NORTH FORK TOUTLE RIVER FISH PASSAGE AND SEDIMENT ASSESSMENT

Submitted to:

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EXECUTIVE SUMMARY

Chapter 1: Introduction

The North Fork Toutle River basin drains the northwest slope of Mount St Helens and adjacent mountainous terrain in southwest Washington State. On 18 May 1980, Mount St. Helens erupted, spewing ash, melting snow and ice, and causing a major debris avalanche and lahars that buried the North Fork Toutle River valley. Historically the North Fork supported large runs of coho salmon, winter steelhead, and spring and fall Chinook salmon. The coho salmon and steelhead populations were part of larger metapopulations that have since been listed as threatened species under the Endangered Species Act.[1] Spring and fall Chinook salmon, which are also listed as threatened species, no longer return to the North Fork above its confluence with the Green River.

One of several actions taken by the US Army Corps of Engineers (Corps) to reduce the risk of flooding after the eruption was to construct the Sediment Retention Structure (SRS) in 1989. In the two decades since, an estimated 105.3 million cubic yards (mcy) of sand and silt have accumulated in a large sediment plain upstream of the SRS. Although the amount of material being eroded and transported by the North Fork has declined over time, the SRS has become less effective at trapping it. Significant quantities of sediment continue to be conveyed downstream to the Cowlitz and Columbia Rivers, where much of it is deposited and causes the river bed to aggrade. To address this problem, the Corps is currently evaluating several alternatives to remove or sequester sediment in the Toutle, Cowlitz and lower Columbia rivers. Two of these measures, including raising the height of the SRS and spillway, and deploying grade control structures to promote additional sediment deposition in the sediment plain, will directly affect fish passage conditions in the lower North Fork Toutle River. To avoid unwanted impacts, sediment and fish management objectives and actions will need to be reconciled and carefully coordinated in the future.

The SRS was constructed with no special provision for enabling upstream volitional fish passage. Instead, the Corps built a fish collection facility (FCF) approximately 2 km downstream of the SRS. The facility is used to trap adult salmonids that are migrating upstream; captured fish are loaded into water tanks and transported by truck to release sites on Alder and Hoffstadt Creeks, located 11 and 24 river km, respectively, upstream of the SRS. Along with the upper mainstem North Fork Toutle River, these two streams contain the primary spawning and rearing habitat in the upper watershed.

AMEC Earth & Environmental, Inc. (AMEC) and the Lower Columbia Fish Recovery Board (LCFRB) received funding from the Salmon Recovery Funding Board to address sedimentation and fish passage issues on the North Fork Toutle River, which is considered a key priority in the Lower Columbia Salmon Recovery and Fish & Wildlife Sub-basin Plan (LCFRB 2004). The goal of the project was to identify measures that would restore volitional upstream passage of wild coho salmon and steelhead trout to spawning habitat in the North Fork Toutle River upstream of the SRS. To achieve this goal, we focused on three specific objectives: 1) determine the

[1] Respectively, Lower Columbia River Coho Salmon Evolutionarily Significant Unit, listed as threatened on June 28, 2005; and Lower Columbia River Steelhead Trout Distinct Population Segment, listed on March 19, 1998.

trapping efficiency of the FCF and assess the movements of coho and steelhead in the vicinity of the facility; 2) evaluate the movements of coho and steelhead above the SRS and determine whether they can successfully navigate the sediment plain; and 3) develop conceptual level solutions for improving fish passage at the FCF and through the sediment plain. We also evaluated plans and design drawings provided by the Corps for a fish channel that would enable coho salmon and steelhead trout to volitionally ascend the SRS spillway.

The results of this study are discussed in light of previous research on the movement and fate of adult coho salmon and steelhead in the North Fork Toutle River watershed (Kock 2007) and various sediment control measures that have been recently proposed by the Corps.

Chapter 2: Trapping Efficiency of the Fish Collection Facility

To address the first study objective, AMEC and its partners (US Geological Survey and the Cowlitz Indian Tribe) investigated adult fish behavior and migratory movements in the immediate vicinity of the FCF. Using radio-tags, we tracked adult coho salmon and steelhead to estimate the proportion of returning fish that were successfully captured by the FCF, and to identify patterns in the movements and distribution of fish that might reveal specific locations or times when passage is impeded.

The original study plan called for trapping 30 coho salmon and 30 steelhead at the FCF, fitting them with radio-transmitters, releasing them below the FCF, and monitoring their subsequent movements. Due to the small number of adult coho salmon and steelhead trout that returned to the FCF in the fall of 2008 and spring of 2009, respectively, the Washington Department of Fish and Wildlife requested that radio-tracking activities be scaled back to minimize the potential for adversely affecting both species. As a result, for each fish that received radio-transmitters, a minimum of three additional fish were released untagged into the upper watershed. We selected subjects for tagging over the entire period that fish were collected at the FCF. This precautionary measure reduced final sample sizes for this component of the project to 9 coho salmon and 11 steelhead trout.

The coho salmon and steelhead used in this study were collected at the FCF, anesthetized, implanted gastrically with radio-transmitters, and released downstream of the facility. Fish were tracked with a combination of receivers located at fixed sites and receivers transported by vehicle and on foot. Trapping efficiency was calculated by dividing the number of tagged fish recaptured at the FCF by the total number tagged and released downstream of the facility. In addition, we compared the observed fish movements with hydrologic information to identify any correlation between the timing of upstream migration and flows. To complement findings from the tagging study, a Dual Frequency Identification Sonar (DIDSON) was deployed for a short period of time at the entrance to the FCF ladder to quantify the total number of fish holding in the FCF pool.

We tagged a total of nine coho salmon (7 male and 2 female) in October, 2008, and released them several kilometers downstream. Eight of the nine coho migrated upstream from the release site to the vicinity of the Green River confluence, but none returned to the FCF. Therefore, the calculated trapping efficiency was zero, although clearly there is some error in this number since a total of 108 coho were captured during the season. Four coho eventually moved back downstream from the Green River confluence. The other four coho may have left the study area by ascending the Green River or may have been caught by sport fishermen. We were unable to determine the final locations and dispositions of the tagged fish. Due to concerns that the lack of returns may be a result of the downstream distance of the release site, tagging effects, or trap-shy behavior, we reconsidered our release site during the steelhead study, with the intent of improving the likelihood that we would observe fish in the FCF. While our results are not conclusive, we believe that the trapping efficiency for coho salmon is very low, and that under certain conditions a partial barrier to fish passage may form between the Green River confluence and the FCF.

Eleven steelhead were tagged (5 male and 6 female) in March and April, 2009, and released immediately below the FCF, above the Green River confluence. Results are not strictly comparable for coho and steelhead due to the different release locations. Of the 11 steelhead released, three were recaptured in the trap. Therefore, the calculated trapping efficiency was 27 percent. In addition, six re-entered the FCF but were not captured, and two never re-entered the FCF. Tagged fish may have behaved differently when they encountered the FCF for a second time, and were therefore probably more likely to avoid capture than naïve fish. Depending on flow conditions, we believe that a significant proportion of the steelhead arriving at the FCF are not subsequently captured in the facility.

The behavior of steelhead within the FCF, in particular their bi-directional movements in the ladder and ability to leave the holding vault, highlights some of the problems with the structure and its operation. Various factors affecting the trapping efficiency of the FCF, as they relate to the facility's configuration and operation, are discussed in Chapter 4.

There was no obvious correlation between river discharge and fish movement for either species. The DIDSON did not observe any coho near the entrance to the FCF, probably because it was deployed after the majority of the coho had returned to the subbasin. During the steelhead study, the DIDSON detected four fish entering and 30 fish exiting the ladder entrance.

Chapter 3: Migration Behavior in the Sediment Plain

The second study component, which also employed radio-telemetry techniques, was focused on monitoring coho salmon and steelhead movements in the 3.8 mile reach immediately upstream of the SRS. Similar to the first study, we attempted to calculate a passage success rate and to identify locations in the sediment plain where fish appeared to either be delayed or prevented from ascending further upstream. The physical processes and conditions that influence passage success through the sediment plain are discussed in detail in Chapter 4.

Fewer fish returned to the North Fork Toutle River than expected in 2008 and 2009, so sample sizes were reduced. Originally, 30 coho salmon and 30 steelhead were to be tagged and released above the SRS. Final sample sizes were 10 fish of each species, including the 3 steelhead that had been recaptured in the FCF trapping efficiency study. Methods for capturing, tagging, and tracking coho salmon and steelhead were the same as described for that study. Tagged fish were released a few hundred meters upstream of the SRS on the south end of the SRS (to discourage the likelihood that they would swim downstream through the spillway on the north end), and tracked as they made their way to the mouths of tributary streams or to RM

32.0, which marked the upstream end of the sediment plain. We were unable to determine whether tagged fish eventually entered into tributaries of the sediment plain, or continued higher up the North Fork drainage, and whether they spawned in either of these areas.

Ten coho salmon (5 males and 5 females) were tagged in November, 2008. Seven of the ten fish exhibited repeated movement between the SRS (RM 28.2) and Eco Park Resort (RM 29.1) fixed receiver sites until the end of December. Four coho ascended as far as RM 30.0 but were later detected downstream, indicating that they did not pass successfully beyond that point. None of the tagged fish released immediately upstream the SRS were subsequently detected at RM 32.0; from this we infer that a barrier to coho migration was present in the upper 2 miles of the sediment plain, at least under the conditions that prevailed during the course of the study.

Ten steelhead (all female) were tagged between March and May, 2009. Three of these fish had been recaptured in the FCF after being used for the study described above. All ten tagged steelhead navigated the sediment plain to locations past the Ecopark site; five were detected upstream of RM 30.0; and two were detected above RM 32.0 (i.e., the head of the sediment plain). The furthest upstream that any steelhead were detected was RM 35.0 near the Hoffstadt Creek confluence. The passage success rate for steelhead was at least 20 percent. If we assume that two additional fish that were last detected at the Alder Creek site eventually spawned in that stream, then the passage rate was 40 percent.

Our results provide evidence that both coho and steelhead experience adverse passage conditions when swimming upstream through the sediment plain. We were unable to pinpoint specific features or locations that might pose problems for upstream migrants. Further study is recommended before a final decision is made regarding which actions should be taken to ensure that fish are able to reach spawning grounds in the upper watershed.

Chapter 4: Conceptual Solutions to Improve Fish Passage

AMEC's fisheries biologists, hydraulic engineer and fluvial geomorphologist were asked to characterize conditions affecting fish collection and transport at the FCF and fish passage through the SRS spillway and sediment plain, and to develop conceptual level ideas for improving fish passage. The results of their assessment formed the basis for conclusions and recommendations related to existing conditions and potential solutions to fish passage problems in the North Fork Toutle River. Input to assessment included data collected in the radio-telemetry studies of fish movement; direct on-site observations and measurements; information conveyed during meetings with Corps and WDFW personnel; and review of design drawings and relevant peer-reviewed and gray literature. Because the Corps had independently initiated a feasibility and design study of a fish passage channel in the SRS spillway, we reviewed their plans and offered suggestions for improvement.

Additional observations and findings related to the SRS spillway and FCF were addressed in Technical Memoranda that were prepared previously by AMEC; the memoranda are appended to this report.

FCF

Since its construction in 1989, the FCF has fallen into a serious state of disrepair due to recurring damage caused by high flows and sediment loads, and by a chronic lack of funding to maintain and operate the facility. Although trap and haul operations have enabled coho and steelhead populations to persist in the North Fork Toutle River subbasin, the decline in their numbers over the past two decades can be partially attributed to the poor performance of the FCF. Unless steps are taken to either refurbish the facility or to enable volitional passage through the SRS spillway and sediment plain, it is highly probable that populations of coho and steelhead will become functionally extinct in the near future.

In the first section of Chapter 4, we describe the current problems and various measures that might be implemented to improve the effectiveness of the FCF over the short-, intermediate-, and long-term. Assumptions related to these different timelines enable us to prioritize actions to address observed problems. The short-term strategy assumes that the FCF will need to be refurbished and operated over the next 3-5 years while sediment control and fish passage improvements are being implemented by the Corps. The long-term strategy assumes that the proposed volitional fish channel in the SRS spillway has been built and proven to be effective at passing fish up- and downstream, and that conditions in the sediment plain allow fish to move freely into tributaries and upper areas of the watershed. If sediment retention structures are built in the sediment plain, we assume that they will result in relatively stable channels that are deep enough and not so steep as to impede fish.

Intermediate-term actions are those necessary to keep the FCF operational until fish passage conditions associated with the long-range vision are met. Again, we assume that the goal is for fish to be able to swim volitionally through the SRS spillway and sediment plain, and be able to access spawning areas upstream with minimal delay or injury.

Because the Corps has not finalized plans for modifying the SRS spillway or constructing grade control/sediment retention structures in the sediment plain, it is unclear what role the FCF will play in the future. In the meantime, given the precarious state of coho salmon and steelhead populations in the North Fork Toutle River, the short-term improvements to the FCF and the changes in trapping and hauling operations that we recommend should be implemented without further delay.

The extensive list of current problems with the FCF that was conveyed by AMEC to the WDFW in a technical memorandum (Appendix B) are summarized and elaborated upon in this report. In general, the debilitating effects of high flows and constant inputs of large quantities of sediment, in concert with design flaws, breakdowns, and inadequate resources, have resulted in a facility that is only marginally functional and is expected to become completely inoperable in the next three to five years.

