is changed. This effects the following calibrations:
 - Calibrate FV3-7 and FV1-1 coefficients.
 - Changes estimate of flow from north entrance (continuity); revise coefficients as needed.
 - Revise of diffuser coefficients along the north conduit; incorporating the revised geometries of FG3-3 & FG3-6 (half open).
4. South Conduit Diffusers Calibration:

The south conduit diffuser coefficients were recalibrated based on the pressure transducer reading on 7/2/03. The main unknowns are the losses between the gate orifice and the exit through the gratings:

Assumptions and data applied to determine diffuser loss coefficients:

Sharp edged orifice $K_g = 1.5$ (for all other orifices along conduit)

Tube shaped orifice $K_{g22} = 1.1$ —based on 0.7 tube factor from fig 14.3, Miller, *Internal Flow Systems* (1978) (for FG2-22, 22a & 22b)

Surface area of grating (A_{dc}) = 676.8 ft²

Friction Losses along Conduit

Conduit Flow area (A) = 32.2 * 5 = 161 ft²

Conduit length = 738 ft

Conduit roughness (k_s) = 0.006 ft (2* roughness from HDC 224-1 for rect. concrete conduits)

Hydraulic Diameter (D) of conduit = $4 * 161 / (2 * (32.2 * 5)) = 8.66$ ft

$D/k_s = 1400$

Friction factor (f) = 0.0183 (Assume fully turbulent in Moody Diagram)

$$\text{Average head loss along conduit} = \left(\frac{0.5 * Q}{A} \right)^2 * \frac{fL}{D * 2g}$$

For Q = 678 cfs, conduit headloss (HLC) is only 0.1 feet

Average head loss across diffuser units:

Z1 = Average head in channel 7/2/03 = 16.2 ft

Z2 = Average head in conduit 7/2/03 = 17.5 – HLC/2 = 17.4 ft

DH = average head drop across diffusers = 17.4 – 16.2 = 1.2 ft (= 0.5 psi)

Determine Kd for diffuser based on diffuser grating area (Adc) by solving the following equation:

$$Q = n_{22} * \sqrt{\frac{2g * DH}{\left(\frac{Kg_{22}}{Ag_{22}^2} + 3 * \frac{Kd}{Adc^2} \right)}} + \sum_i^k n_i * \sqrt{\frac{2g * DH}{\left(\frac{Kg_i}{Ag_i^2} + \frac{Kd}{Adc^2} \right)}}$$

In which,

Q = Total South Conduit discharge = 678 cfs (on 7/2/03)

Kd = Minor loss coefficient based on diffuser grating area (Adc)

n₂₂ = number of FG2-22 diffuser open = 3

Ag₂₂ = area of gate orifice opening for diffuser FG2-22 (a & b) = 16 ft²

n_i = number of same size orifices that are open

‘i’ pertains to subsequent open diffusers other than FG2-22

Ag_i = area of gate orifice opening for diffuser i

Obtaining Kd through iterative means, the total composite minor loss coefficient (Ki) is obtained for each diffuser unit (except Fg2-22) from the following adjustment.

$$K_i = Kg_i + Kd * \left(\frac{Ag_i}{Adc} \right)^2$$

A special adjustment must be made for the 3 FG2-22 diffusers, since all 3 openings discharge into a single diffuser chamber—hence the 3 X the flow areas in the following equation.

$$K_{22} = Kg_{22} + Kd * \left(\frac{3 * Ag_{22}}{Adc} \right)^2$$

Table 2 shows the calibrated loss coefficients for the south AWS conduit diffusers.

Table 2 A Branch South AWS diffuser Coefficients

i Diffusers (FG2-i)	ni Number of Diffusers	Ds Square Dim. (ft)	Agi Orifice Area (ft ²)	D Equiv. Dia. (ft)	K Pipes 'D' D' (in)	Diff. Loss Coeff. K _i
22, 22a, 22b	3	4.00	16.0	4.51	54.2	1.9
15 - 21	5	3.08	9.5	3.48	41.8	1.5
12 - 14	3	3.00	9.0	3.39	40.6	1.5
10 - 11	2	2.92	8.5	3.29	39.5	1.5
9	1	2.83	8.0	3.20	38.4	1.5
8	1	2.75	7.6	3.10	37.2	1.5
6 - 7	2	2.67	7.1	3.01	36.1	1.5
5	1	2.58	6.7	2.91	35.0	1.5
4	1	2.50	6.3	2.82	33.9	1.5
2-3	2	4.00	16.0	4.51	54.2	1.1

These coefficients were also simulated to obtain differential head results of 1.5 ft and 2.0 between conduit and ladder for the first two data sets, Aug 02 and Oct 02, respectively.

5. Fish Valves Calibration:

Since the fish valve flow rates will be pre-calculated in the excel macro, the HDC Chart 320 (Hydraulic Design Criteria (HDC), Waterways Experiment Station) was used to provide the discharge coefficients (CD) to calculate the flow rates. However, the measured flow rates (after adjustments for the 17%) were still significantly higher than the rates produced by the CD from HDC. Table 1 shows the boundary conditions and a comparison of the (adjusted) fish valve flow measurements versus the computed flow rates using discharge coefficients from HDC 320 under the same boundary conditions. The bottom of the table shows the ratios of measured flows to HDC flows. For each valve, there is a case of where the measured flow is nearly 40% higher, whereas the rest of the cases are between 10-15%. The information below the table included the gross average ratio (skewed by the high values), the median values and the average of the two lower values—which are about the same as the medians.

Table 3 Comparison of Adjusted Fish Valve Flow Measurements and Computed Flow Rates from Discharge Coefficients from HDC 320 under Equivalent Boundary Conditions

	8/15/02		10/10/02		7/2/03	
	FV1-1	FV3-7	FV1-1	FV3-7	FV1-1	FV3-7
Opening	3.7	1.25	3.0	1.3	2.9	2.85
FB	75.0		75.5		75.4	
TW	13.3		10.1		14.88	
Q meas	808	310	874	261	678	536
Q HDC	752	222	630	234	611	471
Ratio	1.074	1.394	1.386	1.117	1.109	1.138
	Gross Ave	Gross Ave	Median	Median	Low Ave	Low Ave
Ratio	FV1-1	FV3-7	FV1-1	FV3-7	FV1-1	FV3-7
Qm/Qhdc	1.174	1.204	1.109	1.138	1.091	1.127

A balance was sought from the above data to produce a global ratio to be applied to both valves—between the gross average and the median values. The selected ratios are shown below:

	USE	USE	To apply to Macro for	
Ratio	FV1-1	FV3-7	Fish Valves Computations:	
Qm/Qhdc	1.165	1.165	Q-macro = Q-HDC * Ratio	

In which,

Q-macro = Computed flow rate for the pre-calculation excel macro and the ultimate flow rate for the HELCRABS model due to the adjustments from the macro

Q-HDC = Flow rate computed using HDC 320 discharge coefficients

Ratio = 1.165 for both valves (applied to Q-HDC)

The following table shows a comparison of the computed macro flow rates and the (adjusted) measured flows rates, both for individual dates and in total. In general to balance between the high and low ratios, the total of the macro flows will be about 2% lower overall than the total of the measured flow rates.

Table 4 Ratios to Applied for Final Computation of Fish Valve Discharge Rates Using HDC 320 Discharge Coefficients and Comparative Results

	8/15/02		10/10/02		7/2/03	
	FV1-1	FV3-7	FV1-1	FV3-7	FV1-1	FV3-7
Q macro	877	259	734	272	712	549
Q Meas	808	310	874	261	678	536
diff	69	-51	-139	11	34	13
% diff	9%	-16%	-16%	4%	5%	2%

	Σ FV1-1	Σ FV3-7	sum both
Q macro	2323	1080	3403
Q meas	2359	1107	3466
diff	-36	-27	-63
% diff	-2%	-2%	-2%

Table 5 shows the continuity comparison between the computed system inflow rates and the measured (plus estimated) system outflow rates. Even though the computed inflow rates are 2% low compared to the measure inflow rates, they are still 1% higher overall than the measured outflow rates—another factor in balancing the differences in the determination of the FV ratios. The best correlation between inflow & outflow occurs with the 07-02-03 data, which was the most reliable flow measurement of the data sets and best represents the present operation of the Fishway (powerhouse telescoping gates bulk-headed off).

Table 5 Quantitative Comparison of Computed System Inflows Versus Measured (& Estimated) System Outflow Rates

Target data for Model					Revised CDs	
Total Computed Inflow (cfs)						
date	Ladder	North AWS	South AWS	Total Inflow (Qi)	diff Qi -Qo	% diff
8/15/02	130	272	734	1136	-131	-12%
10/10/02	106	549	712	1367	183	13%
7/2/03	122	259	877	1257	-22	-2%
Sum inflow				3761	30	1%
Total System Discharge (cfs)						
cc =0.25 cc=0.05						
date	PH gates (Estimated)	So Entrance	No Entrance (Estimated)	Total outflow (Qo)		
8/15/02	364	398	505	1267		
10/10/02		517	667	1184		
7/2/03		696	582	1279		
Sum outflow				3731		

6. North Conduit Diffusers Calibration:

There is no pressure or hydraulic gradeline data available for the north conduit, so a combination of theoretical methods and assumptions were applied. It was stated in the Modifications for Peaking Report that the north AWS conduit would be operated at an average pressure of 5 psi at FG3-5 (pool 19). No pressure transducer was installed in the conduit but it can be assumed that the operation table for the FV3-7 was developed with the intent to operate around 5 psi at FG3-5.

The new geometrical information was incorporated. While the sizes of the gate orifice openings are identical (3 x 3 ft) along the north conduit, the sizes of the diffusion chambers are different. The left side of the following table shows the gross areas of the diffusion chambers for each diffuser. The upper right has the typical geometrical dimensions and loss coefficients for the dropshafts that branch down from the conduit to the diffuser gates and chambers. The lower left part includes the dimensions of the special orifice in the AWS conduit floor that replaces the typical larger drop shaft (plugged) for FG3-4. The bottom left of the table has the assumed partial opening of FG3-6.

Table 6 Geometry of North Conduit diffusion chambers, intake wells and assumed FG3-6 partial Gate Opening

North Branch Diffuser Chambers				Typical Branch into Well		
Diffusers	Width	Length	Agr-Gross	Width (ft.)	Height (ft)	Aw - Area ft ²
FG3-n	(ft)	(ft)	Area (ft ²)			
3	15	17.5	262.5	4	6.5	26.0
4	15	17.5	262.5	Ke	Kb	Kw
5	15	24.5	367.5	0.3	0.9	1.2
6	15	26	390.0	Special Case for Diffuser 3		
7	15	26	390.0	Intake Orifice from AWS conduit		
8	15	26	390.0	Width (ft)	Length (ft)	Ao - Area ft ²
9	15	26	390.0	1.33	5.5	7.3
				Ke	Kexp	Ko
Partial Opening at Diffuser No. FG3-6 = 1.5 ft				0.3	0.7	1

To estimate the losses for the flow turning upward from the diffusion chamber into the channel, a manifold methodology was applied by dividing the exit area into 3 to 4 four outlets of a manifold. The methodology is documented in pages 254-258 of Miller (1978) and figures 13.21 & 13.23. The individual losses are accumulated and combined into a single loss coefficient based on the flow area (67.5 ft²) of the chamber before the flow bends. There is a baffle-block upstream of the 'manifold' and about 5' downstream of the diffuser gate. The baffle loss is estimated to be 2 x the loss coefficient for rounds bars at 50% blockage or 2.0.

The following table shows the loss coefficients for the 'manifold' and the baffle block based on flow area 67.5 ft².

Table 7 Diffusion chamber loss coefficients-Kdc

Manifold flow area = 67.5ft ²				
Diffuser	Lengths	Manifold Loss coeff.	Baffle Block	Total Kdc
FG3-3	17.5	0.59	4	4.59
FG3-4	17.5	0.59	4	4.59
FG3-5	24.5	0.27	4	4.27
FG3-6	26	0.24	4	4.24
FG3-7	26	0.24	4	4.24
FG3-8	26	0.24	4	4.24
FG3-9	26	0.24	4	4.24

Additional assumptions:

Tube shaped orifice $K_g = 1.1$ (for all orifices, same as FG2-22 in So AWS conduit),

Sharp edged orifice $K_g = 1.5$ (for partially opened FG3-6)

Grating loss coefficient $K_{gr} = 0.8$ (based on 70% opening for rectangular bars in Fig. 14.8, Miller (1978) and based on the gross area of each diffuser grating area.

The individual losses are combined and adjusted into a single loss coefficient based on the diffuser gate opening area. the general equation is applicable for all diffusers except FG3-3 (for partially open FG3-6, only the open area (4.5 ft²) is used for A_g instead of the normal 9.0.

$$K_i = K_{g_i} + K_{dc} * \left(\frac{A_{g_i}}{A_{dc}} \right)^2 + K_w * \left(\frac{A_{g_i}}{A_w} \right)^2 + K_{gr} * \left(\frac{A_{g_i}}{A_{gr}} \right)^2$$

In which,

K_i = total diffuser loss coefficient for diffuser i based on diffuser gate area A_{g_i}

K_{g_i} = loss coefficient for gate opening orifice

A_{g_i} = Area of diffuser gate opening (9 ft² normal, 4.5 for partial open FG3-6)

K_{dc} = diffusion chamber loss coefficient (see Table 7)

A_{dc} = Area of diffusion chamber for horizontal flow = 67.5 ft²

K_w = sum of intake and bend loss for intake well or branch (see upper right Table 6)

A_w = area of intake branch = 26 ft²

K_{gr} = loss coefficient through grating = 0.8

A_{gr} = gross area of grating flow area (See left side of Table 6)

For Diffuser FG3-3, the equation is slightly different replacing the intake loss (K_w) with the loss (K_o) of the special orifice intake.

$$K_{FG3-3} = K_{g_i} + K_{dc} * \left(\frac{A_{g_i}}{A_{dc}} \right)^2 + K_o * \left(\frac{A_{g_i}}{A_o} \right)^2 + K_{gr} * \left(\frac{A_{g_i}}{A_{gr}} \right)^2$$

In which,

K_{FG3-3} = total diffuser loss coefficient for diffuser FG3-3 based on diffuser gate area

Ko = loss coefficient for special intake orifice = 1.0 (see lower left Table 6)

Ao = Area of special intake orifice = 7.33 ft²

The final calculated values are shown below in the following table (the grating losses were negligible when adjusted to the gate area). The values between Kg and Ki are the coefficients for the chamber, intake well, and orifice intake adjusted for the gate areas. The applications of these coefficients with the updated FV3-7 flow rates produced pressure differentials (at FG3-5) of 5.8, 3.5 and 5.0 psi respectively for tests data 8-15-02, 10-10-02 & 7-02-03. These results are acceptable for the assumption that the system operation was devised to produce pressure differentials around 5 psi.

Table 8 Total Diffuser Loss Coefficients (Ki) for North AWS Conduit

Diffusers	No	sq Dim (ft)	area (ft ²)	K Pipes D' (ft)	K Pipes D' (in)	Kg	Kdc-adj	Kw-adj	Ko-adj	Ki sum
FG3-3	1	3.00	9.0	3.39	40.6	1.10	0.08	0.00	1.5	2.7
FG3-4	1	3.00	9.0	3.39	40.6	1.10	0.08	0.14		1.3
FG3-5	1	3.00	9.0	3.39	40.6	1.10	0.08	0.14		1.3
FG3-6*	1	2.12	4.5	2.39	28.7	1.50	0.02	0.04		1.6
FG3-6	1	3.00	9.0	3.39	40.6	1.10	0.08	0.14		1.3
FG3-7 - 9	3	3.00	9.0	3.39	40.6	1.10	0.08	0.14		1.3

* partially open (1/2) when in closed position

7. Manning's Roughness for Powerhouse Collection Channel Calibration:

The changes in water surface for the three different test dates were used to recalibrate the Manning's roughness. The optimum value was found to be 0.035 as shown in the summary table below. While this value seems to be on the high side, it is incorporating the form losses due to the projection parts of the powerhouse telescoping gates and the energy losses from the diffuser upward influxes.

Table 9 Comparison of Model results versus Measured results Using Manning's Roughness n = 0.035

Change in Powerhouse Channel Levels (No > So)					
	Change in Water level from North to South PH Channel (ft)				
Test Date	8/15/02	10/10/02	7/2/03		Average
Measured	0.00	0.10	0.09		0.06
Model	0.03	0.06	0.08		0.06
Diff	0.03	-0.04	-0.01		-0.01

8. Explanation of the APPENDIX; replacement tables.

All of the above data is incorporating in the following tables in the appendix that should replace those same tables provided in the Cook Memorandum.

Table 10 replaces **CATALOGUE OF DIAMETER & LOSS CHANGES to HELCRABS GEOMETRY & COEFFICIENT FILES** on pages 12-13 of the Cook Memo. This table documents all of the changes made to the data files for the Kentucky pipes for the pressurized flow. The yellow highlighted items are changes from the Cook Memorandum. Also an additional line was added to delineate the difference between partially open and fully open FG3-6.

Table 11 replaces **CATALOGUE OF DIAMETER & LOSS CHANGES to HELCRABS GEOMETRY & COEFFICIENT FILES** on pages 14-15 of the Cook Memo. These tables pertain to the changes in entrance weir geometry and coefficients. The only changes from the Cook Memorandum were contraction coefficient at WG-64 and WG-1, again highlighted in yellow. The change at WG-64 was a slight adjustment (from 0.03 to 0.05) to improve overall continuity between system inflows and outflows. The change for WG-1 was a smaller adjustment (0.07 to 0.08) to maintain consistency with the adjustment at WG-64, since both weirs are located similarly—second in line—with respect to the corner of the junction of the powerhouse channel and entrance bays.

Table 12 is an additional table that shows the revised Manning's roughness for the powerhouse channel.

APPENDIX

Table 10 **CATALOGUE OF DIAMETER & LOSS CHANGES to HELCRABS GEOMETRY & COEFFICIENT FILES (*REVISED*)**

IN File Location: [PIPES] Changes to File Geometry							IN File Location: [PIPES] Loss Coefficient Changes						
		File Changes							File Changes				
		Length (ft)		Pipe Dia. (in)					Roughness e (0.001 ft)	Minor Loss coef			
Link	Valve or Diffuser	From	To	From	To		Reason	Link		Diffuser	From	To	
1		80.0		116.0		A	1		4		0.6	2.0	A, B, D
2	FV3-7	200.0		90.0	101.6	A	2	FV3-7	4	5.1	xxxx		A, B
3		200.0		3.0	101.6	A	3		4	5.1	0	macro	A, B, E
4		5.0		60.8	70.3	A	4		4	5.2	0		A, B
5	FG3-13	1.5		36.0	40.6	A	5	FG3-13	4	4.8	2.5	1000	A, B, D
6		200.0		90.0	101.6	A	6		4	5.1	0.1		A, B
7		6.0		60.8	70.3	A	7		4	5.2	0		A, B
8	FG3-12	1.5		36.0	40.6	A	8	FG3-12	4	4.8	2.5	1000	A, B, D
9		45.0		90.0	101.6	A	9		4	5.1	0.1		A, B
10		7.0		60.8	70.3	A	10		4	5.2	0		A, B
11	FG3-11	1.5		36.0	40.6	A	11	FG3-11	4	4.8	2.5	1000	A, B, D
12		45.0		90.0	101.6	A	12		4	5.1	0.1		A, B
13		8.0		60.8	70.3	A	13		4	5.2	0		A, B
14	FG3-10	1.5		36.0	40.6	A	14	FG3-10	4	4.8	2.5	1000	A, B, D
15		45.0		90.0	101.6	A	15		4	5.1	0.1		A, B
16		9.0		60.8	70.3	A	16		4	5.2	0		A, B
17	FG3-9	1.5		36.0	40.6	A	17	FG3-9	4	4.8	2.5	1.3	A, B, C
18		45.0		90.0	101.6	A	18		4	5.1	0.1		A, B
19		10.0		60.8	70.3	A	19		4	5.2	0		A, B
20	FG3-8	1.5		36.0	40.6	A	20	FG3-8	4	4.8	2.5	1.3	A, B, C
21		45.0		90.0	101.6	A	21		4	5.1	0.1		A, B
22		12.0		60.8	70.3	A	22		4	5.2	0		A, B
23	FG3-7	1.5		36.0	40.6	A	23	FG3-7	4	4.8	2.5	1.3	A, B, C
24		45.0		90.0	101.6	A	24		4	5.1	0.1		A, B
25		13.0		60.8	70.3	A	25		4	5.2	0		A, B
26a	FG3-6	1.5		36.0	23.5	A	26a	FG3-6	4	5.1	2.5	1.6	A, B, C
26b	FG3-6			36.0	40.6	A	26b	FG3-6	4	4.8	2.5	1.3	A, B, C
27		45.0		90.0	101.6	A	27		4	5.1	0.1		A, B
28		19.0		60.8	70.3	A	28		4	5.2	0		A, B
29	FG3-5	1.5		36.0	40.6	A	29	FG3-5	4	4.8	2.5	1.3	A, B, C
30		45.0		90.0	101.6	A	30		4	5.1	0.1		A, B
31		21.0		60.8	70.3	A	31		4	5.2	0		A, B
32	FG3-4	1.5		36.0	40.6	A	32	FG3-4	4	4.8	2.5	1.3	A, B, C
33		3.0		90.0	101.6	A	33		4	5.1	0.1		A, B
34		8.0		90.0	101.6	A	34		4	5.1	0		A, B

IN File Location: [PIPES] Changes to File Geometry							IN File Location: [PIPES] Loss Coefficient Changes						
	Valve or Diffuser	File Changes				Reason		Valve or Diffuser	File Changes				Reason
		Length (ft)		Pipe Dia. (in)					Roughness e (0.001 ft)		Minor Loss coef		
Link		From	To	From	To		Link		From	To	From	To	
35		1.5		25.6	36.6	A	35		4	6.4	1.77	1.0	A, B
36		40.0		98.8	111.5	A	36		4	5.1	1.2	0.0	A, B
37		8.0		60.8	70.3	A	37		4	5.2	1.55	0.0	A, B, C
38	FG3-3	1.5		36.0	40.6	A	38	FG3-3	4	4.8	2.5	1.2	A, B
39	FV3-8	300.0		90.0		A, B	39	FV3-8	4	5.1	0		A, B
40		25.0		90.0	101.6	A	40		4	5.1	0.4		A, B
41	FG-22-c	1.5		48.0	54.2	A	41	FG-22-c	4	4.9	2.5	1.9	A, B, C
42		15.0		104.8	176.5	A	42		4	11.0	0.1		A, B
43	FG-22-b	1.5		48.0	54.2	A	43	FG-22-b	4	4.9	2.5	1.9	A, B, C
44		15.0		104.8	176.5	A	44		4	11.0	0.1		A, B
45	FG-22-a	1.5		48.0	54.2	A	45	FG-22-a	4	4.9	2.5	1.9	A, B, C
46		30.0		104.8	176.5	A	46		4	11.0	0.1		A, B
47	FG2-21	1.5		28.0	41.8	A	47	FG2-21	4	4.8	2.5	1.5	A, B, C
48		40.0		104.8	176.5	A	48		4	11.0	0.1		A, B
49	FG2-20	1.5		28.0	41.8	A	49	FG2-20	4	4.8	2.5	1.5	A, B, C
50		45.0		104.8	176.5	A	50		4	11.0	0.1		A, B
51	FG2-17	1.5		27.0	41.8	A	51	FG2-17	4	4.8	2.5	1.5	A, B, C
52		40.0		104.8	176.5	A	52		4	11.0	0.1		A, B
53	FG2-12	1.5		26.0	40.6	A	53	FG2-12	4	4.8	2.5	1.5	A, B, C
54		45.0		104.8	176.5	A	54		4	11.0	0.1		A, B
55	FG2-7	1.5		25.0	36.1	A	55	FG2-7	4	4.8	2.5	1.5	A, B, C
56		40.0		104.8	176.5	A	56		4	11.0	0.1		A, B
57	FG2-4	1.5		24.0	33.9	A	57	FG2-4	4	4.8	2.5	1.5	A, B, C
58		40.0		104.8	176.5	A	58		4	11.0	0.1		A, B
59		115.0		140.4	106.5	A,B	59		4	5.2	0.4	10.0	A, B
60		40.0		96.0	106.5	A	60		4	5.2	0		A, B
61	FV1-1	40.0		96.0	106.5	A,B	61	FV1-1	4	5.2	xxxx		A, B
62		20.0		96.0	106.5	A	62		4	5.2	3	macro	A, B, E
63	FG2-6	1.5		32.0	36.1	A	63	FG2-6	4	4.8	2.5	1.5	A, B, C
64		45.0		104.8	176.5	A	64		4	11.0	0.1		A, B
65	FG2-5	1.5		31.0	35.0	A	65	FG2-5	4	4.8	2.5	1.5	A, B, C
66		40.0		104.8	176.5	A	66		4	11.0	0.1		A, B
67	FG2-11	1.5		35.0	39.5	A	67	FG2-11	4	4.8	2.5	1.5	A, B, C
68		40.0		104.8	176.5	A	68		4	11.0	0.1		A, B
69	FG2-10	1.5		35.0	39.5	A	69	FG2-10	4	4.8	2.5	1.5	A, B, C
70		45.0		104.8	176.5	A	70		4	11.0	0.1		A, B
71	FG2-9	1.5		34.0	38.4	A	71	FG2-9	4	4.8	2.5	1.5	A, B, C
72		40.0		104.8	176.5	A	72		4	11.0	0.1		A, B
73	FG2-8	1.5		33.0	37.2	A	73	FG2-8	4	4.8	2.5	1.5	A, B, C
74		45.0		104.8	176.5	A	74		4	11.0	0.1		A, B

IN File Location: [PIPES] Changes to File Geometry							IN File Location: [PIPES] Loss Coefficient Changes						
		File Changes							File Changes				
Link	Valve or Diffuser	Length (ft)		Pipe Dia. (in)			Link	Valve or Diffuser	Roughness e (0.001 ft)		Minor Loss coef		
		From	To	From	To				Reason	From	To	From	
75	FG2-16	1.5		37.0	41.8	A	75	FG2-16	4	4.8	2.5	1.5	A, B, C
76		45.0		104.8	176.5	A	76		4	11.0	0.1		A, B
77	FG2-15	1.5		37.0	41.8	A	77	FG2-15	4	4.8	2.5	1.5	A, B, C
78		45.0		104.8	176.5	A	78		4	11.0	0.1		A, B
79	FG2-14	1.5		37.0	40.6	A	79	FG2-14	4	4.8	2.5	1.5	A, B, C
80		45.0		104.8	176.5	A	80		4	11.0	0.1		A, B
81	FG2-13	1.5		37.0	40.6	A	81	FG2-13	4	4.8	2.5	1.5	A, B, C
82		45.0		104.8	176.5	A	82		4	11.0	0.1		A, B
83	FG2-19	1.5		37.0	41.8	A	83	FG2-19	4	4.8	2.5	1.5	A, B, C
84		45.0		104.8	176.5	A	84		4	11.0	0.1		A, B
85	FG2-18	1.5		37.0	41.8	A	85	FG2-18	4	4.8	2.5	1.5	A, B, C
86		40.0		104.8	176.5	A	86		4	11.0	0.1		A, B
87		40.0		104.8	176.5	A	87		4	11.0	0.1		A, B
88	FG2-3	1.5		29.0	54.2	A	88	FG2-3	4	4.9	2.5	1.1	A, B, C
89		40.0		104.8	176.5	A	89		4	11.0	0.1		A, B
90	FG2-2	1.5		28.0	54.2	A	90	FG2-2	4	4.9	2.5	1.1	A, B, C
91	FG2-1	1.5		27.0	54.2	A	91	FG2-1	4	4.9	2.5	1000	A, B
92		100.0		104.8	176.5	A	92		4	11.0	0		A, B
A. Geometry changed to diameter of equivalent flow area							A. Geometry changed to diameter of equivalent flow area causes changes to coeff. (K2 = K1(D2/d1)^2)						
B. Correction to geometry							B. Roughness (e) increased for rectangular conduits due to larger wetted perimeter						
^ FG3-6 is held 1/2 open when in closed position (for TW < 19.5')							C. Minor loss coefficients (K) for diffusers calibrated from data						
^ FG3-6 is full open for TW > 19.5'							D. Minor Loss corrected from Geometry						
							E. Minor Loss Coeff. Adjusted by Pre-calculation Excel Macro						

Table 11 CATALOGUE OF CHANGES of WEIR COEFFICIENTS to HELCRABS GEOMETRY & COEFFICIENT FILE (*REVISED*)

AREA of CONCERN: ENTRANCE WEIR 2 (South Entrance, north slot)						CHANGES to File		line 1 starts at weir no (2)
Page No.	Line no.	Item No.	Variable	Program Function	Variable name in Function	From	To	Purpose of Change
3	2	1	contr. Coeff	Slot_ Discharge	ContCoef	0.19	0.25	Accounts for flow contraction; increased because u/s bend > 90 deg.
3	3	2	Weir Width	"	Width	8.25	8.0	Corrected per mods shown in drawing 6 in NHC report for Mods to 1st PH entrances (1993)
3	3	1	entrance invert	"	Invert	-2.0	2.0	Corrected per asbuilt drawings, I.E = +2 at So entrance
3	3	2	h1/p eqn barrier	"	Klimit	2.5	5	More accurate Cw for H1/p > 2.5; Cw is higher at H1/p > 2.5
3	5	1	c1_high	"	c1_HI	0.6	1.011	Adjust Cw for H1/P > 5 to approach theory and prototype data. Assumes constant Cw for H1/P > 5
3	5	2	c2_high Kr	"	c2_HI	0.5275	0	"
3	8	1	Min weir elev	Ent_Q	ent_min	6.5	2	Corrected per mods shown in drawing 7 in NHC report for Mods to 1st PH entrances (1993)
3	8	2	Max weir elev	Ent_Q	ent_max	36.5	18	Corrected per mods shown in drawing 7 in NHC report (1993)
AREA of CONCERN: ENTRANCE WEIR 1 (South Entrance, south slot)						CHANGES to File		line 1 starts at weir no (1)
Page No.	Line no.	Item No.	Variable	Program Function	Variable name in Function	From	To	Purpose of Change
3	3	1	contr. Coeff	Slot_ Discharge	ContCoef	0.19	0.08	Accounts for flow contraction; NHC HELCRABS Report had 0.05 instead of 0.19; increased from 0.05 because u/s bend > 90 deg.
3	4	1	entrance invert	"	Invert	-2.0	2.0	Corrected per asbuilt drawings, I.E = +2 at So entrance
3	4	2	h1/p eqn barrier	"	Klimit	2.5	5	More accurate Cw for H1/p > 2.5; Cw is higher at H1/p > 2.5
3	7	1	c1_high	"	c1_HI	0.6	1.011	Adjust Cw for H1/P > 5 to closer to theoretical and data measurements. Assumes flat curve for H1/P > 5
3	7	2	c2_high Kr	"	c2_HI	0.5275	0	"
3	8	2	Max weir elev	Ent_Q	ent_max	23.5	26	Corrected per mods shown in drawing 7 in NHC report (1993)
AREA of CONCERN: POWERHOUSE CHANNEL ORIFICE GATES # 62, 58, 34, 21, 9						CHANGES to File		Line 1 starts at gate number
2	4	2	h1/p eqn barrier	"	Klimit	2.5	5	More accurate Cw for H1/p > 2.5; Cw is higher at H1/p > 2.5
2	7	1	c1_high	"	c1_HI	0.6	1.011	Adjust Cw for H1/P > 5 to closer to theoretical and data measurements. Assumes flat curve for H1/P > 5
2	7	2	c2_high Kr	"	c2_HI	0.5275	0	"

Table 11 (Continued)

AREA of CONCERN: ENTRANCE WEIR 65 (North Entrance, north slot) line 1starts at weir no (65)								
						CHANGES to File		
Page No.	Line no.	Item No.	Variable	Program Function	Variable name in Function	From	To	Purpose of Change
2	2	1	contr. Coeff	Slot_ Discharge	ContCoef	0.19	0.14	Accounts for flow contraction; reduced because u/s bend < 90 deg.
2	3	1	entrance invert	"	Invert	-2.0	0.0	Corrected per asbuilt drawings, I.E = 0 at North entrance
2	3	2	h1/p eqn barrier	"	Klimit	2.5	5	More accurate Cw for H1/p > 2.5; Cw is higher at H1/p > 2.5
2	5	1	c1_high	"	c1_HI	0.6	1.011	Adjust Cw for H1/P > 5 to approach theory and prototype data.
2	5	2	c2_high Kr	"	c2_HI	0.5275	0	Assumes constant Cw for H1/P > 5
AREA of CONCERN: ENTRANCE WEIR 64 (North Entrance, south slot) line 1starts at weir no (64)								
						CHANGES to File		
Page No.	Line no.	Item No.	Variable	Program Function	Variable name in Function	From	To	Purpose of Change
2	2	1	contr. Coeff	Slot_ Discharge	ContCoef	0.19	0.05	Accounts for flow contraction; NHC HELCRABS Report had 0.05 instead of 0.19; reduced further because u/s bend < 90 deg.
2	2	2	Weir Width	"	Width	8.25	8.0	Corrected per mods shown in drawing 4 in NHC report for Mods to 1st PH entrances (1993)
2	3	1	entrance invert	"	Invert	-2.0	0.0	Corrected per asbuilt drawings, I.E = 0 at North entrance
2	3	2	h1/p eqn barrier	"	Klimit	2.5	5	More accurate Cw for H1/p > 2.5; Cw is higher at H1/p > 2.5
2	5	1	c1_high	"	c1_HI	0.6	1.011	Adjust Cw for H1/P > 5 to closer to theoretical and data measurements. Assumes flat curve for H1/P > 5
2	5	2	c2_high Kr	"	c2_HI	0.5275	0	
2	8	2	Max weir elev	Ent_Q	ent_max	23	18	Corrected per mods shown in drawing 5 in NHC report for Mods to 1st PH entrances (1993)

Table 12 Changes to Manning's Roughness in Powerhouse Channel

AREA of CONCERN: Powerhouse Collection Channel								
						CHANGES to File		
Page No	Line no.,	item no.	Relevant Function or Subroutine	Variable name in Function	From	To	Purpose of Change	
1	2	2	Backwater()	BWn(1,2)	0.125	0.035	Represents Manning's n value. too high in model. Revised roughness calibrated from water surface level data	
1	3	2	Backwater()	BWn(2,2)	0.080	0.035		

Memorandum for the Record:

Jan. 15, 2003

From: Stephen Schlenker, EC-HD

Problem: Problems with A Branch HELCRABS Model Accuracy

Options:

- A. Develop Macro to pre-address model deficiencies before running
- or
- B. Rewrite A Branch Model In-house (probably using excel & VB macro)

Description of Deficiencies in A Branch HELCRABS Model

1. Inappropriate use of Kentucky Pipes for A Branch. The model uses a sub-program called Kentucky Pipes to simulate the hydraulics in the AWS conduits. This program works off two basics assumptions:
 - a. All conduits are circular and
 - b. All flow is pressurized in the conduits.