We propose a long-term strategy for the FCF that harmonizes fisheries management goals with efforts to control sediment in the watershed, which is necessarily the Corps' top priority. Within that context, we encourage reestablishing connectivity throughout the lower North Fork Toutle River by 1) decommissioning the FCF and replacing the barrier dam with a short fishway or restored river channel; 2) modifying the SRS spillway according to commonly accepted design criteria to enable the volitional passage of coho and steelhead; 3) incorporating a fish trap in the lower end of the spillway fish channel to retain the flexibility to trap and haul fish to spawning areas, and to manipulate the number and relative proportion of natural and hatchery fish passed upstream; and 4) implement grade control, sediment stabilization and habitat restoration measures (e.g., revegetation) in the sediment plain that promote the formation of a single channel that allows fish to pass upstream with minimal delay.

Recognizing that implementing a successful long-range plan requires significant time, resources, and coordination between managers and stakeholders, and assuming that the current FCF would need to remain operational until full volitional passage is restored, we describe measures that would need to be implemented immediately to prevent further degradation of the FCF. The short term plan envisions an initial 3 to 5 year period during which further monitoring, research, planning, design and implementation of additional improvements are expected to occur. We recommend the following specific short-term actions:

- Modifying the stoplog bay sill;
- Flushing the existing sediment sluice;
- Installing an operable gate at the intake to exclude sediment when FCF is not operating;
- Replacing gates and gate lifts and/or installing side-constricting orifice inserts to enhance the velocity of attraction flows;
- Replacing collection pool finger gate; and
- Repairing or replacing several other miscellaneous items.

The estimated total cost of these improvements, including an allowance for unidentified items and contingency, is $460,000.

Due to the unpredictable physical environment and the high degree of uncertainty surrounding the management of fish and sediment in the North Fork Toutle River watershed, it is difficult to lay out an exact course of action. Nevertheless, several additional improvements will probably need to be made if the long-range vision is to be realized. Intermediate-term actions address three primary structural elements of the FCF, as well as operational issues, including:

- Modifying the water intake components of the FCF to: 1) exclude as much sediment as possible from entering the FCF; 2) more effectively sluice sediment that has accumulated in the settling basin; and 3) create a second settling basin in parallel with the existing basin so that the trap can continue to operate during maintenance or cleaning operations;
- Redesigning and modifying the internal components of the FCF to create 1) a second fish collection pool and crowder in parallel with the first that allows one to be operated while the other is cleaned; 2) improved fishway panels; 3) better self-cleaning properties; and 4) the ability to handle higher flow rates;
- Arresting and reversing degradation of the FCF tailwater pool to ensure that fish can access the fishway entrance; and

- Improving FCF operations by: 1) acquiring multi-purpose equipment such as a mobile crane, small loader, etc. to assist with fish handling and sediment removal; 2) increasing staff levels; and 3) implementing a more formal process for collecting and transporting fish and removing sediment.

The costs for construction items described in the first three bullets above are estimated to be $2.5 M for modifying the water intake; $3.3 M for modifying the internal components; and $2.1M for restoring the FCF tailwater. When allowances for unlisted items and contingency are added, the total estimated cost for intermediate-term modifications to the FCF comes to $7.9 M.

We estimate an additional $300,000 per year will be needed to provide for adequate staffing and direct costs to operate and maintain the renovated FCF. A sinking fund for facility reconstruction or replacement in the future is not included in this annual cost.

SRS Spillway

At the urging of the Cowlitz Indian Tribe, WDFW, LCFRB, recreational fishing organizations and local residents, the Corps conducted a reconnaissance level study of potential ecosystem restoration work in the North Fork Toutle basin. In 2007, the Corps determined that actions to facilitate fish passage at the SRS are subsumed under their existing project authority. They evaluated several alternative configurations for modifying the SRS spillway and in 2009 developed 90 percent design drawings for a preferred alternative. AMEC reviewed the preferred alternative design and provided feedback to the Corps as a technical memorandum (Appendix A).

The Corps' preferred alternative was to make improvements to the spillway that would direct and confine flow to a fish passage channel within the spillway in order to minimize the opportunity for false passage routes; reduce the height of the falls and cascades to a series of vertical drops measuring no more than 3 feet in height; and add thalweg pools to the channel so that fish are able to rest and orient themselves for leaping or swimming upstream.

The proffered "jumps and pools" channel design resembles a conventional "pool and weir" configuration except that it requires fish to leap greater heights at certain locations than is normally the case in a conventional pool and weir-type fish ladder. The fishway entrance appears to meet criteria for sufficient attraction flows (4 to 8 feet per second); however, not enough detail is available to determine whether the plunge pool depth below the first jump meets depth requirements (4 feet minimum; recommended 6 feet). The minimum depth of fish channel runs in the Corps' design drawings is depicted as 0.6 feet, which is less than the recommended fish passage standard of 1 foot; however, hydraulic modeling shows that the one foot depth will be achieved under most flow conditions. More importantly, the prolonged, relatively steep gradient of the channel (6.4 percent) will pose a significant challenge in that it will require fish to swim at burst (maximum) speed over short distances. However, the Corps appears to have designed a sufficient number of pools that will allow fish to rest as they make their way up the channel.

The pool dimensions in the Corps' plan are unconventional, but from a plan view perspective meet the minimum criteria. Pools that do not produce a stilling or eddying effect on the flow will have relatively low value as resting and jump staging areas. The proposed pool depth of three feet is lower than the desired minimum depth of four feet. Lacking adequate depth, a pool may not provide the hydraulic conditions a fish needs to leap over the drop at the head of the pool, even if the height of the drop is within the leaping ability of the target species of fish.

Further design detail is needed as to how the fish channel exit is to be configured to exclude sediment while at the same time effectively directing flow into the fishway and guiding fish upstream. A compromise must be achieved between extending the fishway too far into the sediment plain, where the channel is actively moving and could close off the fishway exit, and too close to the spillway lip, where fallback might occur. Fallback, defined as the passive or active movement of fish downstream, is likely to negatively affect fish that end up in areas of the spillway that are outside the fish channel.

Sediment Plain

We describe the recent geomorphologic history of the North Fork Toutle River basin, including the physical disturbance caused by the 1980 eruption of Mount St. Helens, the subsequent evolution of the channel morphology, and the steps taken to minimize adverse impacts to people living in areas downstream. Our characterization of the sediment plain, especially as it relates to fish passage, is based on field trips to the SRS and sediment plain; meetings with the US Army Corps of Engineers, the WDFW, Cowlitz Indian Tribe, and knowledgeable citizens; and a review of relevant scientific literature and unpublished data. The resulting reconnaissance-level assessment describes both challenges and opportunities for stabilizing the sediment plain and establishing a single, main channel that could improve opportunities for fish passage and reestablish mainstem-tributary connections.

Our primary recommendation to improve fish passage in the sediment plain is to use “soft” engineering solutions, such as pile-dikes, GeoTubes®, and engineered large woody debris structures to encourage the process of channel incision, in combination with aggressive plantings of native grasses and forbs, willows, cottonwoods, and other plants that will help reduce the potential for channel avulsion and erosion.

Detailed hydraulic and sediment modeling should be performed to determine where GeoTubes, LWD and other roughness elements should be positioned within the sediment plain to enhance existing preferential flow paths and encourage the establishment of stable channel boundaries. The natural revegetation of exposed sediments by wind and water-borne seeds should be augmented by direct seeding and planting of vegetation capable of growing in fine substrate, depositional habitats. The development of a mature riparian plant community is expected to take several decades.

The flow and sediment processes affecting the sediment plain are complex and therefore a ‘one size fits all’ solution is not recommended. The strategic placement of a series of smaller structures to encourage local sediment deposition and the formation of a stable, dominant channel that allow for fish passage is preferred over the construction of another sediment retention structure across the entire sediment plain. The effects of location, size, spacing and orientation of the smaller structures on local hydraulic conditions and sediment transport processes should be carefully monitored. A particular configuration might be more effective than another for a specific flow, or produce different results if located in an aggrading reach as opposed to a reach that is eroding or transporting sediment. Monitoring results should be used to recalibrate hydraulic and sediment transport models to better to understand and plan further modifications to the sediment plain.

With regard to meeting the goal of ensuring safe passage of upstream migrating fish through the sediment plain, we recommend the following actions:

- Develop an appropriate conceptual model for channel evolution to use as a framework for planning and monitoring sediment plain stabilization activities;
- Evaluate long-term trends in hydrologic, hydraulic and sediment transport conditions in the North Fork Toutle River drainage using best available data;
- Consider the influence of climate change, volcanic activity, timber harvest and other external controlling factors on sediment plain processes;
- Analyze sediment aggradation, degradation, or transfer at finer spatial and temporal scales to identify dynamic versus stable reaches;
- For each reach, specify the number, type and location of structures that would stabilize channels and create suitable fish passage conditions;
- Model the potential erosion or deposition, channel geometry and revegetation patterns for different scenario configurations;
- Develop a planting plan and an effective monitoring and adaptive management plan;
- Deploy structures in desired configurations and implement planting plan; and
- Monitor performance and modify plans and actions, as appropriate.

Sediment plain restoration requires a long-term commitment to data collection, analysis and planning. In the meantime, it would be prudent to act quickly to prevent the situation from becoming worse. Despite the hard work and good intentions of many capable individuals, the current approach to managing the FCF, SRS and sediment plain is uncoordinated and only marginally successful. A collaborative, well-funded effort is needed to create a sustainable system that achieves multiple management objectives.

Chapter 5: Conclusions and Recommendations

This chapter summarizes key information presented in earlier chapters and offers several observations meant to improve fish passage in the North Fork Toutle River subbasin. Our overarching goal is to rebuild populations of anadromous salmonids in the watershed to viable levels, and to improve the quality and health of the ecosystem upon which they depend. This goal will be attained only if fish are able to access high quality spawning habitat and produce viable offspring. Due to the inefficiency and debilitated state of the existing FCF, we recommend that volitional fish passage – via either natural or artificial channels – be the preferred long-term alternative. This option, however, is fraught with uncertainty and risk; therefore, we recommend that a formal research, monitoring and adaptive management program be developed and implemented in conjunction with the engineering solutions discussed in this report.

Our conclusions and recommendations build upon the substantial effort of other entities involved in the management of the North Fork Toutle River watershed and its resources. We focus not only on various problems and potential solutions associated with the FCF, SRS spillway, and sediment plain, but also on broader fish and sediment management issues. For example, we recommend that managers consider the ecological needs of “lesser” fish species such as cutthroat trout and Pacific lamprey in the design and construction of fish passage structures. We also emphasize that spring and fall Chinook salmon, once abundant within the Cowlitz and Toutle river systems, are logical candidates for reintroduction into the North Fork drainage.

The engineering solutions we propose for improving fish passage at these facilities and locations are necessarily preliminary and require further elaboration. The challenges facing us, however, require our immediate attention. The next steps include not only committing to a course of action, but also identifying sources of funding and the roles and responsibilities of various parties. We recommend that representatives of the Corps, WDFW, Cowlitz Indian Tribe, Lower Columbia Fish Recovery Board, and other interested groups and individuals convene to define short- and long-term actions, develop a long-range budget and fundraising strategy, and allocate effort and responsibility among the relevant parties. Ideally, the plans to reduce flooding risks and recover fish populations will need to be developed and implemented in a coordinated fashion. We are hopeful that common solutions can be found that will achieve efficiencies while meeting multiple societal goals. A single-focus or small-scale approach will be unsuccessful unless it is carefully coordinated with other management efforts in the basin.

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1.0 INTRODUCTION

Background

Originating primarily on the north-facing slopes of Mount St. Helens in southwest Washington, the North Fork Toutle River upstream of its confluence with the Green River drains 396 km^2 of mountainous terrain. The North Fork flows west to join first with the Green River and then with the South Fork Toutle River, forming the Toutle River. The mainstem Toutle enters the Cowlitz River just north of the town of Castle Rock. The lower Cowlitz River flows in a southerly direction 32 km to its confluence with the Lower Columbia River near Longview, Washington (Figure 1).

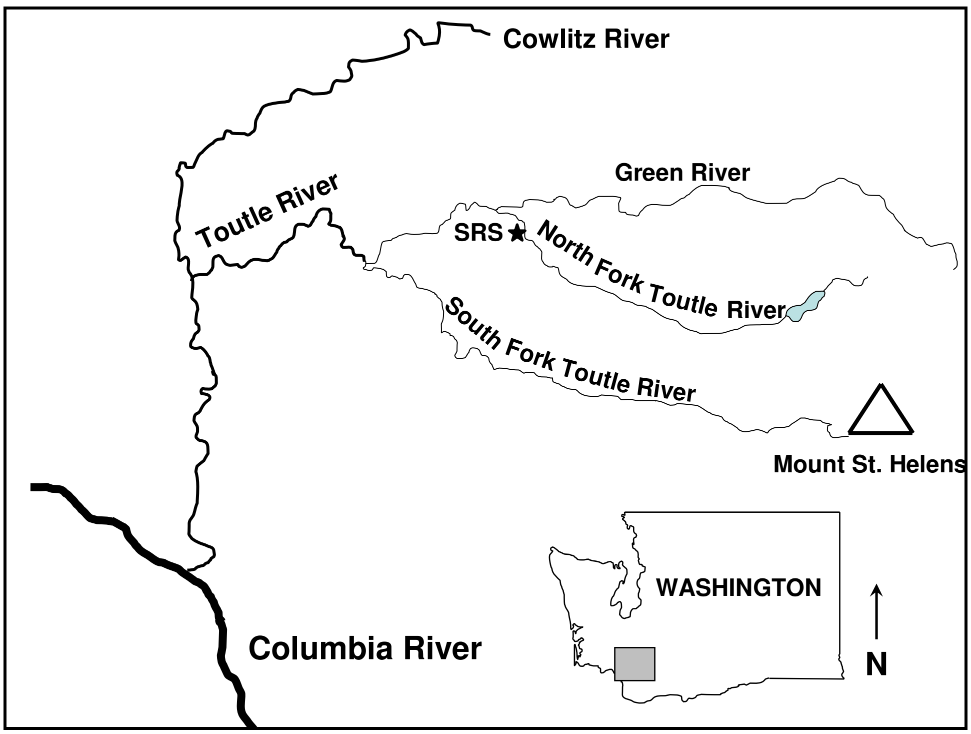


Figure 1 Location of the North Fork Toutle River and the U.S. Army Corps of Engineers' Sediment Retention Structure (SRS).