Both assumptions are incorrect. The conduits are rectangular. However we have been able to address this difference through complex adjustments to the geometry files for the model.

The second assumption (pressurized flow) presents a greater problem. The flow is indeed pressurized in the lower portions of the AWS conduits--the proportion depending on tailrace level. However, the fish valves are located at levels above the pressurized sections (Inverts at FV1-1 and FV3-7 are 48.6 and 58 feet, respectively. Only an exceptionally high tailrace level, perhaps > 35, might cause one of the conduits, FV1-1, to become fully pressurized.) This means the valves actually discharge to atmosphere into steep conduits that run open channel down to a lower 'reservoir' in the AWS system. Consequently, all AWS inflow is controlled through the Tainter valves, independent of tailrace level or the level of the AWS 'reservoir', and is strictly a function of forebay level, invert elevation, and gate opening.

The problem is the Kentucky pipe program treats the valves as operating under pressure--ignoring the physical constraints of the high inverts of the valves. Essentially the program uses the head difference between the forebay and the lower reservoirs in the AWS to determine the head drops across the fish valves and compute the valve discharges. The head drops across the fish valves are vastly overestimated and thus the AWS inflow rates are also overestimated. An additional consequence is the pressure gradelines in the lower conduits are overestimated, thus exaggerating the pressure differences between the AWS conduits and the ladder. So in spite of our geometric corrections, the program overestimates:

1. AWS and system flows
2. AWS pressures (significant when evaluating in terms of operational constraints, 5 psi difference)

2. Program does not run on NT machines.
3. Spatially Varied Flow. Model does not properly account for spatially varied flow in open channel (powerhouse channel) water surface profiles.
4. Channel velocities. In computing the channel velocities, the invert for the Powerhouse channel is hard-wired into the program code; the current level (-2 feet) is correct but the program prevents future modifications.
5. Entrance weirs. Entrance weir equation format is limited and prevents the application of the best theoretical equations

Solutions

In order to perform an evaluation of the ladder system, deficiencies 2 – 5 represent obstacles that do not prevent reasonably accurate simulations. We have found ways to mitigate or circumvent them. The first deficiency represents a major roadblock. There are two ways to address this problem:

1. Develop Excel macro to pre-address chief model deficiency before running program.
 - a. First compute flows through the fish tainter valves
 - b. Perform open channel profile to determine water levels in ladder
 - c. Estimate pressure differential between AWS and ladder
 - d. Determine magnitude of head difference between fish valves and AWS pressure gradeline (reservoir).
 - e. Estimate the magnitude of variable minor loss coefficients (K) for insertion into Kentucky pipes that will create the correct head differences across the fish valves and would allow the program to compute the correct flow rates through the fish valves.
 - f. Insert K values into program geometry files, and run HELCRABS model.

Pros

- Less time and labor cost
- Have invested time in fixing geometry files for program

Cons

- Solution is a complicated adjustment to a serious problem
- Still cannot fix other deficiencies (described above)
- Special upfront macro may present difficulties to future project users

2. Rewrite A branch model in-house
 - a. Use Excel program for input interface with either VB macro driver or Fortran executable
 - b. This model would incorporate the functions described above up to step 1-d,
 - c. Complete computational process through automatic and iterative simulations of the AWS conduit flows & ladder water surface profiles until inflows match outflows (Detailed procedure below)

Pros

- More accurate simulation of hydraulic conditions
- Eliminate model deficiencies (described above)
- Eliminates the need for Kentucky Pipes
- Rectangular conduits would be used in the AWS simulations—this means the geometry would be represented as shown in the drawings rather than having adjusted circular dimensions for the purpose of running in Kentucky pipes
- Eliminate need to run on Pre-NT computers (i.e. lap tops)
- Output can be managed and provided in a more useful and graphic format
- We have control of the code!
- Will have head start on phase 2 or 3 of HELCRABS

Cons

- Extra time & labor costs
- Lost time already invested in HELCRABS model

Other Mitigating Factors

Time thus invested would not be total loss.

- Geometry has been investigated and corrected in several places
- Better understanding of how the system works

Time required to make the model functional requires many of the same steps that are required to re-write the model in-house.

Procedure to develop in-house A branch model

Input:

External parameters: Forebay, Tailrace Level(s)

Settings: Fish Valves (FV1-1, FV3-7, 3-8)

Control ladder head (1 or 1.3)

Diffuser openings

Entrance weir settings

Powerhouse gate settings

Required Work Sheets with Geometry Data:

1. Powerhouse Channel with entrances extending up to ladder (geometry, Manning's n, diffuser locations, ladder geometry and coefficients)
2. North AWS (geometry, links, nodes, e, K, reservoirs)
3. South AWS (geometry, links, nodes, e, K, reservoirs)

Basic Procedure

1. Compute Inflows
 - FV1-1
 - FV3-7
 - Ladder Inflow (control head)
2. Program guesses initial 3 parameters
 - Entrance head at south entrance (f(QT, weirs & tailrace)
 - EGL_n at d/s end of North Conduit (f(5 psi at FG3-5)
 - EGL_s at d/s end of South conduit (f(5 psi at FG2-5)
3. Perform water surface (spatially varied flow) profile across PH channel and up ladder to junction pool to start spreadsheet 1
 - i. Start with guessed head at south entrance
 - ii. Program assumes an initial distribution of diffusers flows from each conduit into open channel system based on fish valve flows
 - iii. Perform a backwater profile past north entrance.
 - iv. Check if sum of entrance and powerhouse discharges = sum of inflows
 1. $Q_{no\ ent} + Q_{no\ ent} + Q_{phgates} = Q_{fv1-1} + Q_{fv3-7} + \text{Ladder } Q$
 2. If not re-guess head at So entrance and repeat steps ii-iv until convergence
 - v. Continue backwater up ladder to junction pool
4. Perform closed conduit computations AWS conduits (sheets 2 & 3)
 - i. Insert reservoir elevations for each diffusers (open or closed)
 - ii. If FV3-8 open, compute Q3-8 based on head difference at downstream ends of both sections
 - iii. Initial Q in each conduit is dependent on Q3-8
 - iv. Compute pressurized flow computations backwaters up each conduit to location where HGL < top of conduit

- v. Keep tabs of flow rates in both conduits
- vi. Re-guess EGLn (secant method) if $Q_{aws} \neq Q_{fv}$ in North
- vii. Re-guess EGLs if $Q_{aws} \neq Q_{fv}$ in South
- viii. Repeat steps ii – vii until convergence in both conduits
- 5. Repeat Step 3 (open channel sheet 1)
 - i. start with previous head at south entrance
 - ii. Insert revised diffuser flows
 - iii. alter entrance heads until till convergence on inflow & outflows
 - iv. If no change in entrance head, done
- 6. Repeat Step 4 (AWS conduits)
 - i. insert revised reservoir levels
 - ii. alter EGLi's as needed till sum $Q_{aws} = Q_{fv}$ in each conduit
 - iii. if no change in EGLi, done

MEMORANDUM FOR THE RECORD:

Sept. 26, 2003

FROM: Sean Askelson, EC-HD**TITLE:** Pre-Adjustment Macro for HELCRABS A Branch Model**GENERAL:**

A special model pre-adjustment or “pre-calculation” excel macro was created to compensate for the improper assumption applied with the use of Kentucky Pipes in the A Branch HELCRABS model. The incorrect assumption assumes pressurized flow through the AWS fish valves that control the AWS inflow; whereas in reality, the fish valves are located at elevations that are normally above levels that would be pressurized. The objective of the macro is to make sure the HELCRABS model produces the correct fish valve discharge (based on the invert elevation or HGL elevation) and provide an accurate level of the hydraulic gradeline within the AWS conduits so that system pressures may be more accurately estimated.

The macro accomplishes this by adjusting certain pipe coefficients that artificially reduce the amount of energy downstream of the tainter valves and ensure the model computes the correct discharge from the valves. The first step of the macro is to compute what the flow rates should be from the fish valves as a function of forebay and gate opening. The next step inserts the valve flow rate into another sheet that computes the flows and head losses through the diffusers and AWS conduit to determine the HGL level below the fish valve. The program then back-calculates the artificial minor loss coefficients in each conduit for substitution into the K-pipes data file so that it produces the correct flow rates and HGL’s in the AWS. It is cumbersome to operate and maintain. Additionally, it is not following proper hydraulic theory. The model user is essentially “tricking” a pressurized system model to produce the correct valve discharges and hydraulic gradelines below the valves.

INPUTS:

- Forebay (FB) level (ft)
- Tailwater (TW) level (ft)
- Entrance Head Estimate (usually 1-1.5 ft)
- Head on Weirs (usually 1-1.2 ft)
- FV1-1 Opening
- FV3-7 Opening (automatically calculated from lookup  e for FB 74.5 ft)
- Entrance weirs WG-65, WG-64, WG-2, WG-1 settings. If closed, make higher than TW (40 ft works well)
- Diffuser settings, either open or closed. They automatically highlight if they should be on per Fish Passage Plan (FPP).
- Choose if FG3-6 is partially open or fully open.

OPTIONS:

Create new HELCRABS INPUTS – YES or NO

- If YES, must set MODEL DIRECTORY. FV-Flows and all RUN files must be in this directory (runs much quicker if you do not create HELCRABS Inputs)

HIDE ALL SHEETS – YES or NO

PROGRAM STEPS:

1. Establish the water surface elevation or hydraulic gradeline (HGL) from the input data to determine the open channel boundary conditions for each AWS diffuser:
 - The water surface elevation in the powerhouse channel (PCC) is set at TW+Entrance Head for each open diffuser gate (the head changes across the PCC due to open channel flow losses are neglected).
 - The water surface elevation in the ladder diffusers is set at TW+Entrance Head or weir elevation + head on weirs, whichever is greater for each open diffuser gate.
 - If the diffuser gate is closed, the water level is set arbitrarily at 1000 ft.
2. Establish initial guess for the HGL with the AWS conduit immediately downstream of each fish valve. The initial HGL is set to the valve invert (Z) elevation. This is just a seed value to start the calculations.
3. Compute the flows rates through each fish valve.
 - The flow rate through a valve is a function of geometry, contraction coefficient and head difference across the valve:

$$Q = CG_0B(2gH)^{1/2} \quad (\text{cfs})$$

K_e = entrance loss K_e is assumed to be 0.1, based on Cook memorandum.

C = contraction coefficient

G_0 = Valve Opening (ft)

B = valve width

Z = Invert elevation (ft)

g = Gravity (32.2 ft/s²)

H = Head difference across valve (ft)

- Determine Contraction Coefficient (C), which is a function of G_0 and valve geometry represented by the angle β between the valve and invert.
 - β = angle between the tangent line from the lower face of tainter valve and the invert
 - $\beta = \cos^{-1}(y-G_0)/R$
 - R = the radius of the skin plate for the tainter valve
 - y = vertical distance between the valve trunnion and the invert
- If the invert surface is sloped (as in FV1-1) β was adjusted by subtracting the angle of the slope from the value of β

- The contraction coefficient is interpolated as a function of G_0 and β from the HDC chart 320-3
 - C is adjusted by a multiplier of 1.165 (calibrated from flow measurement data)
 - Determine head (H) on each valve:
 - If HGL downstream of the valve is greater than (G_0C+Z)

$$H = FB - (K_E Q^2 / (2gA^2)) - HGL_v$$

$$HGL_v = \text{HGL immediately downstream of valve}$$
 - If HGL downstream of the gate is less than or equal to G_0C+Z

$$H = FB - (K_E Q^2 / (2gA^2)) - G_0C - Z$$
 - The visual basic goal seek function was used to solve for Q with this equation:

$$Q - CG_0B(2gH)^{1/2} = 0$$
4. Route computed fish valve flows through AWS conduits and diffusers
- The flow rates for both fish valves are next imported into the pressurized pipe portion of the workbook. Using the input sheets from the HELCRABS model, an identical pipe network has been set up in Excel.
 - Flow is routed through the open diffuser gates (previously entered) and solved to match the flow calculated through the gates using the following process.
 - The process used to calculate the flow in the pressurized pipe network goes as follows:
 - HGL set at the start of the pipe just downstream of the gates. The HGL is iterated until the flows through the pipe network equal the flows from the gate calculations.
 - At each pipe, the HGL at the start of the pipe is either given (FB or set and iterated). The HGL is calculated at the end of the pipe by subtracting the losses:
 - o Friction losses:

$$\text{Friction loss (between nodes)} = f * (\text{Length} * \text{Velocity}^2) / (\text{Diameter} * 2 * g)$$
(f is calculated using the Reynolds number and solving the Moody equation).
 - o Minor losses:

$$\text{Minor head loss} = \text{Minor loss coefficients} * ((\text{Area}^2) / (2 * g))$$
 - Iterate on target HGL_v until the summation of the flow rates from the open diffusers on each conduit match the respective fish valve discharge rates (solve system continuity).
5. If the new target HGL_v from the last step is both greater than the valve invert (Z) and does not match the last HGL_v used to compute the valve discharge rates, a

solution must be obtained through additional iterations between the valve computations (Step 3) and the AWS computations (Step 4).

- Iterate between the HGL_v assumed downstream of the gate in the fish valve computation and the HGL_v determined in the pressurized pipe portion.
- Repeat Step 3: The AWS calculated HGL_v is reinserted into the fish valve flow calculation and a new fish valve flow is computed.
 - This HGL_v is saved for a future comparison ($HGL_{original}$).
- Repeat Step 4: The new flow is put back into the AWS calculations and routed once again by varying HGL_v .
 - This new HGL is saved as well (HGL_{new}). The two HGL values are compared, if the difference is greater than $\Delta 0.2$ ft, an iterative process is initiated:

$$HGL_{original} = HGL_{original} \pm (HGL_{original} - HGL_{new})/4$$

in which the $\pm$ sign is:

positive (+) if $HGL_{original}$ is greater than HGL_{new} ; and
negative (-) if $HGL_{original}$ is less than HGL_{new} ,

- This process is run 25 times to ensure the difference between HGL_{new} & $HGL_{original}$ is minimal ($< \Delta 0.2$ ft).
 - Upon solution, the new fish valve flows are calculated, new $HGL_{original}$ is obtained, AWS flows routed, new HGL_{new} (HGL_v) is obtained.
 - Once this process is done, the HGL_v needed downstream of the gates is known. This HGL_v will give the required flow through the each branch as calculated in the valve flow calculations.
6. Compute phony minor loss coefficients downstream of each fish valve to be applied to the program data files.
- Compute a phony minor loss coefficient to obtain this required HGL_v in the model.
 - Using Goalseek in the visual basic macro, the minor loss coefficient is determined from the following equation:

$$HGL_1 - \left\{ KV_{HC} + \frac{f_v L_v}{D_v} \right\} \left(\frac{Q}{A_v} \right)^2 \frac{1}{2g} - \left\{ K_{ph} + \frac{f_p L_p}{D_p} \right\} \left(\frac{Q}{A_p} \right)^2 \frac{1}{2g} - HGL_v \equiv 0$$

In which;

HGL_1 = hydraulic gradeline upstream of the fish valve (ft)

KV_{HC} = minor loss coefficient used in the HELCRABS model for the fish valve
= $(1/CD^2)$;

$CD = 0.74 + x_{minor} * (-0.5 + x_{minor} * (1.1 + x_{minor} * (-1.1 + x_{minor} * 0.69)))$

$x_{minor} = G_0/G_{max}$ in program

Q = valve flow rate (cfs)

A_v = Area of valve (fully open) (ft^2)

K_{ph} = phony minor loss coefficient used to force model to produce correct fish valve flow rates and HGL_v below the valves in the HELCRABS model simulations

- Now, we have determined the flow through each of the fish valves, the required HGL in the AWS conduit that gives the fish valve flow through the AWS system and a phony minor loss coefficient to obtain this HGL in the model.
7. The final step in the macro is to create new HELCRABS input or data file sheets.
 - The fish valve settings, entrance gate settings, fish ladder head, FB and TW are all entered into the INP file and saved as RUN.INP.
 - The phony minor loss coefficients for pipes 3 and 60 and the required settings for diffuser FG3-6 are entered into the IN file and saved as RUN.IN.
 8. Enter diffuser gate settings into the HELCRABS GUI interface, along with the final FB setting.
 9. Run the HELCRABS Bonneville A Branch model with the following command line: BONNA RUN RUN

MEMORANDUM FOR RECORD

FROM: Kyle McCune

SUBJECT: Report on data collection on the A Branch of the Bradford Island Fish Ladder August 15, 2002

DATE: August 22, 2002

Attendees: Kyle McCune, EC-HD
Steve Schlenker, EC-HD
Sean Askelson, EC-HD
Jacob Macdonald, EC-HD
Laurie Rice, EC-HD
James Stafford, EC-HD
Martin Monnig, HDC

Trip Objectives:

1. Collect data to verify the Bradford Island A Branch Fish Ladder HELCRABS numerical model under a fixed forebay and tailrace condition.

Data Collection:

The team arrived at the project and organized at the Bradford Island fish exit at 8:00 AM. Fixed forebay and tailrace conditions were coordinated with the Reservoir Control Center (RCC) for 9:00 AM to 3:00 PM prior to the visit and therefore data collection was to begin at 9:00 AM. As a result of the complexity of the A Branch ladder system, many locations of hydraulic interest for the purposes of calibrating the model were not accessible to the measurement team (see July 31 A Branch trip report for details). Because of this, no flow data could be collected for the ladder fish entrances. Instead we will rely on flow measurements from all water intake sources and document head drop at all fish entrances. Therefore data was collected from four locations: The South Auxiliary Water Supply (AWS) intake, the North AWS intake, the fish ladder exit slot and ladder augmentation flow channel, and to provide powerhouse channel flow at a single location measurements were also attempted along the powerhouse channel prior to entrance gates 1 and 2. The general layout of the A Branch system and the locations where measurements took place are provided as Figure 1 of this report.

Ladder Flow (Fish Exit and Ladder Augmentation Flow Channel)

The over flow weir ladder flow was measured by taking a measurement through the fish exit slot and the ladder augmentation flow channel adjacent to it. The fish exit slot is approximately 2 ft wide and has an invert elevation at 63 ft. Ideally flow measurements are taken at a number of locations across the channel width to get a representative velocity distribution. Due to the narrowness of the slot only a single set of measurements could be obtained from the middle of the slot at 5 depths. The measured flow through the fish exit slot was 124 cubic feet per second (cfs). Due to the fact that the velocities were only measured at the center of the slot, where they are theoretically the highest, this value is likely high.

The ladder augmentation flow was measured at the channel intake adjacent to the fish exit slot. The original plan was to have project personnel remove the walkway grating over the trash rack in order to gain access but the team found that they could maneuver the price meter from above without removing the trash racks. The flow measured at this location was 135 cfs. The data sheets for both of these locations are included at the back of this trip report.

North AWS Intakes

Flow through the North AWS was measured through four bulkhead slots just downstream of the intake trash racks. The location provided easy access to the channel at a point where the flow was relatively uniform. The flow for the North AWS measurements were 108 cfs through bulkhead slot 1 (numbered from east to west), 65 cfs through bulkhead slot 2, 85 cfs through bulkhead slot 3, and 108 cfs through bulkhead slot 4 for a total AWS flow of 366 cfs.

South AWS Intakes

The South AWS intake flow was measured from the trash rack walkway running north to south that screens the combined intake flow for the fish locks (now out of service) and the South AWS. This location is actually upstream of the South AWS but since the fish locks are no longer in service 100% of the flow through this transect feeds the South AWS. Though easily accessible the floor along this location goes from horizontal over the first 19 ft (from south) and then slopes 1:1 over the remaining 11 ft. So that an accurate depth could be recorded, the price meter depth was re-zeroed at each measurement location over the sloped portion of the transect. In order to keep measurements in uniform areas the flows were taken at the same depth intervals with additional locations added, at locations where the channel bottom was deeper. The flow through the South AWS intake was measured at 870 cfs. Figure 1 shows the location of the South AWS sampling and Figure 2 shows, spatially, the velocities measured at the transect. The data sheet for the South AWS is also attached to this trip report.

Entrances

The A Branch Ladder has a total of nine locations through which fish can enter the ladder in the vicinity of the powerhouse channel. Though these are not all open simultaneously, the number that are open and the fact that the powerhouse channel runs under the powerhouse tailrace deck and is largely inaccessible makes measurement unfeasible. The only location providing sufficient access is a portion of the channel downstream of sluice gate #9. No sources or sinks of water lie between this location and the entrance weirs and therefore this measurement is representative of water exiting through the south exit weirs (in this case Gate #1). The flow through the Powerhouse Channel at location 2 of Figure 1 was measured to be 412 cfs.

Discharge Calculations:

The total flow through the various sampling transects is determined by first calculating an integrated average velocity across the channel at each depth and then integrating the resultant averages again over all depths. The edge of the flow field was extrapolated linearly from the two outermost measurements at a given depth. If the extrapolated value at a channel edge would be greater than the two measure values used to extrapolate it that velocity would be set to the adjacent measurement. The total integrated average velocity was then multiplied by the total cross-sectional area to get a flow rate.

Conclusions:

In total, approximately 1,500 cfs was flowing into the A Branch at the time of this measurement. Conditions during this site visit will be used as input into the HELCRABS A Branch Fishway model. Results from the model run will then be compared to the actual flows measured in order to determine whether deficiencies exist in the model. In addition a second data collection trip is planned for late September 2002. Data collected during this second site visit will be treated the same and used as a second set of conditions for model comparison.

BONNEVILLE A BRANCH FISHWAY VELOCITY DATA									
NORTH AWS INTAKE BULKHEAD SLOTS					Data Collectors: SA JM LR				
SLOT 1									
Date: 8/15/02									
Time: start 09:00 end 09:50					AWS Intake Tainter Gate Data				
Forebay Level = start 75.10 end 75.00					FG3-7 start				
Tailrace Level = start 13.60 end 13.50					Opening (ft) 1.25 ft				
					Distance to WS d/s of gate (ft) 15.60 +/- 1 ft				
					Head d/s of Gate:				
Intake Number from East AWS INTAKE BULKHEAD SLOT									
Price Meter B9369 $V = 0.03 + 2.27548 * (\text{rotations/time})$					Price Meter Rotations per Count = 1.00				
POINT VELOCITY AND FLOW MEASUREMENTS IN AWS:									
Z ₁₅ = Meas. Distance to WS 9.69 ft (from 85 deck)					check 11.21 ft				
WS = Water Surface Elev 75.31 ft (= 85 - Z ₁₅)					B = Channel Width = 11.0 ft				
Y = Measured Depth = 21.31 ft (= WS - 54)					Deck elev = 85.0 ft				
					Zi = INVERT = 54.0 ft				
X1 = Side Edge width inc= 3					Approx internal dimension = 4.2 ft				
Y1 = Vertical edge height incr= 3					Number of Internal X Increments = 1.0				
					Number of Internal Y Increments = 5.0				

BONNEVILLE A BRANCH FISHWAY VELOCITY DATA							
NORTH AWS INTAKE BULKHEAD SLOTS				Data Collectors: SA JM LR			
SLOT 1				Date: 8/15/02			
NORTH AWS INTAKE MEASUREMENTS				Time: 09:00 09:50			
Bulkhead Slot 1			(measured from north side of slot)				
Horiz. No.:	Formula for Distance from surface (pm)	Depth from Surface (ft)	Vert. Sect. No. :	1	2	3	Average Integrated Velocity
			Est Dist. from left side (ft)	1.5	5.5	9.5	
			Actual dist from left side	1.5	5.5	9.5	
1	0.5 * Y1	1.50	Counts	18	15	6	0.68 ft/s
			duration	45	45	45	
			VELOCITY	0.94	0.79	0.33	
2	$Y1 + (Y-2*Y1) * 0.1$	4.50	Counts	13	12	15	0.70 ft/s
			duration	45	45	45	
			VELOCITY	0.69	0.64	0.79	
3	$Y1 + (Y-2*Y1) * 0.3$	7.60	Counts	14	16	6	0.63
			duration	45	45	45	
			VELOCITY	0.74	0.84	0.33	
4	Y/2	10.70	Counts	4	3	5	0.23 ft/s
			duration	45	45	45	
			VELOCITY	0.23	0.18	0.28	
5	$Y1 + (Y-2*Y1) * 0.7$	13.70	Counts	8	15	7	0.53 ft/s
			duration	45	45	45	
			VELOCITY	0.43	0.79	0.38	
6	$Y1 + (Y-2*Y1) * 0.9$	16.80	Counts	7	4	8	0.34 ft/s
			duration	45	45	45	
			VELOCITY	0.38	0.23	0.43	
7	Y - 0.5 * Y1	19.80	Counts	4	1	1	0.13 ft/s
			duration	45	45	45	
			VELOCITY	0.23	0.08	0.08	
Total Average Integrated Velocity =				0.46 ft/s			
Total Computed AWS FLOW RATE =				108.73 cfs (= B * Y * V)			

BONNEVILLE A BRANCH FISHWAY VELOCITY DATA			
NORTH AWS INTAKE BULKHEAD SLOTS		Data Collectors: SA JM LR	
SLOT 2			
Date: 8/15/02			
Time:	start end 09:50 10:25		
Forebay Level =	start end 75.00 75.00		
Tailrace Level =	start end 13.50 13.50		
Intake Number from East AWS INTAKE BULKHEAD SLOT		East 1 2 3 4 Q West 	
Price Meter B939369 $V = 0.03 + 2.27548 * (\text{rotations}/\text{time})$		Price Meter Rotations per Count = 1.00	
POINT VELOCITY AND FLOW MEASUREMENTS IN AWS:			
Z_{15} = Meas. Distance to WS 9.65 ft (from 85 deck)		check 11.01 ft	
WS = Water Surface Elev 75.35 ft (= 85 - Z_{15})		B = Channel Width = 10.8 ft	
Y = Measured Depth = 21.35 ft (= WS - 54)		Deck elev = 85.0 ft	
		Z_i = INVERT = 54.0 ft	
X1 = Side Edge width inc= 3		Approx internal dimension = 4.2 ft	
Y1 = Vertical edge height incr= 3		Number of Internal X Increments = 1.0 Number of Internal Y Increments = 5.0	

BONNEVILLE A BRANCH FISHWAY VELOCITY DATA							
NORTH AWS INTAKE BULKHEAD SLOTS				Data Collectors: SA JM LR			
SLOT 2				Date: 8/15/02			
NORTH AWS INTAKE MEASUREMENTS				Time: 09:50 10:25			
Bulkhead Slot 2				(measured from east side of slot)			
Horiz. No.:	Formula for Distance from surface (pm)	Depth from Surface (ft)	Vert. Sect. No. :	1	2	3	Average Integrated Velocity
			Est Dist. from left sidee (ft)	1.5	5.4	9.5	
			Actual dist from left side	1.5	5.4	9.5	
1	0.5 * Y1	1.50	Counts	3	2	8	0.24 ft/s
			duration	45	45	45	
			VELOCITY	0.18	0.13	0.43	
2	$Y1 + (Y-2*Y1) * 0.1$	4.50	Counts	6	8	6	0.37 ft/s
			duration	45	45	45	
			VELOCITY	0.33	0.43	0.33	
3	$Y1 + (Y-2*Y1) * 0.3$	7.60	Counts	11	7	6	0.43 ft/s
			duration	45	45	45	
			VELOCITY	0.59	0.38	0.33	
4	Y/2	10.70	Counts	4	3	2	0.18 ft/s
			duration	45	45	45	
			VELOCITY	0.23	0.18	0.13	
5	$Y1 + (Y-2*Y1) * 0.7$	13.80	Counts	8	8	4	0.37 ft/s
			duration	45	45	45	
			VELOCITY	0.43	0.43	0.23	
6	$Y1 + (Y-2*Y1) * 0.9$	16.80	Counts	3	2	5	0.20 ft/s
			duration	45	45	45	
			VELOCITY	0.18	0.13	0.28	
7	Y - 0.5 * Y1	19.90	Counts	1	2	5	0.16 ft/s
			duration	45	45	45	
			VELOCITY	0.08	0.13	0.28	
Total Average Integrated Velocity =				0.28 ft/s			
Total Computed AWS FLOW RATE =				65.29 cfs (= B * Y * V)			

BONNEVILLE A BRANCH FISHWAY VELOCITY DATA

NORTH AWS INTAKE BULKHEAD SLOTS

Data Collectors:

SA JM LR

SLOT 3

Date: 8/15/02

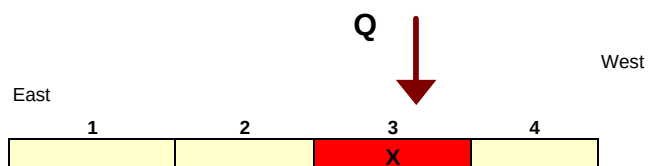
Time: start end
10:25 11:00

Forebay Level = start end
75.00 75.10

Tailrace Level = start end
13.50 13.30

Intake Number from East

AWS INTAKE BULKHEAD SLOT



Price Meter B939369

 $V = 0.03 + 2.27548 * (\text{rotations/time})$

Price Meter Rotations per Count = 1.00

POINT VELOCITY AND FLOW MEASUREMENTS IN AWS:

 Z_{15} = Meas. Distance to WS 9.59 ft (from 85 deck)WS = Water Surface Elev 75.41 ft (= 85 - Z_{15}) Y = Measured Depth = 21.41 ft (=WS - 54)

X1 = Side Edge width inc= 3

Y1 = Vertical edge height incr 3

check 11.01 ft

B = Channel Width = 10.8 ft

Deck elev = 85.0 ft

Zi = INVERT = 54.0 ft

Aprox internal dimension = 4.2 ft Div

Number of Internal X Increments = 1.0 2

Number of Internal Y Increments = 5.0 10

BONNEVILLE A BRANCH FISHWAY VELOCITY DATA

NORTH AWS INTAKE BULKHEAD SLOTS

Data Collectors:

SA

JM

LR

SLOT 3

Date:

8/15/02

NORTH AWS INTAKE MEASUREMENTS

Time:

10:25

11:00

Bulkhead Slot 3

(measured from east side of slot)

Horiz. No.:	Formula for Distance from surface (pm)	Depth from Surface (ft)	Vert. Sect. No. :	1	2	3	Average Integrated Velocity
			Est Dist. from left sidee (ft)	1.5	5.4	9.5	
			Actual dist from left side	1.5	5.4	9.5	
1	$0.5 * Y1$	1.50	Counts	15	8	5	
			duration	45	45	45	
			VELOCITY	0.79	0.43	0.28	0.50 ft/s
2	$Y1 + (Y-2*Y1) * 0.1$	4.50	Counts	12	11	6	
			duration	45	45	45	
			VELOCITY	0.64	0.59	0.33	0.52 ft/s
3	$Y1 + (Y-2*Y1) * 0.3$	7.60	Counts	8	9	8	
			duration	45	45	45	
			VELOCITY	0.43	0.49	0.43	0.45 ft/s
4	$Y/2$	10.70	Counts	3	4	2	
			duration	45	45	45	
			VELOCITY	0.18	0.23	0.13	0.18 ft/s
5	$Y1 + (Y-2*Y1) * 0.7$	13.80	Counts	6	10	7	
			duration	45	45	45	
			VELOCITY	0.33	0.54	0.38	0.41 ft/s
6	$Y1 + (Y-2*Y1) * 0.9$	16.90	Counts	6	5	8	
			duration	45	45	45	
			VELOCITY	0.33	0.28	0.43	0.35 ft/s
7	$Y - 0.5 * Y1$	19.90	Counts	3	2	2	
			duration	45	45	45	
			VELOCITY	0.18	0.13	0.13	0.15 ft/s
Total Average Integrated Velocity =				0.36 ft/s			
Total Computed AWS FLOW RATE =				85.77 cfs (= B * Y * V)			

BONNEVILLE A BRANCH FISHWAY VELOCITY DATA			
NORTH AWS INTAKE BULKHEAD SLOTS		Data Collectors: SA JM LR	
SLOT 4			
Date: 8/15/02			
Time: start 11:00 end 11:35			
Forebay Level = start 75.10 end 75.40			
Tailrace Level = start 13.30 end 13.30			
Intake Number from East			
AWS INTAKE BULKHEAD SLOT			
Price Meter B939369		Price Meter Rotations per Count = 1.00	
$V = 0.03 + 2.27548 * (\text{rotations/time})$			
POINT VELOCITY AND FLOW MEASUREMENTS IN AWS:			
Z ₁₅ = Meas. Distance to WS 9.55 ft (from 85 deck)		check 11.01 ft	
WS = Water Surface Elev 75.45 ft (= 85 - Z ₁₅)		B = Channel Width = 10.8 ft	
Y = Measured Depth = 21.45 ft (= WS - 54)		Deck elev = 85.0 ft	
		Zi = INVERT = 54.0 ft	
X1 = Side Edge width inc= 3		Approx internal dimension = 4.2 ft	
Y1 = Vertical edge height incr= 3		Number of Internal X Increments = 1.0	
		Number of Internal Y Increments = 5.0	

BONNEVILLE A BRANCH FISHWAY VELOCITY DATA							
NORTH AWS INTAKE BULKHEAD SLOTS				Data Collectors: SA JM LR			
SLOT 4				Date: 8/15/02			
NORTH AWS INTAKE MEASUREMENTS				Time: 11:00 11:35			
Bulkhead Slot 4		(measured from east side of slot)					
Horiz. No.:	Formula for Distance from surface (pm)	Depth from Surface (ft)	Vert. Sect. No. :	1	2	3	Average Integrated Velocity
			Est Dist. from left sidee (ft)	1.5	5.4	9.5	
			Actual dist from left side	1.5	5.4	9.5	
1	0.5 * Y1	1.50	Counts	2	4	4	0.20 ft/s
			duration	45	45	45	
			VELOCITY	0.13	0.23	0.23	
2	$Y1 + (Y-2*Y1) * 0.1$	4.50	Counts	10	6	8	0.43 ft/s
			duration	45	45	45	
			VELOCITY	0.54	0.33	0.43	
3	$Y1 + (Y-2*Y1) * 0.3$	7.60	Counts	4	7	11	0.40 ft/s
			duration	45	45	45	
			VELOCITY	0.23	0.38	0.59	
4	Y/2	10.70	Counts	13	10	12	0.62 ft/s
			duration	45	45	45	
			VELOCITY	0.69	0.54	0.64	
5	$Y1 + (Y-2*Y1) * 0.7$	13.80	Counts	18	15	18	0.89 ft/s
			duration	45	45	45	
			VELOCITY	0.94	0.79	0.94	
6	$Y1 + (Y-2*Y1) * 0.9$	16.90	Counts	12	10	8	0.53 ft/s
			duration	45	45	45	
			VELOCITY	0.64	0.54	0.43	
7	Y - 0.5 * Y1	19.90	Counts	4	1	3	0.16 ft/s
			duration	45	45	45	
			VELOCITY	0.23	0.08	0.18	
Total Average Integrated Velocity =				0.46 ft/s			
Total Computed AWS FLOW RATE =				108.93 cfs (= B * Y * V)			

BONNEVILLE A BRANCH FISHWAY VELOCITY DATA

SOUTH AWS INTAKE (FV1-1)

(from catwalk)

Date: 8/15/02 Time: 9:25 10:35 Data Collectors: KCM MM JS

Time: start 9:25 end 10:35

AWS Intake Tainter Gate Data

Forebay Level = start 75.20 end 75.30

Tailrace Level = start 13.60 end 13.30

FV1-1 start end
Opening (ft) 3.70 3.70
Distance to WS d/s of gate (ft) 23.15 23.00 +/- 1ft
Head d/s of Gate: NR NR

INSTRUMENT Price Meter X

Price Meter Rotations per Count = 1.00 (if used) $V = 0.03 + 2.27548 * (\text{rotations/time})$

POINT VELOCITY AND FLOW MEASUREMENTS IN SOUTH AWS:

Left Edge Invert Measurement

Z₁₅ = Meas. Distance to WS

WS = Water Surface Elev

Z_b = Dist from WS to bottom using PM

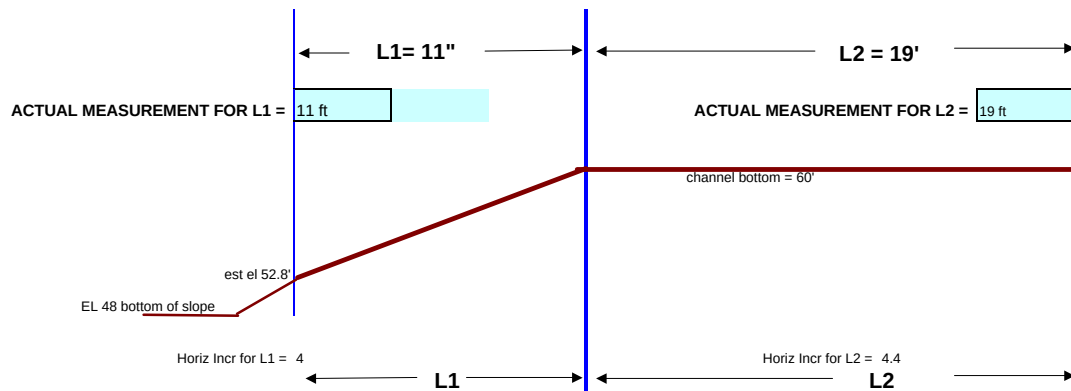
Meas Invert = WS - Z_b =

15 ft	(Est Invert)
	52.8

B = Channel Width = 30.0 ft
DECK elev = 85.0 ft
Catwalk elev = 82.70 ft

CHECK

30 ft



BONNEVILLE A BRANCH FISHWAY VELOCITY DATA												
SOUTH AWS INTAKE (FV1-1) (from catwalk)												
Date: 8/15/02		Time: 9:25		10:35		Data Collectors: KCM MM JS						
SOUTH AWS INTAKE (FV1-1) (from catwalk)												
		Est Invert	54.6		58.2	60	60	60	60	60		
		Meas invert										
		FLOW DEPTH	24.9	21.1	17.5	15.0	15.0	15.0	15.0	15.0		
Horiz. No.:	EST Distance from surface (PM)	ACTUAL Depth from Surface (ft)	Vert. Sect. No.:	1	2	3	4	5	6	7	8	Ave Vel
			Est Dist. from Left Edge (ft)	2.0		6.0	10.2	14.6	19.0	23.4	27.8	
			Actual Dist from left side	2.0	5.7	9.4	13.0	16.8	20.6	24.4	28.2	
1	1.0		Counts	37	15	14	0	0	13	35	4	0.77
			duration	45	45	45	45	45	45	45	45	
			VELOCITY	1.90	0.79	0.74	0.03	0.03	0.69	1.80	0.23	
2	4.0		Counts	32	45	47	52	46	46	51	33	2.16
			duration	45	45	45	45	45	45	45	45	
			VELOCITY	1.65	2.31	2.41	2.66	2.36	2.36	2.61	1.70	
3	7.0		Counts	35	44	44	37	27	34	39	19	1.77
			duration	45	45	45	45	45	45	45	45	
			VELOCITY	1.80	2.25	2.25	1.90	1.40	1.75	2.00	0.99	
4	10.0		Counts	39	39	46	53	45	50	51	28	2.23
			duration	45	45	45	45	45	45	45	45	
			VELOCITY	2.00	2.00	2.36	2.71	2.31	2.56	2.61	1.45	
5	13.0		Counts	39	41	29	18	18	35	44	26	1.60
			duration	45	45	45	45	45	45	45	45	
			VELOCITY	2.00	2.10	1.50	0.94	0.94	1.80	2.25	1.34	
6	16.0		Counts	43	48	18						1.89
			duration	45	45	45						
			VELOCITY	2.20	2.46	0.94						
7	19.0		Counts	46	15							1.57
			duration	45	45							
			VELOCITY	2.36	0.79							
8	22.0		Counts	14								0.74
			duration	45								
			VELOCITY	0.74								
Total Average Integrated Velocity =				1.70 ft/s								
Total Computed AWS FLOW RATE =				870.37 cfs (= B * Y * V)								

BONNEVILLE A BRANCH FISHWAY VELOCITY DATA

SUPPLEMENTAL LADDER DATA

Data Collectors:

KCM

JS

Date:

8/15/02

Time:

11:45

12:15

DIFFUSER DATA

NORTH AWS DIFFUSERS OPEN:

FG3-3	FG3-4	FG3-5	FG3-6	FG3-7	FG3-8	FG3-9	
OPEN	CLOSED	CLOSED	OPEN	CLOSED	CLOSED	CLOSED	 North

SOUTH AWS DIFFUSERS OPEN:

FG2-2	3	4	5	6	7	8	9	10	11
CLOSED	CLOSED	OPEN	CLOSED	CLOSED	CLOSED	OPEN	CLOSED	CLOSED	CLOSED

SOUTH AWS DIFFUSERS OPEN (Continued)

FG2-12	13	14	15	16	17	18	19	20	21
OPEN	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	OPEN	OPEN	OPEN

FG2-22:

22 - A

22 - B

22 - C

OPEN

OPEN

OPEN

POWER HOUSE CHANNEL DATA

	VELOCITY	CHA WS LEVEL	dist to WS
Sonic Meter Readout	NR	NR	NR
Mechanical Meter Readout	2.50	14.80	NR

B = Channel Width = 17.58 ft

DECK ELEVATION = 55.0 ft

Zi = INVERT = 0.0 ft

TELESCOPING GATES OPEN:

9	21	34	51	62	
OPEN	OPEN	OPEN	OPEN	OPEN	 North

ENTRANCE DATA

NORTH ENTRANCH WEIR GATE DATA

Distance to Water:

WATER LEVEL ELEV:

	SW-64	SW-65
OPEN ?	OPEN	CLOSED
Crest Elevation	5.50	26.00

Tailrace Level :

U/s Staff Gage:

start	end	Ref EL	start	end
NR	NR	NR	13.80	13.80
start	end	Ref EL	start	end
NR	NR	NR	15.20	15.20

SOUTH ENTRANCH WEIR GATE DATA

Distance to Water:

WATER LEVEL ELEV:

	SW-1	SW-2
OPEN ?	CLOSED	OPEN
Crest Elevation	26.20	5.90

Tailrace Level :

U/s Staff Gage:

start	end	Ref EL	start	end
NR	NR	NR	13.70	13.70
start	end	Ref EL	start	end
NR	NR	NR	15.10	15.10

NOTE:

1. NR - Not Recorded
2. Values are checked against fishway inspection report for the same day (8/15/02)

BONNEVILLE A BRANCH FISHWAY VELOCITY DATA

SOUTH POWERHOUSE CHANNEL

Data Collectors:

KLM MM JS

Date: 8/15/02 Time: 10:50 11:45

start end

start end

At FG2-3

Distance to Water:

WATER LEVEL ELEV:

SOUTH ENTRANCH WEIR GATE DATA

Tailrace Level :

start end Ref EL start end

75.10 75.40

SW-1 SW-2

OPEN ?

X

Crest Elevation

U/s Staff Gage:

start end Ref EL start end

INSTRUMENT

Price Meter

X

Price Meter Rotations per Count = 1.00

 $V = 0.03 + 2.27548 * (\text{rotations/time})$

POINT VELOCITY AND FLOW MEASUREMENTS:

 Z_{15} = Meas. Distance to WS =

ft (from 55 level)

B = Channel Width = 17.58 ft

WS = Water Surface Elevation =

ft (= 55 - Z_{15})

DECK ELEVATION = 55.0 ft

Y = Measured Channel Depth =

16.10

ft (=WS - 0)

 Z_i = INVERT = 0.0 ft

X1 = Side Edge width incr =

2 ft

Aprox internal dimension =

4.0 ft Div by

Y1 = Vertical edge height incr =

3 ft

Number of Internal X Increments =

2.0 4

Number of Internal Y Increments =

3.0 6

Horiz. No.:	Formula for depthn below surface (pm)	Depth from Surface (ft)		Vert. Sect. No. : Est Dist. from west Edge (ft) Actual Dist (ft) from Fft side	1	2	3	4	Average Velocity
1	0.5 * Y1	1.50	Counts	Counts	27	32	36	37	
			duration	duration	60	45	45	45	
			VELOCITY	VELOCITY	1.05	1.65	1.85	1.90	1.66 ft/s
2	Y1 + (Y-2*Y1)/6	4.00	Counts	Counts	29	38	37	38	
			duration	duration	45	45	45	45	
			VELOCITY	VELOCITY	1.50	1.95	1.90	1.95	1.85 ft/s
3	Y/2	8.00	Counts	Counts	28	35	41	36	
			duration	duration	45	45	45	45	
			VELOCITY	VELOCITY	1.45	1.80	2.10	1.85	1.80 ft/s
4	Y1 + 5* (Y-2*Y1)/6	12.00	Counts	Counts	13	33	32	25	
			duration	duration	45	45	45	45	
			VELOCITY	VELOCITY	0.69	1.70	1.65	1.29	1.34 ft/s
5	Y - 0.5*Y1	14.50	Counts	Counts	6	7	10	11	
			duration	duration	45	45	45	45	
			VELOCITY	VELOCITY	0.33	0.38	0.54	0.59	0.47 ft/s

Total Average Integrated Velocity =

1.46 ft/s

Total Computed FLOW RATE =

412.88 cfs

(= B * Y * V)

BONNEVILLE A BRANCH FISHWAY VELOCITY DATA

EXIT CHANNEL

Data Collectors: SA JM LR MM

Date: 8/15/02 Time: 12:40 13:25

Forebay Level = 75.50 75.50

Head on Picketed Lead =

INSTRUMENT

Price Meter

B9369

Price Meter Rotations per Count = 1.00

V = 0.03 + 2.27548 * (rotations/time)

POINT VELOCITY AND FLOW MEASUREMENTS:

Z₁₅ = Meas. Distance to WS = 10.46 ft (from 86.5 level) B = Channel Width = 2.26 ft
 WS = Water Surface Elevation = 76.04 ft (= 86.5 - Z₁₅) DECK ELEVATION = 86.5 ft
 Y = Measured Channel Depth = 13.04 ft (= WS - 63) Zi = INVERT = 63.0 ft

X1 = Side Edge width incr = 1 ft Approx internal dimension = 3.0 ft Div by 2
 Y1 = Vertical edge height incr = 2 ft Number of Internal X Increments = 1.0
 Number of Internal Y Increments = 3.0 6

* measurments are optional depending on flow conditions

Horiz. No.:	Formula for depth below surface (pm)	Depth from Surface (ft)		Vert. Sect. No. :	1*	2	3*	Average Velocity
				Est Dist. from Left Edge (ft)	0.5	1.13	1.76	
				Actual Dist (ft) from Fft side				
1	0.5 * Y1	1.00	Counts	Counts		83		
			duration	duration		45		
			VELOCITY	VELOCITY		4.23		4.23 ft/s
2	Y1 + (Y-2*Y1)/6	3.50	Counts	Counts		57		
			duration	duration		45		
			VELOCITY	VELOCITY		2.91		2.91 ft/s
3	Y/2	6.50	Counts	Counts		79		
			duration	duration		45		
			VELOCITY	VELOCITY		4.02		4.02 ft/s
4	Y1 + 5* (Y-2*Y1)/6	9.50	Counts	Counts		110		
			duration	duration		45		
			VELOCITY	VELOCITY		5.59		5.59 ft/s
5	Y - 0.5*Y1	12.00	Counts	Counts		85		
			duration	duration		45		
			VELOCITY	VELOCITY		4.33		4.33 ft/s

Total Average Integrated Velocity =

4.21 ft/s

Total Computed FLOW RATE =

124.06 cfs

(= B * Y * V)

BONNEVILLE A BRANCH FISHWAY VELOCITY DATA

FV3-9 Intake (Ladder Augmentation flow)

Data Collectors:

SA	JM	LR	MM
----	----	----	----

Date: Time: start 11:50 end 12:30

FV3-9 Tainter Gate Data

Forebay Level = start 75.40 end 75.50

135 start end

Opening (ft) start 1.00 end 1.00
 Distance to WS d/s of gate (ft)

Head d/s of Gate:

US Valve_9.2
DS Valve_16.8

INSTRUMENT

Price Meter

B9369

Price Meter Rotations per Count =

1.00

$$V = 0.03 + 2.27548 * (\text{rotations/time})$$

POINT VELOCITY AND FLOW MEASUREMENTS:

Z₁₅ = Meas. Distance to AWS WS =

10.85 ft (from 86.5 level)

B = Channel Width = 9.00 ft

WS = Water Surface Elevation =

75.65 ft (= 86.5 - Z₁₅)

DECK ELEVATION = 86.5 ft

Y = Measured AWS Channel Depth =

12.65 ft (=WS - 63)

Zi = INVERT = 63.0 ft

X1 = Side Edge width incr =

2 ft

Approx internal dimension =

3.0 ft Div by

Y1 = Vertical edge height incr =

2 ft

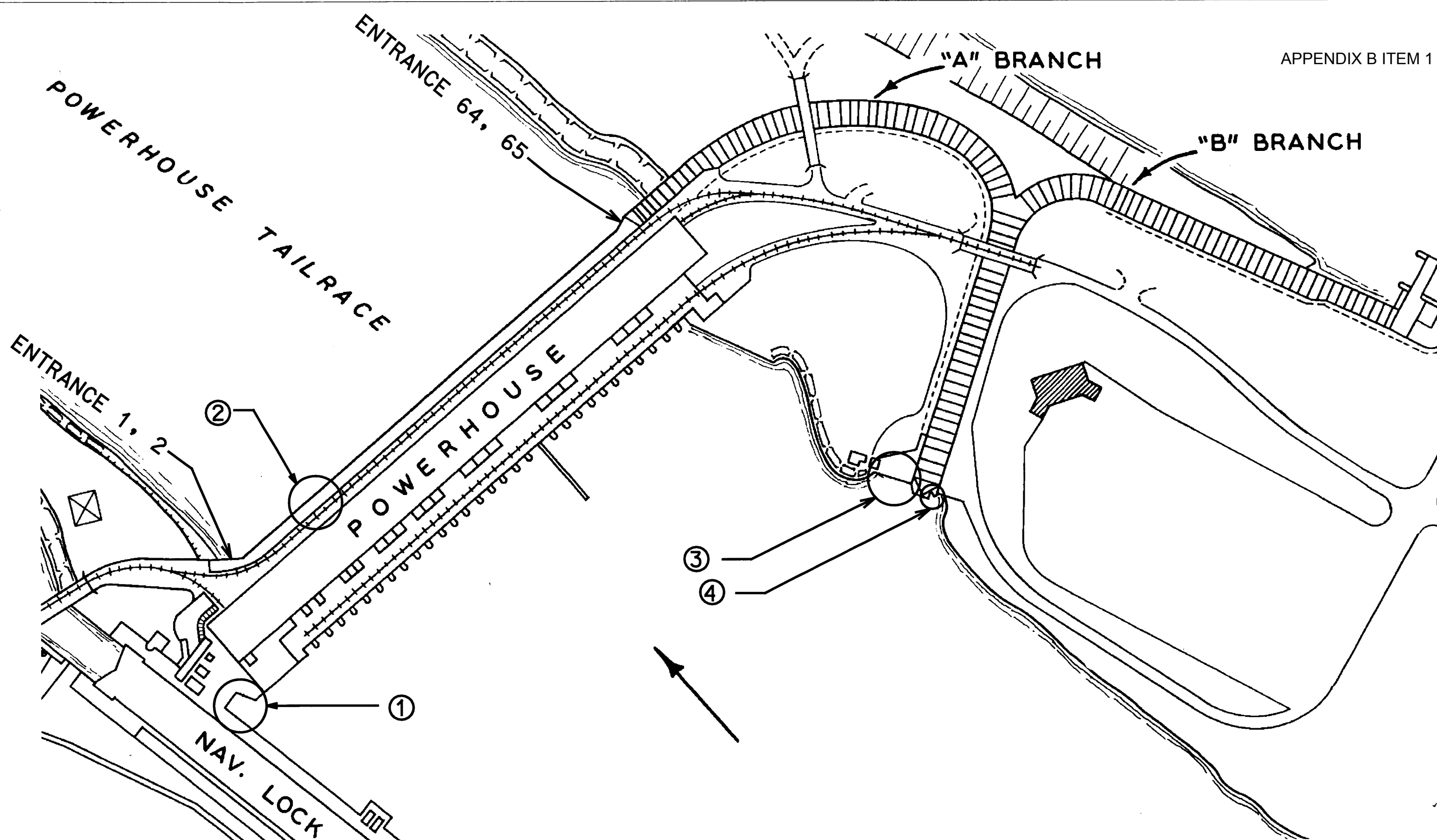
Number of Internal X Increments =

2.0 4

Number of Internal Y Increments =

3.0 6

Horiz. No.:	Formula for depthn below surface (pm)	Depth from Surface (ft)		Vert. Sect. No. :	1	2	3	4	Average Velocity
				Est Dist. from Left Edge (ft)	1.0	3.50	6.50	8.00	
				Actual Dist (ft) from Fft side	1.0	3.5	5.5	8.0	
1	0.5 * Y1	1.00	Counts	Counts	28	24	23	18	1.19 ft/s
			duration	duration	45	45	45	45	
			VELOCITY	VELOCITY	1.45	1.24	1.19	0.94	
2	Y1 + (Y-2*Y1)/6	3.40	Counts	Counts	29	26	25	18	1.24 ft/s
			duration	duration	45	45	45	45	
			VELOCITY	VELOCITY	1.50	1.34	1.29	0.94	
3	Y/2	6.30	Counts	Counts	23	22	26	24	1.22 ft/s
			duration	duration	45	45	45	45	
			VELOCITY	VELOCITY	1.19	1.14	1.34	1.24	
4	Y1 + 5* (Y-2*Y1)/6	9.20	Counts	Counts	22	22	23	22	1.15 ft/s
			duration	duration	45	45	45	45	
			VELOCITY	VELOCITY	1.14	1.14	1.19	1.14	
5	Y - 0.5*Y1	11.70	Counts	Counts	25	21	22	19	1.12 ft/s
			duration	duration	45	45	45	45	
			VELOCITY	VELOCITY	1.29	1.09	1.14	0.99	
Total Average Integrated Velocity =					1.19 ft/s				
Total Computed FLOW RATE =					135.29 cfs (= B * Y * V)				



- ① SOUTH AUXILIARY WATER SUPPLY INTAKE
- ② SOUTH POWERHOUSE CHANNEL
- ③ NORTH AUXILIARY WATER SUPPLY INTAKE
- ④ FISH EXIT CHANNEL AND LADDER AUGMENTATION FLOW CHANNEL

FIGURE 1

A_BRANCH DATA
COLLECTION LOCATIONS
AUGUST 15, 2002

SOUTH AUXILIARY WATER SUPPLY CROSS-SECTION

APPENDIX B ITEM 1

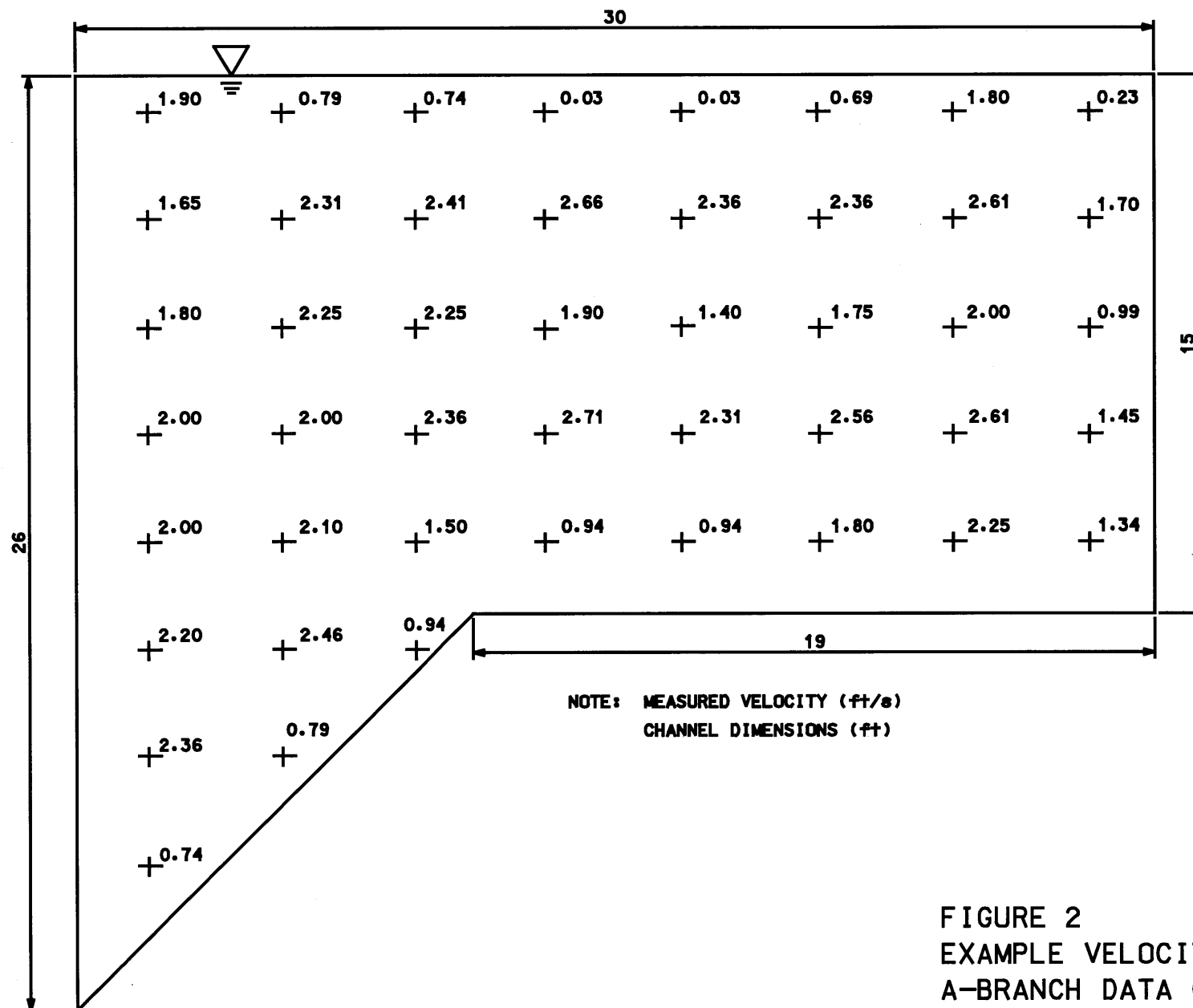


FIGURE 2
EXAMPLE VELOCITY MEASUREMENTS
A-BRANCH DATA COLLECTION
AUGUST 15, 2002 APPENDIX B

MEMORANDUM FOR RECORD

FROM: Kyle McCune

SUBJECT: Report on data collection on the A Branch of the Bradford Island Fish Ladder October 10, 2002

DATE: October 21, 2002

Attendees: Kyle McCune, EC-HD
Steve Schlenker, EC-HD
Sean Askelson, EC-HD
Jacob Macdonald, EC-HD
Harry Galanopoulos, EC-HD

Trip Objectives:

1. Collect data to verify the Bradford Island A Branch Fish Ladder HELCRABS numerical model under a fixed forebay and tailrace condition.

Data Collection:

The team arrived at the project and organized at the Bradford Island fish exit at 9:00 AM. Fixed forebay and tailrace conditions were coordinated with the Reservoir Control Center (RCC) for 10:00 AM to 4:00 PM prior to the visit and therefore data collection was to begin at 10:00 AM. Consistent with the August 15 data collection, data was collected from four locations: The South Auxiliary Water Supply (AWS) intake, the North AWS intake, the fish ladder exit slot and ladder augmentation flow channel, and to provide powerhouse channel flow at a single location measurements were also attempted along the powerhouse channel prior to entrance gates 1 and 2. The general layout of the A Branch system and the locations where measurements took place are provided as Figure 1 of this report.

Future operations of the ladder call for the powerhouse channel entrances to be closed. To get an idea of the impact of this on the powerhouse channel flow the powerhouse channel gates were closed during these measurements. Measurements with the powerhouse channel entrances closed will also help provide a calibration data set for the numerical model.

Ladder Flow (Fish Exit and Ladder Augmentation Flow Channel)

The ladder weir flow was measured by taking a measurement through the fish exit slot and the ladder augmentation flow channel adjacent to it. The fish exit slot is approximately 2 ft wide and has an invert elevation at 63 ft. Ideally flow measurements are taken at a number of locations across the channel width to get a representative velocity distribution. Due to the narrowness of the slot only a single set of measurements could be obtained from the middle of the slot at 5 depths (at the surface two locations were measured but were subsequently average because the price meter moved and the measurements overlapped). The measured flow through the fish exit slot was 113 cubic feet per second (cfs). Due to the fact that the velocities were in effect measured at the center of the slot, where they are theoretically the highest, this value is likely high.

The ladder augmentation flow was measured at the channel intake adjacent to the fish exit slot. As with the August 15 data collection at this location, the team members took measurements by maneuvering the price meter from above the grating without removing the trash racks. The flow measured at this location was 78 cfs. The data sheets for both of these locations are included at the back of this trip report.

North AWS Intakes

Flow through the North AWS was measured through four bulkhead slots just downstream of the intake trash racks. The location provided easy access to the channel at a point where the flow was relatively uniform. The flow for the North AWS measurements were 98 cfs through bulkhead slot 1 (numbered from east to west), 87 cfs through bulkhead slot 2, 73 cfs through bulkhead slot 3, and 64 cfs through bulkhead slot 4 for a total AWS flow of 322 cfs.

South AWS Intakes

The South AWS intake flow was measured from the trash rack walkway running north to south that screens the combined intake flow for the fish locks (now out of service) and the South AWS. This location is actually upstream of the South AWS but since the fish locks are no longer in service 100% of the flow through this transect feeds the South AWS. Though easily accessible the floor along this location goes from horizontal over the first 19.2 ft (from south) and then slopes 1:1 over the remaining 12.2 ft. So that an accurate depth could be recorded, the price meter depth was re-zeroed at each measurement location over the sloped portion of the transect. In order to keep measurements in uniform areas the flows were taken at the same depth intervals with additional locations added, at locations where the channel bottom was deeper. The flow through the South AWS intake was measured at 816 cfs. Figure 1 shows the location of the South AWS sampling and Figure 2 shows, spatially, the velocities measured at the transect. The data sheet for the South AWS is also attached to this trip report.

Entrances

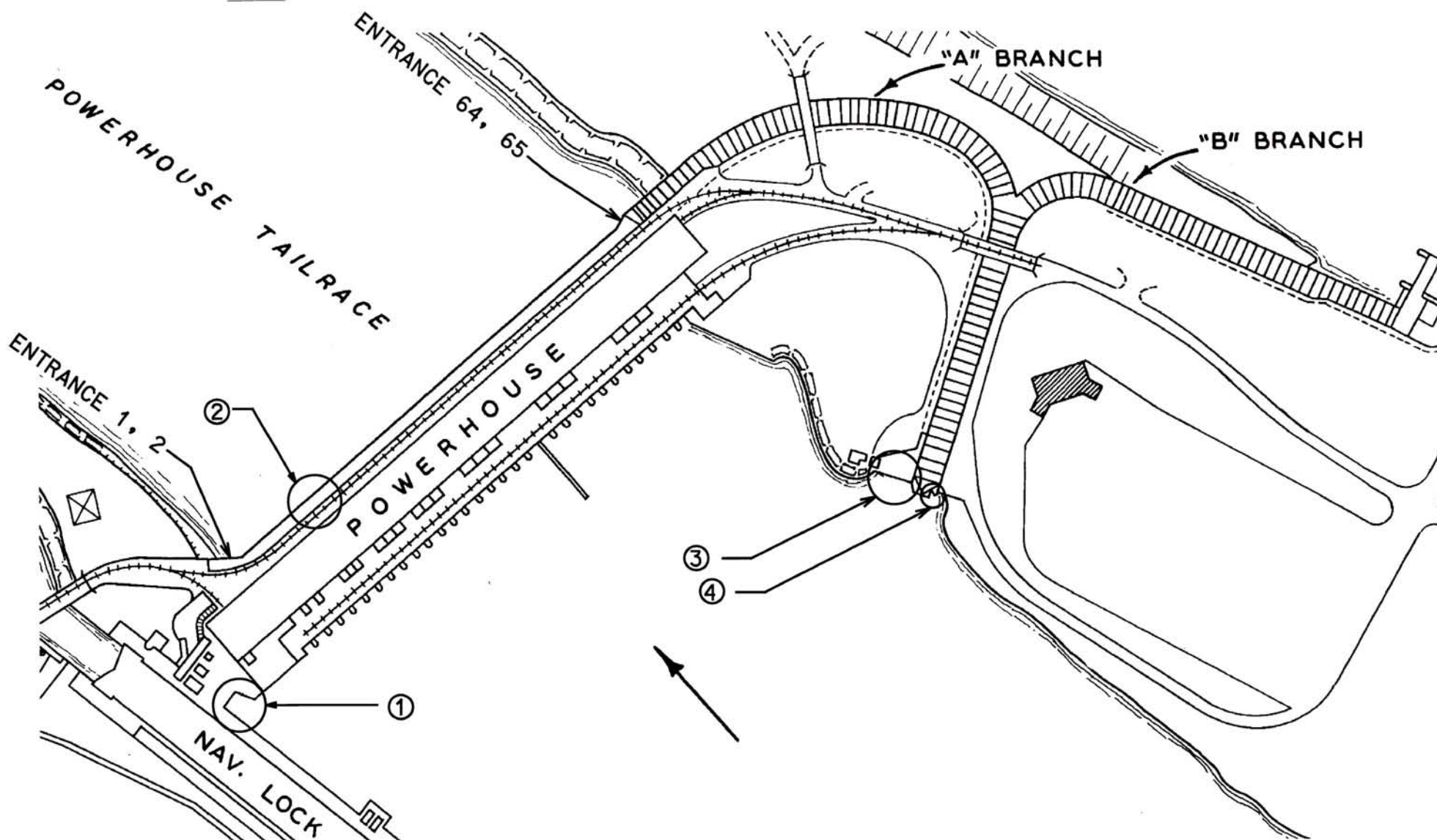
The A Branch Ladder has a total of nine locations through which fish can enter the ladder in the vicinity of the powerhouse channel. Though the powerhouse channel gates were closed for this test, the fact that the powerhouse channel runs under the powerhouse tailrace deck and is largely inaccessible makes measurement unfeasible. The only location providing sufficient access is a portion of the channel downstream of sluice gate #9. No sources or sinks of water lie between this location and the entrance were and therefore this measurement is representative of water exiting through the south exit weirs (in this case Gate #1). The flow through the Powerhouse Channel at location 2 of Figure 1 was measured to be 533 cfs.