On the morning of 18 May, 1980, Mount St. Helens erupted, spewing pumice, ash, and gas that flattened trees in an 11-mile radius, 180-degree arc north of the mountain. The volcano's north flank collapsed, creating a landslide that buried 59 square kilometers (23 square miles) of the North Fork Toutle River valley to a mean depth of 45 meters. Melting snow and ice triggered a succession of lahars that rapidly swept down the valley, entraining trees, large rocks, and sediment along the way. The debris torrent destroyed bridges and homes, reduced the flood-carrying capacity of the lower Cowlitz River by 85 percent, and deposited more than 45 million cubic yards (mcy) of sediment in the Columbia River.

President Ronald Reagan declared a national emergency and directed the U.S. Army Corps of Engineers (Corps), the federal agency responsible for flood control and improving the nation's rivers and harbors for navigation, to develop and implement short- and long-term response plans for addressing problems caused by the Mount St. Helens eruption. Short-term measures included dredging the Toutle, Cowlitz, and Columbia Rivers, armoring riverbanks and raising and extending levees along the lower river, and constructing debris dams on the North and South Fork Toutle Rivers to facilitate the deposition and storage of sediment within the active river channel. Prompt action by the Corps and its contractors resulted in the opening of the Columbia River navigation channel to most vessels within two weeks of the eruption, and averting flooding on the lower Cowlitz during the following winter.

By mid-1981, the Corps had dredged over 100 mcy of sediment, primarily from the Cowlitz and Columbia Rivers. In an attempt to reduce the amount of sediment transported downstream from the upper basin, where previously deposited material was being continually eroded, the Corps constructed sediment retention structures, dubbed “N-1” and “S-1,” respectively, across the North Fork and South Fork of the Toutle River. N-1 was the larger of the two structures, measuring 43-feet (ft) high and 6,100-ft long. N-1 was damaged by high flows in December 1981 and after repeated attempts to repair and improve it proved unsuccessful, it was eventually abandoned in favor of a more durable structure.

In 1987, construction began on the North Fork Toutle Sediment Retention Structure (hereafter referred to as the SRS) approximately 5 miles downstream of the original N-1 structure. The SRS consists of a 125-ft high, 1,800-ft long earthen dam (Figure 2), that was designed to impound water, creating a stilling action that allowed sediment to settle out behind the dam. Water was discharged through an outlet structure at the SRS that consisted of six rows of pipes. The rows were successively closed as sediment levels rose. By 1998, the uppermost row of outlet pipes had been closed, and a large sediment plain comprising progressively finer layers of silt and sand formed upstream of the dam. From then on, the North Fork Toutle River was routed through the spillway located at the north end of the SRS.

Figure 2 USGS Photograph of the Sediment Retention Structure (SRS) taken in 1989. Photo by Steve Brantley, available from the USGS Cascade Volcano Observatory (http://vulcan.wr.usgs.gov/Volcanoes/MSH/Images/MSH80/framework.html).

The SRS spillway is a 2,200-ft long unlined, rough-bed channel that tapers down from 400-ft wide at its upper end to 250-ft wide at its terminus. The elevation loss between the crest and downstream end of the spillway is 140 ft, resulting in an average gradient of about 6.4 percent. Flooding in 1996 damaged the spillway, necessitating several minor repairs. Subsequent flows caused further erosion and deposited several large trees in the spillway. At present, water flows through a series of high-velocity cascades, pools, and high-velocity connecting channels before ending in a 6-foot vertical drop at the base of the spillway.

Sediment Concerns

Although the SRS successfully intercepted and stored large quantities of sediment, the amount of sediment retained each year has decreased significantly over time. Between 1989 and 1998, an estimated 87.7 mcy settled out behind the SRS. From 1998 to 2007, another 17.6 mcy had accumulated (Kuhn 2009). The decrease in deposition rate was not due to a lack of suitable storage space; the Corps estimates that 258 mcy of sediment will eventually settle out upstream of the SRS. Rather, the SRS no longer impounds large volumes of water, so conditions that promote sediment deposition are not as prevalent, especially in the forebay of the dam. Thus, even though there has been an overall reduction in sediment load, a relatively high proportion of the sediment arriving at the SRS either does not settle out and continues downstream, or is deposited and remobilized by subsequent freshets. A study published in 2002 by the Corps, titled "Mount St. Helens Engineering Reanalysis," indicated that roughly 60 percent of the fine sediment and sand arriving at the SRS passes over the spillway. The report concludes that unless preventative measures are taken, the bed of the Cowlitz River downstream of the Toutle confluence will aggrade by approximately 5 to 10 ft by the year 2035, the Congressionally authorized life of the project. The predicted increase in bed elevation, if realized, would significantly increase the risk of flooding in downriver areas.

In response to this information, the Corps reinitiated long-term sediment management planning to maintain authorized levels of flood protection in the lower Cowlitz River, and navigation on the Columbia River.[2] Congressional funding was received in 2007-08 to monitor and model sediment transport in the basin, conduct interim dredging in the lower Cowlitz River, and commence work on a long-term sediment management strategy. The Corps is currently exploring alternatives to control sediment and reduce the flood risk to downriver communities. The Corps initially identified 16 potential measures for controlling sediment in the Toutle and Cowlitz watersheds (Table 1). After further refinement and evaluation, the Corps in 2009 pared the list to eight alternatives that will be assessed further, both individually and in combination, with respect to their ability to cost-effectively meet the sediment and flood reduction goals, with minimal impact to fish and wildlife and cultural resources. Assessment of the alternatives will include data collection, modeling, development of conceptual designs, pilot testing, and cost-benefit analysis. Unlike the emergency response in the 1980s, the Corps must evaluate alternatives under stringent environmental regulations (Kuhn 2009).

2 The Corps' authority on this project was established in the Supplemental Appropriations Act for 1985, Public Law 99-88, Statute 318.

Table 1 Measures considered by the Corps for potential long-term sediment control in the Toutle-Cowlitz watersheds. Highlighted measures have been selected for further refinement and evaluation (Source: U.S. Army Corps of Engineers, Portland District).

Measures
1. Debris avalanche stabilization
2. Elk Rock sediment dam
3. Sediment plain grade-building structures
4. Sediment plain sump
5. Raised SRS dam and spillway
6. Raised SRS spillway
7. Stabilization of banks
8. LT1 sump
9. Expand floodplain on Toutle River
10. Modified operation of Mossyrock Dam
11. Levee improvements
12. Cowlitz River dredging
13. Expand floodplain on Cowlitz River
14. Horseshoe Bend sump or cutoff
15. Reconnect old channel near mouth of Cowlitz
16. **Dikes at mouth of Cowlitz**

Based on the Corps' modeling studies, 85 percent of the sediment currently discharged by the Toutle River results from the erosion of banks and in-channel deposits in the North Fork Toutle River above the SRS. To prevent this sediment from traveling downstream, the Corps is contemplating two sediment control alternatives: 1) raising the height of the SRS and spillway, and 2) building multiple small-scale sediment retention structures in the sediment plain upstream of the SRS. Both measures would be expected to increase the amount of sediment retained in the North Fork Toutle River, so that the amount of sediment delivered to the Cowlitz River would decrease over time. Implementation of either of these alternatives would significantly affect physical conditions in the vicinity of the SRS, potentially to the detriment of local fish populations. For example, raising the SRS would require modifying the slope and/or length of the spillway. The sediment plain would be expected to expand in area and rise in elevation as more sediment accumulated behind the SRS. The lower segments of the tributaries that currently enter the sediment plain – Alder, Hoffstadt, Deer, and Bear Creeks – would also fill with sediment, resulting in the loss of a significant amount of rearing and spawning habitat.

The potential impact of the two alternatives on local fish populations, as well as the efficacy of measures designed to mitigate their impact, would need to be carefully considered. For this reason, as discussed below, actions to improve fish passage through or around the SRS have been temporarily put on hold.

Fish Passage Concerns

No provision was made for fish passage through the SRS at the time of its construction or when repairs were made a decade later. Recent studies, reported below, have determined that the spillway, as it exists today, is a complete barrier to upstream migrating coho salmon and a partial barrier to steelhead. As mitigation, the Corps constructed a Fish Collection Facility (FCF) on the North Fork Toutle River less than 1 mile below the spillway soon after the SRS was built. The FCF consists of a 22-ft high concrete barrier dam, a short fish ladder, and a holding pool that serves as a fish trap (Figure 3). The barrier dam, which spans the entire North Fork Toutle River channel, prevents fish from swimming directly upstream. Fish are able to volitionally enter the fishway, ascend the ladder and enter a trap at its upper end, where they hold until being netted and transferred to a transport tank. Collected fish are transported by truck to tributary release sites in Alder Creek, Hoffstadt Creek, and more recently Bear Creek, all located upstream of the SRS.

Figure 3 Components of the Fish Collection Facility (FCF). Counter-clockwise from top: the fish barrier dam; fish ladder; and terminal trap.

The Washington State Department of Fish and Wildlife (WDFW; formerly, Department of Game) assumed responsibility for operating the FCF and transporting fish above the SRS in the early 1990s. In recent years, WDFW personnel have been assisted by volunteers from recreational fishing organizations, the Cowlitz Indian Tribe, and U.S. Geological Survey (USGS) researchers. Despite their best efforts, the FCF is routinely disabled by the massive quantities of sediment that enter the facility. If left untended, sediment clogs orifices and entryways of the FCF and significantly reduces depths and volumes of water within the fishway entrance, pools and holding area. There has been a chronic shortage of funds necessary to operate the FCF and maintain it in proper functioning condition. During the adult salmonid migration period (i.e., August-December for coho, and March-May for steelhead), fish are able to enter the FCF 24 hours a day over a two-day period extending from Wednesday to Friday morning. On Friday morning, fish that have entered the facility are collected, transferred to transport tanks, and hauled by truck to release sites. The FCF is then cleaned of debris and sediment, shut down for the following four days and re-opened the following Wednesday. Previous studies documented, and the present study confirmed, that a significant proportion of the fish that arrive at the FCF do not enter the facility, either because they elect not to, or because the entrance to the facility is blocked for significant periods of time.

With the help of WDFW, Cowlitz Indian Tribe and local conservation groups, the Corps received federal funding through the Energy and Water Development Appropriations Act of 2006 (Public Law 109-103, November 19, 2005) to "conduct a General Reevaluation Study on the Mount St. Helens project to determine if ecosystem restoration actions are prudent in the Cowlitz and Toutle watersheds for species that have been listed as being of economic importance and threatened or endangered" (119 Stat. 2249). The Corps study noted the precipitous declines in local fish populations that have occurred over the past two decades, concluded that inadequate fish passage was partly responsible for those declines, and indicated that modifying the SRS spillway so that migrating fish could pass safely and volitionally upstream would result in significant benefits to endangered species. Importantly, the Corps determined that actions to facilitate fish passage at the SRS are appropriate and reasonable under their original authority for the project.

Subsequent funding in 2008 enabled the Corps to investigate options that would enable fish to successfully navigate the existing SRS spillway in both up and downstream directions. The Corp recommended modifying the spillway to create a single low-flow channel comprised of a series of pools and runs designed to meet state and federal fish passage criteria. Further detail of the spillway plan is available in the Corps' draft "Mount St. Helens Sediment Retention Structure Volitional Fish Passage Design Documentation Report" (USACE 2008) and the 90 percent engineering level design (USACE 2009).

The Corps anticipates that the proposed spillway fish passage structure will be constructed in the near future under its existing project authority. In the interim, however, the two sediment control alternatives that are being explored (mentioned above) would potentially require modification of the proposed design. These measures, which are discussed in further detail below, would significantly alter hydraulic conditions within the spillway and the sediment plain upstream of the SRS. Construction has, therefore, been postponed pending a decision to develop and implement one or both sediment control alternatives. Assuming that fish passage through the SRS remains a primary goal, the SRS spillway fish passage structure would be redesigned and, if technically feasible and cost-effective, implemented in conjunction with the sediment control measures.

Fisheries Resources

The Toutle River system historically supported large populations of spring and fall Chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*O. kisutch*), chum salmon (*O. keta*), winter steelhead (*O. mykiss*), and coastal cutthroat trout (*O. clarki clarki*). No evidence exists to suggest that a viable population of bull trout (*Salvelinus confluentus*) historically occurred within the watershed.