Discharge Calculations:

The total flow through the various sampling transects is determined by first calculating an integrated average velocity across the channel at each depth and then integrating the resultant averages again over all depths. The edge of the flow field was extrapolated linearly from the two outermost measurements at a given depth. If the extrapolated value at a channel edge would be greater than the two measure values used to extrapolate it that velocity would be set to the adjacent measurement. The total integrated average velocity was then multiplied by the total cross-sectional area to get a flow rate.

Conclusions:

In total, approximately 1,330 cfs was flowing into the A Branch at the time of this measurement. Conditions during this site visit will be used as input into the HELCRABS A Branch Fishway model. Results from the model run will then be compared to the actual flows measured in order to determine whether deficiencies exist in the model.



- ① SOUTH AUXILIARY WATER SUPPLY INTAKE
- ② SOUTH POWERHOUSE CHANNEL
- ③ NORTH AUXILIARY WATER SUPPLY INTAKE
- ④ FISH EXIT CHANNEL AND LADDER AUGMENTATION FLOW CHANNEL

Figure 1
Bonneville A Branch Fish Ladder
Measurement Locations
October 10, 2002

SOUTH AUXILIARY WATER SUPPLY CROSS-SECTION

APPENDIX B ITEM 2

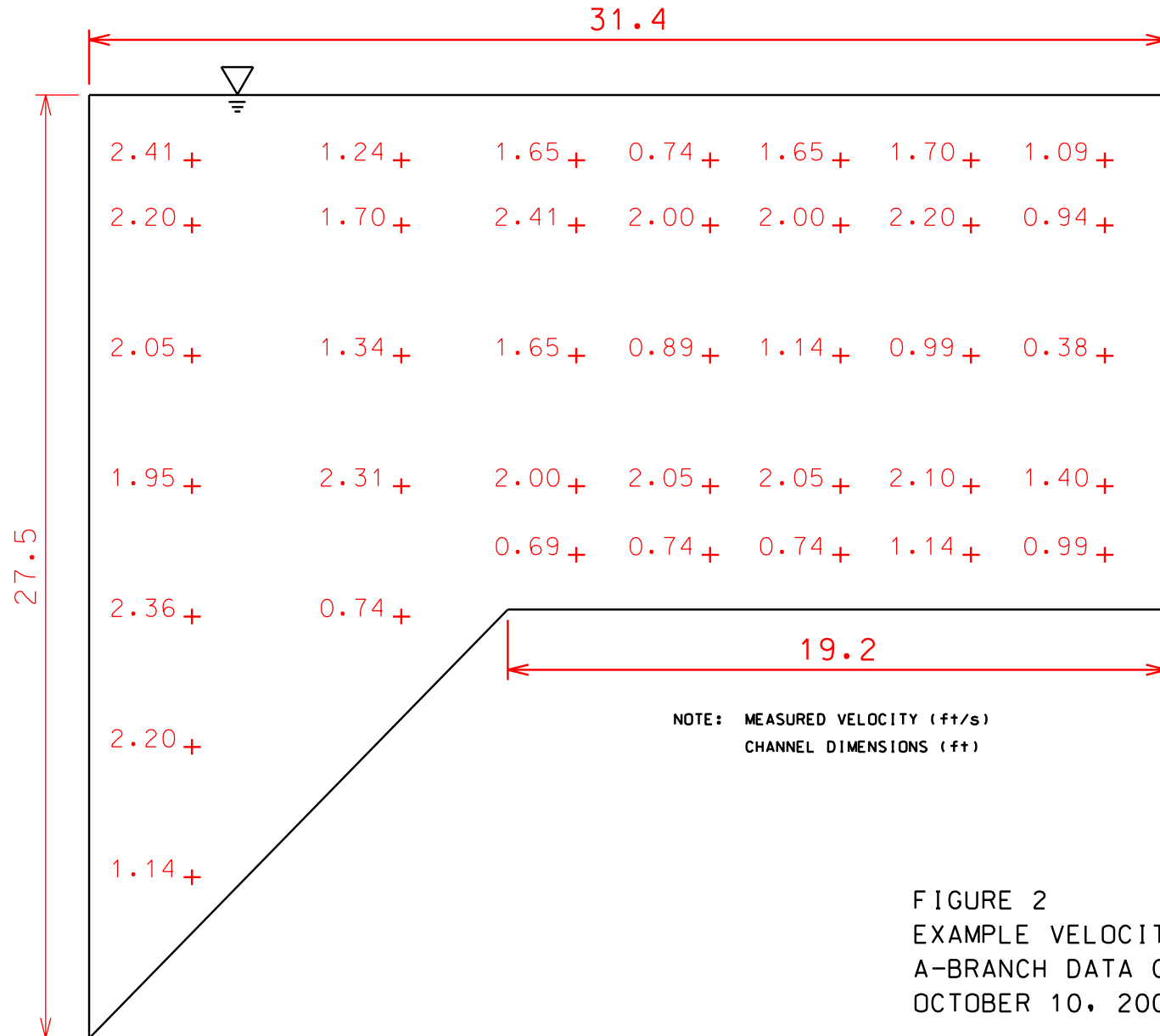


FIGURE 2
EXAMPLE VELOCITY MEASUREMENTS
A-BRANCH DATA COLLECTION
OCTOBER 10, 2002

BONNEVILLE A BRANCH FISHWAY VELOCITY DATA

NORTH AWS INTAKE BULKHEAD SLOTS

Data Collectors:

JM

SA

SLOT 1

Date: 10/10/2002

Time: start 11:30 end 13:00

start 75.70 end 75.80

Forebay Level =

start 10.20 end 10.10

Tailrace Level =

AWS Intake Tainter Gate Data

FG3-7

Opening (ft)

start 1.30 end 1.30

Distance to WS d/s of gate (ft)

17-30* 19.00

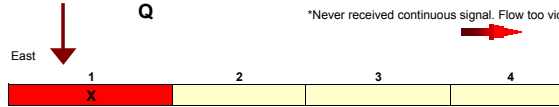
Head d/s of Gate:

68-55 66.00

*Never received continuous signal. Flow too violent and aerated.
West

Intake Number from East

AWS INTAKE BULKHEAD SLOT



Price Meter Vertical Sect. 1

V = 0.03+2.27548*(rotations/time)

Pygmy Meter Vertical Sect.2-3

V = (rotations/time)*1ft

Price Meter Rotations per Count = 1.00

Price Meter Rotations per Count = 1.00

POINT VELOCITY AND FLOW MEASUREMENTS IN AWS:

Z₁₅ = Meas. Distance to WS 9.28 ft (from 85 deck)WS = Water Surface Elev 75.72 ft (= 85 - Z₁₅)

Y = Measured Depth = 21.72 ft (=WS - 54)

check

B = Channel Width = 11.2 ft

Deck elev = 85.0 ft

Zi = INVERT = 54.0 ft

X1 = Side Edge width inc= 3
Y1 = Vertical edge height incr = 3Approx internal dimension = 4.2 ft Div
Number of Internal X Increments = 1.0 2
Number of Internal Y Increments = 5.0 10

BONNEVILLE A BRANCH FISHWAY VELOCITY DATA

NORTH AWS INTAKE BULKHEAD SLOTS

Data Collectors:

JM

SA

SLOT 1

Date:

10/10/2002

NORTH AWS INTAKE MEASUREMENTS

Time:

11:30

13:00

Bulkhead Slot 1			(measured from east side of slot)				
Horiz. No.:	Formula for Distance from surface (pm)	Depth from Surface (ft)	Vert. Sect. No. :	1	2	3	Average Integrated Velocity
			Est Dist. from left sidee (ft)	1.5	5.5	9.5	
			Actual dist from left side	1.5	5.6	9.7	
1	0.5 * Y1	1.50	Counts	12	36	30	ft/s
			duration	60	45	45	
			VELOCITY	0.49	0.80	0.67	
2	Y1 + (Y-2*Y1) * 0.1	4.60	Counts	18	10	25	ft/s
			duration	60	45	45	
			VELOCITY	0.71	0.22	0.56	
3	Y1 + (Y-2*Y1) * 0.3	7.70	Counts	12	19	18	ft/s
			duration	60	45	45	
			VELOCITY	0.49	0.42	0.40	
4	Y/2	10.90	Counts	10	25	13	ft/s
			duration	60	45	45	
			VELOCITY	0.41	0.56	0.29	
5	Y1 + (Y-2*Y1) * 0.7	14.00	Counts	8	26	35	ft/s
			duration	60	45	45	
			VELOCITY	0.33	0.58	0.78	
6	Y1 + (Y-2*Y1) * 0.9	17.10	Counts	2	15	17	ft/s
			duration	60	45	45	
			VELOCITY	0.11	0.33	0.38	
7	Y - 0.5 * Y1	20.20	Counts	0	1	3	ft/s
			duration	60	45	45	
			VELOCITY	0.03	0.02	0.07	
Total Average Integrated Velocity =				0.40 ft/s			
Total Computed AWS FLOW RATE =				98 cfs (= B * Y * V)			

NOTES:

NR - Data Not Recorded at time of data collection.

NA - Not Available as a result of data was not recorded.

BONNEVILLE A BRANCH FISHWAY VELOCITY DATA

NORTH AWS INTAKE BULKHEAD SLOTS

Data Collectors:

JM

SA

SLOT 2

Date: 10/10/2002

Time: start end
13:00 13:30

Forebay Level =

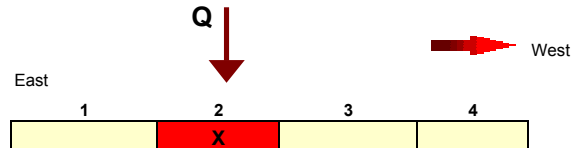
start end
75.80 75.90

Tailrace Level =

start end
10.10 10.10

Intake Number from East

AWS INTAKE BULKHEAD SLOT



Pygmy Meter X
V = 1ft * (rotations/time)

Price Meter Rotations per Count = 1.00

POINT VELOCITY AND FLOW MEASUREMENTS IN AWS:

Z₁₅ = Meas. Distance to WS 9.30 ft (from 85 deck)WS = Water Surface Elev 75.70 ft (= 85 - Z₁₅)

Y = Measured Depth = 21.70 ft (= WS - 54)

X1 = Side Edge width inc= 3
Y1 = Vertical edge height incr = 3

check
B = Channel Width = 11.0 ft
Deck elev = 85.0 ft
Zi = INVERT = 54.0 ft

Approx internal dimension = 4.2 ft Div
Number of Internal X Increments = 1.0 2
Number of Internal Y Increments = 5.0 10

BONNEVILLE A BRANCH FISHWAY VELOCITY DATA

NORTH AWS INTAKE BULKHEAD SLOTS

Data Collectors:

JM

SA

SLOT 2

Date:

10/10/2002

NORTH AWS INTAKE MEASUREMENTS

Time:

13:00

13:30

Bulkhead Slot

2

(measured from east side of slot)

Horiz. No.:	Formula for Distance from surface (pm)	Depth from Surface (ft)	Vert. Sect. No. :	1	2	3	Average Integrated Velocity	
			Est Dist. from left sidee (ft)	1.5	5.4	9.5		
			Actual dist from left side	1.5	5.6	9.7		
1	$0.5 * Y1$	1.50	Counts	20	23	0		
			duration	45	45	45		
			VELOCITY	0.44	0.51	0.00	0.33 ft/s	0.32
2	$Y1 + (Y-2*Y1) * 0.1$	4.60	Counts	28	21	22		
			duration	45	45	45		
			VELOCITY	0.62	0.47	0.49	0.54 ft/s	0.53
3	$Y1 + (Y-2*Y1) * 0.3$	7.70	Counts	16	13	24		
			duration	45	45	45		
			VELOCITY	0.36	0.29	0.53	0.41	0.39
4	$Y/2$	10.90	Counts	15	13	26		
			duration	45	45	45		
			VELOCITY	0.33	0.29	0.58	0.41 ft/s	0.40
5	$Y1 + (Y-2*Y1) * 0.7$	14.00	Counts	21	26	28		
			duration	45	45	45		
			VELOCITY	0.47	0.58	0.62	0.55 ft/s	0.56
6	$Y1 + (Y-2*Y1) * 0.9$	17.10	Counts	7	11	6		
			duration	45	45	45		
			VELOCITY	0.16	0.24	0.13	0.16 ft/s	0.18
7	$Y - 0.5 * Y1$	20.20	Counts	0	0	0		
			duration	45	45	45		
			VELOCITY	0.00	0.00	0.00	0.00 ft/s	0.00
Total Average Integrated Velocity =				0.34 ft/s				
Total Computed AWS FLOW RATE =				81 cfs				(= B * Y * V)

NOTES:

NR - Data Not Recorded at time of data collection.

NA - Not Available as a result of data was not recorded.

BONNEVILLE A BRANCH FISHWAY VELOCITY DATA

NORTH AWS INTAKE BULKHEAD SLOTS

Data Collectors:

JM	SA	
----	----	--

SLOT 3

Date: 10/10/2002

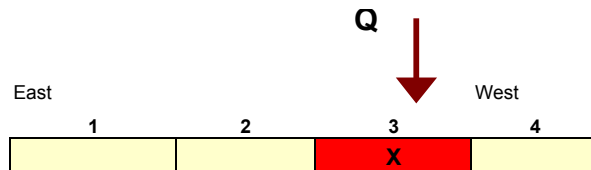
Time: start end
13:30 14:15

Forebay Level = start end
75.90 76.00

Tailrace Level = start end
10.10 10.10

Intake Number from East

AWS INTAKE BULKHEAD SLOT



Pygmy Meter X
V = 1ft * (rotations/time)

Price Meter Rotations per Count = 1.00

POINT VELOCITY AND FLOW MEASUREMENTS IN AWS:

Z₁₅ = Meas. Distance to WS 9.35 ft (from 85 deck)

WS = Water Surface Elev 75.65 ft (= 85 - Z₁₅)

Y = Measured Depth = 21.65 ft (=WS - 54)

X1 = Side Edge width inc= 3
Y1 = Vertical edge height inc= 3

check
B = Channel Width = 11.0 ft
Deck elev = 85.0 ft
Zi = INVERT = 54.0 ft

Approx internal dimension = 4.2 ft Div
Number of Internal X Increments = 1.0 2
Number of Internal Y Increments = 5.0 10

BONNEVILLE A BRANCH FISHWAY VELOCITY DATA

NORTH AWS INTAKE BULKHEAD SLOTS

Data Collectors:

JM

SA

SLOT 3

Date:

10/10/2002

NORTH AWS INTAKE MEASUREMENTS

Time:

13:30

14:15

Bulkhead Slot 3

(measured from east side of slot)

Horiz. No.:	Formula for Distance from surface (pm)	Depth from Surface (ft)	Vert. Sect. No. :	1	2	3	Average Integrated Velocity	
			Est Dist. from left sidee (ft)	1.5	5.4	9.5		
			Actual dist from left side	1.5	5.6	9.7		
1	0.5 * Y1	1.50	Counts	23	26	25	0.52	ft/s
			duration	45	45	45		
			VELOCITY	0.51	0.58	0.56		
2	Y1 + (Y-2*Y1) * 0.1	4.60	Counts	13	29	7	0.37	ft/s
			duration	45	45	45		
			VELOCITY	0.29	0.64	0.16		
3	Y1 + (Y-2*Y1) * 0.3	7.70	Counts	13	15	10	0.29	
			duration	45	45	45		
			VELOCITY	0.29	0.33	0.22		
4	Y/2	10.90	Counts	10	11	7	0.21	ft/s
			duration	45	45	45		
			VELOCITY	0.22	0.24	0.16		
5	Y1 + (Y-2*Y1) * 0.7	14.00	Counts	25	19	20	0.48	ft/s
			duration	45	45	45		
			VELOCITY	0.56	0.42	0.44		
6	Y1 + (Y-2*Y1) * 0.9	17.10	Counts	1	9	15	0.15	ft/s
			duration	45	45	45		
			VELOCITY	0.02	0.20	0.33		
7	Y - 0.5 * Y1	20.20	Counts	0	0	0	0.00	ft/s
			duration	45	45	45		
			VELOCITY	0.00	0.00	0.00		
Total Average Integrated Velocity =				0.29 ft/s				
Total Computed AWS FLOW RATE =				69 cfs		(= B * Y * V)		

NOTES:

NR - Data Not Recorded at time of data collection.

NA - Not Available as a result of data was not recorded.

BONNEVILLE A BRANCH FISHWAY VELOCITY DATA

NORTH AWS INTAKE BULKHEAD SLOTS

Data Collectors:

JM

SA

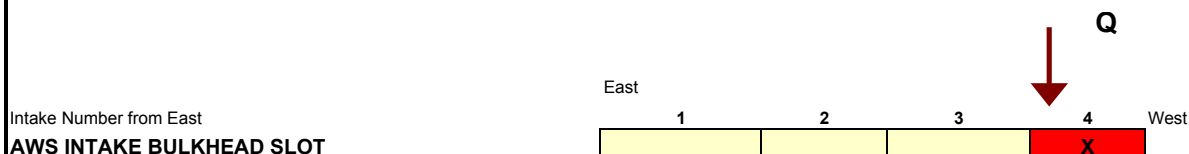
SLOT 4

Date: 10/10/2002

Time: start 14:20 end 15:10

Forebay Level = start 76.00 end 76.00

Tailrace Level = start 10.10 end 10.10



Pygmy Meter X

 $V = 1 \text{ ft} \cdot (\text{rotations/time})$

Price Meter Rotations per Count = NA

POINT VELOCITY AND FLOW MEASUREMENTS IN AWS:

 Z_{15} = Meas. Distance to WS 9.52 ft (from 85 deck)WS = Water Surface Elev 75.48 ft (= 85 - Z_{15}) Y = Measured Depth = 21.48 ft (= WS - 54)

X1 = Side Edge width inc= 3

Y1 = Vertical edge height incr = 3

check

B = Channel Width = 11.0 ft

Deck elev = 85.0 ft

Zi = INVERT = 54.0 ft

Approx internal dimension = 4.2 ft Div

Number of Internal X Increments = 1.0 2

Number of Internal Y Increments = 5.0 10

BONNEVILLE A BRANCH FISHWAY VELOCITY DATA

NORTH AWS INTAKE BULKHEAD SLOTS

Data Collectors:

JM

SA

SLOT 4

Date:

10/10/2002

NORTH AWS INTAKE MEASUREMENTS

Time:

14:20

15:10

Bulkhead Slot 4

(measured from east side of slot)

Horiz. No.:	Formula for Distance from surface (pm)	Depth from Surface (ft)	Vert. Sect. No. :	1	2	3	Average Integrated Velocity	
			Est Dist. from left sidee (ft)	1.5	5.5	9.5		
			Actual dist from left side	1.5	5.6	9.7		
1	0.5 * Y1	1.50	Counts	20	19	22	0.47 ft/s	0.45
			duration	45	45	45		
			VELOCITY	0.44	0.42	0.49		
2	$Y1 + (Y-2*Y1) * 0.1$	4.60	Counts	5	10	0	0.12 ft/s	0.11
			duration	45	45	45		
			VELOCITY	0.11	0.22	0.00		
3	$Y1 + (Y-2*Y1) * 0.3$	7.70	Counts	10	0	2	0.10	0.09
			duration	45	45	45		
			VELOCITY	0.22	0.00	0.04		
4	Y/2	10.80	Counts	23	0	10	0.27 ft/s	0.24
			duration	45	45	45		
			VELOCITY	0.51	0.00	0.22		
5	$Y1 + (Y-2*Y1) * 0.7$	14.00	Counts	24	27	22	0.54 ft/s	0.54
			duration	45	45	45		
			VELOCITY	0.53	0.60	0.49		
6	$Y1 + (Y-2*Y1) * 0.9$	17.00	Counts	15	21	10	0.34 ft/s	0.34
			duration	45	45	45		
			VELOCITY	0.33	0.47	0.22		
7	Y - 0.5 * Y1	20.00	Counts	0	0	2	0.01 ft/s	0.01
			duration	45	45	45		
			VELOCITY	0.00	0.00	0.04		
Total Average Integrated Velocity =				0.26 ft/s				
Total Computed AWS FLOW RATE =				62 cfs		(= B * Y * V)		

NOTES:

NR - Data Not Recorded at time of data collection.

NA - Not Available as a result of data was not recorded.

BONNEVILLE A BRANCH FISHWAY VELOCITY DATA**EXIT CHANNEL**

Data Collectors:

JM SA SS

Date: 10/10/2002 Time:

start	end
9:40	10:15

Forebay Level =

start	end
75.70	75.70

Head on Picketed Lead =

start	end
1.00	1.00

INSTRUMENT

Price Meter

X

Price Meter Rotations per Count = 1.00

 $V = 0.03 + 2.27548 * (\text{rotations/time})$ **POINT VELOCITY AND FLOW MEASUREMENTS:**

Z_{15} = Meas. Distance to WS = 11.50 ft (from 86.5 level) B = Channel Width = 2.26 ft

WS = Water Surface Elevation = 75.00 ft (= 86.5 - Z_{15}) **DECK ELEVATION** = 86.5 ft

Y = Measured Channel Depth = 12.00 ft (= WS - 63) **Z_i = INVERT** = 63.0 ft

X_1 = Side Edge width incr = 1 ft Approx internal dimension = 3.0 ft Div by

Y_1 = Vertical edge height incr = 2 ft Number of Internal X Increments = 1.0 2

Number of Internal Y Increments = 3.0 6

Horiz. No.:	Formula for depthn below surface (pm)	Depth from Surface (ft)	Vert. Sect. No. :	1*	2	3*	Average Velocity
			Est Dist. from Left Edge (ft)	0.5	1.13	1.76	
			Actual Dist (ft) from Fft side	0.5	1.1	1.8	
1	0.5 * Y_1	1.00	Counts	137	147	141	
			duration	45	45	45	
			VELOCITY	6.96	7.46	7.16	ft/s
2	$Y_1 + (Y - 2 * Y_1) / 6$	3.30	Counts	132	134		
			duration	45	45		
			VELOCITY	6.70	6.81		ft/s
3	$Y / 2$	6.00	Counts	52	48		
			duration	45	45		
			VELOCITY	2.66	2.46		ft/s
4	$Y_1 + 5 * (Y - 2 * Y_1) / 6$	8.70	Counts	95	89		
			duration	45	45		
			VELOCITY	4.83	4.53		ft/s
5	$Y - 0.5 * Y_1$	11.00	Counts	82	80		
			duration	45	45		
			VELOCITY	4.18	4.08		ft/s
Total Average Integrated Velocity =				4.98 ft/s			
Total Computed FLOW RATE =				135 cfs			(= $B * Y * V$)

NOTES:

NR - Data Not Recorded at time of data collection.

NA - Not Available as a result of data was not recorded.

* measurments are optional depending on flow conditions

BONNEVILLE A BRANCH FISHWAY VELOCITY DATA

SOUTH POWERHOUSE CHANNEL

Data Collectors:

KM

HG

Date: 10/10/2002 Time: 12:00 13:00

start end
start end

Distance to Water:

WATER LEVEL ELEV:

Tailrace Level :

start	end	Ref EL	start	end
45.30	45.30	55.3	10.00	10.00

U/s Staff Gage:

start	end	Ref EL	start	end
43.60	43.60	55.0	11.40	11.40

SOUTH ENTRANCH WEIR GATE DATA

	SW-1	SW-2
OPEN ?	NA	2.00
Crest Elevation	NA	2.00

INSTRUMENT

Price Meter

X

Price Meter Rotations per Count =

1.00

V = 0.03 + 2.27548 * (rotations/time)

POINT VELOCITY AND FLOW MEASUREMENTS:

Z₁₅ = Meas. Distance to WS =

11.20 ft (from 55 level)

B = Channel Width = 17.58 ft

WS = Water Surface Elevation =

11.20 ft (= 55 - Z₁₅)

DECK ELEVATION = 55.0 ft

Y = Measured Channel Depth =

13.20 ft (=WS - 0)

Zi = INVERT = -2.0 ft

X1 = Side Edge width incr =

2 ft

Approx internal dimension =

3.0 ft

Div by

Y1 = Vertical edge height incr =

2 ft

Number of Internal X Increments =

2.0 4

Number of Internal Y Increments =

3.0 6

Horiz. No.:	Formula for depth below surface (pm)	Depth from Surface (ft)	Vert. Sect. No. :	1	2	3	4	Average Velocity
			Est Dist. from west Edge (ft)	1.0	5.50	10.08	14.08	
			Actual Dist (ft) from Fft side					
1	0.5 * Y1	1.00	Counts	31	47	57	57	
			duration	45	45	45	45	
			VELOCITY	1.60	2.41	2.91	2.91	ft/s
2	Y1 + (Y-2*Y1)/6	3.50	Counts	29	62	65	63	
			duration	45	45	45	45	
			VELOCITY	1.50	3.17	3.32	3.22	ft/s
3	Y/2	6.60	Counts	31	55	59	57	
			duration	45	45	45	45	
			VELOCITY	1.60	2.81	3.01	2.91	ft/s
4	Y1 + 5* (Y-2*Y1)/6	9.70	Counts	30	36	38	47	
			duration	45	45	45	45	
			VELOCITY	1.55	1.85	1.95	2.41	ft/s
5	Y - 0.5*Y1	12.20	Counts	20	10	16	12	
			duration	45	45	45	45	
			VELOCITY	1.04	0.54	0.84	0.64	ft/s
Total Average Integrated Velocity =				2.19	ft/s			
Total Computed FLOW RATE =				509	cfs	(= B * Y * V)		

NOTES:

NR - Data Not Recorded at time of data collection.

NA - Not Available as a result of data was not recorded.

BONNEVILLE A BRANCH FISHWAY VELOCITY DATA

SOUTH AWS INTAKE (FV1-1)

(from catwalk)

Date: 10/10/2002

Time: 10:00

Data Collectors: KM

HG

Time: start 10:00 end 11:30

AWS Intake Tainter Gate Data

Forebay Level =

start 75.40 end 75.50

Tailrace Level =

end 10.10 10.10

FV1-1		start	end
Opening (ft)		3.00	3.00
Distance to WS d/s of gate (ft)		23.00	23.00
Head d/s of Gate:		62.00	62.00

INSTRUMENT

Price Meter

X

Price Meter Rotations per Count = 1.00 (if used)

 $V = 0.03 + 2.27548 * (\text{rotations/time})$

POINT VELOCITY AND FLOW MEASUREMENTS IN SOUTH AWS:

CHECK

Left Edge Invert Measurement

 Z_{15} = Meas. Distance to WS

7.20

WS = Water Surface Elev

75.50

 Z_b = Dist from WS to bottom using PM

27.50

(Est Invert:)

Meas Invert = $WS - Z_b =$

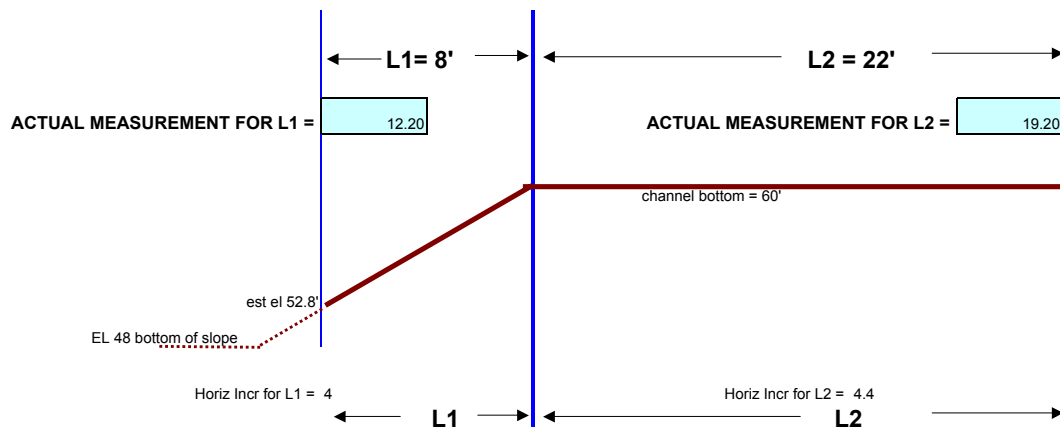
48.00

52.8

0.50

B = Channel Width =	31.5 ft
DECK elev =	85.0 ft
Catwalk elev =	82.7 ft

31.50



BONNEVILLE A BRANCH FISHWAY VELOCITY DATA

SOUTH AWS INTAKE (FV1-1)

(from catwalk)

Date: 10/10/2002

Time: 10:00

Data Collectors: KM

HG

SOUTH AWS INTAKE (FV1-1)

(from catwalk)

			Est Invert	54.6	58.2	60	60	60	60	60	
			Meas invert	50.9	56.9	60.0	60.0	60.0	60.0	60.0	
			FLOW DEPTH	24.6	18.6	15.5	15.5	15.5	15.5	15.5	
Horiz. No.:	EST Distance from surface (PM)	ACTUAL Depth from Surface (ft)	Vert. Sect. No. :	1	2	3	4	5	6	7	Average Integrated Velocity
			Est Dist. from Left Edge (ft)	2.0	6.0	10.2	14.6	19.0	23.4	27.8	
			Actual Dist from left side	3.0	9.1	14.2	18.1	21.9	25.7	29.6	
1	1.0	1.90	Counts	47	24	32	14	32	33	21	1.54 ft/s
			duration	45	45	45	45	45	45	45	
			VELOCITY	2.41	1.24	1.65	0.74	1.65	1.70	1.09	
2	4.0	3.80	Counts	43	33	47	39	39	43	18	1.92 ft/s
			duration	45	45	45	45	45	45	45	
			VELOCITY	2.20	1.70	2.41	2.00	2.00	2.20	0.94	
3	7.0	7.60	Counts	40	26	32	17	22	19	7	1.28
			duration	45	45	45	45	45	45	45	
			VELOCITY	2.05	1.34	1.65	0.89	1.14	0.99	0.38	
4	10.0	11.40	Counts	38	45	39	40	40	41	27	1.97 ft/s
			duration	45	45	45	45	45	45	45	
			VELOCITY	1.95	2.31	2.00	2.05	2.05	2.10	1.40	
5	13.0	15.2 (13.4) ¹	Counts	46	14	13	11	14	22	19	1.65/0.83 ft/s
			duration	45	45	45	45	45	45	45	
			VELOCITY	2.36	0.74	0.69	0.59	0.74	1.14	0.99	
6	16.0	19.00	Counts	43							2.80 ft/s
			duration	45							
			VELOCITY	2.20							
7	19.0	22.80	Counts	22							1.14 ft/s
			duration	45							
			VELOCITY	1.14							
Total Average Integrated Velocity = 1.60 ft/s											
Total Computed AWS FLOW RATE = 873.71 cfs (= B * Y * V)											

NOTES:

1. Horizontal invert section (locations 3 through 7) were taken at 13.4 ft of depth. Locations 1 and 2 were taken at 15.2 ft of depth.

NR - Data Not Recorded at time of data collection.

NA - Not Available as a result of data was not recorded.

BONNEVILLE A BRANCH FISHWAY VELOCITY DATA**FV3-9 Intake (Ladder Augmentation flow)**

Data Collectors:

JM SA SS

Date:

10/10/2002

Time:

start	end
10:25	11:35

FV3-9 Tainter Gate Data

Forebay Level =

start	end
75.70	75.70

Opening (ft)

start	end
0.50	0.50

Distance to WS d/s of gate (ft)

start	end
18.30	17.00

<- Note 1

Head on Picketed Lead =

start	end
1.00	1.00

Head d/s of Gate:

start	end
68.20	68.00

INSTRUMENT

Price Meter

X

Price Meter Rotations per Count =

1.00

 $V = 0.03 + 2.27548 * (\text{rotations/time})$ **POINT VELOCITY AND FLOW MEASUREMENTS:** Z_{15} = Meas. Distance to AWS WS =

10.80 ft (from 86.5 level)

B = Channel Width = 9.50 ft

WS = Water Surface Elevation =

75.70 ft (= 86.5 - Z_{15})

DECK ELEVATION = 86.5 ft

Y = Measured AWS Channel Depth =

12.70 ft (=WS - 63)

Zi = INVERT = 63.0 ft

X1 = Side Edge width incr =

2 ft

Approx internal dimension =

3.0 ft

Div by

Y1 = Vertical edge height incr =

2 ft

Number of Internal X Increments =

2.0

4

Number of Internal Y Increments =

3.0

6

Horiz. No.:	Formula for depthn below surface (pm)	Depth from Surface (ft)		Vert. Sect. No. :	1	2	3	4	Average Velocity
				Est Dist. from Left Edge (ft)	1.0	3.50	6.50	8.00	
				Actual Dist (ft) from Fft side	1.00	3.50	5.75	9.17	
1	0.5 * Y1	1.00	Counts	Counts	11	17	19	19	ft/s
			duration	duration	45	45	45	45	
			VELOCITY	VELOCITY	0.59	0.89	0.99	0.99	
2	Y1 + (Y-2*Y1)/6	3.40	Counts	Counts	12	17	17	17	ft/s
			duration	duration	45	45	45	45	
			VELOCITY	VELOCITY	0.64	0.89	0.89	0.89	
3	Y/2	6.30	Counts	Counts	9	14	15	12	ft/s
			duration	duration	45	45	45	45	
			VELOCITY	VELOCITY	0.49	0.74	0.79	0.64	
4	Y1 + 5* (Y-2*Y1)/6	9.30	Counts	Counts	6	9	8	7	ft/s
			duration	duration	45	45	45	45	
			VELOCITY	VELOCITY	0.33	0.49	0.43	0.38	
5	Y - 0.5*Y1	11.70	Counts	Counts	4	9	10	10	ft/s
			duration	duration	45	45	45	45	
			VELOCITY	VELOCITY	0.23	0.49	0.54	0.54	
Total Average Integrated Velocity =					0.64 ft/s				
Total Computed FLOW RATE =					77 cfs (= B * Y * V)				

NOTES:

1. Reference elevation at FV3-9 varies depending on where the measurement is taken. The start reference elevation was 86.5 and the end reference elevation was at 85.