As many as 20,000 spring Chinook salmon and 40,000 fall Chinook salmon were estimated to have returned each year to spawn in Toutle River watershed (LCFRB 2004). The North Fork was primarily used by spring Chinook salmon (Myers, et al. 2006), which tend to return to spawn earlier at higher elevations streams than do fall Chinook. Today, fewer than 200 spring Chinook and 300 fall Chinook return to the Toutle River system each year. Neither race of Chinook currently spawns in the North Fork Toutle River. Escapement goals have not been established for this species in the North Fork Toutle River, even though spring Chinook were historically present and presumably could be reintroduced into the upper watershed.

The number of winter steelhead that historically returned to the Toutle River watershed numbered between 7,000 and 15,000 fish. During the period 1985-1989, escapement levels dropped to an average of 2,743. On the North Fork of the Toutle River, the number of steelhead returning each year over the past decade has been variable, but has never exceeded 400 fish and a consistent decline since 2004 led to a low of 84 adult steelhead returning to the North Fork in 2009. The escapement goal for winter steelhead returning to the North Fork is 700 fish per year, although a habitat-based production model estimates the North Fork could produce 3,500 steelhead per year (LCFRB 2004).

The number of early and late returning coho salmon that spawn naturally in the North Fork Toutle River, described as “extensive” by Bryant (1949), has also dropped precipitously. Upwards of 60,000 fish are estimated to have returned historically to the Toutle basin each year to spawn. Coho numbers had already begun to decline in the 1940s due to overfishing and habitat degradation; during the 1972-1979 period just prior to the 1980 eruption of Mount St. Helens, an estimated 1,743 coho returned each year to the basin. The number of adult coho returning to the North Fork Toutle River continues to decline. Over the past decade, coho escapements ranged from only 66 to 564 fish and most recently numbered 108 fish in 2008 (J. Henning, WDFW, personal communication). While the adopted goal for North Fork Toutle coho is 600 per year (LCFRB 2004), proposed updates to the Lower Columbia Fish Recovery Plan may increase the target escapement to 3,800 coho (E. Asher, LCFRB, personal communication, 2010).

The Willamette-Lower Columbia Technical Recovery Team (TRT) – the panel of salmon experts convened by NOAA Fisheries to develop salmon recovery criteria and goals for ESA listed fish –

and the LCFRB have identified the recovery of North Fork Toutle River winter steelhead and coho salmon populations as key to the recovery of their associated ESUs. Both the TRT and LCFRB consider the North Fork Toutle River winter steelhead and coho salmon populations, whose current viability is rated low, to be 'core' or 'primary' populations that must be returned to a high level of viability if their respective ESUs are to persist.

The SRS severely limits access by anadromous salmonids to approximately 50 miles of upstream habitat in the North Fork Toutle and tributaries, and thus represents a significant impediment to the long-term recovery of anadromous steelhead and coho populations. The SRS is located in an area of the Toutle watershed considered to have high-restoration potential (LCFRB 2004). The FCF and associated trap-and-haul operations are inefficient, expose fish to high levels of stress due to handling, and are subject to the vagaries of long-term funding. These problems are exacerbated by locally dynamic environmental conditions and the highly variable status of habitat and production in areas upstream of the SRS.

The Lower Columbia Fish Recovery Plan identifies the remediation of passage problems created by the SRS and FCF as the top priority recovery action in the Toutle River subbasin. The biological and engineering feasibility assessment of the SRS spillway and FCF described in this report provide information necessary to implement appropriate fish passage and habitat restoration measures in subsequent phases of the project.

Additional information on the abundance, distribution and ecology of these species can be found in the *Lower Columbia Salmon Recovery and Fish and Wildlife Subbasin Plan, Volume II – Subbasin Plan, Chapter E – Cowlitz, Coweeman and Toutle* (LCFRB 2004), and the *Cowlitz River Subbasin Summary* (Northwest Power Planning Council 2002).

Project Purpose and Scope

AMEC Earth & Environmental, Inc. (AMEC) and the Lower Columbia Fish Recovery Board (LCFRB) received funding from the Salmon Recovery Funding Board (SRFB) to address fish passage issues on the North Fork Toutle River, which is considered a key priority in the Lower Columbia River Salmon Recovery Sub-basin Plan. The goal of the project, which has been modified slightly from the one originally proposed, is to assess current conditions of the FCF, spillway and sediment plain with respect to their effect on the upstream movements of adult coho salmon and steelhead trout, and to recommend ways in which fish passage could be improved.

Due to the Corps decision in 2007[3] to investigate the potential for modifying the SRS spillway to enable volitional fish passage and improving the FCF, the objectives of the project were reformulated to focus on the application of engineering and biological criteria to improve fish collection at the FCF, and fish passage through the SRS spillway and sediment plain. Because the investigations reported for this project were conducted during the same period that the Corps was undertaking its studies, it was not possible to fully synchronize the two efforts. Nevertheless, the Corps was consulted for information regarding their proposed plans, and an

3 The Corps decision to undertake the investigation was announced after SRFB grant funding had been awarded.

attempt was made to review and comment on their proposals, with the goal of providing a realistic assessment and strengthening the results of the two projects.

As articulated in the project proposal, the specific goal was to complete the second phase of a five-phase study, described as follows:

Phase I: Radiotelemetry study to determine current coho and steelhead distribution and habitat use above SRS;

Phase II: Biological and engineering feasibility assessment of fish passage and collection measures;

Phase III: Design and construction of modifications to enable fish passage through the SRS and/or improvements to FCF;

Phase IV: Habitat restoration project feasibility and prioritization; and

Phase V: Design and construction of habitat restoration projects.

Phase I comprised radiotelemetry studies completed by AMEC and its partners (USGS and the Cowlitz Indian Tribe) in 2005-2007 (Kock, et al. 2007), and a series of follow up studies that were undertaken as part of the current project. Previous Phase I studies determined that the SRS spillway is a complete barrier to upstream migrating coho salmon and that only a fraction of the steelhead that arrive at the base of the spillway are able to ascend it successfully (Kock, et al 2007). It was also determined that fish are able to ascend upstream through the sediment plain, and that fish released in tributaries remain in them through the spawning period. It should be cautioned that these conclusions were based on relative small number of detections of radio-tagged subjects and therefore, should be considered qualitative.

Two Phase II radiotelemetry studies were designed to explore some of questions raised by the Phase I studies. In the first study, AMEC and its partners investigated adult fish behavior and migratory movements in the immediate vicinity of the FCF. We radio-tagged and tracked fish in an attempt to identify fine-scale movement patterns that might reveal specific locations where passage is impeded. We also estimated the collection efficiency of the FCF based on recapture rates for fish that been previously captured, tagged, and released downstream of the facility. The results of this study are presented in Chapter 2.

The second Phase II radio-telemetry study consisted of monitoring the movements of radio-tagged fish released at the downstream end of the sediment plain. Based on subsequent detections and interpretations of fish behavior, we calculated a passage success rate and identified general areas in the sediment plain where passage might be impeded. The results of this study are described in Chapter 3.

The remaining Phase II project activities, described in Chapter 4, consisted of: assessing the current condition of the FCF and recommending short- and long-term measures that would improve its function; evaluating the fishway structure proposed by the Corps for the SRS spillway; and assessing fish passage conditions in the sediment plain. Based on this assessment, AMEC's fisheries biologists, hydraulic engineer, and fluvial geomorphologist proposed conceptual level solutions for improving fish passage at the FCF and through the SRS spillway and sediment plain.

The final section of this report (Chapter 5) summarizes our results and recommendations and, assuming that the extirpation of local salmon and steelhead populations is not an option, discusses the next steps towards implementing these improvements within the NF Toutle basin. The decision to proceed with the implementation of one or more of these recommendations will depend on the Corps' overall strategy to address continuing sediment problems, the success of measures designed to facilitate volitional passage through the spillway and sediment plain, and the availability of funding.

2.0 TRAPPING EFFICIENCY OF THE FISH COLLECTION FACILITY

OBJECTIVES

The objectives of this study were to 1) quantify trapping efficiency of the current FCF structure under typical operations; and 2) use fine-scale fish movement information to identify structural or operational factors that may limit the number of fish captured in the trap. We used radiotelemetry techniques, described below, to address these objectives.

Concurrently, the USGS conducted a pilot study of fish behavior at the FCF using a dual-frequency identification sonar (DIDSON) camera. The objective of the study was to quantify and compare the total number of fish holding in the FCF pool, with the number of fish that entered, and were captured in the trap.

METHODS

Capture and Tagging

All study fish were subjected to normal handling procedures by WDFW staff and were then gastrically fitted with a radio transmitter using methods described by Keefer et al (2004). During each tagging day we prepared an anesthetic bath by bubbling carbon dioxide gas (30 L/min) into 378 liters of river water for 4 minutes. WDFW staff hand netted fish from the trap and placed them into the anesthetic. Once fish lost equilibrium, we removed them from the bath, determined gender, measured length and collected scale samples. We attached a Floy tag (Floy Tag, Inc., Seattle, Washington) to each steelhead on the dorsal portion of the fish to be able to identify repeat spawners. We used 7-V radio transmitters from Lotek Wireless, Inc. (Newmarket, Ontario) that measured 8.25 centimeters (cm) in length, 1.27 cm in diameter, weighed 13 grams in water, and had a rated operating life of 296 days. Transmitters emitted a signal every five seconds and operated on one of four radio frequencies with unique codes, allowing individual fish identification. To increase roughness and reduce the likelihood of transmitter regurgitation, we placed a single band of silicon surgical tubing (~5 millimeters [mm]-wide; 3-mm thick; 12-mm inside diameter) around the transmitter (near the top). We bent the antenna where it exited from the mouth so that it trailed alongside the fish externally. After tagging, we placed fish in either a 111 liter (FCF and SRS release groups) or 1,514 liter (tributary release group) oxygenated transport tank, where they were held until release (usually within one hour).

We prepared to tag fish for the time periods of 10 October to 28 November, 2008, and 13 March to 26 May, 2009 (coho and steelhead respectively) but did not always have sufficient numbers of fish in the trap to tag. Washington Department of Fish and Wildlife operated the FCF Wednesday through Friday each week, with processing and tagging occurring each Friday. Through an adaptive management process with WDFW, we agreed to radio-tag only one of every four fish captured in the trap, with the remaining three fish transferred to upper watershed release sites as part of the normal trap and haul operation. This process ensured that our study would not impact the success of the run disproportionately to its size. We attempted to tag an equal number of males and females to account for any behavioral differences due to gender.

We assumed that all fish selected for tagging were of natural origin as indicated by the presence of the adipose fin.

Releases

We released tagged coho downstream of the FCF at RM 20.5 near Kid Valley (46°21’22”N, 122°38’46”W; Figure 4). We selected this release site, approximately 6 RM downstream of the FCF, to allow tagged fish to recover from anesthesia and resume normal migration behavior prior to being evaluated at the FCF.

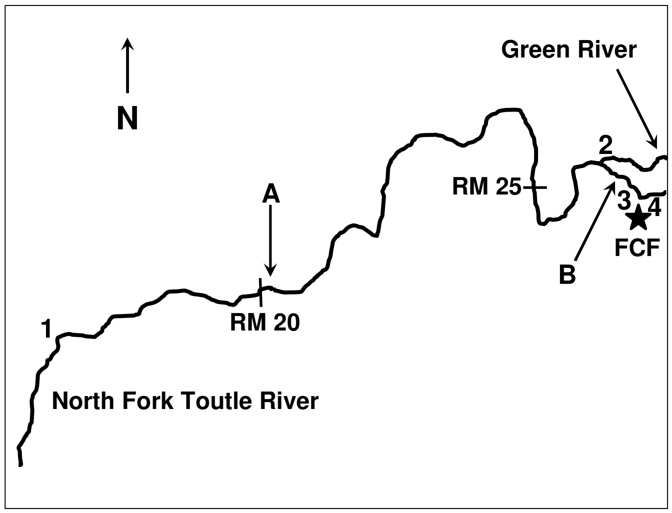


Figure 4 Map of the study area, showing location of the Fish Collection Facility (FCF), release location of coho (A) and steelhead (B), fixed telemetry sites (1-4). River Miles 20 and 25 (measured from the confluence with the Cowlitz River) are shown for reference.

Following the coho evaluation (see results, below), we altered the release location for radio-tagged steelhead. Steelhead were released immediately downstream of the FCF at RM 26.7 in the holding pool (46°22’20”N, 122°34’38”W; Figure 4). We selected this release site to increase the likelihood that tagged fish would return to the FCF, and thus provide better information about how fish behave inside the ladder and trap.

Tracking

We used a combination of fixed telemetry sites and mobile tracking equipment to monitor the movements of tagged fish continuously throughout the study period. Fixed telemetry sites consisted of one or two 3-element Yagi antennas connected to an SRX-600 telemetry receiver (Lotek Wireless, Inc., Newmarket, Ontario) that monitored four frequencies for 7 seconds each, resulting in an overall scan period of 28 seconds.