NR - Data Not Recorded at time of Data collection.

NA - Not Available as a result of data was not recorded.

MEMORANDUM FOR RECORD

FROM: Sean K Askelson

SUBJECT: Report on data collection on the A Branch of the Bradford Island Fish Ladder July 2, 2003

DATE: July 10, 2003

Attendees: Steve Schlenker, EC-HD
Sean Askelson, EC-HD
Jacob Macdonald, EC-HD
Laurie Rice, EC-HD
Paul Williams, EC-HD

Trip Objectives:

1. Collect data to verify the Bradford Island A Branch Fish Ladder HELCRABS numerical model under a fixed forebay and tailrace condition.

Data Collection:

Data was collected at both A and B Branch fish ladders for this trip. After completing B Branch measurements, the team moved to A Branch and started collecting data at 1:30 PM. Tests had been performed A Branch previously on Aug 15, 2002 and Oct 10, 2002. The team decided to attempt another test here on the same day as the B Branch test since the tailrace was higher this day and there have been problems with the results of the previous tests (particularly at the North AWS intake).

Project assistance was provided throughout the day. The riggers removed the bulkhead slot covers at the North AWS Intake for measurement. Project Biologist Tim Darland and Student Scott Stettler were often on hand to assist us in our flow measurements.

Fixed forebay and tailrace conditions were coordinated with the Reservoir Control Center (RCC) for 7:00 AM to 4:00 PM prior to the visit and therefore data collection was to begin at 7:00 AM. As a result of the complexity of the A Branch ladder system, many locations of hydraulic interest for the purposes of

calibrating the model were not accessible to the measurement team (see July 31, 2002 A Branch trip report for details). Because of this, no flow data could be directly collected for the ladder fish entrances. Instead we rely on flow measurements from all water intake sources and document head drop at all fish entrances. However, an indirect measurement for the South Entrance is attainable by measuring the flow in the South Powerhouse Channel downstream of the most downstream open diffuser (FG2-4). Therefore flow data was collected from four locations: The South Auxiliary Water Supply (AWS) intake, the North AWS intake, and the south powerhouse channel flow between FG2-4 and the south entrance (Wg-1 and Wg-2). Head data was collected at all flow measurement locations, and both entrance locations and at weir 67 for the control section. The general layout of the A Branch system and the locations where measurements took place are provided as Figure 1 of this report.

The forebay ranged from 75.2' to 75.8', the tailwater ranged from 14.6' to 15.1' and the entrance head ranged from 1.3' to 1.5' during the testing period.

Project data during the total testing period has ranges for 75.1 -75.8 feet for the forebay and 14.6 – 15.1 for the tailrace. It was noted that the pressure transducers need to be recalibrated in some locations. The following differences (direct measurement versus simultaneous readings reported from the control room) were recorded:

<u>Location</u>	<u>Difference (Measured-Project data)</u>
North Entrance Tailrace	+0.50' $\pm$ 0.05'
North PH channel	+0.26' $\pm$ 0.05'
North Entrance Head	-0.26' $\pm$ 0.05'
Central PH channel	+0.05' $\pm$ 0.05'
South Entrance Tailrace	+0.05' $\pm$ 0.05'
South PH channel	+0.14' $\pm$ 0.05'
South Entrance Head	+0.09' $\pm$ 0.05'

The project data is provided to the nearest 0.1 feet, whereas the measured data to the nearest 0.01' (if using the same stillwell). Hence the $\pm$ 0.05' is included with the recorded differences.

Fishladder Flow (Fish Exit and Ladder Augmentation Flow Channel)

Bonneville A and B Branch share a common ladder exit. The flow in the upper common section of the ladder was not directly measured this trip. Measurements have been taken during previous (2002) A Branch tests for both

1.0' and 1.3' head on the picketed lead. The flow rates were 212 cfs and 262 cfs respectively. It is assumed there is an equal distribution of flow between the A and B Branches. The head on the picketed lead during this test was 1.2' so the flow from the upper section of the ladder is about 119 cfs.

North AWS Intakes

Flow through the North AWS was measured through four bulkhead slots just downstream of the intake trash racks. The location provided easy access to the channel at a point where the flow was relatively uniform. The flow for the North AWS measurements were 169 cfs through bulkhead slot 1 (numbered from east to west), 164 cfs through bulkhead slot 2, 108 cfs through bulkhead slot 3, and 90 cfs through bulkhead slot 4 for a total AWS flow of 531 cfs.

The methodology for flow measurements were improved compared to previous tests using a pygmy price meter. For this test, an acoustic doppler velocimeter (adv) was inserted into a pre-drilled hole in 75 lb lead fish. The adv was suspended from above into the flow using a standard price meter reel and bridgeboard. Jacob MacDonald devised the latest improvement: the addition of a string interconnected aluminum rods or guiding rod. The guiding rod ran adjacent to the reel cord and was rigidly connected to the adv unit at the bottom. The rod string was restricted from rotation in the horizontal plane and was used to orient the adv directly into the flow so that the x-axis represented the velocity normal to the cross-sectional plane of flow measurement.

Sean Askelson utilized the 3-Dimensional adv data to compare the computed flows rates from the x component versus the total velocity. The total velocities represent what would have been measured by a pygmy meter without the guiding rods, as in previous tests. The comparison showed that the total velocity measurement overestimated the AWS intake flow by 17%. This percentage can be applied as a correction factor to the previous North AWS measurements, which are believed to be unreasonably high.

In the future the guiding rod string can be employed for either adv or price meter. One drawback is that it is rather time consuming and labor intensive. However, Jacob plans to streamline this technique.

South AWS Intakes

The South AWS intake flow was measured from the trash rack walkway running north to south that screens the combined intake flow for the fish locks (now out of service) and the South AWS. This location is actually upstream of the South AWS but since the fish locks are no longer in service 100% of the flow through this transect feeds the South AWS. Though easily accessible the floor along this

location goes from horizontal over the first 19 ft (from south) and then slopes 1:1 over the remaining 11 ft. So that an accurate depth could be recorded, the price meter depth was re-zeroed at each measurement location over the sloped portion of the transect. In order to keep measurements in uniform areas the flows were taken at the same depth intervals with additional locations added, at locations where the channel bottom was deeper. The flow through the South AWS intake was measured at 678 cfs. Figure 1 shows the location of the South AWS sampling and Figure 2 shows, spatially, the velocities measured at the transect. The data sheet for the South AWS is also attached to this trip report.

Entrances

The A Branch Fishway presently has two entrance locations (North and South entrances). Previously it had six additional locations--telescoping powerhouse gates numbers 5, 12, 34, 51, 58 & 62--through which fish could enter the ladder along the powerhouse channel. During the 2002 measurements, the telescoping gates were open on Aug 15 and were closed at the request of EC-HD on Oct 10. These telescoping gates were permanently closed in February 2003. This leaves the two main entrances locations that remain open. Direct measurements are not feasible in either entrance location. The only location providing sufficient access is a portion of the channel downstream of diffuser FG2-4. No sources or sinks of water lie between this location and the entrance and therefore this measurement is representative of water exiting through the south entrance weirs (in this case WG-2). The flow through the Powerhouse Channel at location 2 of Figure 1 was measured to be 674 cfs.

A sonic meter is located in the north powerhouse channel just downstream of the north entrance. The precise location is just upstream of the diffuser gate actuator for FG2-20, and 3 feet above the channel bottom. Tim Darland recorded the velocity at 4:20 PM just after the measurements in the south powerhouse channel were completed. The sonic meter read 1.27 ft/s and the water surface elevation was measured to be 16.56 feet. If the sonic meter represents an average velocity, then this translates to an estimated flow rate of 414 cfs at this location.

Discharge Calculations:

The total flow through the various sampling transects is determined by first calculating an integrated average velocity across the channel at each depth and then integrating the resultant averages again over all depths. The edge of the flow field was extrapolated linearly from the two outermost measurements at a given depth. If the extrapolated value at a channel edge would be greater than the two measure values used to extrapolate it that velocity would be set to the

adjacent measurement. The total integrated average velocity was then multiplied by the total cross-sectional area to get a flow rate.

Conclusions:

In total, approximately 1,333 cfs was flowing into the A Branch at the time of this measurement. The table below lists a summary of the measurements taken during this test. (The detailed data sheets are included in the Appendix at the end of this report.) The difference between the total measured system inflows (North AWS, South AWS and ladder flows) and total measured system outflows (North entrance and South Entrance) is about 65 cfs, or 5% difference.

Table 1. Summary of Flow Measurements for A Branch Fishway, 7/2/2003

Bonneville A Branch Fishway: Summary Flow Measurements, 7/2/2003									
Flow Exiting System (cfs)				Flow Entering System (cfs)					
Location	Flow (cfs)			Location	Flow (cfs)	Slot 1	Slot 2	Slot 3	Slot 4
South PH Channel (So Entr)	674			North AWS	536	168	165	111	92
North Entrance (est.)	595	(est) ¹		South AWS	678				
				subtotal AWS	1214				
				Fishladder Flow	119	(est) ²			
TOTAL ENTRANCE DISCHARGE				TOTAL INFLOW					
	1269	cfs			1333	cfs			
Difference (inflow - Outflow) = 65 cfs									
% Difference = 5%									
General Data				Comparison of normal velocity to total vel. in North AWS slot meas.					
Start Time	13:30			Vx = Velocity component normal to measuring plane					
End Time	17:45			Vt = Total Velocity Magnitude = sqrt(Vx ² +Vy ² +Vz ²)					
Min FB	75.08 ft			Qx = Flow passing cross-section = A * Vx (correct discharge)					
Max FB	75.80 ft			Qpm = Flow computation replicating Price meter measurement = Vt * A					
Min TW	14.65 ft					Slot 1	Slot 2	Slot 3	Slot 4
Max TW	15.10 ft					Slot 5	Total		
Min head	1.35 ft			Vx	0.71	0.70	0.46	0.39	0.56
Max Head	1.46 ft			Vt	0.83	0.77	0.60	0.50	0.68
Head on ladder control wier (67)	1.20 ft			Qx	168	165	111	92	536
				Qpm	197	183	144	118	643
				Ratio for correction to be applied to previous North AWS slot meas.					
				= Qx/Qpm = 83% % reduction = (Qt-Qx)/(Qt) = 17%					
Footnotes:									
¹ North Entrance Flow Estimated from head meas. and following formula:				² ladder flow interpolated from previous measurments					
¹ Qne = L * CW * H1 ^{1.5} * (1-(H2/H1) ^{1.5}) ^{0.385}				for Head = 1.0' and Head =1.3'					
				Head in this measurement = 1.2'					
L =	8.0 ft								
CW = f (H1/W=1.9) = (2/3) sqrt(2g) * 0.76 =	4.07								
H1 = Zch - Zweir =	16.46 - 5.8 = 10.8 ft								
H2 = Tw - Zweir =	15.1 - 5.8 = 9.3 ft								

Given the assumptions regarding the edges of the flow cross-sections and the difficult measuring locations, the total error is definitely within acceptable limits. Some difference between inflow and outflow is expected due to the system wide

leakage from to the ground water table or tailrace. There are well-documented joint problems in the North AWS conduit and A Branch ladder. The south conduit is also known to have leakage problems. Overall, this test represents a significant improvement over the previous tests and provides essential data for the application to the computer program.

Conditions during this site visit will be used as input into the HELCRABS A Branch Fishway model. Results from the model run will be compared to the actual flows and velocities measured in order to determine whether deficiencies exist in the model and where necessary recalibrate relevant coefficients.

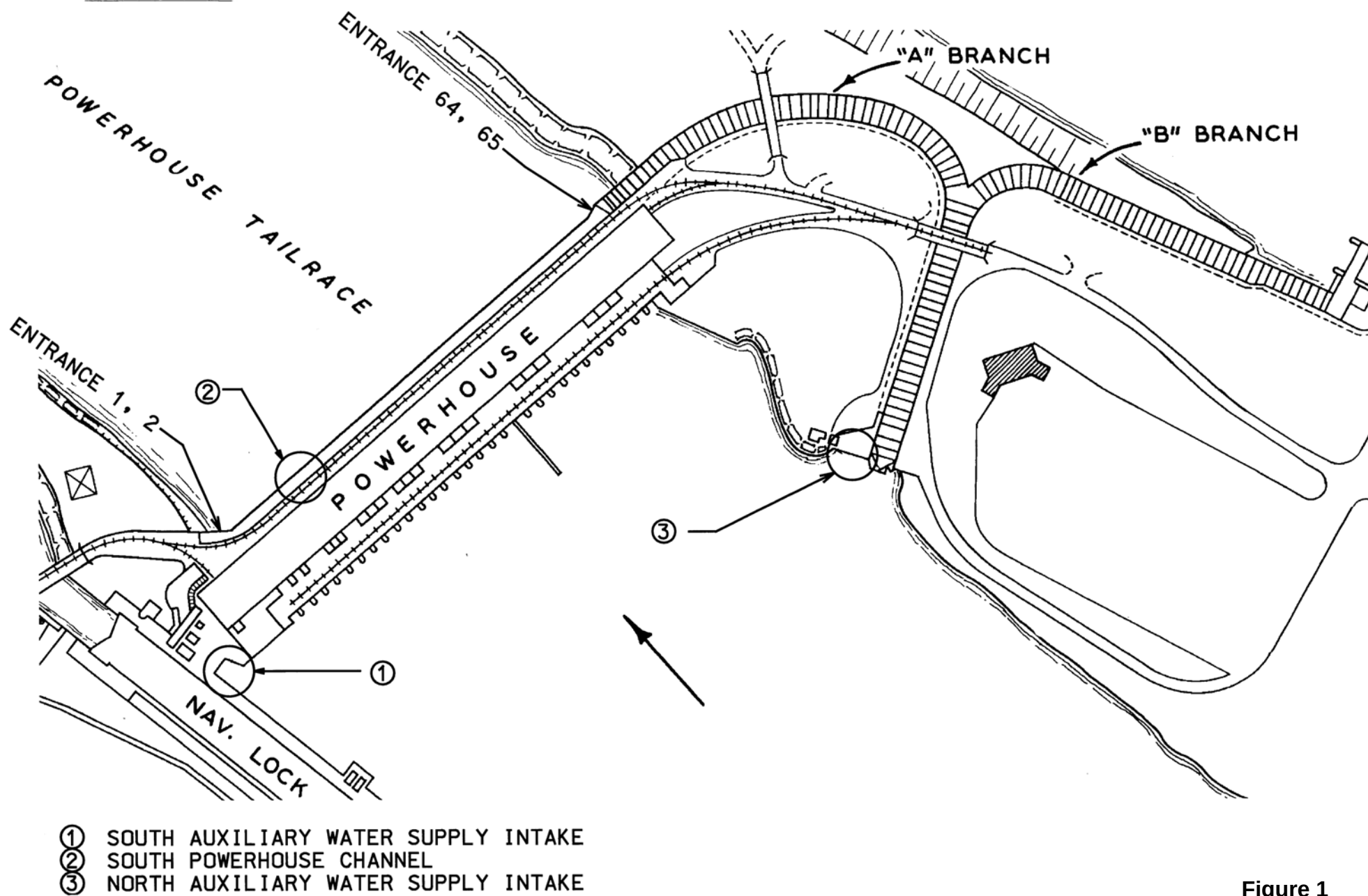


Figure 1
 Bradfor Island A Branch
 Measurement Locations
 July 2, 2003

APPENDIX B ITEM 3

Velocity Cross-Section of South Auxiliary
Water Supply Intake Looking Upstream
Velocities in ft./sec.

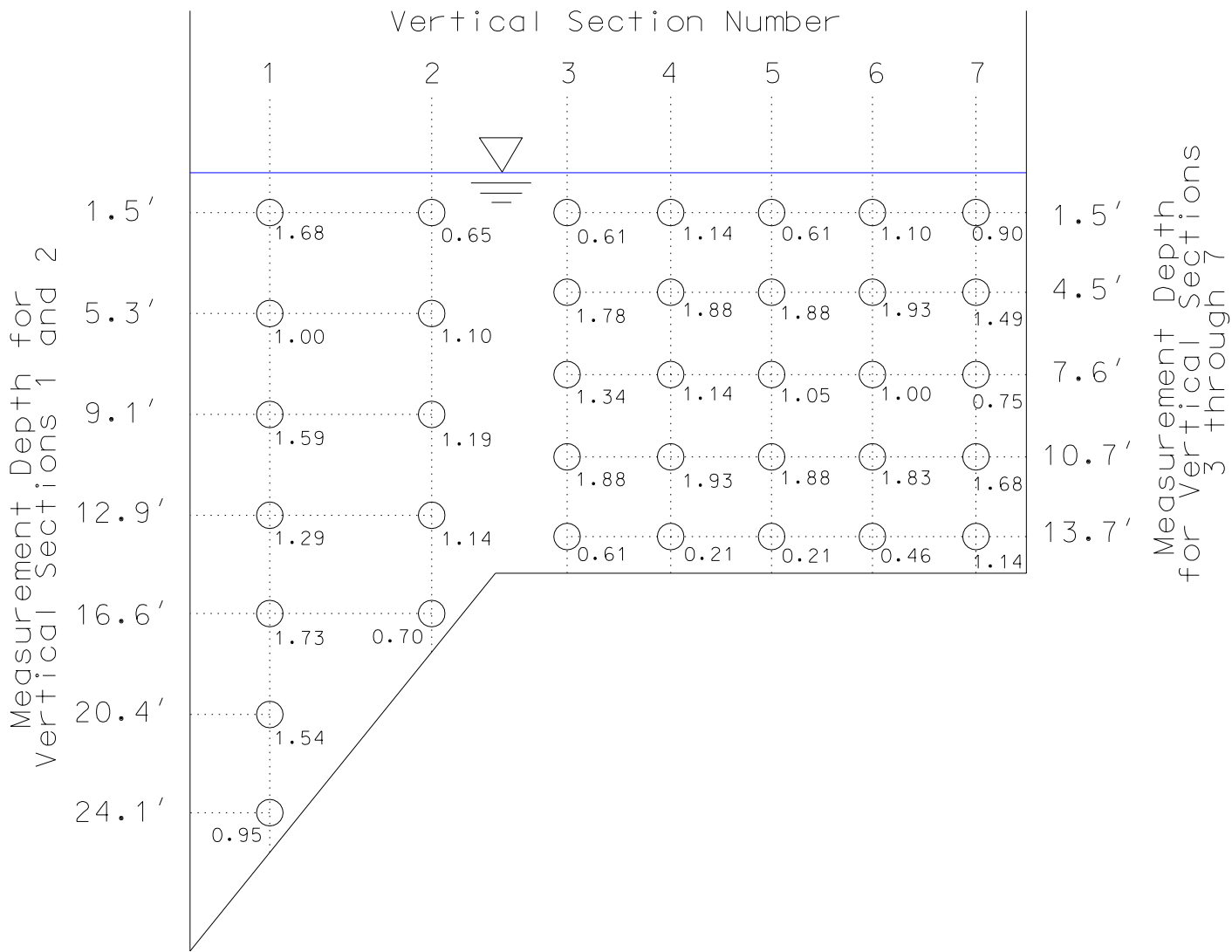


Figure 2
Bradford Island A Branch
Example Velocity Cross-Section
APPENDIX B
July 2, 2003 45

BONNEVILLE A BRANCH FISHWAY VELOCITY DATA

FV3-9 Intake (Ladder Augmentation flow)

Data Collectors: SJS

Date: 7/2/2003 Time: start end 17:00

FV3-9 Tainter Gate Data

Forebay Level =

start	end
	75.80
start	end
135	1.20

Opening (ft) 0.90
Distance to WS d/s of gate (ft) 18.25

start	end
	0.90 US Valve_9.2
	18.25 DS Valve_16.8
	68.25

Head d/s of Gate:

INSTRUMENT

Price Meter

Price Meter Rotations per Count =

$$V = 0.03 + 2.27548 * (\text{rotations/time})$$

POINT VELOCITY AND FLOW MEASUREMENTS:

Z₁₅ = Meas. Distance to AWS WS =

ft (from 86.5 level)

B = Channel Width = 9.00 ft

WS = Water Surface Elevation =

ft (= 86.5 - Z₁₅)

DECK ELEVATION = 86.5 ft

Y = Measured AWS Channel Depth =

ft (=WS - 63)

Zi = INVERT = 63.0 ft

X1 = Side Edge width incr =

2 ft

Approx internal dimension =

3.0 ft Div by

Y1 = Vertical edge height incr =

2 ft

Number of Internal X Increments =

2.0 4

Number of Internal Y Increments =

3.0 6

Horiz. No.:	Formula for depthn below surface (pm)	Depth from Surface (ft)	Vert. Sect. No. :	1	2	3	4	Average Velocity
			Est Dist. from Left Edge (ft)	1.0	3.50	6.50	8.00	
			Actual Dist (ft) from Fft side	1.0	3.5	5.5	8.0	
1	0.5 * Y1		Counts					
			duration					
			VELOCITY					ft/s
2	Y1 + (Y-2*Y1)/6		Counts					
			duration					
			VELOCITY					ft/s
3	Y/2		Counts					
			duration					
			VELOCITY					ft/s
4	Y1 + 5* (Y-2*Y1)/6		Counts					
			duration					
			VELOCITY					ft/s
5	Y - 0.5*Y1		Counts					
			duration					
			VELOCITY					ft/s
Total Average Integrated Velocity =				ft/s				
Total Computed FLOW RATE =				cfs	(= B * Y * V)			

BONNEVILLE A BRANCH FISHWAY VELOCITY DATA																																			
SOUTH POWERHOUSE CHANNEL				Data Collectors: SA SJS Tim Darland																															
Date: 7/2/2003		Time: 15:15 16:15																																	
start end start end																																			
Distance to Water: <table border="1" style="width: 100%; text-align: center;"> <tr><th>start</th><th>end</th><th>Ref EL</th><th>start</th><th>end</th></tr> <tr><td>40.65</td><td>40.45</td><td>55.0</td><td>14.65</td><td>14.85</td></tr> </table> WATER LEVEL ELEV: <table border="1" style="width: 100%; text-align: center;"> <tr><th>start</th><th>end</th><th>Ref EL</th><th>start</th><th>end</th></tr> <tr><td>38.96</td><td>38.80</td><td>55.0</td><td>16.04</td><td>16.20</td></tr> </table>				start	end	Ref EL	start	end	40.65	40.45	55.0	14.65	14.85	start	end	Ref EL	start	end	38.96	38.80	55.0	16.04	16.20	At FG2-3 SOUTH ENTRANCH WEIR GATE DATA <table border="1" style="width: 100%; text-align: center;"> <tr><th>SW-1</th><th>SW-2</th></tr> <tr><td>OPEN ?</td><td>X</td></tr> <tr><td>Crest Elevation</td><td>3.80</td></tr> </table>						SW-1	SW-2	OPEN ?	X	Crest Elevation	3.80
start	end	Ref EL	start	end																															
40.65	40.45	55.0	14.65	14.85																															
start	end	Ref EL	start	end																															
38.96	38.80	55.0	16.04	16.20																															
SW-1	SW-2																																		
OPEN ?	X																																		
Crest Elevation	3.80																																		
Tailrace Level :																																			
U/s Staff Gage:																																			
Entrance Head = 1.39 1.35 ft																																			
HGL level time: 17.50 15:30 (Reported from Project Control Room)																																			
South ASW conduit head near South PH stillwell:																																			
INSTRUMENT				Price Meter 1			Price Meter Rotations per Count = 1.00																												
V = 2.2048 * (rotations/time) + 0.0178																																			
POINT VELOCITY AND FLOW MEASUREMENTS:																																			
Z ₁₅ = Meas. Distance to WS = 38.96 ft (from 55 level)				B = Channel Width = 17.58 ft																															
WS = Water Surface Elevation = 16.04 ft (= 55 - Z ₁₅)				DECK ELEVATION = 55.0 ft																															
Y = Measured Channel Depth = 18.04 ft (= WS - 0)				Zi = INVERT = -2.0 ft																															
X1 = Side Edge width incr = 2 ft				Approx internal dimension = 4.0 ft				Div by																											
Y1 = Vertical edge height incr = 3 ft				Number of Internal X Increments = 2.0				4																											
				Number of Internal Y Increments = 3.0				6																											
Horiz. No.:	Formula for depthn below surface (pm)	Depth from Surface (ft)	Vert. Sect. No. : Est Dist. from left Edge (ft) Actual Dist (ft) from left (west) side	1 1.0	2 5.50	3 10.08	4 14.08	Average Velocity																											
1	0.5 * Y1	1.00	Counts	23	47	53	55																												
			duration	45	45	45	45																												
			VELOCITY	1.14	2.32	2.61	2.71	2.31 ft/s																											
2	Y1 + (Y-2*Y1)/6	5.00	Counts	19	64	60	60																												
			duration	45	45	45	45																												
			VELOCITY	0.95	3.15	2.96	2.96	2.63 ft/s																											
3	Y/2	9.00	Counts	4	62	66	55																												
			duration	45	45	45	45																												
			VELOCITY	0.21	3.06	3.25	2.71	2.33 ft/s																											
4	Y1 + 5* (Y-2*Y1)/6	13.00	Counts	27	40	45	42																												
			duration	45	45	45	45																												
			VELOCITY	1.34	1.98	2.22	2.08	1.92 ft/s																											
5	Y - 0.5*Y1	17.00	Counts	14	30	19	33																												
			duration	45	45	45	45																												
			VELOCITY	0.70	1.49	0.95	1.63	1.28 ft/s																											
Total Average Integrated Velocity =				2.12 ft/s																															
Total Computed FLOW RATE =				674 cfs (= B * Y * V)																															

BONNEVILLE A BRANCH FISHWAY VELOCITY DATA

SOUTH AWS INTAKE (FV1-1)

(from catwalk)

Date: 7/2/2003

Time: 13:40 15:00

Data Collectors: SA SJS Tim Darland

Time: start 13:40 end 15:00

AWS Intake Tainter Gate Data

Forebay Level =

start 75.08 end 75.39

FV1-1 start end
Opening (ft) 2.90

Tailrace Level =

end

Distance to WS d/s of gate (ft)
Head d/s of Gate:

INSTRUMENT

Price Meter X

Price Meter Rotations per Count = 1.00 (if used) $V = 0.03 + 2.27548 * (\text{rotations/time})$

POINT VELOCITY AND FLOW MEASUREMENTS IN SOUTH AWS:

Left Edge Invert Measurement

Z₁₅ = Meas. Distance to WS

10.25

WS = Water Surface Elev

75.08

Z_b = Dist from WS to bottom using PM

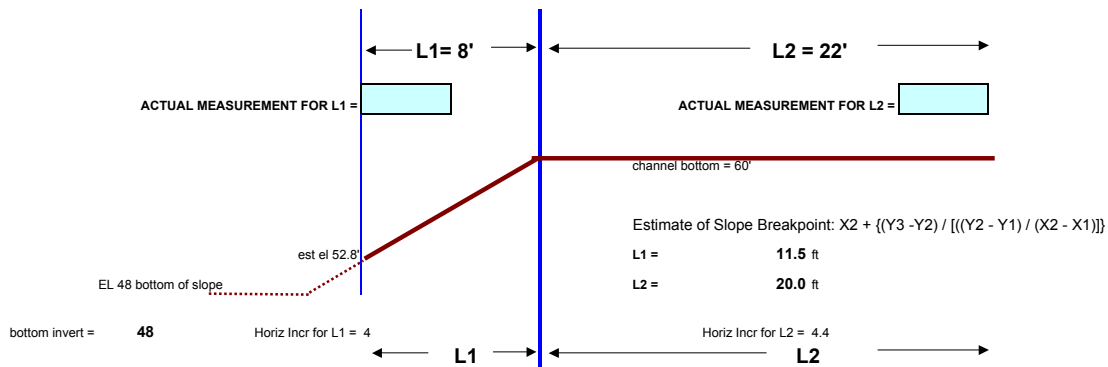
(Est Invert.)

Meas Invert = WS - Z_b =

Left edge projection weighting factor = 0.50

B = Channel Width = 31.5 ft
DECK elev = 85.0 ft
Catwalk elev = 82.7 ft

CHECK



APPENDIX B ITEM 3

SOUTH AWS INTAKE (FV1-1)				(from catwalk)									
Maximum Depth = Min { (X1 - 0) * (Y1-Y2)/(X2-X1) + Y1 } ; (FB-48) }				Est Invert	54.6	58.2	60	60	60	60	60		
				Meas invert									
				FLOW DEPTH	25.6	18.1	15.2				15.1		
MAXIMUM DEPTH = 27.08 ft													
Horiz. No.:	EST Distance from surface (PM)	ACTUAL Depth from Surface (ft) Columns 1 & 2	ACTUAL Depth from Surface (ft) Columns 3-7	Vert. Sect. No. :	1	2	3	4	5	6	7	Average Integrated Velocity	str ave
				Est Dist. from Left Edge (ft)	2.0	6.0	10.2	14.6	19.0	23.4	27.8		
				Actual Dist from left side	3.0	9.1	14.2	18.1	21.9	25.7	29.6		
1	1.9	1.5	1.50	Counts	34	13	12	23	12	22	18	1.20 ft/s	0.97
				duration	45	45	45	45	45	45	45		
				VELOCITY	1.68	0.65	0.61	1.14	0.61	1.10	0.90		
2	3.8	5.3	4.50	Counts	20	22	36	38	38	39	30	1.06 ft/s	1.59
				duration	45	45	45	45	45	45	45		
				VELOCITY	1.00	1.10	1.78	1.88	1.88	1.93	1.49		
3	7.6	9.1	7.60	Counts	32	24	27	23	21	20	15	1.43 ft/s	1.22
				duration	45	45	45	45	45	45	45		
				VELOCITY	1.59	1.19	1.34	1.14	1.05	1.00	0.75		
4	11.4	12.9	10.70	Counts	26	23	38	39	38	37	34	1.22 ft/s	1.66
				duration	45	45	45	45	45	45	45		
				VELOCITY	1.29	1.14	1.88	1.93	1.88	1.83	1.68		
5	15.2	16.6	13.7	Counts	35	14	12	4	4	9	23	1.21 ft/s	0.65
				duration	45	45	45	45	45	45	45		
				VELOCITY	1.73	0.70	0.61	0.21	0.21	0.46	1.14		
6	19.0	20.4		Counts	31							1.60 ft/s	1.54
				duration	45								
				VELOCITY	1.54								
7	22.8	24.1		Counts	19							0.95 ft/s	0.95
				duration	45								
				VELOCITY	0.95								
Total Average Integrated Velocity Columns :												1.21	
Total Computed AWS FLOW RATE =												678 cfs (= B * Y * V)	
												1.23	

BONNEVILLE A BRANCH FISHWAY VELOCITY DATA

NORTH AWS INTAKE BULKHEAD SLOTS

Data Collectors:

LR

JM

PW

SLOT 1

Date: 7/2/2003

Time: start end
13:30 15:00

AWS Intake Tainter Gate Data

Forebay Level =

start end
75.20

Tailrace Level =

start end

FG3-7

Opening (ft)

start
2.85 ft

Distance to WS d/s of gate (ft)

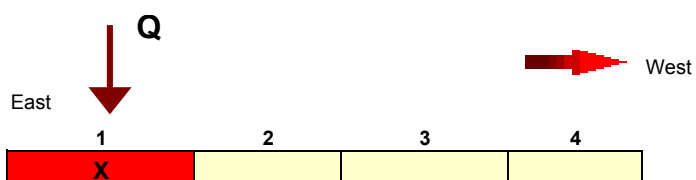
+- 1 ft

Head d/s of Gate:

start

Intake Number from East

AWS INTAKE BULKHEAD SLOT



ADV

X

Price Meter

$$V = 0.03 + 2.27548 * (\text{rotations/time})$$

Price Meter Rotations per Count =

POINT VELOCITY AND FLOW MEASUREMENTS IN AWS:

Z₁₅ = Meas. Distance to WS 9.80 ft (from 85 deck)WS = Water Surface Elev 75.20 ft (= 85 - Z₁₅)

Y = Measured Depth = 21.20 ft (= WS - 54)

X1 = Side Edge width inc=

3

Y1 = Vertical edge height inc=

3

B = Channel Width =

11.2 ft

Deck elev =

85.0 ft

Zi = INVERT =

54.0 ft

Aprox internal dimension =

4.2 ft

Number of Internal X Increments =

1.0

Number of Internal Y Increments =

5.0

BONNEVILLE A BRANCH FISHWAY VELOCITY DATA							
NORTH AWS INTAKE BULKHEAD SLOTS				Data Collectors: LR JM PW			
SLOT 1				Date: 7/2/2003			
NORTH AWS INTAKE MEASUREMENTS				Time: 13:30 15:00			
Bulkhead Slot 1			(measured from north side of slot)				
Horiz. No.:	Formula for Distance from surface (pm)	Depth from Surface (ft)	Vert. Sect. No. :	1	2	3	Average Integrated Velocity
			Est Dist. from left sidee (ft)	1.5	5.5	9.5	
			Actual dist from left side	1.5	5.5	9.5	
1	0.5 * Y1	1.50	Counts				1.41 ft/s
			duration	a11.Vu	a12.Vu	a13.Vu	
			VELOCITY	1.46	1.48	1.31	
2	$Y1 + (Y-2*Y1) * 0.1$	4.50	Counts				1.21 ft/s
			duration	a21.Vu	a22.Vu	a23.Vu	
			VELOCITY	0.99	1.52	1.15	
3	$Y1 + (Y-2*Y1) * 0.3$	7.60	Counts				1.23 ft/s
			duration	a31.Vu	a32.Vu	a33.Vu	
			VELOCITY	1.07	1.25	1.36	
4	Y/2	10.60	Counts				0.68 ft/s
			duration	a41.Vu	a42.Vu	a43.Vu	
			VELOCITY	0.35	0.38	1.32	
5	$Y1 + (Y-2*Y1) * 0.7$	13.60	Counts				0.29 ft/s
			duration	a51.Vu	a52.Vu	a53.Vu	
			VELOCITY	-0.15	0.50	0.54	
6	$Y1 + (Y-2*Y1) * 0.9$	16.70	Counts				0.27 ft/s
			duration	a61.Vu	a62.Vu	a63.Vu	
			VELOCITY	-0.13	0.27	0.68	
7	Y - 0.5 * Y1	19.70	Counts				-0.15 ft/s
			duration	a71.Vu	a72.Vu	a73.Vu	
			VELOCITY	-0.39	0.01	-0.05	
Total Average Integrated Velocity =				0.71 ft/s			
Total Computed AWS FLOW RATE =				168 cfs (= B * Y * V)			