We established fixed telemetry sites at seven locations within the study reach (Figures 4 and 5):

- Downstream of the coho release location at approximately RM 16
- Confluence of the Green and North Fork Toutle Rivers at RM 26.5

- FCF Ladder Entrance
- FCF Ladder Step 1
- FCF Ladder Bend 1
- FCF Ladder Bend 2
- FCF Ladder Holding Pool Entrance

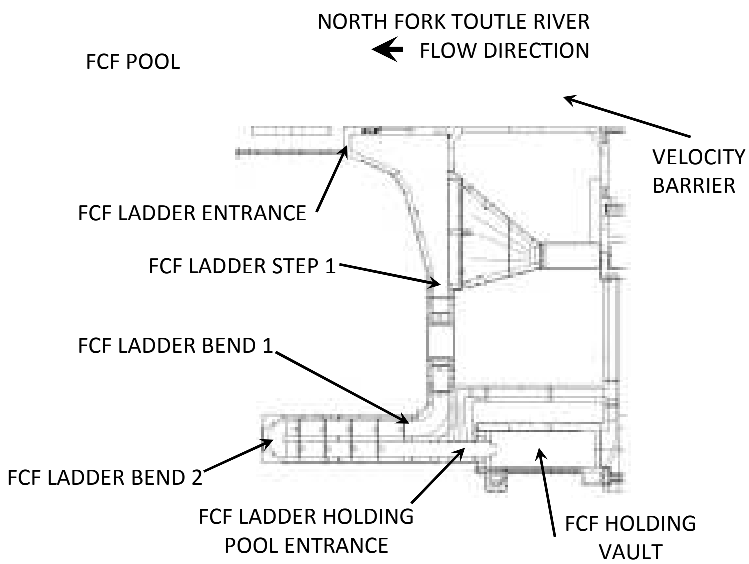


Figure 5 FCF Schematic and Antenna Locations

Monitoring equipment installed at the fixed sites scanned continuously for radio-tagged fish between 10 October and 12 December, 2008 and from 13 March until 20 June, 2009. One exception was the fixed site at RM 16, which we did not use during the steelhead evaluation because the release site was closer to the FCF, upstream of the Green River confluence site.

We used mobile tracking equipment - which consisted of a 3-element Yagi antenna connected to a telemetry receiver - once per week by driving slowly along roads located within the study area until a signal was detected. Upon detecting a signal, we recorded the date, time, tag number, location to the nearest tenth of a river mile, and attempted to triangulate a more precise location of the signal source. We concentrated our efforts downstream of the FCF because this area was most pertinent to our objective.

Data Analysis

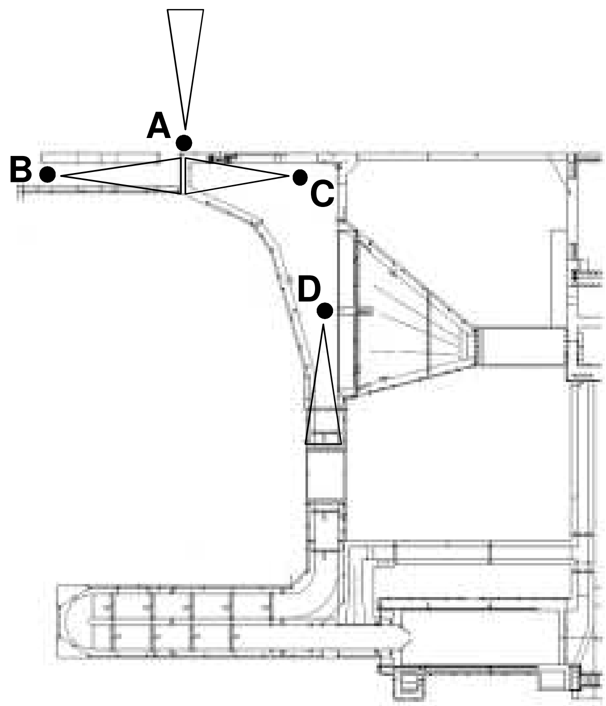
We uploaded data from the fixed telemetry sites weekly and incorporated them into a database. We then merged the data with mobile tracking results and the tagging and release records to create a single dataset containing complete detection histories of all radio-tagged fish. From these histories, we summarized movement patterns of individual fish and compared by species to address research objectives.

We calculated trapping efficiency by dividing the number of tagged fish that were recaptured by the total number released below the FCF. More detailed information regarding fish behavior was observed by interpreting radio-tracking data. For each individual fish we noted the farthest upstream movement in the North Fork Toutle River and the location where the fish was last detected.

Additionally, we compiled hydrographic information, collected by the USGS gauge 14240525 located on the North Fork Toutle River at RM 26.6, and compared it to the timing of observed fish movements to identify a possible correlation between upstream fish movement and flow-related cues. Hydrographic data consisted of a daily series of mean discharges during the study period (to represent conditions that tagged fish experienced), and the average of daily mean discharge for each day of the study period over the past 18 years (1990 to 2008; to represent conditions that fish normally experienced). We aligned current and average historic flows with known fish locations on a daily basis and used a graphical approach to confirm whether changing hydraulic conditions affected the relative success of fish passage.

DIDSON

A dual-frequency identification sonar (DIDSON; Sound Metrics Corp., Lake Forest Park, Washington) was deployed in and around the FCF to observe fish behavior and supplement findings from the radiotelemetry evaluation. The DIDSON is an underwater imaging device that forms near-video-quality images through the use of acoustic beams. The device has a field-of-view that is 29^{o} wide in the horizontal plane and 8.5^{o} deep in the vertical plane. The DIDSON was deployed at four locations during the study period (Figure 6; Table 2). The combined effects of turbulence and turbidity severely compromised image quality at three of the four locations (locations A, B, and D in Figure 6). Because of the reduced effectiveness of the DIDSON at these locations, methods and results hereafter refer only to the sampling location near the FCF entrance (location C in Figure 6). On each sampling date the DIDSON was positioned inside the FCF. The DIDSON was programmed to observe the area located 2 meters away from the camera at the nearest point and 6.5 meters away from the camera at the farthest point, to provide a total field-of-view that was 4.5 meters long. The FCF entrance was located approximately 6 meters from the camera which allowed us to observe the area located immediately upstream of the entrance (Figure 6). Images were monitored real-time on a laptop computer and recorded continuously to an external data storage device. The DIDSON monitored this location from 08:46 to 15:00 on 12 December, 2008 and from 09:50 on 9 April, 2009 to 07:00 on 10 April, 2009. Images were reviewed to enumerate to total number of fish that entered and exited the FCF.



● = DIDSON location

= approximate field-of-view

Figure 6 Diagram of the fish collection facility (FCF) on the North Fork Toutle River showing the locations where a dual-frequency identification sonar (DIDSON) was deployed during 2008 and 2009. Letters in the figure correspond to sampling dates in Table 2 of this report.

Table 2 Sampling dates and locations at the fish collection facility (FCF) on the North Fork Toutle River for a dual-frequency identification sonar (DIDSON). Sampling locations are shown in Figure 6 of this report.

Sampling dates	Sampling locations
October 6-7, 2008	A, B
November 24-28, 2008	B, D
December 12, 2008	C
March 20, 2009	A
April 9-10, 2009	C
April 15-16, 2009	A, D

Our radiotelemetry study benefited from the deployment of the DIDSON camera because the camera was able to provide a general picture of fish behavior at one specific location. In contrast, the radiotelemetry data provided information for individual fish across a larger area.

RESULTS

Coho

During the 2008 coho migration season, a total of 115 adult and 12 jack coho were captured in the FCF, 19 of which we tagged for one of the two studies described in this report (Table 3). For the trapping efficiency study, we tagged and released nine coho salmon on two dates in October 2008 (Table 4). The study group included eight males, and one female. The average fork length of tagged fish was 78 cm (Standard Error [SE] = 1.6 cm). None of the tagged coho were recaptured in the FCF trap.

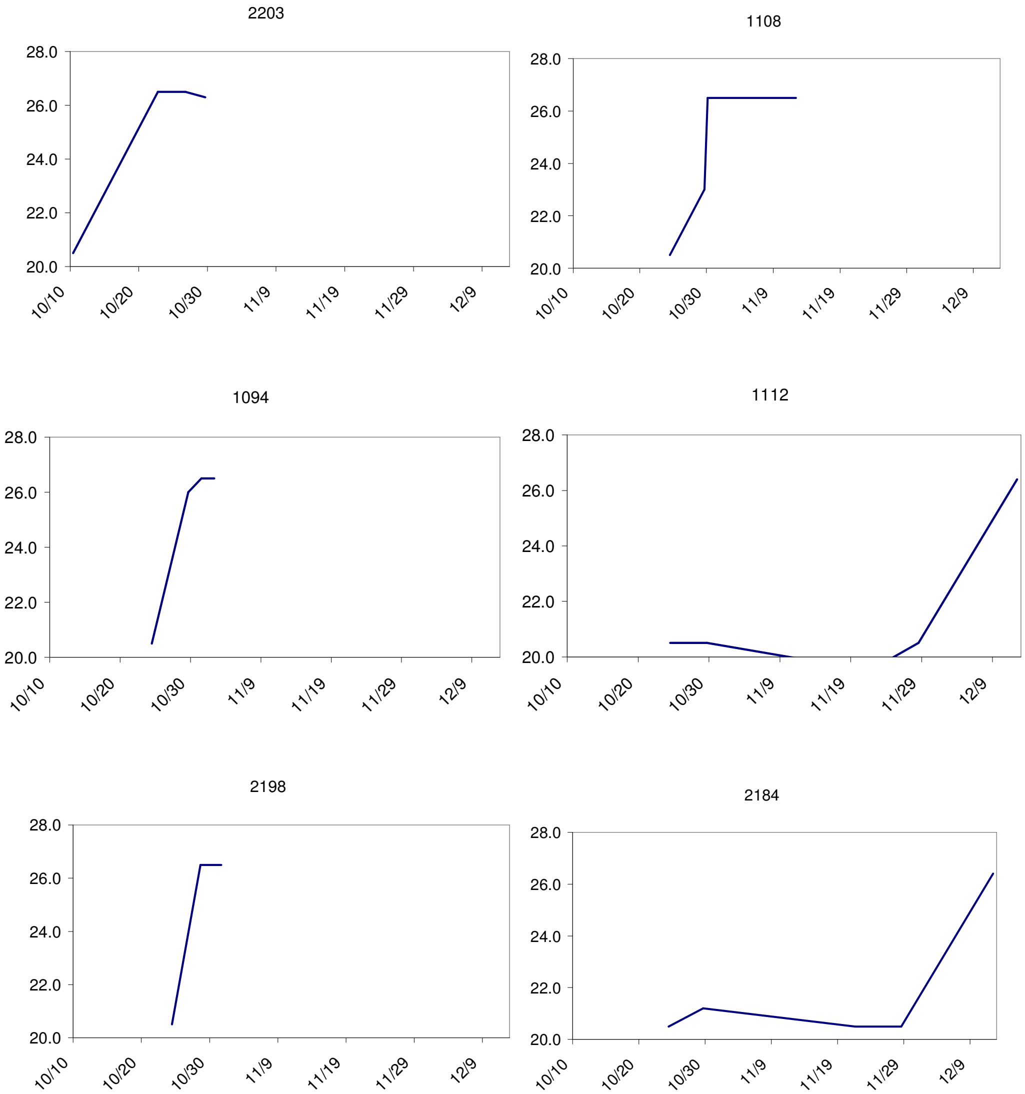
Table 3 Weekly contents of the FCF trap during the 2008 coho migration season and a summary of the fate of trapped fish. Does not include include jacks. "-" indicates tagging operations were either not planned or cancelled.

2008 Coho	Trucked		FCF Study		Sed Plain Study		Total in Trap
	M	F	M	F	M	F	
Date							
9/12/2008	1	0	-	-	-	-	1
9/19/2008	2	0	-	-	-	-	2
9/26/2008	1	2	-	-	-	-	3
10/3/2008	2	0	-	-	-	-	2
10/10/2008	3	0	1	0	0	0	4
10/17/2008	3	2	-	-	-	-	5
10/24/2008	5	3	7	1	0	0	16
10/31/2008	5	8	-	-	-	-	13
11/7/2008	25	20	0	0	3	3	51
11/14/2008	6	8	0	0	2	2	18
Totals	**53**	**43**	**8**	**1**	**5**	**5**	**115**

Table 4 Coho radio-tagged for the FCF trapping efficiency study and a summary of each fish's detection history. None of the tagged coho were recaptured in the FCF trap.

Tag Number	Release Date	Sex	Fork Length	Upstream Extent	Last Detection	Date of Last Detection
2203	10/10/08	M	70	Green River (RM 26.5)	RM 26.3	10/29/08
1094	10/24/08	M	79	Green River (RM 26.5)	Green River	11/02/08
1099	10/24/08	M	83	NA	NA	10/24/08
2198	10/24/08	F	74	Green River (RM 26.5)	Green River	10/31/08
2207	10/24/08	M	79	Green River (RM 26.5)	Green River	10/31/08
1108	10/24/08	M	79	Green River (RM 26.5)	Green River	11/12/08
1112	10/24/08	M	84	RM 26.4	RM 26.4	12/12/08
2184	10/24/08	M	79	RM 26.04	RM 26.4	12/12/08
2186	10/24/08	M	72	Green River (RM 26.5)	RM 26.4	12/12/08

None of the tagged coho moved upstream further than the fixed monitoring site at the Green River confluence (RM 26.5). The fixed telemetry equipment detected six of the tagged fish (67%) at this site. Additionally, we detected two fish as far upstream as RM 26.4 with mobile tracking equipment that were not detected by the fixed equipment. Of the nine tagged fish, one fish was never detected after release. We did not determine the ultimate fate of these fish because it was outside of the project scope. Of the six tagged fish that moved upstream to the Green River confluence, four were last detected at this point, which may indicate that they continued up the Green River or were captured in the recreational fishery. The two remaining fish were last detected downstream of the confluence. The average residence time at the Green River confluence was 4.4 days (Figure 7).