BONNEVILLE A BRANCH FISHWAY VELOCITY DATA			
NORTH AWS INTAKE BULKHEAD SLOTS		Data Collectors: JM LR PW	
SLOT 2			
Date: 7/2/2003			
Time:	start	end	
	15:10	16:00	
Forebay Level =	start	end	
	75.50		
Tailrace Level =	start	end	
			
Q West			
Intake Number from East			
AWS INTAKE BULKHEAD SLOT			
ADV X			
Price Meter 		Price Meter Rotations per Count = 	
$V = 0.03 + 2.27548 * (\text{rotations/time})$			
POINT VELOCITY AND FLOW MEASUREMENTS IN AWS:			
Z₁₅ = Meas. Distance to WS 9.50 ft (from 85 deck)		check ft	
WS = Water Surface Elev 75.50 ft (= 85 - Z ₁₅)		B = Channel Width = 11.0 ft	
Y = Measured Depth = 21.50 ft (=WS - 54)		Deck elev = 85.0 ft	
		Zi = INVERT = 54.0 ft	
X1 = Side Edge width inc= 3		Approx internal dimension = 4.2 ft	
Y1 = Vertical edge height incr 3		Number of Internal X Increments = 1.0	
		Number of Internal Y Increments = 5.0	

BONNEVILLE A BRANCH FISHWAY VELOCITY DATA							
NORTH AWS INTAKE BULKHEAD SLOTS				Data Collectors: JM LR PW			
SLOT 2				Date: 7/2/2003			
NORTH AWS INTAKE MEASUREMENTS				Time: 15:10 16:00			
Bulkhead Slot 2				(measured from east side of slot)			
Horiz. No.:	Formula for Distance from surface (pm)	Depth from Surface (ft)	Vert. Sect. No. :	1	2	3	Average Integrated Velocity
			Est Dist. from left sidee (ft)	1.5	5.4	9.5	
			Actual dist from left side	1.5	5.5	9.5	
1	0.5 * Y1	1.50	Counts				0.94 ft/s
			duration	b11.Vu	b12.Vu	b13.Vu	
			VELOCITY	1.04	1.06	0.74	
2	$Y1 + (Y-2*Y1) * 0.1$	4.60	Counts				1.34 ft/s
			duration	b21.Vu	b22.Vu	b23.Vu	
			VELOCITY	1.31	1.31	1.41	
3	$Y1 + (Y-2*Y1) * 0.3$	7.70	Counts				0.76 ft/s
			duration	b31.Vu	b32.Vu	b33.Vu	
			VELOCITY	0.81	0.89	0.60	
4	Y/2	10.80	Counts				0.88 ft/s
			duration	b41.Vu	b42.Vu	b43.Vu	
			VELOCITY	0.72	1.03	0.92	
5	$Y1 + (Y-2*Y1) * 0.7$	13.90	Counts				0.72 ft/s
			duration	b51.Vu	b52.Vu	b53.Vu	
			VELOCITY	0.55	1.03	0.62	
6	$Y1 + (Y-2*Y1) * 0.9$	17.00	Counts				0.31 ft/s
			duration	b61.Vu	b62.Vu	b63.Vu	
			VELOCITY	0.26	#N/A	0.37	
7	Y - 0.5 * Y1	20.00	Counts				-0.10 ft/s
			duration	b71.Vu	b72.Vu	b73.Vu	
			VELOCITY	-0.01	#N/A	-0.18	
Total Average Integrated Velocity =				0.70 ft/s			
Total Computed AWS FLOW RATE =				165 cfs (= B * Y * V)			

BONNEVILLE A BRANCH FISHWAY VELOCITY DATA

NORTH AWS INTAKE BULKHEAD SLOTS

Data Collectors:

JM

LR

PW

SLOT 3

Date: 7/2/2003

Time:

start

end

start

end

Forebay Level =

75.80

start

end

Tailrace Level =

Q

West

East

Intake Number from East

AWS INTAKE BULKHEAD SLOT

1

2

3

4

X

ADV

X

Price Meter

$$V = 0.03 + 2.27548 * (\text{rotations/time})$$

Price Meter Rotations per Count =

POINT VELOCITY AND FLOW MEASUREMENTS IN AWS:

Z₁₅ = Meas. Distance to WS 9.20 ft (from 85 deck)WS = Water Surface Elev 75.80 ft (= 85 - Z₁₅)

Y = Measured Depth = 21.80 ft (= WS - 54)

X1 = Side Edge width inc= 3

Y1 = Vertical edge height incr 3

check ft

B = Channel Width = 11.0 ft

Deck elev = 85.0 ft

Zi = INVERT = 54.0 ft

Aprox internal dimension = 4.2 ft

Number of Internal X Increments = 1.0

Number of Internal Y Increments = 5.0

BONNEVILLE A BRANCH FISHWAY VELOCITY DATA

NORTH AWS INTAKE BULKHEAD SLOTS

Data Collectors:

JM

LR

PW

SLOT 3

Date:

7/2/2003

NORTH AWS INTAKE MEASUREMENTS

Time:

Bulkhead Slot 3

(measured from east side of slot)

Horiz. No.:	Formula for Distance from surface (pm)	Depth from Surface (ft)	Vert. Sect. No. :	1	2	3	Average Integrated Velocity
			Est Dist. from left sidee (ft)	1.5	5.4	9.5	
			Actual dist from left side	1.5	5.5	9.5	
1	$0.5 * Y1$	1.50	Counts				
			duration	c11.Vu	c12.Vu	c13.Vu	
			VELOCITY	0.57	1.08	1.08	0.90 ft/s
2	$Y1 + (Y-2*Y1) * 0.1$	4.60	Counts				
			duration	c21.Vu	c22.Vu	c23.Vu	
			VELOCITY	0.81	1.14	0.77	0.90 ft/s
3	$Y1 + (Y-2*Y1) * 0.3$	7.70	Counts				
			duration	c31.Vu	c32.Vu	c33.Vu	
			VELOCITY	0.81	0.91	1.07	0.93 ft/s
4	$Y/2$	10.90	Counts				
			duration	c41.Vu	c42.Vu	c43.Vu	
			VELOCITY	0.05	0.22	0.24	0.17 ft/s
5	$Y1 + (Y-2*Y1) * 0.7$	14.10	Counts				
			duration	c51.Vu	c52.Vu	c53.Vu	
			VELOCITY	0.39	0.31	0.53	0.41 ft/s
6	$Y1 + (Y-2*Y1) * 0.9$	17.20	Counts				
			duration	c61.Vu	c62.Vu	c63.Vu	
			VELOCITY	0.25	0.29	0.07	0.20 ft/s
7	$Y - 0.5 * Y1$	20.30	Counts				
			duration	c71.Vu	c72.Vu	c73.Vu	
			VELOCITY	-0.10	-0.37	-0.31	-0.26 ft/s
Total Average Integrated Velocity =				0.46 ft/s			
Total Computed AWS FLOW RATE =				111 cfs (= B * Y * V)			

BONNEVILLE A BRANCH FISHWAY VELOCITY DATA				
NORTH AWS INTAKE BULKHEAD SLOTS		Data Collectors: LR JM PW		
SLOT 4				
Date: 7/2/2003				
Time:	start end 16:15 17:45			
	start end 75.60			
Forebay Level =				
Tailrace Level =				
Intake Number from East East X West AWS INTAKE BULKHEAD SLOT ADV X Price Meter $V = 0.03 + 2.27548 * (\text{rotations/time})$ Price Meter Rotations per Count =				
POINT VELOCITY AND FLOW MEASUREMENTS IN AWS:				
Z_{15} = Meas. Distance to WS 9.40 ft (from 85 deck)		check ft		
WS = Water Surface Elev 75.60 ft (= 85 - Z_{15})		B = Channel Width = 11.0 ft		
Y = Measured Depth = 21.60 ft (= WS - 54)		Deck elev = 85.0 ft		
Zi = INVERT = 54.0 ft		Approx internal dimension = 4.2 ft		
X1 = Side Edge width inc= 3		Number of Internal X Increments = 1.0		
Y1 = Vertical edge height incr 3		Number of Internal Y Increments = 5.0		

BONNEVILLE A BRANCH FISHWAY VELOCITY DATA							
NORTH AWS INTAKE BULKHEAD SLOTS				Data Collectors: LR JM PW			
SLOT 4				Date: 7/2/2003			
NORTH AWS INTAKE MEASUREMENTS				Time: 16:15 17:45			
Bulkhead Slot 4			(measured from east side of slot)				
Horiz. No.:	Formula for Distance from surface (pm)	Depth from Surface (ft)	Vert. Sect. No. :	1	2	3	Average Integrated Velocity
			Est Dist. from left sidee (ft)	1.5	5.5	9.5	
			Actual dist from left side	1.5	5.5	9.5	
1	0.5 * Y1	1.50	Counts				0.63 ft/s
			duration	d11.Vu	d12.Vu	d13.Vu	
			VELOCITY	0.58	0.81	0.53	
2	$Y1 + (Y-2*Y1) * 0.1$	4.60	Counts				0.76 ft/s
			duration	d21.Vu	d22.Vu	d23.Vu	
			VELOCITY	0.99	0.80	0.51	
3	$Y1 + (Y-2*Y1) * 0.3$	7.70	Counts				0.85 ft/s
			duration	d31.Vu	d32.Vu	d33.Vu	
			VELOCITY	0.77	0.88	0.89	
4	Y/2	10.80	Counts				0.28 ft/s
			duration	d41.Vu	d42.Vu	d43.Vu	
			VELOCITY	0.10	0.46	0.29	
5	$Y1 + (Y-2*Y1) * 0.7$	13.90	Counts				0.26 ft/s
			duration	d51.Vu	d52.Vu	d53.Vu	
			VELOCITY	0.34	0.30	0.15	
6	$Y1 + (Y-2*Y1) * 0.9$	17.00	Counts				0.21 ft/s
			duration	d61.Vu	d62.Vu	d63.Vu	
			VELOCITY	0.18	0.27	0.17	
7	Y - 0.5 * Y1	20.10	Counts				-0.29 ft/s
			duration	d71.Vu	d72.Vu	d73.Vu	
			VELOCITY	-0.17	-0.37	-0.31	
Total Average Integrated Velocity =				0.39 ft/s			
Total Computed AWS FLOW RATE =				92 cfs (= B * Y * V)			

Appendix C

Model Output For Data Collection Conditions

This appendix contains output files for the operations and conditions encountered during the data collection for the model calibration. As described in the main body the data collection was taken under two operational settings over two separate days. The .TXT File is the output of the closed conduit program and the .PRN is the output from the open channel program. The Table below provides relevant information for each of these model runs.

File Name	Date	Forebay (ft NVGD)	Tailrace (ft NVGD)	Operation of Powerhouse Telescoping Gates
0815rev.TXT	15 Aug 2002	75.2	13.75	#9, 21, 34, 58, & 62 open
0815rev.PRN	15 Aug 2002	75.2	13.75	#9, 21, 34, 58, & 62 open
1010rev.TXT	10 Oct 2002	75.8	10.0	Temporarily closed
1010rev. PRN	10 Oct 2002	75.8	10.0	Temporarily closed
0702rev.TXT	2 Jul 2003	75.4	14.88	Permanently closed
0702rev.PRN	2 Jul 2003	75.4	14.88	Permanently closed

Appendix B of this report provides the actual measurements taken during the data collection as well as the operations and conditions for each data set.

0815rev.txt

FLOWRATE IS EXPRESSED IN CFS AND PRESSURE IN PSIG

A SUMMARY OF THE ORIGINAL DATA FOLLOWS

THE DARCY WEISBACH HEAD LOSS EQUATION IS USED, THE KINEMATIC VIS. = .0000100

PIPE NO.	NODE NOS.	LENGTH (FEET)	DIAMETER (INCHES)	ROUGHNESS	MINOR LOSS K	FIXED GRADE
1	0 1	80.0	116.0	4.0	2.00	75.16
2	1 2	200.0	98.0	5.1	41.25	
3	2 113	200.0	101.6	5.1	79.81	
4	113 1130	5.0	70.3	5.2	.00	
5	1130 0	1.5	40.6	4.8	1.00	1000.00
LINE 5	IS CLOSED					
6	113 112	200.0	101.6	5.1	.10	
7	112 1120	6.0	70.3	5.2	.00	
8	1120 0	1.5	40.6	4.8	1.00	1000.00
LINE 8	IS CLOSED					
9	112 111	45.0	101.6	5.1	.10	
10	111 1110	7.0	70.3	5.2	.00	
11	1110 0	1.5	40.6	4.8	1.00	1000.00
LINE 11	IS CLOSED					
12	111 110	45.0	101.6	5.1	.10	
13	110 1100	8.0	70.3	5.2	.00	
14	1100 0	1.5	40.6	4.8	1.00	1000.00
LINE 14	IS CLOSED					
15	110 109	45.0	101.6	5.1	.10	
16	109 1090	9.0	70.3	5.2	.00	
17	1090 0	1.5	40.6	4.8	1.30	1000.00
LINE 17	IS CLOSED					
18	109 108	45.0	101.6	5.1	.10	
19	108 1080	10.0	70.3	5.2	.10	
20	1080 0	1.5	40.6	4.8	1.30	1000.00
LINE 20	IS CLOSED					
21	108 107	45.0	101.6	5.1	.10	
22	107 1070	12.0	70.3	5.2	.00	
23	1070 0	1.5	40.6	4.8	1.30	1000.00
LINE 23	IS CLOSED					
24	107 106	45.0	101.6	5.1	.10	
25	106 1060	13.0	70.3	5.2	.00	
26	1060 0	1.5	28.7	4.8	1.60	23.11
27	106 105	45.0	101.6	5.1	.10	
28	105 1050	19.0	70.3	5.2	.00	
29	1050 0	1.5	40.6	4.8	1.30	1000.00
LINE 29	IS CLOSED					
30	105 104	45.0	101.6	5.1	.10	
31	104 1040	21.0	70.3	5.2	.00	
32	1040 0	1.5	40.6	4.8	1.30	1000.00
LINE 32	IS CLOSED					
33	104 3	3.0	101.6	5.1	.10	
34	3 4	8.0	101.6	5.1	.00	
35	4 5	1.0	36.7	5.1	.00	
36	5 103	19.0	70.3	5.1	.00	
37	103 1030	1.0	70.3	5.2	.00	

APPENDIX C- Item 1

0815rev.txt

38	1030	0	1.5	40.6	4.8	2.70	15.73
39	4	102	300.0	.5	5.1	100.00	
40	102	921	25.0	101.6	5.1	.40	
41	921	0	1.5	54.2	4.9	1.90	15.17
42	921	922	15.0	176.5	11.0	.10	
43	922	0	1.5	54.2	4.9	1.90	15.14
44	922	923	15.0	176.5	11.0	.10	
45	923	0	1.5	54.2	4.9	1.90	15.18
46	923	221	30.0	176.5	11.0	.10	
47	221	0	1.5	41.8	4.8	1.50	15.18
48	221	220	40.0	176.5	11.0	.10	
49	220	0	1.5	41.8	4.8	1.50	15.17
50	220	219	45.0	176.5	11.0	.10	
51	217	0	1.5	41.8	4.8	1.50	1000.00
LINE	51	IS CLOSED					
52	217	216	40.0	176.5	11.0	.10	
53	212	0	1.5	40.6	4.8	1.50	15.13
54	212	211	45.0	176.5	11.0	.10	
55	207	0	1.5	36.1	4.8	1.50	1000.00
LINE	55	IS CLOSED					
56	207	206	40.0	176.5	11.0	.10	
57	204	0	1.5	33.9	4.8	1.50	15.10
58	204	203	40.0	176.5	11.0	.10	
59	9	10	50.0	106.5	5.2	10.00	
60	10	11	24.0	106.5	5.2	2.04	
61	11	12	12.0	106.5	5.2	5.84	
62	12	0	4.0	106.5	5.2	.30	75.16
63	206	0	1.5	36.1	4.8	1.50	1000.00
LINE	63	IS CLOSED					
64	206	205	45.0	176.5	11.0	.10	
65	205	0	1.5	35.0	4.8	1.50	1000.00
LINE	65	IS CLOSED					
66	205	204	40.0	176.5	11.0	.10	
67	211	0	1.5	39.5	4.8	1.50	1000.00
LINE	67	IS CLOSED					
68	211	210	40.0	176.5	11.0	.10	
69	210	0	1.5	39.5	4.8	1.50	1000.00
LINE	69	IS CLOSED					
70	210	209	45.0	176.5	11.0	.10	
71	209	0	1.5	38.4	4.8	1.50	1000.00
LINE	71	IS CLOSED					
72	209	208	40.0	176.5	11.0	.10	
73	208	0	1.5	37.2	4.8	1.50	15.12
74	208	207	45.0	176.5	11.0	.10	
75	216	0	1.5	41.8	4.8	1.50	1000.00
LINE	75	IS CLOSED					
76	216	215	45.0	176.5	11.0	.10	
77	215	0	1.5	41.8	4.8	1.50	1000.00
LINE	77	IS CLOSED					
78	215	214	40.0	176.5	11.0	.10	
79	214	0	1.5	40.6	4.8	1.50	1000.00
LINE	79	IS CLOSED					
80	214	213	45.0	176.5	11.0	.10	
81	213	0	1.5	40.6	4.8	1.50	1000.00
LINE	81	IS CLOSED					
82	213	212	40.0	176.5	11.0	.10	
83	219	0	1.5	41.8	4.8	1.50	15.17
84	219	218	40.0	176.5	11.0	.10	
85	218	0	1.5	41.8	4.8	1.50	1000.00
LINE	85	IS CLOSED					
86	218	217	40.0	176.5	11.0	.10	
87	203	202	40.0	176.5	11.0	.10	
88	203	0	1.5	54.2	4.9	1.10	1000.00

0815rev.txt

LINE	88	IS CLOSED					
	89	202 201	40.0	176.5	11.0	.10	
	90	202 0	1.5	54.2	4.9	1.10	1000.00
LINE	90	IS CLOSED					
	91	1140 0	1.5	54.2	4.9	1.10	1000.00
LINE	91	IS CLOSED					
	92	201 9	84.0	176.5	11.0	.00	
	93	1140 201	84.0	234.5	7.4	4.00	

JUNCTION	NUMBER	DEMAND	ELEVATION	CONNECTING	PIPES
	1	.00	.00	1 2	
	2	.00	.00	2 3	
	3	.00	.00	33 34	
	4	.00	.00	34 35	39
	5	.00	.00	35 36	
	9	.00	.00	59 92	
	10	.00	.00	59 60	
	11	.00	.00	60 61	
	12	.00	.00	61 62	
	102	.00	.00	39 40	
	103	.00	.00	36 37	
	104	.00	.00	30 31	33
	105	.00	.00	27 28	30
	106	.00	.00	24 25	27
	107	.00	.00	21 22	24
	108	.00	.00	18 19	21
	109	.00	.00	15 16	18
	110	.00	.00	12 13	15
	111	.00	.00	9 10	12
	112	.00	.00	6 7	9
	113	.00	.00	3 4	6
	201	.00	.00	89 92	93
	202	.00	.00	87 89	90
	203	.00	.00	58 87	88
	204	.00	.00	57 58	66
	205	.00	.00	64 65	66
	206	.00	.00	56 63	64
	207	.00	.00	55 56	74
	208	.00	.00	72 73	74
	209	.00	.00	70 71	72
	210	.00	.00	68 69	70
	211	.00	.00	54 67	68
	212	.00	.00	53 54	82
	213	.00	.00	80 81	82
	214	.00	.00	78 79	80
	215	.00	.00	76 77	78
	216	.00	.00	52 75	76
	217	.00	.00	51 52	86
	218	.00	.00	84 85	86
	219	.00	.00	50 83	84
	220	.00	.00	48 49	50
	221	.00	.00	46 47	48
	921	.00	.00	40 41	42
	922	.00	.00	42 43	44
	923	.00	.00	44 45	46
	1030	.00	.00	37 38	
	1040	.00	.00	31 32	
	1050	.00	.00	28 29	
	1060	.00	.00	25 26	
	1070	.00	.00	22 23	
	1080	.00	.00	19 20	
	1090	.00	.00	16 17	

```

                                0815rev.txt
1100          .00          .00          13          14
1110          .00          .00          10          11
1120          .00          .00          7           8
1130          .00          .00          4           5
1140          .00          .00          91          93

```

OUTPUT SELECTION: ALL RESULTS ARE OUTPUT EACH PERIOD

THIS SYSTEM HAS 93 PIPES WITH 57 JUNCTIONS , 0 LOOPS AND 37 FGNS

THE RESULTS ARE OBTAINED AFTER 4 TRIALS WITH AN ACCURACY = .00381

BONNEVILLE FIRST POWERHOUSE FISHLADDER

Auxillary water supply system

tailwater elevation = _____

PIPE NO.	NODE NOS.	FLOWRATE	HEAD LOSS	PUMP HEAD	MINOR LOSS	VELOCITY	HL/1000
1	0 1	259.34	.03	.00	.39	3.53	.33
2	1 2	259.34	.17	.00	15.70	4.95	.83
3	2 113	259.34	.14	.00	26.29	4.61	.68
4	113 1130	.00	.00	.00	.00	.00	.00
LINE 5	IS CLOSED						
6	113 112	259.34	.14	.00	.03	4.61	.68
7	112 1120	.00	.00	.00	.00	.00	.00
LINE 8	IS CLOSED						
9	112 111	259.34	.03	.00	.03	4.61	.68
10	111 1110	.00	.00	.00	.00	.00	.00
LINE 11	IS CLOSED						
12	111 110	259.34	.03	.00	.03	4.61	.68
13	110 1100	.00	.00	.00	.00	.00	.00
LINE 14	IS CLOSED						
15	110 109	259.34	.03	.00	.03	4.61	.68
16	109 1090	.00	.00	.00	.00	.00	.00
LINE 17	IS CLOSED						
18	109 108	259.34	.03	.00	.03	4.61	.68
19	108 1080	.00	.00	.00	.00	.00	.00
LINE 20	IS CLOSED						
21	108 107	259.34	.03	.00	.03	4.61	.68
22	107 1070	.00	.00	.00	.00	.00	.00
LINE 23	IS CLOSED						
24	107 106	259.34	.03	.00	.03	4.61	.68
25	106 1060	84.09	.01	.00	.00	3.12	.50
26	1060 0	84.09	.08	.00	8.70	18.72	53.48
27	106 105	175.25	.01	.00	.02	3.11	.31
28	105 1050	.00	.00	.00	.00	.00	.00
LINE 29	IS CLOSED						
30	105 104	175.25	.01	.00	.02	3.11	.31
31	104 1040	.00	.00	.00	.00	.00	.00
LINE 32	IS CLOSED						
33	104 3	175.25	.00	.00	.02	3.11	.31
34	3 4	175.25	.00	.00	.00	3.11	.31
35	4 5	175.25	.06	.00	.00	23.88	64.84
36	5 103	175.25	.04	.00	.00	6.50	2.14
37	103 1030	175.25	.00	.00	.00	6.50	2.15
38	1030 0	175.25	.06	.00	15.93	19.49	37.45
39	4 102	.00	13.26	.00	1.53	.99	44.20
40	102 921	.00	.00	.00	.00	.00	.00

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41	921	0	128.19	.01	.00	1.89	8.00	4.43
42	921	922	-128.19	.00	.00	.00	-.75	-.01
43	922	0	129.24	.01	.00	1.92	8.07	4.51
44	922	923	-257.43	.00	.00	.00	-1.52	-.04
45	923	0	128.03	.01	.00	1.88	7.99	4.42
46	923	221	-385.46	.00	.00	-.01	-2.27	-.10
47	221	0	85.84	.01	.00	1.89	9.01	7.73
48	221	220	-471.31	-.01	.00	-.01	-2.77	-.15
49	220	0	86.47	.01	.00	1.92	9.07	7.85
50	220	219	-557.78	-.01	.00	-.02	-3.28	-.21
LINE	51	IS CLOSED						
52	217	216	-644.83	-.01	.00	-.02	-3.80	-.28
53	212	0	87.77	.01	.00	2.22	9.76	9.42
54	212	211	-732.60	-.02	.00	-.03	-4.31	-.36
LINE	55	IS CLOSED						
56	207	206	-809.33	-.02	.00	-.04	-4.76	-.44
57	204	0	66.78	.02	.00	2.64	10.65	14.07
58	204	203	-876.11	-.02	.00	-.04	-5.16	-.52
59	9	10	-876.11	-.30	.00	-31.14	-14.16	-6.09
60	10	11	-876.11	-.15	.00	-6.37	-14.16	-6.09
61	11	12	-876.11	-.07	.00	-18.19	-14.16	-6.09
62	12	0	-876.11	-.02	.00	-.93	-14.16	-6.09
LINE	63	IS CLOSED						
64	206	205	-809.33	-.02	.00	-.04	-4.76	-.44
LINE	65	IS CLOSED						
66	205	204	-809.33	-.02	.00	-.04	-4.76	-.44
LINE	67	IS CLOSED						
68	211	210	-732.60	-.01	.00	-.03	-4.31	-.36
LINE	69	IS CLOSED						
70	210	209	-732.60	-.02	.00	-.03	-4.31	-.36
LINE	71	IS CLOSED						
72	209	208	-732.60	-.01	.00	-.03	-4.31	-.36
73	208	0	76.73	.02	.00	2.41	10.17	11.39
74	208	207	-809.33	-.02	.00	-.04	-4.76	-.44
LINE	75	IS CLOSED						
76	216	215	-644.83	-.01	.00	-.02	-3.80	-.28
LINE	77	IS CLOSED						
78	215	214	-644.83	-.01	.00	-.02	-3.80	-.28
LINE	79	IS CLOSED						
80	214	213	-644.83	-.01	.00	-.02	-3.80	-.28
LINE	81	IS CLOSED						
82	213	212	-644.83	-.01	.00	-.02	-3.80	-.28
83	219	0	87.05	.01	.00	1.94	9.14	7.95
84	219	218	-644.83	-.01	.00	-.02	-3.80	-.28
LINE	85	IS CLOSED						
86	218	217	-644.83	-.01	.00	-.02	-3.80	-.28
87	203	202	-876.11	-.02	.00	-.04	-5.16	-.52
LINE	88	IS CLOSED						
89	202	201	-876.11	-.02	.00	-.04	-5.16	-.52
LINE	90	IS CLOSED						
LINE	91	IS CLOSED						
92	201	9	-876.11	-.04	.00	.00	-5.16	-.52
93	1140	201	.00	.00	.00	.00	.00	.00

JUNCTION	NUMBER	DEMAND	GRADE LINE	ELEVATION	PRESSURE
	1	.00	74.75		
	2	.00	58.88		
	3	.00	31.83		
	4	.00	31.85		
	5	.00	31.76		
	9	.00	17.99		
	10	.00	49.43		

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11	.00	55.94
12	.00	74.20
102	.00	17.07
103	.00	31.72
104	.00	31.84
105	.00	31.87
106	.00	31.90
107	.00	31.96
108	.00	32.03
109	.00	32.09
110	.00	32.15
111	.00	32.22
112	.00	32.28
113	.00	32.45
201	.00	17.94
202	.00	17.88
203	.00	17.82
204	.00	17.77
205	.00	17.70
206	.00	17.65
207	.00	17.60
208	.00	17.54
209	.00	17.50
210	.00	17.45
211	.00	17.41
212	.00	17.36
213	.00	17.33
214	.00	17.30
215	.00	17.26
216	.00	17.23
217	.00	17.19
218	.00	17.16
219	.00	17.13
220	.00	17.10
221	.00	17.08
921	.00	17.07
922	.00	17.07
923	.00	17.07
1030	.00	31.72
1040	.00	31.84
1050	.00	31.87
1060	.00	31.89
1070	.00	31.96
1080	.00	32.03
1090	.00	32.09
1100	.00	32.15
1110	.00	32.22
1120	.00	32.28
1130	.00	32.45
1140	.00	17.94

THE NET SYSTEM DEMAND = .00

SUMMARY OF INFLOWS(+) AND OUTFLOWS(-) FROM FIXED GRADE NODES

PIPE NUMBER	FLOWRATE
1	259.34
26	-84.09
38	-175.25
41	-128.19
43	-129.24
45	-128.03
47	-85.84

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49	-86.47
53	-87.77
57	-66.78
62	876.11
73	-76.73
83	-87.05

THE NET FLOW INTO THE SYSTEM FROM FIXED GRADE NODES = 1135.45
THE NET FLOW OUT OF THE SYSTEM INTO FIXED GRADE NODES = -1135.45

A SUMMARY OF CONDITIONS SPECIFIED FOR THE NEXT SIMULATION FOLLOWS

Fish Passage Program version 2.0

Input File:fish.inp
Output File:fish.out
Data File:bonna.fdr

BONNEVILLE

Tailwater: 13.75 13.75 (N&S)
Head @ Top Weir: 1.20

Fish Ladder Discharge: 238.75
Weir Component: 189.81
Orifice Component: 48.94

Weir no.	Weir Width	Crest Len	Crest Elev	W.S. Elev	Q	Weir Q	Orifice Q	h0	h1	h2	Weir Vel	Weir Coef
Collection Channel				15.17								
10	30.00	30.00	8.50	15.23	378.71	369.27	11.50	0.07	6.73	6.67	1.83	4.50
11	30.00	30.00	9.75	15.33	378.71	365.35	13.83	0.09	5.58	5.48	2.18	4.50
12	30.00	30.00	11.00	15.47	378.71	362.13	17.37	0.15	4.47	4.33	2.70	4.50
13	30.00	30.00	12.25	15.73	378.71	355.31	22.86	0.26	3.48	3.22	3.40	4.50
Ladder Diffuser				3 Discharge:	175.24	Vel:	0.61					
14	30.00	30.00	13.50	15.88	203.47	185.77	17.26	0.15	2.38	2.23	2.60	4.50
15	30.00	30.00	14.75	16.37	203.47	263.55	31.31	0.49	1.62	1.13	5.44	4.50
16	30.00	30.00	16.00	17.14	203.47	164.04	39.50	0.77	1.14	0.37	4.80	4.50
Ladder Diffuser				4 Discharge:	0.00	Vel:	0.00					
17	30.00	30.00	17.00	18.12	203.47	159.21	44.43	0.98	1.12	0.14	4.75	4.50
18	30.00	30.00	18.00	19.11	203.47	158.58	44.87	1.00	1.11	0.12	4.75	4.50
19	33.20	30.00	19.00	20.11	203.47	158.37	44.92	1.00	1.11	0.11	4.75	4.50
Ladder Diffuser				5 Discharge:	0.00	Vel:	0.00					
20	40.00	30.20	20.00	21.11	203.47	158.80	44.87	1.00	1.11	0.11	4.74	4.50
21	40.00	30.20	21.00	22.11	203.47	158.59	44.92	1.00	1.11	0.11	4.74	4.50
22	40.00	30.30	22.00	23.11	203.47	158.48	44.87	1.00	1.11	0.11	4.73	4.50
Ladder Diffuser				6 Discharge:	84.10	Vel:	0.15					
23	40.00	10.40	23.00	24.31	119.37	70.14	49.31	1.20	1.31	0.11	5.15	4.50
24	40.00	10.40	24.00	25.35	119.37	73.46	45.85	1.04	1.35	0.31	5.23	4.50
25	40.00	10.40	25.00	26.36	119.37	74.26	45.16	1.01	1.36	0.35	5.25	4.50

APPENDIX C- Item 2

Ladder Diffuser			7 Discharge:		0.00 Vel:		0.00					
26	40.00	10.40	26.00	27.36	119.37	74.43	44.99	1.00	1.36	0.36	5.25	4.50
27	40.00	10.40	27.00	28.36	119.37	74.45	44.95	1.00	1.36	0.36	5.25	4.50
28	40.00	10.40	28.00	29.36	119.37	74.37	44.92	1.00	1.36	0.36	5.25	4.50
Ladder Diffuser			8 Discharge:		0.00 Vel:		0.00					
29	40.00	10.40	29.00	30.36	119.37	74.49	44.97	1.00	1.36	0.36	5.25	4.50
30	40.00	10.40	30.00	31.36	119.37	74.41	44.92	1.00	1.36	0.36	5.25	4.50
31	40.00	10.40	31.00	32.36	119.37	74.41	44.94	1.00	1.36	0.36	5.25	4.50
Ladder Diffuser			9 Discharge:		0.00 Vel:		0.00					
32	40.00	10.40	32.00	33.36	119.37	74.41	44.94	1.00	1.36	0.36	5.25	4.50
33	40.00	10.40	33.00	34.36	119.37	74.41	44.94	1.00	1.36	0.36	5.25	4.50
34	40.00	10.40	34.00	35.36	119.37	74.41	44.94	1.00	1.36	0.36	5.25	4.50
Ladder Diffuser			10 Discharge:		0.00 Vel:		0.00					
35	40.00	10.40	35.00	36.36	119.37	74.41	44.94	1.00	1.36	0.36	5.25	4.50
36	40.00	10.40	36.00	37.36	119.37	74.41	44.94	1.00	1.36	0.36	5.25	4.50
37	40.00	10.40	37.00	38.36	119.37	74.41	44.94	1.00	1.36	0.36	5.25	4.50
Ladder Diffuser			11 Discharge:		0.00 Vel:		0.00					
38	40.00	10.40	38.00	39.36	119.37	74.41	44.94	1.00	1.36	0.36	5.25	4.50
39	40.00	10.40	39.00	40.36	119.37	74.41	44.94	1.00	1.36	0.36	5.25	4.50
40	40.00	10.40	40.00	41.36	119.37	74.41	44.94	1.00	1.36	0.36	5.25	4.50
Ladder Diffuser			12 Discharge:		0.00 Vel:		0.00					
41	40.00	10.40	41.00	42.36	119.37	74.41	44.94	1.00	1.36	0.36	5.25	4.50
42	40.00	10.40	42.00	43.36	119.37	74.41	44.94	1.00	1.36	0.36	5.25	4.50
43	40.00	10.40	43.00	44.36	119.37	74.41	44.94	1.00	1.36	0.36	5.25	4.50
44	40.00	10.40	44.00	45.36	119.37	74.41	44.94	1.00	1.36	0.36	5.25	4.50
45	40.00	10.40	45.00	46.36	119.37	74.41	44.94	1.00	1.36	0.36	5.25	4.50
46	40.00	10.40	46.00	47.36	119.37	74.41	44.94	1.00	1.36	0.36	5.25	4.50
47	40.00	10.40	47.00	48.36	119.37	74.41	44.94	1.00	1.36	0.36	5.25	4.50
48	40.00	10.40	48.00	49.36	119.37	74.41	44.94	1.00	1.36	0.36	5.25	4.50
49	40.00	10.40	49.00	50.36	119.37	74.41	44.94	1.00	1.36	0.36	5.25	4.50
50	40.00	10.40	50.00	51.36	119.37	74.41	44.94	1.00	1.36	0.36	5.25	4.50
51	40.00	10.40	51.00	52.36	119.37	74.41	44.94	1.00	1.36	0.36	5.25	4.50
52	40.00	10.40	52.00	53.36	119.37	74.41	44.94	1.00	1.36	0.36	5.25	4.50
53	40.00	10.40	53.00	54.36	119.37	74.41	44.94	1.00	1.36	0.36	5.25	4.50
Ladder Diffuser			13 Discharge:		0.00 Vel:		0.00 @ 50%					
54	57.00	57.00	54.00	55.01	238.75	202.43	36.16	0.65	1.01	0.36	3.52	3.50
55	47.00	47.00	55.00	56.11	238.75	191.45	47.06	1.10	1.11	0.01	3.68	3.50
56	42.00	42.00	56.00	57.19	238.75	191.87	46.87	1.09	1.19	0.11	3.82	3.50
57	42.00	42.00	57.00	58.20	238.75	193.76	45.12	1.01	1.20	0.19	3.84	3.50
58	42.00	42.00	58.00	59.20	238.75	193.76	44.94	1.00	1.20	0.20	3.84	3.50
59	42.00	42.00	59.00	60.20	238.75	193.76	44.94	1.00	1.20	0.20	3.84	3.50
60	42.00	42.00	60.00	61.20	238.75	193.76	44.94	1.00	1.20	0.20	3.84	3.50
61	42.00	42.00	61.00	62.20	238.75	193.76	44.94	1.00	1.20	0.20	3.84	3.50

APPENDIX C- Item 2

62	42.00	42.00	62.00	63.20	238.75	193.76	44.94	1.00	1.20	0.20	3.84	3.50
63	42.00	42.00	63.00	64.20	238.75	193.76	44.94	1.00	1.20	0.20	3.84	3.50
64	42.00	42.00	64.00	65.20	238.75	193.76	44.94	1.00	1.20	0.20	3.84	3.50
65	42.00	42.00	65.00	66.20	238.75	193.76	44.94	1.00	1.20	0.20	3.84	3.50

---Entrance----- Gate No.	Discharge (cfs)	---PCC Diffuser----- No.	Discharge (cfs)	Velocity (fps)	-----PCC----- Discharge (cfs)	Velocity (fps)	Elev (ft)	--Distance to- South Entrance (ft)
		223	128.19	0.47	378.71			
65	0.00				506.90	1.68	15.17	912.
	Weir Elev: 40.00 ft							
	Head: 1.39 ft				506.90	1.68	15.14	905.
		222	129.24	0.47				
					636.14	2.11	15.14	898.
64	495.18							
	Weir Elev: 5.50 ft							
		221	128.03	0.47				
					140.96	0.47	15.12	890.
62	74.65				268.99	0.89	15.18	884.
					194.34	0.64	15.17	860.
		210	85.84	0.14	280.18	0.93	15.18	852.
		200	86.47	0.14				
					366.65	1.21	15.17	814.
58	74.31							
					292.34	0.97	15.16	805.
		190	87.05	0.14				
					379.39	1.26	15.17	770.
		180	0.00	0.00				
					379.39	1.26	15.15	730.
		170	0.00	0.00				
					379.39	1.26	15.15	690.
		160	0.00	0.00				
					379.39	1.26	15.15	650.
		150	0.00	0.00				
					379.39	1.26	15.14	610.
		140	0.00	0.00				
					379.39	1.26	15.14	570.