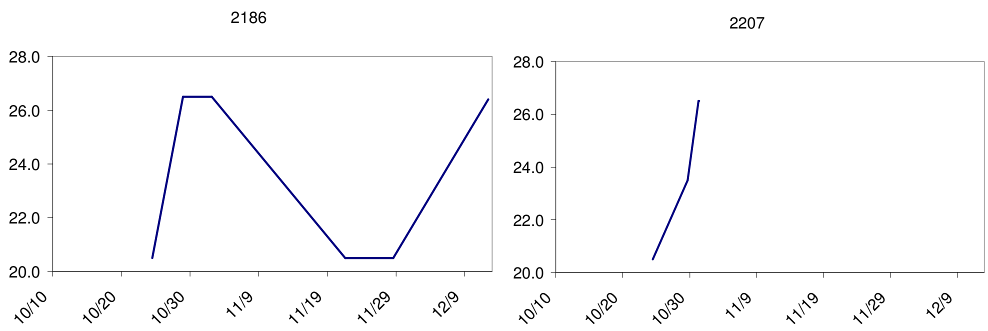


Figure 7 Upstream migration timing of coho salmon as shown by River Mile location (y-axis) according to date (x-axis). None of the tagged coho moved up the North Fork Toutle River beyond the confluence of the Green River at RM 26.5.

In early November 2008, during the coho evaluation, the fixed site at RM 16 was vandalized and damaged. Continuous records of the time period after this date are therefore lacking. It is possible that some coho may have passed back downstream of this site undetected.

Daily mean discharge for the North Fork Toutle River during the coho study period (63 daily records between 10 October and 12 December) averaged 574 cubic feet per second (cfs); lower than the 806 cfs long-term average for the same seasonal period. The minimum and maximum daily mean discharges during the coho study period were 218 cfs and 4,590 cfs, respectively. The maximum daily mean discharge occurred during a three day high-flow event in mid-November (Figure 8), after which flows returned back to below 900 cfs for the remainder of the study period.

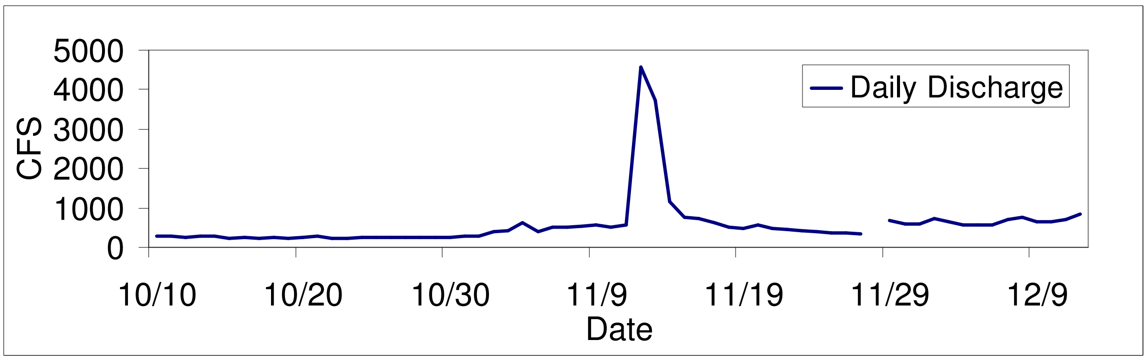


Figure 8 Daily Mean Discharge during the coho study period: 10 October - 12 December, 2008.

The upstream movements of radio-tagged coho occurred during periods of stable low flows, not in response to increased flows or during the high flow event as observed by Kock et al (2007). For example, three tagged coho were detected on fixed sites both before and after the high-flow event in mid-November. These fish were all detected lower in the system following the high-flow event relative to where they were detected before the flow spike.

Deployment of the DIDSON camera did not contribute to research findings during the coho salmon evaluation. Although the DIDSON was deployed near the FCF entrance on 12

December, 2008, no coho salmon were observed during the monitoring period. FCF trap counts during that week showed that no coho salmon were collected which suggests that few fish were present during that monitoring period.

Steelhead

During the 2009 steelhead migration season, a total of 89 fish were captured in the FCF, 21 of which we tagged for one of the two studies described in this report (Table 5).

We tagged and released eleven steelhead between 13 March and 24 April 2009 (Table 6). The study group included six females and five males. The average fork length of radio-tagged fish was 70 cm (SE = 1.4 cm). Three tagged steelhead were recaptured in the trap, resulting in a trapping efficiency of 27 percent (SE = ±13%). All three recaptured steelhead were female. The three recaptured fish moved from the FCF ladder entrance to the entrance to the trap vault in an average of 83 minutes. This trapping efficiency should not be compared to that calculated for coho, since the release location was different between the two studies.

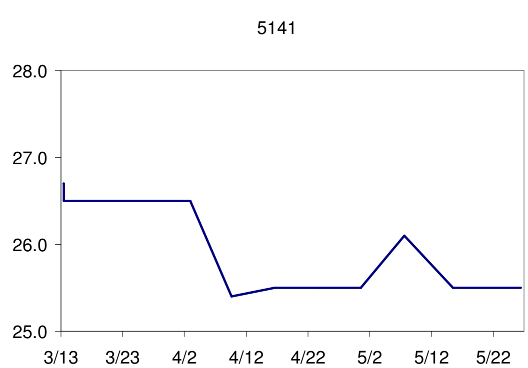
Table 5 Weekly contents of the FCF trap during the 2009 steelhead migration season and a summary of the fate of trapped fish. Three fish, radio-tagged for the FCF study, were recaptured and used in the Sediment Plain study; they are counted in this table but are not included in the population total (89 steelhead). "-" indicates tagging operations were either not planned or cancelled.

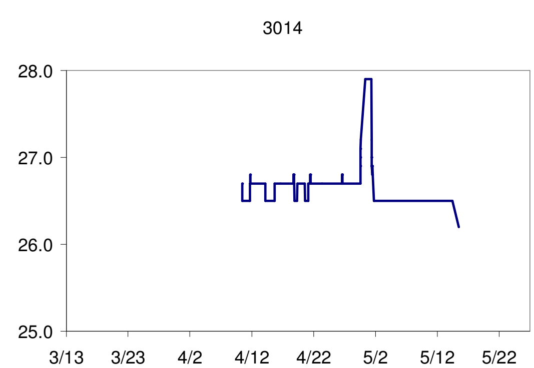
2009 Steelhead	Trucked		FCF Study		Sed Plain Study		Total in Trap
	M	F	M	F	M	F	
Date							
11/21/2008	1	0	-	-	-	-	1
11/26/2008	0	1	-	-	-	-	1
2/20/2009	1	0	-	-	-	-	1
3/13/2009	1	6	0	2	0	0	9
3/20/2009	2	10	0	2	0	2	16
3/27/2009	4	2	0	1	0	1	8
4/3/2009	3	3	1	0	0	1	8
4/10/2009	4	12	1	1	0	3	21
4/17/2009	5	4	2	0	0	1	12
4/24/2009	3	5	1	0	0	1	10
5/1/2009	1	2	0	0	0	1	4
5/8/2009	0	1	0	0	0	0	1
Totals	25	46	5	6	0	10	92

Table 6 Steelhead radio-tagged for the FCF trapping efficiency study and a summary of each fish's detection history

Tag Number	Release Date	Sex	Fork Length	Upstream Extent	Last Detection	Date of Last Detection
5141	03/13/09	F	75	FCF Pool	RM 25.5	05/26/09
20083	03/13/09	F	64	Recaptured	Recaptured	03/20/09
3010	03/20/09	F	78	Recaptured	Recaptured	03/26/09
5130	03/20/09	F	68	Ladder Entrance	RM 25.5	05/15/09
5114	03/27/09	F	67	Recaptured	Recaptured	04/08/09
20088	04/03/09	M	69	FCF Holding Vault	RM 26.2	05/15/09
3014	04/10/09	M	66	FCF Holding Vault	RM 26.2	05/15/09
5138	04/10/09	F	67	FCF Pool	RM 22.1	04/16/09
3030	04/17/09	M	77	Ladder Entrance	Green River	04/27/09
3035	04/17/09	M	67	Ladder Entrance	Green River	05/18/09
5132	04/24/09	M	69	FCF Holding Vault	RM 26.5	05/15/09

Eight tagged steelhead were not recaptured at the FCF. The upstream extent of these fish was as follows: two never re-entered any part of the FCF, three re-entered the FCF but did not ascend beyond the ladder entrance, and three ascended back up to the holding vault but were not recaptured. We did not determine the ultimate fate of tagged fish that were not recaptured because it was outside of the project scope. It is possible that these fish either ascended the Green River, migrated back downstream, or were captured in the recreational fishery. Three of our study fish were last detected at the Green River confluence, and five were last detected at locations downstream of the confluence (Figure 9).





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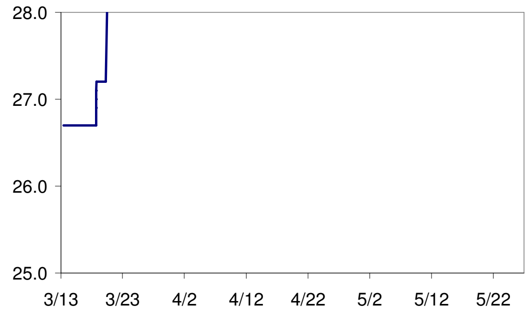

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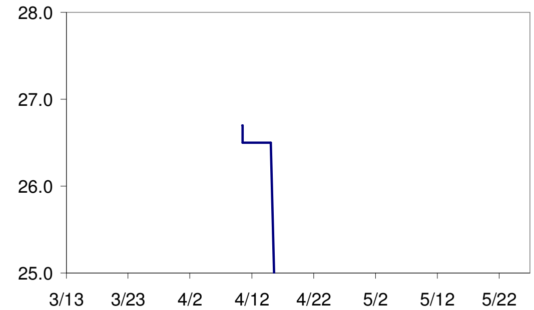

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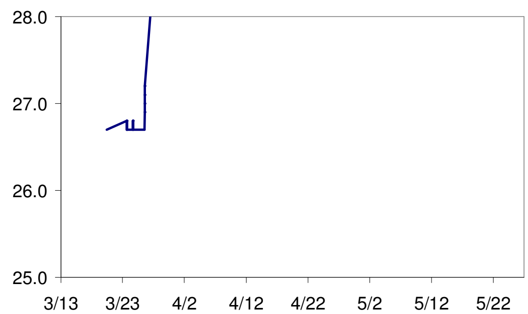

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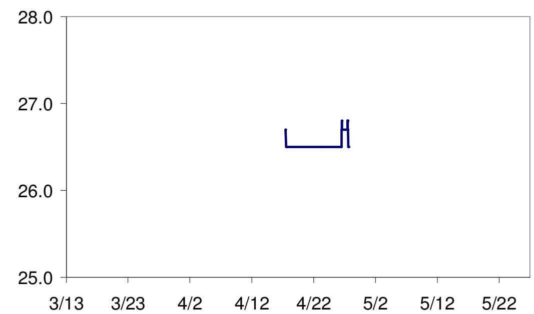

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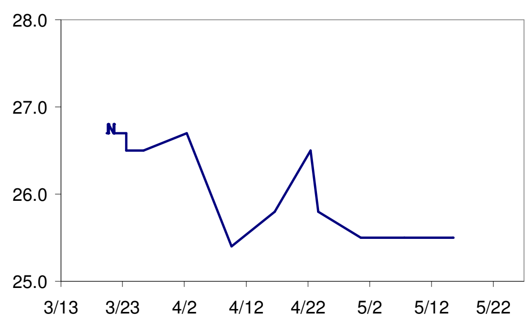

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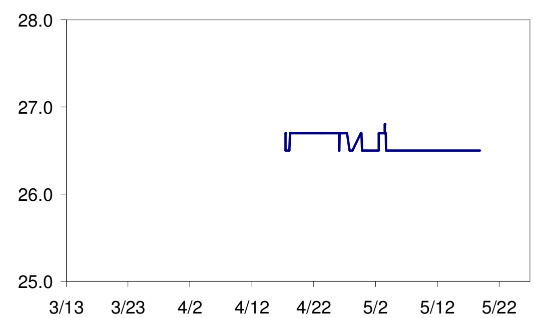

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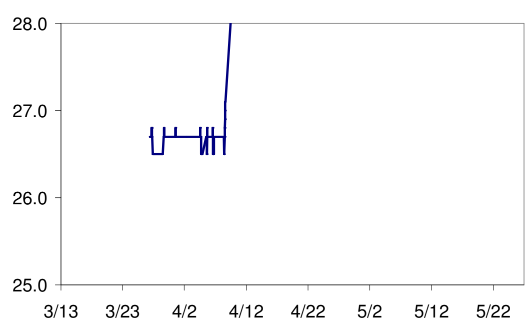

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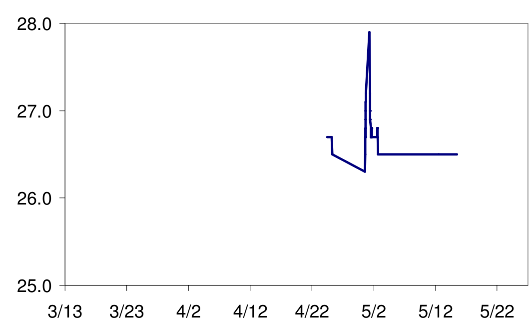


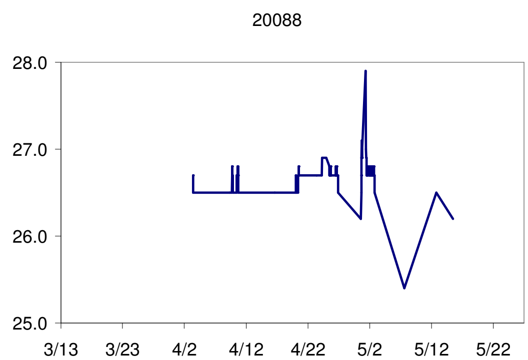


Figure 9 Upstream migration timing of steelhead as shown by River Mile location (y-axis) according to date (x-axis). For illustrative purposes, the relatively short distance between the FCF Pool (RM 26.7) and the FCF holding vault from which fish are recaptured, is represented in the following way: Ladder Entrance = RM 26.8; Ladder Step 1 = RM 26.9; Ladder Bend 1 = RM 27.0; Ladder Bend 2 = RM 27.1; Ladder Holding Vault Entrance = RM 27.2; Holding Vault = RM 27.9; Recapture = RM 28.0.

During the steelhead study period (75 records between 13 March and 26 April), daily mean discharge for the North Fork Toutle River averaged 822 cfs, slightly lower (13.5% less) than the 950 cfs long-term average for this period. The minimum and maximum daily mean discharge during the steelhead study period was 353 cfs and 1,540 cfs, respectively. Flows during this time period generally increased, with repeated spikes in the hydrograph occurring on a period of approximately 4-5 days (Figure 10).

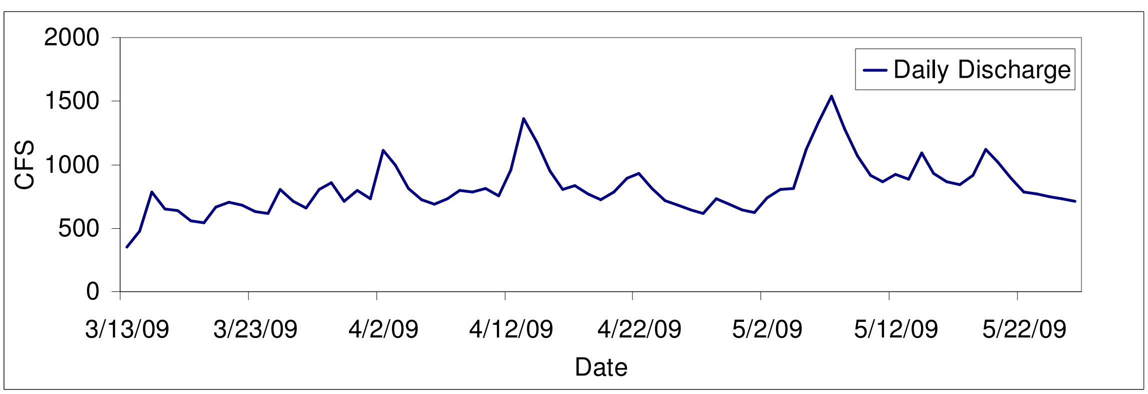


Figure 10 Daily Mean Discharge during the steelhead study period: 13 March – 26 May, 2009

The DIDSON camera successfully recorded several steelhead near the FCF entrance during period of deployment in April (Figure 11). We counted a total of 34 steelhead over the course of the 21 hour spring 2009 evaluation period. Most fish (30 fish; 88%) were observed moving downstream and out of the FCF compared to the number of fish (4 fish; 12%) that were observed entering the structure.

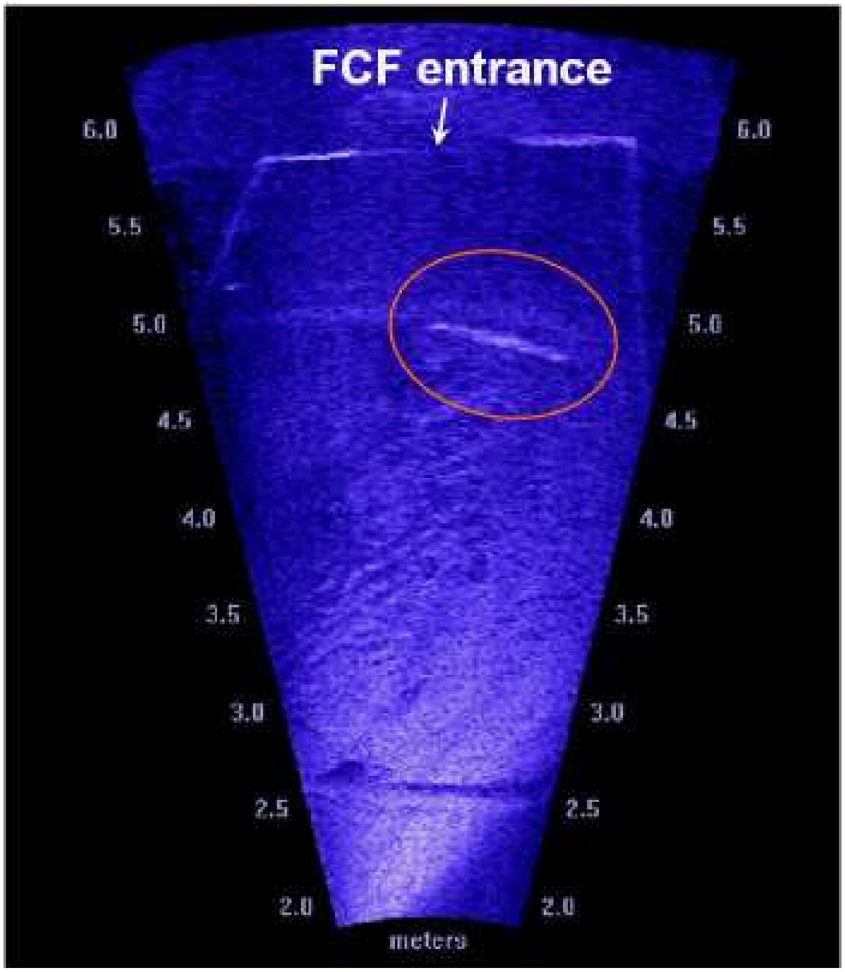


Figure 11 Image recorded by the acoustic camera at the FCF ladder entrance on the North Fork Toutle River during 2009. The circled object is a steelhead that was observed passing upstream through the FCF entrance.

DISCUSSION

We did not randomly select fish to tag; therefore, we cannot extrapolate the observed trapping efficiency rates to the rates expected for the total respective coho and steelhead populations. We tagged and evaluated the behavior of fish that had already demonstrated their ability to successfully swim into the FCF trap, which may have selected for fish that had a higher than average fitness level and made them more likely than the rest of the population to re-enter the trap. Conversely, tagged fish may have had a fitness disadvantage resulting from the stress of anesthesia, handling and tag insertion. This stress may have induced “trap-shy” behavior, making tagged fish less inclined to repeat the experience for a second time.

In future studies, we recommend collecting fish downstream of the FCF prior to any exposure to the study area. This approach would allow assessment of naïve fish, and therefore, provide the most unbiased perspective on how fish behave near the FCF. Although we considered this approach for this study, consultation with WDFW recommended that we use fish collected at the

FCF to minimize impacts to the remainder of the run. No reliable estimate of the total number of each species that returned to the North Fork Toutle below the FCF is available that would allow a comparison of trap efficiency rates between tagged and non-tagged fish.

Below, we interpret the results of this study with the intent of identifying specific areas where hydraulic conditions may be responsible for limiting upstream passage success. However, water quality characteristics, most notably the high turbidity in the North Fork Toutle, should not be discounted as potential deterrents to upstream fish migration. The avoidance of suspended volcanic ash by Chinook salmon (Whitman et al 1982) and increased stray rates by Toutle River steelhead following the eruption (Leider 1989), in addition to any “trap-shy” behavior mentioned above, suggest that confounding behavioral factors may limit the power of conclusions that relate specifically to the physical ability of fish to ascend past problem areas within and below the FCF.

Coho

None of our radio-tagged coho were recaptured in the FCF trap, but the trapping efficiency for coho is clearly not zero, since a total of 127 untagged coho were captured over the course of the season (Table 3 above). In addition to the potential tag effects described above, this apparent discrepancy between the observed trapping efficiency and that for the population as a whole may also be due to the low sample size.

After tagging and release, most of our study fish (89%) repeated their upstream migration to within a few hundred yards of the FCF, near the Green River confluence. However, none continued past the confluence toward the FCF. Half of these fish were later detected downstream, indicating they did not continue up into the Green River. We did not determine whether tagged fish were alive or dead at the time of last detection, so there is a possibility that some of the apparent downstream movement was due to carcasses drifting downstream with the current. The other half of the fish that moved upstream to the Green River confluence were last detected at the Green River fixed site. This finding suggests the possibility that these fish may have left the study area by ascending the Green River, instead of the North Fork Toutle mainstem. We were unable to confirm the final locations of the tagged fish and did not attempt to find tagged fish that may have migrated further up the Green River or downstream of RM 20. It is also possible that the tagged fish were removed from this location through the recreational fishery.

The behavior of tagged coho can be interpreted in different ways. There may be at least a partial impediment to fish passage between the Green River confluence and the FCF pool at the flow levels that were experienced during this time period. In fact, substantial erosion of the natural channel bed below the FCF pool was noted by the hydraulic engineer during the site visit (see Chapter 4 and Appendix B - Technical Memorandum sent to WDFW). This erosion resulted in a much steeper approach to the FCF pool below the velocity barrier, and created several small cascades and falls which may deter a large percentage of coho from ascending to the FCF pool and ladder entrance. This condition would be especially prominent during low-flow conditions.

The difficulties we encountered with deployment of the DIDSON camera (e.g., extremely high turbidity, rapid sedimentation around the unit, and short time interval for monitoring) prevented us from making confident conclusions about fish behavior near the entrance to the fish ladder. However, for the time it was deployed, no coho salmon were observed near the FCF ladder, which may suggest that their migration was blocked somewhere further downstream, or that there were simply no fish during this later part of the migration season. During the FCF operations on 12 December 2008, WDFW collected no coho from the holding vault.

Steelhead

The rate of recapture that we observed for steelhead was also relatively low; although the small sample size resulted in a wide margin of error. If we assume a representative sample, then trapping efficiency of steelhead, with 95 percent confidence, is between zero and 57 percent[4].

Steelhead results are not comparable to the coho results due to the difference in release locations. Radio-tagged coho had to travel upstream several miles, were confronted with a navigational choice at the Green River confluence, and may have been faced with partial barriers in the section of the North Fork Toutle between the Green River confluence and the FCF. In contrast, steelhead were released upstream of the Green River confluence, into the pool immediately below the FCF. Due to the location of the release site relative to the velocity barrier, fish were not able to move upstream until the trap resumed its operations. This release site also reduced the likelihood of tagged fish choosing the Green River as an alternative pathway, and avoided the stream reach that may have posed passage issues for coho.

The behavior of steelhead within the FCF raises concerns with the effectiveness of the trap structure and the operational methods. Three tagged fish were able to re-ascend the ladder and enter into the holding vault, yet were not recaptured. This indicates that the finger weirs at the entrance to the holding vault are not effective at preventing fish from escaping. Additionally, it is possible that the method used for extracting fish from the holding vault, which involves lowering water levels, having staff enter the trap, and hand-netting fish individually from the vault, may encourage fish to exit back downstream (this process is described in further detail in the FCF Technical memorandum, Appendix B). This ad hoc method was developed to make up for the fact that the crowder and other systems do not function as they were intended.

Results from the DIDSON study during the steelhead season were somewhat inconclusive due to the limited capability of the equipment in the conditions that were present. It appears that steelhead move freely in and out of the ladder entrance and up and down the FCF ladder. This finding is supported by the radiotelemetry data. We assume that the DIDSON recorded every fish that passed the camera while it was recording. While we cannot identify individual fish using the DIDSON, we can accurately enumerate fish and determine their direction of travel. Therefore, the actual number of fish observed may be less than the number counted. In fact, one of the tagged fish moved from the FCF pool into the ladder entrance and then back into the FCF pool twice during the time the DIDSON was deployed in this area. Regardless of the problems posed by potential double reporting of fish, between 26 and 30 steelhead were observed moving downstream out of the FCF once the flows were adjusted to begin removing

[4] Confidence interval based on two-tailed t-distribution and 10 degrees of freedom

fish from the holding vault. On this date, 20 steelhead were captured in the trap. The unrestricted movements of steelhead within the ladder and trap suggest that trapping efficiency could be improved.

3.0 MIGRATION BEHAVIOR IN THE SEDIMENT PLAIN

OBJECTIVES

The objectives of this study were to 1) determine the proportion of coho and steelhead that successfully navigate through the sediment plain, 2) determine where those fish disperse in the upper watershed, and 3) identify potential blockages to upstream fish passage in the sediment plain. We used radiotelemetry to address these objectives.

METHODS

Capture and Tagging

The methods for capture and tagging are described in Chapter 2.