APPENDIX C- Item 2

		130	0.00	0.00				
		120	87.77	0.14	379.39	1.26	15.14	530.
34	73.23				467.15	1.55	15.13	490.
		110	0.00	0.00	393.92	1.31	15.12	480.
		100	0.00	0.00	393.92	1.31	15.13	450.
		90	0.00	0.00	393.92	1.31	15.12	410.
		80	76.74	0.12	393.92	1.31	15.12	365.
21	72.75				470.66	1.56	15.12	325.
		70	0.00	0.00	397.91	1.32	15.10	300.
		60	0.00	0.00	397.91	1.32	15.11	285.
		50	0.00	0.00	397.91	1.32	15.11	245.
		40	66.78	0.11	397.91	1.32	15.10	205.
9	72.35				464.69	1.55	15.10	165.
		30	0.00	0.00	392.34	1.30	15.09	140.
		20	0.00	0.00	392.34	1.30	15.09	120.
2	392.33				392.34	1.15	15.09	80.
	Weir Elev: 5.90 ft				0.01	0.00	15.09	15.
		14	0.00	0.00	0.01	0.00	15.11	15.
1	0.00				0.01	0.00	15.11	0.
	Weir Elev: 40.00 ft							
	Head: 1.36 ft							

Summary Table						
			Tailwater Elevation(N&S):		13.75	13.75
			Channel Head:		1.39	1.36
Inflows			Q	V	Outflows	
-----					-----	
Fish Ladder	Discharge	:	238.75		B Branch Fish Ladder:	119.37
Ladder	Diffuser	6:	84.10	0.15	Entrance 65:	0.00
Ladder	Diffuser	3:	175.24	0.61	Entrance 64:	495.18
	PCC Diffuser	223:	128.19	0.47	Entrance 62:	74.65
	PCC Diffuser	222:	129.24	0.47	Entrance 58:	74.31
	PCC Diffuser	221:	128.03	0.47	Entrance 34:	73.23
	PCC Diffuser	210:	85.84	0.14	Entrance 21:	72.75
	PCC Diffuser	200:	86.47	0.14	Entrance 9:	72.35
	PCC Diffuser	190:	87.05	0.14	Entrance 2:	392.33
	PCC Diffuser	120:	87.77	0.14	Entrance 1:	0.00
	PCC Diffuser	80:	76.74	0.12		
	PCC Diffuser	40:	66.78	0.11		
Total Inflow:			1374.18		Total Outflow:	1374.17

JUNCTION NUMBER DEMAND
 THE NET SYSTEM DEMAND = .00

SUMMARY OF INFLOWS(+) AND OUTFLOWS(-) FROM FIXED GRADE NODES

PIPE NUMBER	FLOWRATE	GRADE
1	259.34	75.16
26	-84.09	23.11
38	-175.25	15.73
41	-128.19	15.17
43	-129.24	15.14
45	-128.03	15.18
47	-85.84	15.18
49	-86.47	15.17

53	-87.77	15.13
57	-66.78	15.10
62	876.11	75.16
73	-76.73	15.12
83	-87.05	15.17

THE NET FLOW INTO THE SYSTEM FROM FIXED GRADE NODES = 1135.45
THE NET FLOW OUT OF THE SYSTEM INTO FIXED GRADE NODES = -1135.45

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FLOWRATE IS EXPRESSED IN CFS AND PRESSURE IN PSIG

A SUMMARY OF THE ORIGINAL DATA FOLLOWS

THE DARCY WEISBACH HEAD LOSS EQUATION IS USED, THE KINEMATIC VIS. = .0000100

PIPE NO.	NODE NOS.	LENGTH (FEET)	DIAMETER (INCHES)	ROUGHNESS	MINOR LOSS K	FIXED GRADE
1	0 1	80.0	116.0	4.0	2.00	75.76
2	1 2	200.0	98.0	5.1	38.43	
3	2 113	200.0	101.6	5.1	72.75	
4	113 1130	5.0	70.3	5.2	.00	
5	1130 0	1.5	40.6	4.8	1.00	1000.00
LINE 5	IS CLOSED					
6	113 112	200.0	101.6	5.1	.10	
7	112 1120	6.0	70.3	5.2	.00	
8	1120 0	1.5	40.6	4.8	1.00	1000.00
LINE 8	IS CLOSED					
9	112 111	45.0	101.6	5.1	.10	
10	111 1110	7.0	70.3	5.2	.00	
11	1110 0	1.5	40.6	4.8	1.00	1000.00
LINE 11	IS CLOSED					
12	111 110	45.0	101.6	5.1	.10	
13	110 1100	8.0	70.3	5.2	.00	
14	1100 0	1.5	40.6	4.8	1.00	1000.00
LINE 14	IS CLOSED					
15	110 109	45.0	101.6	5.1	.10	
16	109 1090	9.0	70.3	5.2	.00	
17	1090 0	1.5	40.6	4.8	1.30	1000.00
LINE 17	IS CLOSED					
18	109 108	45.0	101.6	5.1	.10	
19	108 1080	10.0	70.3	5.2	.10	
20	1080 0	1.5	40.6	4.8	1.30	1000.00
LINE 20	IS CLOSED					
21	108 107	45.0	101.6	5.1	.10	
22	107 1070	12.0	70.3	5.2	.00	
23	1070 0	1.5	40.6	4.8	1.30	1000.00
LINE 23	IS CLOSED					
24	107 106	45.0	101.6	5.1	.10	
25	106 1060	13.0	70.3	5.2	.00	
26	1060 0	1.5	28.7	4.8	1.60	23.00
27	106 105	45.0	101.6	5.1	.10	
28	105 1050	19.0	70.3	5.2	.00	
29	1050 0	1.5	40.6	4.8	1.30	1000.00
LINE 29	IS CLOSED					
30	105 104	45.0	101.6	5.1	.10	
31	104 1040	21.0	70.3	5.2	.00	
32	1040 0	1.5	40.6	4.8	1.30	1000.00
LINE 32	IS CLOSED					
33	104 3	3.0	101.6	5.1	.10	
34	3 4	8.0	101.6	5.1	.00	
35	4 5	1.0	36.7	5.1	.00	
36	5 103	19.0	70.3	5.1	.00	
37	103 1030	1.0	70.3	5.2	.00	

1010rev.txt							
38	1030	0	1.5	40.6	4.8	2.70	14.03
39	4	102	300.0	.5	5.1	100.00	
40	102	921	25.0	101.6	5.1	.40	
41	921	0	1.5	54.2	4.9	1.90	11.39
42	921	922	15.0	176.5	11.0	.10	
43	922	0	1.5	54.2	4.9	1.90	11.36
44	922	923	15.0	176.5	11.0	.10	
45	923	0	1.5	54.2	4.9	1.90	11.42
46	923	221	30.0	176.5	11.0	.10	
47	221	0	1.5	41.8	4.8	1.50	11.42
48	221	220	40.0	176.5	11.0	.10	
49	220	0	1.5	41.8	4.8	1.50	11.42
50	220	219	45.0	176.5	11.0	.10	
51	217	0	1.5	41.8	4.8	1.50	1000.00
LINE	51	IS CLOSED					
52	217	216	40.0	176.5	11.0	.10	
53	212	0	1.5	40.6	4.8	1.50	11.37
54	212	211	45.0	176.5	11.0	.10	
55	207	0	1.5	36.1	4.8	1.50	1000.00
LINE	55	IS CLOSED					
56	207	206	40.0	176.5	11.0	.10	
57	204	0	1.5	33.9	4.8	1.50	11.29
58	204	203	40.0	176.5	11.0	.10	
59	9	10	50.0	106.5	5.2	10.00	
60	10	11	24.0	106.5	5.2	8.57	
61	11	12	12.0	106.5	5.2	9.07	
62	12	0	4.0	106.5	5.2	.30	75.76
63	206	0	1.5	36.1	4.8	1.50	1000.00
LINE	63	IS CLOSED					
64	206	205	45.0	176.5	11.0	.10	
65	205	0	1.5	35.0	4.8	1.50	1000.00
LINE	65	IS CLOSED					
66	205	204	40.0	176.5	11.0	.10	
67	211	0	1.5	39.5	4.8	1.50	1000.00
LINE	67	IS CLOSED					
68	211	210	40.0	176.5	11.0	.10	
69	210	0	1.5	39.5	4.8	1.50	1000.00
LINE	69	IS CLOSED					
70	210	209	45.0	176.5	11.0	.10	
71	209	0	1.5	38.4	4.8	1.50	1000.00
LINE	71	IS CLOSED					
72	209	208	40.0	176.5	11.0	.10	
73	208	0	1.5	37.2	4.8	1.50	11.33
74	208	207	45.0	176.5	11.0	.10	
75	216	0	1.5	41.8	4.8	1.50	1000.00
LINE	75	IS CLOSED					
76	216	215	45.0	176.5	11.0	.10	
77	215	0	1.5	41.8	4.8	1.50	1000.00
LINE	77	IS CLOSED					
78	215	214	40.0	176.5	11.0	.10	
79	214	0	1.5	40.6	4.8	1.50	1000.00
LINE	79	IS CLOSED					
80	214	213	45.0	176.5	11.0	.10	
81	213	0	1.5	40.6	4.8	1.50	1000.00
LINE	81	IS CLOSED					
82	213	212	40.0	176.5	11.0	.10	
83	219	0	1.5	41.8	4.8	1.50	11.41
84	219	218	40.0	176.5	11.0	.10	
85	218	0	1.5	41.8	4.8	1.50	1000.00
LINE	85	IS CLOSED					
86	218	217	40.0	176.5	11.0	.10	
87	203	202	40.0	176.5	11.0	.10	
88	203	0	1.5	54.2	4.9	1.10	1000.00

1010rev.txt

LINE	88	IS	CLOSED					
89	202	201		40.0	176.5	11.0	.10	
90	202	0		1.5	54.2	4.9	1.10	1000.00
LINE	90	IS	CLOSED					
91	1140	0		1.5	54.2	4.9	1.10	1000.00
LINE	91	IS	CLOSED					
92	201	9		84.0	176.5	11.0	.00	
93	1140	201		84.0	234.5	7.4	4.00	

JUNCTION	NUMBER	DEMAND	ELEVATION	CONNECTING	PIPES
1	.00	.00	1	2	
2	.00	.00	2	3	
3	.00	.00	33	34	
4	.00	.00	34	35	39
5	.00	.00	35	36	
9	.00	.00	59	92	
10	.00	.00	59	60	
11	.00	.00	60	61	
12	.00	.00	61	62	
102	.00	.00	39	40	
103	.00	.00	36	37	
104	.00	.00	30	31	33
105	.00	.00	27	28	30
106	.00	.00	24	25	27
107	.00	.00	21	22	24
108	.00	.00	18	19	21
109	.00	.00	15	16	18
110	.00	.00	12	13	15
111	.00	.00	9	10	12
112	.00	.00	6	7	9
113	.00	.00	3	4	6
201	.00	.00	89	92	93
202	.00	.00	87	89	90
203	.00	.00	58	87	88
204	.00	.00	57	58	66
205	.00	.00	64	65	66
206	.00	.00	56	63	64
207	.00	.00	55	56	74
208	.00	.00	72	73	74
209	.00	.00	70	71	72
210	.00	.00	68	69	70
211	.00	.00	54	67	68
212	.00	.00	53	54	82
213	.00	.00	80	81	82
214	.00	.00	78	79	80
215	.00	.00	76	77	78
216	.00	.00	52	75	76
217	.00	.00	51	52	86
218	.00	.00	84	85	86
219	.00	.00	50	83	84
220	.00	.00	48	49	50
221	.00	.00	46	47	48
921	.00	.00	40	41	42
922	.00	.00	42	43	44
923	.00	.00	44	45	46
1030	.00	.00	37	38	
1040	.00	.00	31	32	
1050	.00	.00	28	29	
1060	.00	.00	25	26	
1070	.00	.00	22	23	
1080	.00	.00	19	20	
1090	.00	.00	16	17	

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                                1010rev.txt
1100          .00          .00          13          14
1110          .00          .00          10          11
1120          .00          .00           7           8
1130          .00          .00           4           5
1140          .00          .00          91          93

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OUTPUT SELECTION: ALL RESULTS ARE OUTPUT EACH PERIOD

THIS SYSTEM HAS 93 PIPES WITH 57 JUNCTIONS , 0 LOOPS AND 37 FGNS

THE RESULTS ARE OBTAINED AFTER 4 TRIALS WITH AN ACCURACY = .00207

BONNEVILLE FIRST POWERHOUSE FISHLADDER
 Auxillary water supply system
 tailwater elevation = _____

PIPE NO.	NODE NOS.	FLOWRATE	HEAD LOSS	PUMP HEAD	MINOR LOSS	VELOCITY	HL/1000
1	0 1	271.28	.03	.00	.42	3.70	.36
2	1 2	271.28	.18	.00	16.00	5.18	.90
3	2 113	271.28	.15	.00	26.23	4.82	.75
4	113 1130	.00	.00	.00	.00	.00	.00
LINE 5	IS CLOSED						
6	113 112	271.28	.15	.00	.04	4.82	.75
7	112 1120	.00	.00	.00	.00	.00	.00
LINE 8	IS CLOSED						
9	112 111	271.28	.03	.00	.04	4.82	.75
10	111 1110	.00	.00	.00	.00	.00	.00
LINE 11	IS CLOSED						
12	111 110	271.28	.03	.00	.04	4.82	.75
13	110 1100	.00	.00	.00	.00	.00	.00
LINE 14	IS CLOSED						
15	110 109	271.28	.03	.00	.04	4.82	.75
16	109 1090	.00	.00	.00	.00	.00	.00
LINE 17	IS CLOSED						
18	109 108	271.28	.03	.00	.04	4.82	.75
19	108 1080	.00	.00	.00	.00	.00	.00
LINE 20	IS CLOSED						
21	108 107	271.28	.03	.00	.04	4.82	.75
22	107 1070	.00	.00	.00	.00	.00	.00
LINE 23	IS CLOSED						
24	107 106	271.28	.03	.00	.04	4.82	.75
25	106 1060	85.77	.01	.00	.00	3.18	.52
26	1060 0	85.77	.08	.00	9.06	19.09	55.63
27	106 105	185.50	.02	.00	.02	3.29	.35
28	105 1050	.00	.00	.00	.00	.00	.00
LINE 29	IS CLOSED						
30	105 104	185.50	.02	.00	.02	3.29	.35
31	104 1040	.00	.00	.00	.00	.00	.00
LINE 32	IS CLOSED						
33	104 3	185.50	.00	.00	.02	3.29	.35
34	3 4	185.50	.00	.00	.00	3.29	.35
35	4 5	185.50	.07	.00	.00	25.28	72.64
36	5 103	185.50	.05	.00	.00	6.88	2.40
37	103 1030	185.50	.00	.00	.00	6.88	2.41
38	1030 0	185.50	.06	.00	17.85	20.63	41.96
39	4 102	.00	17.32	.00	2.01	1.14	57.73
40	102 921	.00	.00	.00	.00	.00	.00

1010rev.txt									
41	921	0	108.43	.00	.00	1.35	6.77	3.18	
42	921	922	-108.43	.00	.00	.00	-.64	-.01	
43	922	0	109.65	.00	.00	1.38	6.84	3.25	
44	922	923	-218.08	.00	.00	.00	-1.28	-.03	
45	923	0	107.38	.00	.00	1.32	6.70	3.11	
46	923	221	-325.46	.00	.00	-.01	-1.92	-.07	
47	221	0	72.00	.01	.00	1.33	7.55	5.44	
48	221	220	-397.45	.00	.00	-.01	-2.34	-.11	
49	220	0	72.36	.01	.00	1.34	7.59	5.50	
50	220	219	-469.82	-.01	.00	-.01	-2.77	-.15	
LINE	51	IS CLOSED							
52	217	216	-542.94	-.01	.00	-.02	-3.20	-.20	
53	212	0	73.99	.01	.00	1.58	8.23	6.70	
54	212	211	-616.93	-.01	.00	-.02	-3.63	-.26	
LINE	55	IS CLOSED							
56	207	206	-682.18	-.01	.00	-.03	-4.01	-.31	
57	204	0	57.11	.02	.00	1.93	9.11	10.29	
58	204	203	-739.29	-.01	.00	-.03	-4.35	-.37	
59	9	10	-739.29	-.22	.00	-22.17	-11.95	-4.34	
60	10	11	-739.29	-.10	.00	-19.01	-11.95	-4.34	
61	11	12	-739.29	-.05	.00	-20.12	-11.95	-4.34	
62	12	0	-739.29	-.02	.00	-.67	-11.95	-4.34	
LINE	63	IS CLOSED							
64	206	205	-682.18	-.01	.00	-.03	-4.01	-.31	
LINE	65	IS CLOSED							
66	205	204	-682.18	-.01	.00	-.03	-4.01	-.31	
LINE	67	IS CLOSED							
68	211	210	-616.93	-.01	.00	-.02	-3.63	-.26	
LINE	69	IS CLOSED							
70	210	209	-616.93	-.01	.00	-.02	-3.63	-.26	
LINE	71	IS CLOSED							
72	209	208	-616.93	-.01	.00	-.02	-3.63	-.26	
73	208	0	65.25	.01	.00	1.74	8.65	8.25	
74	208	207	-682.18	-.01	.00	-.03	-4.01	-.31	
LINE	75	IS CLOSED							
76	216	215	-542.94	-.01	.00	-.02	-3.20	-.20	
LINE	77	IS CLOSED							
78	215	214	-542.94	-.01	.00	-.02	-3.20	-.20	
LINE	79	IS CLOSED							
80	214	213	-542.94	-.01	.00	-.02	-3.20	-.20	
LINE	81	IS CLOSED							
82	213	212	-542.94	-.01	.00	-.02	-3.20	-.20	
83	219	0	73.13	.01	.00	1.37	7.67	5.62	
84	219	218	-542.94	-.01	.00	-.02	-3.20	-.20	
LINE	85	IS CLOSED							
86	218	217	-542.94	-.01	.00	-.02	-3.20	-.20	
87	203	202	-739.29	-.01	.00	-.03	-4.35	-.37	
LINE	88	IS CLOSED							
89	202	201	-739.29	-.01	.00	-.03	-4.35	-.37	
LINE	90	IS CLOSED							
LINE	91	IS CLOSED							
92	201	9	-739.29	-.03	.00	.00	-4.35	-.37	
93	1140	201	.00	.00	.00	.00	.00	.00	

JUNCTION	NUMBER	DEMAND	GRADE LINE	ELEVATION	PRESSURE
1		.00	75.31		
2		.00	59.12		
3		.00	32.06		
4		.00	32.07		
5		.00	31.99		
9		.00	13.40		
10		.00	35.79		

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11	.00	54.90
12	.00	75.08
102	.00	12.75
103	.00	31.94
104	.00	32.08
105	.00	32.11
106	.00	32.15
107	.00	32.22
108	.00	32.29
109	.00	32.35
110	.00	32.42
111	.00	32.49
112	.00	32.56
113	.00	32.75
201	.00	13.37
202	.00	13.32
203	.00	13.28
204	.00	13.24
205	.00	13.20
206	.00	13.16
207	.00	13.12
208	.00	13.08
209	.00	13.05
210	.00	13.02
211	.00	12.99
212	.00	12.96
213	.00	12.93
214	.00	12.91
215	.00	12.89
216	.00	12.86
217	.00	12.84
218	.00	12.81
219	.00	12.79
220	.00	12.77
221	.00	12.76
921	.00	12.75
922	.00	12.75
923	.00	12.75
1030	.00	31.94
1040	.00	32.08
1050	.00	32.11
1060	.00	32.14
1070	.00	32.22
1080	.00	32.29
1090	.00	32.35
1100	.00	32.42
1110	.00	32.49
1120	.00	32.56
1130	.00	32.75
1140	.00	13.37

THE NET SYSTEM DEMAND = .00

SUMMARY OF INFLOWS(+) AND OUTFLOWS(-) FROM FIXED GRADE NODES

PIPE NUMBER	FLOWRATE
1	271.28
26	-85.77
38	-185.50
41	-108.43
43	-109.65
45	-107.38
47	-72.00

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49	-72.36
53	-73.99
57	-57.11
62	739.29
73	-65.25
83	-73.13

THE NET FLOW INTO THE SYSTEM FROM FIXED GRADE NODES = 1010.57
THE NET FLOW OUT OF THE SYSTEM INTO FIXED GRADE NODES = -1010.57

A SUMMARY OF CONDITIONS SPECIFIED FOR THE NEXT SIMULATION FOLLOWS

Fish Passage Program version 2.0

Input File:fish.inp
Output File:fish.out
Data File:bonna.fdr

BONNEVILLE

Tailwater: 10.00 10.00 (N&S)
Head @ Top Weir: 1.00

Fish Ladder Discharge: 191.94
Weir Component: 147.00
Orifice Component: 44.94

Weir no.	Weir Width	Crest Len	Crest Elev	W.S. Elev	Q	Weir Q	Orifice Q	h0	h1	h2	Weir Vel	Weir Coef
Collection Channel				11.39								
10	30.00	30.00	8.50	11.69	367.25	342.87	24.61	0.30	3.19	2.89	3.58	4.50
11	30.00	30.00	9.75	12.31	367.25	331.56	35.44	0.62	2.56	1.94	4.31	4.50
12	30.00	30.00	11.00	12.89	367.25	333.29	34.08	0.58	1.89	1.31	5.88	4.50
13	30.00	30.00	12.25	14.03	367.25	319.29	47.92	1.14	1.78	0.64	6.00	4.50
Ladder Diffuser				3 Discharge:	185.51	Vel:	0.64					
14	30.00	30.00	13.50	14.57	181.74	148.56	33.03	0.54	1.07	0.53	4.65	4.50
15	30.00	30.00	14.75	15.74	181.74	133.12	48.72	1.18	0.99	-0.18	4.48	4.50
16	30.00	30.00	16.00	16.98	181.74	131.45	50.08	1.24	0.98	-0.26	4.46	4.50
Ladder Diffuser				4 Discharge:	0.00	Vel:	0.00					
17	30.00	30.00	17.00	18.01	181.74	136.37	45.48	1.02	1.01	-0.02	4.52	4.50
18	30.00	30.00	18.00	19.01	181.74	136.76	44.98	1.00	1.01	0.01	4.52	4.50
19	33.20	30.00	19.00	20.01	181.74	136.73	44.94	1.00	1.01	0.01	4.52	4.50
Ladder Diffuser				5 Discharge:	0.00	Vel:	0.00					
20	40.00	30.20	20.00	21.01	181.74	137.05	44.87	1.00	1.01	0.01	4.51	4.50
21	40.00	30.20	21.00	22.00	181.74	136.85	44.92	1.00	1.00	0.01	4.51	4.50
22	40.00	30.30	22.00	23.00	181.74	136.70	44.87	1.00	1.00	0.00	4.50	4.50
Ladder Diffuser				6 Discharge:	85.77	Vel:	0.15					
23	40.00	10.40	23.00	24.05	95.97	50.02	45.91	1.04	1.05	0.00	4.60	4.50
24	40.00	10.40	24.00	25.06	95.97	50.83	45.19	1.01	1.06	0.05	4.63	4.50
25	40.00	10.40	25.00	26.06	95.97	51.04	45.01	1.00	1.06	0.06	4.63	4.50

APPENDIX C- Item 4

Ladder Diffuser			7 Discharge:		0.00 Vel:		0.00					
26	40.00	10.40	26.00	27.06	95.97	50.97	44.92	1.00	1.06	0.06	4.63	4.50
27	40.00	10.40	27.00	28.06	95.97	51.04	44.96	1.00	1.06	0.06	4.63	4.50
28	40.00	10.40	28.00	29.06	95.97	50.97	44.92	1.00	1.06	0.06	4.63	4.50
Ladder Diffuser			8 Discharge:		0.00 Vel:		0.00					
29	40.00	10.40	29.00	30.06	95.97	51.04	44.96	1.00	1.06	0.06	4.63	4.50
30	40.00	10.40	30.00	31.06	95.97	50.97	44.92	1.00	1.06	0.06	4.63	4.50
31	40.00	10.40	31.00	32.06	95.97	51.04	44.96	1.00	1.06	0.06	4.63	4.50
Ladder Diffuser			9 Discharge:		0.00 Vel:		0.00					
32	40.00	10.40	32.00	33.06	95.97	50.97	44.92	1.00	1.06	0.06	4.63	4.50
33	40.00	10.40	33.00	34.06	95.97	51.04	44.96	1.00	1.06	0.06	4.63	4.50
34	40.00	10.40	34.00	35.06	95.97	50.97	44.92	1.00	1.06	0.06	4.63	4.50
Ladder Diffuser			10 Discharge:		0.00 Vel:		0.00					
35	40.00	10.40	35.00	36.06	95.97	51.04	44.96	1.00	1.06	0.06	4.63	4.50
36	40.00	10.40	36.00	37.06	95.97	50.97	44.92	1.00	1.06	0.06	4.63	4.50
37	40.00	10.40	37.00	38.06	95.97	51.04	44.96	1.00	1.06	0.06	4.63	4.50
Ladder Diffuser			11 Discharge:		0.00 Vel:		0.00					
38	40.00	10.40	38.00	39.06	95.97	50.97	44.92	1.00	1.06	0.06	4.63	4.50
39	40.00	10.40	39.00	40.06	95.97	51.04	44.96	1.00	1.06	0.06	4.63	4.50
40	40.00	10.40	40.00	41.06	95.97	50.97	44.92	1.00	1.06	0.06	4.63	4.50
Ladder Diffuser			12 Discharge:		0.00 Vel:		0.00					
41	40.00	10.40	41.00	42.06	95.97	51.04	44.96	1.00	1.06	0.06	4.63	4.50
42	40.00	10.40	42.00	43.06	95.97	50.97	44.92	1.00	1.06	0.06	4.63	4.50
43	40.00	10.40	43.00	44.06	95.97	51.04	44.96	1.00	1.06	0.06	4.63	4.50
44	40.00	10.40	44.00	45.06	95.97	50.97	44.92	1.00	1.06	0.06	4.63	4.50
45	40.00	10.40	45.00	46.06	95.97	51.04	44.96	1.00	1.06	0.06	4.63	4.50
46	40.00	10.40	46.00	47.06	95.97	50.97	44.92	1.00	1.06	0.06	4.63	4.50
47	40.00	10.40	47.00	48.06	95.97	51.04	44.96	1.00	1.06	0.06	4.63	4.50
48	40.00	10.40	48.00	49.06	95.97	50.97	44.92	1.00	1.06	0.06	4.63	4.50
49	40.00	10.40	49.00	50.06	95.97	51.04	44.96	1.00	1.06	0.06	4.63	4.50
50	40.00	10.40	50.00	51.06	95.97	50.97	44.92	1.00	1.06	0.06	4.63	4.50
51	40.00	10.40	51.00	52.06	95.97	51.04	44.96	1.00	1.06	0.06	4.63	4.50
52	40.00	10.40	52.00	53.06	95.97	50.97	44.92	1.00	1.06	0.06	4.63	4.50
53	40.00	10.40	53.00	54.06	95.97	51.04	44.96	1.00	1.06	0.06	4.63	4.50
Ladder Diffuser			13 Discharge:		0.00 Vel:		0.00 @ 50%					
54	57.00	57.00	54.00	54.84	191.94	152.48	39.60	0.78	0.84	0.06	3.20	3.50
55	47.00	47.00	55.00	55.92	191.94	145.37	46.81	1.08	0.92	-0.16	3.36	3.50
56	42.00	42.00	56.00	56.99	191.94	145.50	46.54	1.07	0.99	-0.08	3.49	3.50
57	42.00	42.00	57.00	58.00	191.94	146.78	45.07	1.01	1.00	-0.01	3.50	3.50
58	42.00	42.00	58.00	59.00	191.94	146.78	44.94	1.00	1.00	0.00	3.50	3.50
59	42.00	42.00	59.00	60.00	191.94	146.78	44.94	1.00	1.00	0.00	3.50	3.50
60	42.00	42.00	60.00	61.00	191.94	146.78	44.94	1.00	1.00	0.00	3.50	3.50
61	42.00	42.00	61.00	62.00	191.94	146.78	44.94	1.00	1.00	0.00	3.50	3.50

APPENDIX C- Item 4

62	42.00	42.00	62.00	63.00	191.94	146.78	44.94	1.00	1.00	0.00	3.50	3.50
63	42.00	42.00	63.00	64.00	191.94	146.78	44.94	1.00	1.00	0.00	3.50	3.50
64	42.00	42.00	64.00	65.00	191.94	146.78	44.94	1.00	1.00	0.00	3.50	3.50
65	42.00	42.00	65.00	66.00	191.94	146.78	44.94	1.00	1.00	0.00	3.50	3.50

---Entrance----- Gate No.	Discharge (cfs)	---PCC Diffuser----- No.	Discharge (cfs)	Velocity (fps)	-----PCC----- Discharge (cfs)	Velocity (fps)	Elev (ft)	--Distance to- South Entrance (ft)
		223	108.42	0.39	367.25			
65	0.00				475.67	2.02	11.39	912.
	Weir Elev: 40.00 ft							
	Head: 1.36 ft				475.67	2.02	11.36	905.
		222	109.64	0.40				
					585.31	2.50	11.36	898.
64	619.84							
	Weir Elev: 2.00 ft							
		221	107.36	0.39	-34.53	-0.15	11.33	890.
					72.83	0.31	11.42	884.
62	0.00				72.83	0.31	11.42	860.
		210	71.99	0.12	144.82	0.61	11.42	852.
		200	72.38	0.12	217.20	0.92	11.42	814.
58	0.00				217.20	0.92	11.41	805.
		190	73.14	0.12	290.34	1.23	11.41	770.
		180	0.00	0.00	290.34	1.23	11.39	730.
		170	0.00	0.00	290.34	1.23	11.39	690.
		160	0.00	0.00	290.34	1.23	11.39	650.
		150	0.00	0.00	290.34	1.23	11.38	610.
		140	0.00	0.00	290.34	1.23	11.38	570.

APPENDIX C- Item 4

		130	0.00	0.00				
		120	73.98	0.12	290.34	1.23	11.37	530.
34	0.00				364.32	1.55	11.37	490.
		110	0.00	0.00	364.32	1.55	11.36	480.
		100	0.00	0.00	364.32	1.55	11.35	450.
		90	0.00	0.00	364.32	1.55	11.34	410.
		80	65.24	0.11	364.32	1.55	11.34	365.
21	0.00				429.57	1.83	11.33	325.
		70	0.00	0.00	429.57	1.83	11.31	300.
		60	0.00	0.00	429.57	1.83	11.31	285.
		50	0.00	0.00	429.57	1.84	11.30	245.
		40	57.12	0.09	429.57	1.84	11.29	205.
9	0.00				486.69	2.08	11.29	165.
		30	0.00	0.00	486.69	2.09	11.26	140.
		20	0.00	0.00	486.69	2.09	11.26	120.
2	486.63				486.69	1.84	11.25	80.
	Weir Elev: 2.00 ft				0.06	0.00	11.25	15.
		14	0.00	0.00	0.06	0.00	11.30	15.
1	0.00				0.06	0.00	11.30	0.
	Weir Elev: 40.00 ft							
	Head: 1.30 ft							

Summary Table						
			Tailwater Elevation(N&S):		10.00	10.00
			Channel Head:		1.36	1.30
Inflows			Q	V	Outflows	
-----					-----	
Fish Ladder	Discharge	:	191.94		B Branch Fish Ladder:	95.97
Ladder	Diffuser	6:	85.77	0.15	Entrance 65:	0.00
Ladder	Diffuser	3:	185.51	0.64	Entrance 64:	619.84
PCC	Diffuser	223:	108.42	0.39	Entrance 62:	0.00
PCC	Diffuser	222:	109.64	0.40	Entrance 58:	0.00
PCC	Diffuser	221:	107.36	0.39	Entrance 34:	0.00
PCC	Diffuser	210:	71.99	0.12	Entrance 21:	0.00
PCC	Diffuser	200:	72.38	0.12	Entrance 9:	0.00
PCC	Diffuser	190:	73.14	0.12	Entrance 2:	486.63
PCC	Diffuser	120:	73.98	0.12	Entrance 1:	0.00
PCC	Diffuser	80:	65.24	0.11		
PCC	Diffuser	40:	57.12	0.09		
Total Inflow:			1202.50		Total Outflow:	1202.44

JUNCTION NUMBER DEMAND
 THE NET SYSTEM DEMAND = .00

SUMMARY OF INFLOWS(+) AND OUTFLOWS(-) FROM FIXED GRADE NODES

PIPE NUMBER	FLOWRATE	GRADE
1	271.28	75.76
26	-85.77	23.00
38	-185.50	14.03
41	-108.43	11.39
43	-109.65	11.36
45	-107.38	11.42
47	-72.00	11.42
49	-72.36	11.42

53	-73.99	11.37
57	-57.11	11.29
62	739.29	75.76
73	-65.25	11.33
83	-73.13	11.41

THE NET FLOW INTO THE SYSTEM FROM FIXED GRADE NODES = 1010.57
THE NET FLOW OUT OF THE SYSTEM INTO FIXED GRADE NODES = -1010.57

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FLOWRATE IS EXPRESSED IN CFS AND PRESSURE IN PSIG

A SUMMARY OF THE ORIGINAL DATA FOLLOWS

THE DARCY WEISBACH HEAD LOSS EQUATION IS USED, THE KINEMATIC VIS. = .0000100

PIPE NO.	NODE NOS.	LENGTH (FEET)	DIAMETER (INCHES)	ROUGHNESS	MINOR LOSS K	FIXED GRADE
1	0 1	80.0	116.0	4.0	2.00	75.43
2	1 2	200.0	98.0	5.1	8.84	
3	2 113	200.0	101.6	5.1	13.43	
4	113 1130	5.0	70.3	5.2	.00	
5	1130 0	1.5	40.6	4.8	1.00	1000.00
LINE 5	IS CLOSED					
6	113 112	200.0	101.6	5.1	.10	
7	112 1120	6.0	70.3	5.2	.00	
8	1120 0	1.5	40.6	4.8	1.00	1000.00
LINE 8	IS CLOSED					
9	112 111	45.0	101.6	5.1	.10	
10	111 1110	7.0	70.3	5.2	.00	
11	1110 0	1.5	40.6	4.8	1.00	1000.00
LINE 11	IS CLOSED					
12	111 110	45.0	101.6	5.1	.10	
13	110 1100	8.0	70.3	5.2	.00	
14	1100 0	1.5	40.6	4.8	1.00	1000.00
LINE 14	IS CLOSED					
15	110 109	45.0	101.6	5.1	.10	
16	109 1090	9.0	70.3	5.2	.00	
17	1090 0	1.5	40.6	4.8	1.30	1000.00
LINE 17	IS CLOSED					
18	109 108	45.0	101.6	5.1	.10	
19	108 1080	10.0	70.3	5.2	.10	
20	1080 0	1.5	40.6	4.8	1.30	1000.00
LINE 20	IS CLOSED					
21	108 107	45.0	101.6	5.1	.10	
22	107 1070	12.0	70.3	5.2	.00	
23	1070 0	1.5	40.6	4.8	1.30	1000.00
LINE 23	IS CLOSED					
24	107 106	45.0	101.6	5.1	.10	
25	106 1060	13.0	70.3	5.2	.00	
26	1060 0	1.5	28.7	4.8	1.60	23.18
27	106 105	45.0	101.6	5.1	.10	
28	105 1050	19.0	70.3	5.2	.00	
29	1050 0	1.5	40.6	4.8	1.30	1000.00
LINE 29	IS CLOSED					
30	105 104	45.0	101.6	5.1	.10	
31	104 1040	21.0	70.3	5.2	.00	
32	1040 0	1.5	40.6	4.8	1.30	19.05
33	104 3	3.0	101.6	5.1	.10	
34	3 4	8.0	101.6	5.1	.00	
35	4 5	1.0	36.7	5.1	.00	
36	5 103	19.0	70.3	5.1	.00	
37	103 1030	1.0	70.3	5.2	.00	
38	1030 0	1.5	40.6	4.8	2.70	17.54

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39	4	102	300.0	.5	5.1	100.00	
40	102	921	25.0	101.6	5.1	.40	
41	921	0	1.5	54.2	4.9	1.90	16.63
42	921	922	15.0	176.5	11.0	.10	
43	922	0	1.5	54.2	4.9	1.90	16.60
44	922	923	15.0	176.5	11.0	.10	
45	923	0	1.5	54.2	4.9	1.90	16.67
46	923	221	30.0	176.5	11.0	.10	
47	221	0	1.5	41.8	4.8	1.50	16.66
48	221	220	40.0	176.5	11.0	.10	
49	220	0	1.5	41.8	4.8	1.50	16.65
50	220	219	45.0	176.5	11.0	.10	
51	217	0	1.5	41.8	4.8	1.50	1000.00
LINE 51	IS CLOSED						
52	217	216	40.0	176.5	11.0	.10	
53	212	0	1.5	40.6	4.8	1.50	16.58
54	212	211	45.0	176.5	11.0	.10	
55	207	0	1.5	36.1	4.8	1.50	1000.00
LINE 55	IS CLOSED						
56	207	206	40.0	176.5	11.0	.10	
57	204	0	1.5	33.9	4.8	1.50	16.49
58	204	203	40.0	176.5	11.0	.10	
59	9	10	50.0	106.5	5.2	10.00	
60	10	11	24.0	106.5	5.2	7.60	
61	11	12	12.0	106.5	5.2	9.71	
62	12	0	4.0	106.5	5.2	.30	75.43
63	206	0	1.5	36.1	4.8	1.50	1000.00
LINE 63	IS CLOSED						
64	206	205	45.0	176.5	11.0	.10	
65	205	0	1.5	35.0	4.8	1.50	1000.00
LINE 65	IS CLOSED						
66	205	204	40.0	176.5	11.0	.10	
67	211	0	1.5	39.5	4.8	1.50	1000.00
LINE 67	IS CLOSED						
68	211	210	40.0	176.5	11.0	.10	
69	210	0	1.5	39.5	4.8	1.50	1000.00
LINE 69	IS CLOSED						
70	210	209	45.0	176.5	11.0	.10	
71	209	0	1.5	38.4	4.8	1.50	1000.00
LINE 71	IS CLOSED						
72	209	208	40.0	176.5	11.0	.10	
73	208	0	1.5	37.2	4.8	1.50	16.54
74	208	207	45.0	176.5	11.0	.10	
75	216	0	1.5	41.8	4.8	1.50	1000.00
LINE 75	IS CLOSED						
76	216	215	45.0	176.5	11.0	.10	
77	215	0	1.5	41.8	4.8	1.50	1000.00
LINE 77	IS CLOSED						
78	215	214	40.0	176.5	11.0	.10	
79	214	0	1.5	40.6	4.8	1.50	1000.00
LINE 79	IS CLOSED						
80	214	213	45.0	176.5	11.0	.10	
81	213	0	1.5	40.6	4.8	1.50	1000.00
LINE 81	IS CLOSED						
82	213	212	40.0	176.5	11.0	.10	
83	219	0	1.5	41.8	4.8	1.50	16.64
84	219	218	40.0	176.5	11.0	.10	
85	218	0	1.5	41.8	4.8	1.50	1000.00
LINE 85	IS CLOSED						
86	218	217	40.0	176.5	11.0	.10	
87	203	202	40.0	176.5	11.0	.10	
88	203	0	1.5	54.2	4.9	1.10	1000.00
LINE 88	IS CLOSED						

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89	202	201	40.0	176.5	11.0	.10	
90	202	0	1.5	54.2	4.9	1.10	1000.00
LINE	90	IS CLOSED					
91	1140	0	1.5	54.2	4.9	1.10	1000.00
LINE	91	IS CLOSED					
92	201	9	84.0	176.5	11.0	.00	
93	1140	201	84.0	234.5	7.4	4.00	

JUNCTION NUMBER	DEMAND	ELEVATION	CONNECTING	PIPES
1	.00	.00	1	2
2	.00	.00	2	3
3	.00	.00	33	34
4	.00	.00	34	35
5	.00	.00	35	36
9	.00	.00	59	92
10	.00	.00	59	60
11	.00	.00	60	61
12	.00	.00	61	62
102	.00	.00	39	40
103	.00	.00	36	37
104	.00	.00	30	31
105	.00	.00	27	28
106	.00	.00	24	25
107	.00	.00	21	22
108	.00	.00	18	19
109	.00	.00	15	16
110	.00	.00	12	13
111	.00	.00	9	10
112	.00	.00	6	7
113	.00	.00	3	4
201	.00	.00	89	92
202	.00	.00	87	89
203	.00	.00	58	87
204	.00	.00	57	58
205	.00	.00	64	65
206	.00	.00	56	63
207	.00	.00	55	56
208	.00	.00	72	73
209	.00	.00	70	71
210	.00	.00	68	69
211	.00	.00	54	67
212	.00	.00	53	54
213	.00	.00	80	81
214	.00	.00	78	79
215	.00	.00	76	77
216	.00	.00	52	75
217	.00	.00	51	52
218	.00	.00	84	85
219	.00	.00	50	83
220	.00	.00	48	49
221	.00	.00	46	47
921	.00	.00	40	41
922	.00	.00	42	43
923	.00	.00	44	45
1030	.00	.00	37	38
1040	.00	.00	31	32
1050	.00	.00	28	29
1060	.00	.00	25	26
1070	.00	.00	22	23
1080	.00	.00	19	20
1090	.00	.00	16	17
1100	.00	.00	13	14

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                                0702rev.txt
1110          .00          .00          10          11
1120          .00          .00          7           8
1130          .00          .00          4           5
1140          .00          .00          91          93

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OUTPUT SELECTION: ALL RESULTS ARE OUTPUT EACH PERIOD

THIS SYSTEM HAS 93 PIPES WITH 57 JUNCTIONS , 0 LOOPS AND 37 FGNS

THE RESULTS ARE OBTAINED AFTER 4 TRIALS WITH AN ACCURACY = .00401

BONNEVILLE FIRST POWERHOUSE FISHLADDER
 Auxillary water supply system
 tailwater elevation = _____

PIPE NO.	NODE NOS.	FLOWRATE	HEAD LOSS	PUMP HEAD	MINOR LOSS	VELOCITY	HL/1000
1	0 1	541.90	.11	.00	1.69	7.38	1.41
2	1 2	541.90	.72	.00	14.68	10.35	3.59
3	2 113	541.90	.59	.00	19.31	9.63	2.97
4	113 1130	.00	.00	.00	.00	.00	.00
LINE 5	IS CLOSED						
6	113 112	541.90	.59	.00	.14	9.63	2.97
7	112 1120	.00	.00	.00	.00	.00	.00
LINE 8	IS CLOSED						
9	112 111	541.90	.13	.00	.14	9.63	2.97
10	111 1110	.00	.00	.00	.00	.00	.00
LINE 11	IS CLOSED						
12	111 110	541.90	.13	.00	.14	9.63	2.97
13	110 1100	.00	.00	.00	.00	.00	.00
LINE 14	IS CLOSED						
15	110 109	541.90	.13	.00	.14	9.63	2.97
16	109 1090	.00	.00	.00	.00	.00	.00
LINE 17	IS CLOSED						
18	109 108	541.90	.13	.00	.14	9.63	2.97
19	108 1080	.00	.00	.00	.00	.00	.00
LINE 20	IS CLOSED						
21	108 107	541.90	.13	.00	.14	9.63	2.97
22	107 1070	.00	.00	.00	.00	.00	.00
LINE 23	IS CLOSED						
24	107 106	541.90	.13	.00	.14	9.63	2.97
25	106 1060	101.22	.01	.00	.00	3.76	.72
26	1060 0	101.22	.12	.00	12.61	22.53	77.45
27	106 105	440.67	.09	.00	.10	7.83	1.97
28	105 1050	.00	.00	.00	.00	.00	.00
LINE 29	IS CLOSED						
30	105 104	440.67	.09	.00	.10	7.83	1.97
31	104 1040	255.39	.10	.00	.00	9.47	4.56
32	1040 0	255.39	.12	.00	16.29	28.41	79.48
33	104 3	185.28	.00	.00	.02	3.29	.35
34	3 4	185.28	.00	.00	.00	3.29	.35
35	4 5	185.28	.07	.00	.00	25.25	72.46
36	5 103	185.28	.05	.00	.00	6.87	2.39
37	103 1030	185.28	.00	.00	.00	6.87	2.40
38	1030 0	185.28	.06	.00	17.80	20.61	41.86
39	4 102	.00	15.84	.00	1.83	1.09	52.80
40	102 921	.00	.00	.00	.00	.00	.00
41	921 0	103.95	.00	.00	1.24	6.49	2.92

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42	921	922	-103.95	.00	.00	.00	-.61	-.01
43	922	0	105.22	.00	.00	1.27	6.57	2.99
44	922	923	-209.17	.00	.00	.00	-1.23	-.03
45	923	0	102.42	.00	.00	1.21	6.39	2.83
46	923	221	-311.58	.00	.00	-.01	-1.83	-.07
47	221	0	68.95	.01	.00	1.22	7.24	4.99
48	221	220	-380.54	.00	.00	-.01	-2.24	-.10
49	220	0	69.56	.01	.00	1.24	7.30	5.08
50	220	219	-450.09	-.01	.00	-.01	-2.65	-.14
LINE 51	IS	CLOSED						
52	217	216	-520.40	-.01	.00	-.01	-3.06	-.18
53	212	0	71.69	.01	.00	1.48	7.97	6.29
54	212	211	-592.10	-.01	.00	-.02	-3.48	-.24
LINE 55	IS	CLOSED						
56	207	206	-655.32	-.01	.00	-.02	-3.86	-.29
57	204	0	55.47	.01	.00	1.82	8.85	9.71
58	204	203	-710.79	-.01	.00	-.03	-4.18	-.34
59	9	10	-710.79	-.20	.00	-20.50	-11.49	-4.01
60	10	11	-710.79	-.10	.00	-15.57	-11.49	-4.01
61	11	12	-710.79	-.05	.00	-19.91	-11.49	-4.01
62	12	0	-710.79	-.02	.00	-.61	-11.49	-4.01
LINE 63	IS	CLOSED						
64	206	205	-655.32	-.01	.00	-.02	-3.86	-.29
LINE 65	IS	CLOSED						
66	205	204	-655.32	-.01	.00	-.02	-3.86	-.29
LINE 67	IS	CLOSED						
68	211	210	-592.10	-.01	.00	-.02	-3.48	-.24
LINE 69	IS	CLOSED						
70	210	209	-592.10	-.01	.00	-.02	-3.48	-.24
LINE 71	IS	CLOSED						
72	209	208	-592.10	-.01	.00	-.02	-3.48	-.24
73	208	0	63.23	.01	.00	1.63	8.38	7.74
74	208	207	-655.32	-.01	.00	-.02	-3.86	-.29
LINE 75	IS	CLOSED						
76	216	215	-520.40	-.01	.00	-.01	-3.06	-.18
LINE 77	IS	CLOSED						
78	215	214	-520.40	-.01	.00	-.01	-3.06	-.18
LINE 79	IS	CLOSED						
80	214	213	-520.40	-.01	.00	-.01	-3.06	-.18
LINE 81	IS	CLOSED						
82	213	212	-520.40	-.01	.00	-.01	-3.06	-.18
83	219	0	70.31	.01	.00	1.27	7.38	5.19
84	219	218	-520.40	-.01	.00	-.01	-3.06	-.18
LINE 85	IS	CLOSED						
86	218	217	-520.40	-.01	.00	-.01	-3.06	-.18
87	203	202	-710.79	-.01	.00	-.03	-4.18	-.34
LINE 88	IS	CLOSED						
89	202	201	-710.79	-.01	.00	-.03	-4.18	-.34
LINE 90	IS	CLOSED						
LINE 91	IS	CLOSED						
92	201	9	-710.79	-.03	.00	.00	-4.18	-.34
93	1140	201	.00	.00	.00	.00	.00	.00

JUNCTION	NUMBER	DEMAND	GRADE	LINE	ELEVATION	PRESSURE
	1	.00		73.62		
	2	.00		58.22		
	3	.00		35.54		
	4	.00		35.55		
	5	.00		35.46		
	9	.00		18.48		
	10	.00		39.18		
	11	.00		54.84		

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12	.00	74.80
102	.00	17.88
103	.00	35.41
104	.00	35.55
105	.00	35.73
106	.00	35.92
107	.00	36.19
108	.00	36.47
109	.00	36.75
110	.00	37.03
111	.00	37.30
112	.00	37.58
113	.00	38.32
201	.00	18.45
202	.00	18.41
203	.00	18.37
204	.00	18.33
205	.00	18.29
206	.00	18.26
207	.00	18.22
208	.00	18.19
209	.00	18.16
210	.00	18.13
211	.00	18.10
212	.00	18.07
213	.00	18.05
214	.00	18.03
215	.00	18.00
216	.00	17.98
217	.00	17.96
218	.00	17.94
219	.00	17.92
220	.00	17.90
221	.00	17.89
921	.00	17.88
922	.00	17.88
923	.00	17.88
1030	.00	35.41
1040	.00	35.46
1050	.00	35.73
1060	.00	35.91
1070	.00	36.19
1080	.00	36.47
1090	.00	36.75
1100	.00	37.03
1110	.00	37.30
1120	.00	37.58
1130	.00	38.32
1140	.00	18.45

THE NET SYSTEM DEMAND = .00

SUMMARY OF INFLOWS(+) AND OUTFLOWS(-) FROM FIXED GRADE NODES

PIPE NUMBER	FLOWRATE
1	541.90
26	-101.22
32	-255.39
38	-185.28
41	-103.95
43	-105.22
45	-102.42
47	-68.95

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49	-69.56
53	-71.69
57	-55.47
62	710.79
73	-63.23
83	-70.31

THE NET FLOW INTO THE SYSTEM FROM FIXED GRADE NODES = 1252.69
THE NET FLOW OUT OF THE SYSTEM INTO FIXED GRADE NODES = -1252.69

A SUMMARY OF CONDITIONS SPECIFIED FOR THE NEXT SIMULATION FOLLOWS

Fish Passage Program version 2.0

Input File:fish.inp
Output File:fish.out
Data File:bonna.fdr

BONNEVILLE

Tailwater: 14.88 14.88 (N&S)
Head @ Top Weir: 1.20

Fish Ladder Discharge: 238.75
Weir Component: 189.81
Orifice Component: 48.94

Weir no.	Weir Width	Crest Len	Crest Elev	W.S. Elev	Q	Weir Q	Orifice Q	h0	h1	h2	Weir Vel	Weir Coef
Collection Channel				16.63								
10	30.00	30.00	8.50	16.76	661.26	643.89	16.44	0.13	8.26	8.13	2.60	4.50
11	30.00	30.00	9.75	16.94	661.26	641.97	19.00	0.18	7.19	7.01	2.98	4.50
12	30.00	30.00	11.00	17.19	661.26	639.49	22.34	0.25	6.19	5.94	3.45	4.50
13	30.00	30.00	12.25	17.54	661.26	634.90	26.68	0.35	5.29	4.94	4.00	4.50
Ladder Diffuser				3 Discharge:	185.27	Vel:	0.64					
14	30.00	30.00	13.50	17.81	475.99	453.40	23.29	0.27	4.31	4.04	3.51	4.50
15	30.00	30.00	14.75	18.26	475.99	445.37	30.22	0.45	3.51	3.06	4.23	4.50
16	30.00	30.00	16.00	19.05	475.99	436.19	40.04	0.79	3.05	2.26	4.76	4.50
Ladder Diffuser				4 Discharge:	255.39	Vel:	0.89					
17	30.00	30.00	17.00	19.26	220.60	200.03	20.21	0.20	2.26	2.05	2.96	4.50
18	30.00	30.00	18.00	19.74	220.60	189.17	31.25	0.48	1.74	1.26	3.62	4.50
19	33.20	30.00	19.00	20.26	220.60	188.21	32.48	0.52	1.26	0.74	4.97	4.50
Ladder Diffuser				5 Discharge:	0.00	Vel:	0.00					
20	40.00	30.20	20.00	21.19	220.60	177.01	43.35	0.93	1.19	0.26	4.91	4.50
21	40.00	30.20	21.00	22.19	220.60	175.92	44.83	1.00	1.19	0.19	4.90	4.50
22	40.00	30.30	22.00	23.18	220.60	175.85	44.87	1.00	1.18	0.19	4.90	4.50
Ladder Diffuser				6 Discharge:	101.23	Vel:	0.18					
23	40.00	10.40	23.00	24.33	119.37	71.44	48.00	1.14	1.33	0.18	5.18	4.50
24	40.00	10.40	24.00	25.36	119.37	73.87	45.61	1.03	1.36	0.33	5.24	4.50
25	40.00	10.40	25.00	26.36	119.37	74.28	45.05	1.01	1.36	0.36	5.25	4.50

Ladder Diffuser			7 Discharge:		0.00 Vel:		0.00					
26	40.00	10.40	26.00	27.36	119.37	74.46	44.99	1.00	1.36	0.36	5.25	4.50
27	40.00	10.40	27.00	28.36	119.37	74.38	44.92	1.00	1.36	0.36	5.25	4.50
28	40.00	10.40	28.00	29.36	119.37	74.35	44.93	1.00	1.36	0.36	5.25	4.50
Ladder Diffuser			8 Discharge:		0.00 Vel:		0.00					
29	40.00	10.40	29.00	30.36	119.37	74.45	44.97	1.00	1.36	0.36	5.25	4.50
30	40.00	10.40	30.00	31.36	119.37	74.37	44.92	1.00	1.36	0.36	5.25	4.50
31	40.00	10.40	31.00	32.36	119.37	74.49	44.97	1.00	1.36	0.36	5.25	4.50
Ladder Diffuser			9 Discharge:		0.00 Vel:		0.00					
32	40.00	10.40	32.00	33.36	119.37	74.41	44.92	1.00	1.36	0.36	5.25	4.50
33	40.00	10.40	33.00	34.36	119.37	74.41	44.94	1.00	1.36	0.36	5.25	4.50
34	40.00	10.40	34.00	35.36	119.37	74.41	44.94	1.00	1.36	0.36	5.25	4.50
Ladder Diffuser			10 Discharge:		0.00 Vel:		0.00					
35	40.00	10.40	35.00	36.36	119.37	74.41	44.94	1.00	1.36	0.36	5.25	4.50
36	40.00	10.40	36.00	37.36	119.37	74.41	44.94	1.00	1.36	0.36	5.25	4.50
37	40.00	10.40	37.00	38.36	119.37	74.41	44.94	1.00	1.36	0.36	5.25	4.50
Ladder Diffuser			11 Discharge:		0.00 Vel:		0.00					
38	40.00	10.40	38.00	39.36	119.37	74.41	44.94	1.00	1.36	0.36	5.25	4.50
39	40.00	10.40	39.00	40.36	119.37	74.41	44.94	1.00	1.36	0.36	5.25	4.50
40	40.00	10.40	40.00	41.36	119.37	74.41	44.94	1.00	1.36	0.36	5.25	4.50
Ladder Diffuser			12 Discharge:		0.00 Vel:		0.00					
41	40.00	10.40	41.00	42.36	119.37	74.41	44.94	1.00	1.36	0.36	5.25	4.50
42	40.00	10.40	42.00	43.36	119.37	74.41	44.94	1.00	1.36	0.36	5.25	4.50
43	40.00	10.40	43.00	44.36	119.37	74.41	44.94	1.00	1.36	0.36	5.25	4.50
44	40.00	10.40	44.00	45.36	119.37	74.41	44.94	1.00	1.36	0.36	5.25	4.50
45	40.00	10.40	45.00	46.36	119.37	74.41	44.94	1.00	1.36	0.36	5.25	4.50
46	40.00	10.40	46.00	47.36	119.37	74.41	44.94	1.00	1.36	0.36	5.25	4.50
47	40.00	10.40	47.00	48.36	119.37	74.41	44.94	1.00	1.36	0.36	5.25	4.50
48	40.00	10.40	48.00	49.36	119.37	74.41	44.94	1.00	1.36	0.36	5.25	4.50
49	40.00	10.40	49.00	50.36	119.37	74.41	44.94	1.00	1.36	0.36	5.25	4.50
50	40.00	10.40	50.00	51.36	119.37	74.41	44.94	1.00	1.36	0.36	5.25	4.50
51	40.00	10.40	51.00	52.36	119.37	74.41	44.94	1.00	1.36	0.36	5.25	4.50
52	40.00	10.40	52.00	53.36	119.37	74.41	44.94	1.00	1.36	0.36	5.25	4.50
53	40.00	10.40	53.00	54.36	119.37	74.41	44.94	1.00	1.36	0.36	5.25	4.50
Ladder Diffuser			13 Discharge:		0.00 Vel:		0.00 @ 50%					
54	57.00	57.00	54.00	55.01	238.75	202.43	36.16	0.65	1.01	0.36	3.52	3.50
55	47.00	47.00	55.00	56.11	238.75	191.45	47.06	1.10	1.11	0.01	3.68	3.50
56	42.00	42.00	56.00	57.19	238.75	191.87	46.87	1.09	1.19	0.11	3.82	3.50
57	42.00	42.00	57.00	58.20	238.75	193.76	45.12	1.01	1.20	0.19	3.84	3.50
58	42.00	42.00	58.00	59.20	238.75	193.76	44.94	1.00	1.20	0.20	3.84	3.50
59	42.00	42.00	59.00	60.20	238.75	193.76	44.94	1.00	1.20	0.20	3.84	3.50
60	42.00	42.00	60.00	61.20	238.75	193.76	44.94	1.00	1.20	0.20	3.84	3.50
61	42.00	42.00	61.00	62.20	238.75	193.76	44.94	1.00	1.20	0.20	3.84	3.50

APPENDIX C- Item 6

62	42.00	42.00	62.00	63.20	238.75	193.76	44.94	1.00	1.20	0.20	3.84	3.50
63	42.00	42.00	63.00	64.20	238.75	193.76	44.94	1.00	1.20	0.20	3.84	3.50
64	42.00	42.00	64.00	65.20	238.75	193.76	44.94	1.00	1.20	0.20	3.84	3.50
65	42.00	42.00	65.00	66.20	238.75	193.76	44.94	1.00	1.20	0.20	3.84	3.50

---Entrance----- Gate No.	Discharge (cfs)	---PCC Diffuser----- No.	Discharge (cfs)	Velocity (fps)	-----PCC----- Discharge (cfs)	Velocity (fps)	Elev (ft)	--Distance to- South Entrance (ft)
		223	103.95	0.38	661.26			
65	0.00				765.22	2.34	16.63	912.
	Weir Elev: 40.00 ft							
	Head: 1.72 ft				765.22	2.34	16.60	905.
		222	105.22	0.38				
					870.44	2.66	16.60	898.
64	616.49							
	Weir Elev: 5.80 ft				253.95	0.77	16.57	890.
		221	102.40	0.37				
					356.36	1.09	16.67	884.
62	0.00							
					356.36	1.09	16.66	860.
		210	68.95	0.11				
					425.31	1.30	16.66	852.
		200	69.56	0.11				
					494.87	1.51	16.65	814.
58	0.00							
					494.87	1.51	16.64	805.
		190	70.31	0.11				
					565.18	1.73	16.64	770.
		180	0.00	0.00				
					565.18	1.73	16.62	730.
		170	0.00	0.00				
					565.18	1.73	16.62	690.
		160	0.00	0.00				
					565.18	1.73	16.61	650.
		150	0.00	0.00				
					565.18	1.73	16.60	610.
		140	0.00	0.00				
					565.18	1.73	16.60	570.

APPENDIX C- Item 6

		130	0.00	0.00				
		120	71.69	0.12	565.18	1.73	16.59	530.
34	0.00				636.87	1.95	16.58	490.
		110	0.00	0.00	636.87	1.95	16.57	480.
		100	0.00	0.00	636.87	1.95	16.56	450.
		90	0.00	0.00	636.87	1.95	16.56	410.
		80	63.23	0.10	636.87	1.95	16.55	365.
21	0.00				700.10	2.15	16.54	325.
		70	0.00	0.00	700.10	2.15	16.52	300.
		60	0.00	0.00	700.10	2.15	16.52	285.
		50	0.00	0.00	700.10	2.15	16.51	245.
		40	55.47	0.09	700.10	2.15	16.50	205.
9	0.00				755.57	2.33	16.49	165.
		30	0.00	0.00	755.57	2.33	16.47	140.
		20	0.00	0.00	755.57	2.33	16.47	120.
2	756.13				755.57	2.05	16.45	80.
	Weir Elev:	3.80 ft						
		14	0.00	0.00	-0.56	0.00	16.45	15.
1	0.00				-0.56	0.00	16.52	15.
	Weir Elev:	40.00 ft						
	Head:	1.64 ft			-0.56	0.00	16.52	0.

Summary Table						
			Tailwater Elevation(N&S):		14.88	14.88
			Channel Head:		1.72	1.64
Inflows			Q	V	Outflows	
-----					-----	
Fish Ladder Discharge	:		238.75		B Branch Fish Ladder:	119.37
Ladder Diffuser	6:		101.23	0.18	Entrance 65:	0.00
Ladder Diffuser	4:		255.39	0.89	Entrance 64:	616.49
Ladder Diffuser	3:		185.27	0.64	Entrance 62:	0.00
PCC Diffuser	223:		103.95	0.38	Entrance 58:	0.00
PCC Diffuser	222:		105.22	0.38	Entrance 34:	0.00
PCC Diffuser	221:		102.40	0.37	Entrance 21:	0.00
PCC Diffuser	210:		68.95	0.11	Entrance 9:	0.00
PCC Diffuser	200:		69.56	0.11	Entrance 2:	756.13
PCC Diffuser	190:		70.31	0.11	Entrance 1:	0.00
PCC Diffuser	120:		71.69	0.12		
PCC Diffuser	80:		63.23	0.10		
PCC Diffuser	40:		55.47	0.09		
Total Inflow:			1491.44		Total Outflow:	1492.00

JUNCTION NUMBER DEMAND
 THE NET SYSTEM DEMAND = .00

SUMMARY OF INFLOWS(+) AND OUTFLOWS(-) FROM FIXED GRADE NODES

PIPE NUMBER	FLOWRATE	GRADE
1	541.90	75.43
26	-101.22	23.18
32	-255.39	19.05
38	-185.28	17.54
41	-103.95	16.63
43	-105.22	16.60
45	-102.42	16.67

47	-68.95	16.66
49	-69.56	16.65
53	-71.69	16.58
57	-55.47	16.49
62	710.79	75.43
73	-63.23	16.54
83	-70.31	16.64

THE NET FLOW INTO THE SYSTEM FROM FIXED GRADE NODES = 1252.69
THE NET FLOW OUT OF THE SYSTEM INTO FIXED GRADE NODES = -1252.69