Releases

We released coho and steelhead upstream of the SRS at RM 28.2, several hundred meters south of the spillway lip (Figure 12; 46°21'33"N, 122°33'06"W). The release site had an area of low flow where the fish could hold easily until fully recovered from the handling and transportation (Figure 13). We transported tagged fish using 111 liter oxygenated holding containers and released them within two hours of tagging.

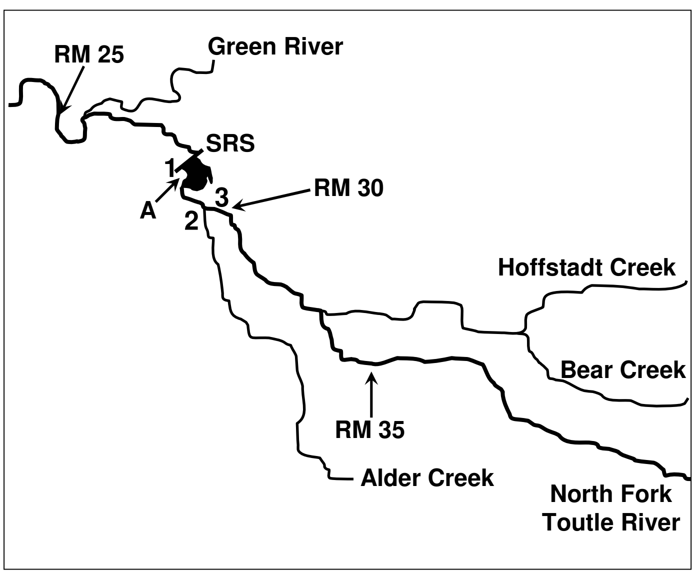


Figure 12 Map of study area showing location of the Sediment Retention Structure (SRS), release location (A), fixed telemetry sites (1-3), and tributary streams. River mile 25, 30, and 35 (measured from the confluence with the Cowlitz River) are shown for reference. RM 32 was considered the upper extent of the sediment plain.

Figure 13 Photograph of Sediment Plain at RM 28.1, looking east.

To increase our sample size, we used both untagged fish according to the adaptive management tagging schedule, and any fish that were recaptured from the FCF trapping efficiency study (Chapter 2).

Tracking

We used a combination of fixed telemetry sites and mobile tracking to monitor the movements of tagged fish continuously throughout the study period. The equipment specifications are described in Chapter 2.

We established fixed telemetry sites at three locations within the study reach (Figure 12):

1. SRS (downstream extent of the sediment plain), RM 28.2
2. Ecopark Resort (North bank of river), RM 29.1
3. Alder Creek (South bank of river), RM 29.9

The first two sites were in place and continuously monitoring for radio-tagged fish between 11 November and 29 December, 2008 and between 20 March and 26 June, 2009. On our visit to the Alder Creek site on 7 November 2008, we discovered that vandalism had rendered the equipment inoperable. We did not immediately replace equipment at the site due to the risk of further loss. Therefore, the Alder Creek fixed site was not used for the coho study;.however, it was replaced and used for the steelhead study.

We scanned the study area with mobile tracking equipment once per week using a 3-element Yagi antenna connected to a telemetry receiver. Mobile tracking efforts consisted of visiting sites accessible by vehicle or foot and surveying the study area to determine the bearing and strength of any signals from tagged fish. We then determined fish locations by triangulation. We were unable to identify the final spawning locations or fate of fish that traveled past the sediment plain due to the absence of access roads to these areas and the difficulty of traveling on the sediment plain itself.

Data Analysis

We uploaded data from the fixed telemetry sites weekly and incorporated them into a database. We then merged the data with mobile tracking results and the tagging and release records to create a single dataset containing complete detection histories of all radio-tagged fish. From these histories, we summarized movement patterns of individual fish and compared by species to address research objectives.

For the purpose of this study we defined the upper extent of the sediment plain to be RM 32. Therefore, we calculated the proportion of fish that successfully ascended the sediment plain by dividing the number of fish that were detected either above RM 32.0 in the mainstem or in Alder Creek (which meets the mainstem at RM 29.5) by the total number of fish released. We identified potential passage problem areas by noting the farthest upstream extent of each fish, as well as the location of the last detection.

Finally we compared the timing of observed fish movements in the sediment plain with hydrographic information collected by the USGS gauge 14240525 located on the North Fork Toutle River at RM 26.6 to identify a possible correlation between upstream fish movement and flow-related cues. We compiled a time series of the daily mean discharge during the study period (to represent conditions that tagged fish experienced) along with the mean daily flows over the same time period for each year between 1990 and 2008 (to represent conditions that fish normally experienced). We aligned current and average historic flows with known fish locations on a daily basis and used a graphical approach to identify any possible correlation between fish migration timing and flow. We also felt it was important to document river discharge during the study period since the hydraulic conditions that fish encounter in the sediment plain vary considerably under different flows.

RESULTS

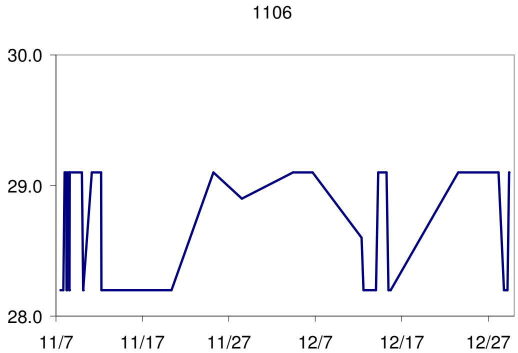
Coho

During the 2008 coho migration season, a total of 115 fish were captured in the FCF, 19 of which we tagged for one of the two studies described in this report (Table 3 above). For the sediment plain study, we tagged and released ten coho salmon on two dates in November (Table 7). The study group included five males and five females and the average fork length for tagged fish was 74 cm (SE = 1.1 cm).

Table 7 Coho radio-tagged for the sediment plain ascension study and a summary of each fish's detection history. None of the tagged coho successfully ascended past the sediment plain.

Tag Number	Release Date	Sex	Fork Length	Upstream Extent	Location of Last Detection	Date of Last Detection
1106	11/07/2008	F	74	Ecopark (RM 29.1)	Ecopark (RM 29.1)	12/29/08
1111	11/07/2008	F	75	Ecopark (RM 29.1)	SRS (RM 28.2)	12/29/08
1119	11/07/2008	F	77	RM 28.6	SRS (RM 28.2)	12/29/08
2190	11/07/2008	M	76	RM 30.0	Ecopark (RM 29.1)	12/27/09
2205	11/07/2009	M	76	Ecopark (RM 29.1)	SRS (RM 28.2)	12/27/09
2206	11/07/2008	M	69	RM 30.0	SRS (RM 28.2)	12/29/08
1113	11/14/2008	F	67	RM 30.0)	Ecopark (RM 29.1)	12/29/08
1116	11/14/2008	F	71	RM 30.0	Ecopark (RM 29.1)	1229/08
2194	11/14/2008	M	72	SRS (RM 28.2)	SRS (RM 28.2)	11/14/08
2196	11/14/2008	M	78	Ecopark (RM 29.1)	Ecopark (RM 29.1)	12/29/08

Coho were detected at the SRS and Ecopark fixed sites regularly throughout the study period (Figure 14). In fact, seven of our 10 study fish exhibited repeated movement between the two fixed sites until the end of December. One fish was never detected above the release site; one was detected with mobile tracking equipment slightly above the release site; and one fish was detected at RM 30.0 with mobile tracking but had not been detected by any fixed sites. A total of four tagged coho were able to reach locations upstream of the Ecopark fixed site (all of them up to RM 30.0) but later fell back downstream. We had difficulty determining the final locations of tagged fish due to accessibility and concluded our tracking efforts in late December. Since none of the tagged coho were detected in the mainstem above the sediment plain, in Alder Creek, or at the Green River site below the dam, it is likely that they were trapped somewhere within the sediment plain or SRS spillway. Thus, we conclude that none of the tagged coho successfully ascended beyond the sediment plain.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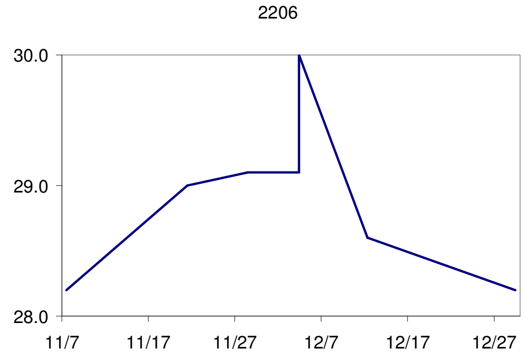
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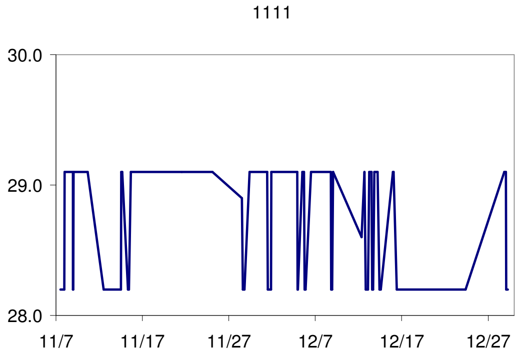
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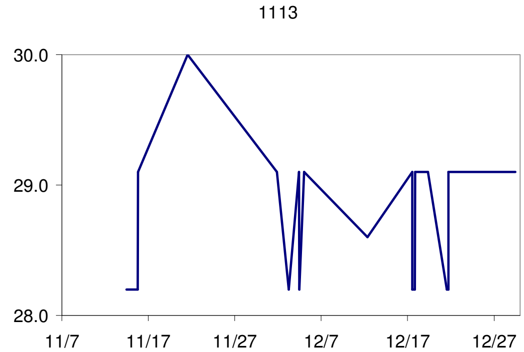
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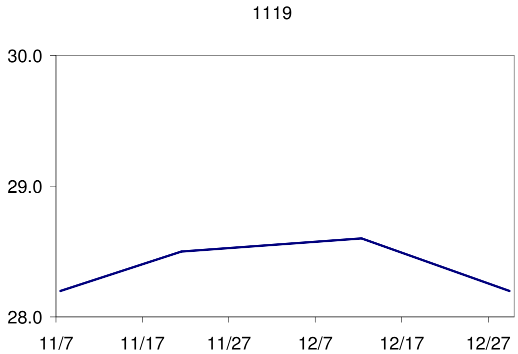
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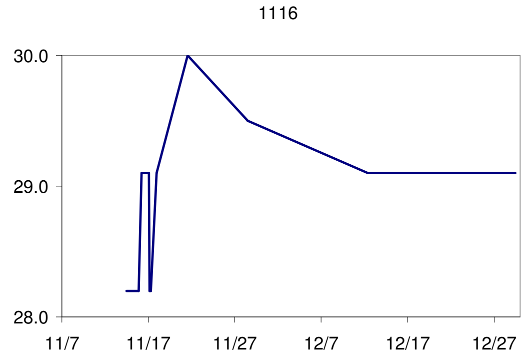
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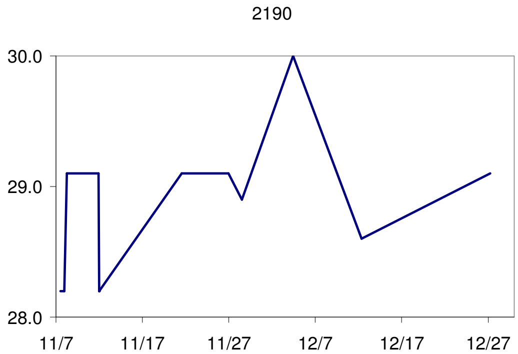
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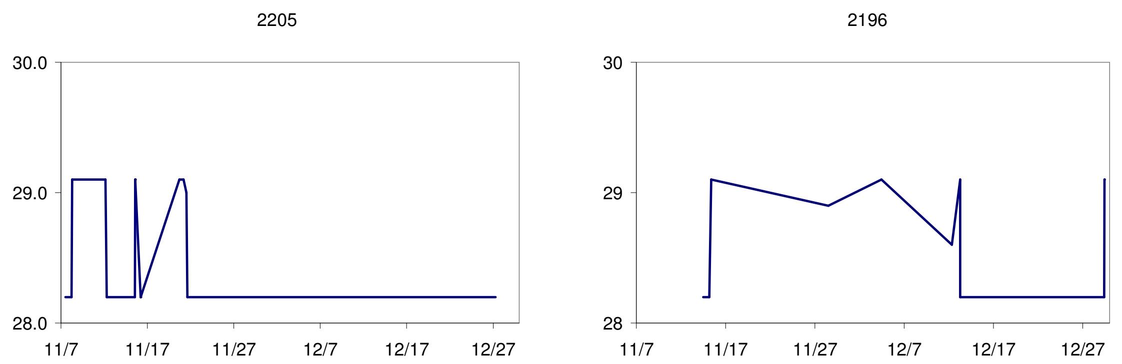


Figure 14 Movement over time of tagged coho salmon released above the SRS. River mile location shown on the y-axis; date shown on the x-axis.

Daily mean discharge for the North Fork Toutle River during the coho study period (52 daily records between 7 November to 29 December 2008) averaged 713 cfs, lower than the long-term average for the same seasonal period of 1,070 cfs. The minimum and maximum daily mean discharge during the coho study period was 343 cfs and 4,590 cfs, respectively. The maximum daily mean discharge occurred during a three day high-flow event in mid-November, after which flows returned back to below 900 cfs for the remainder of the study period (Figure 15).

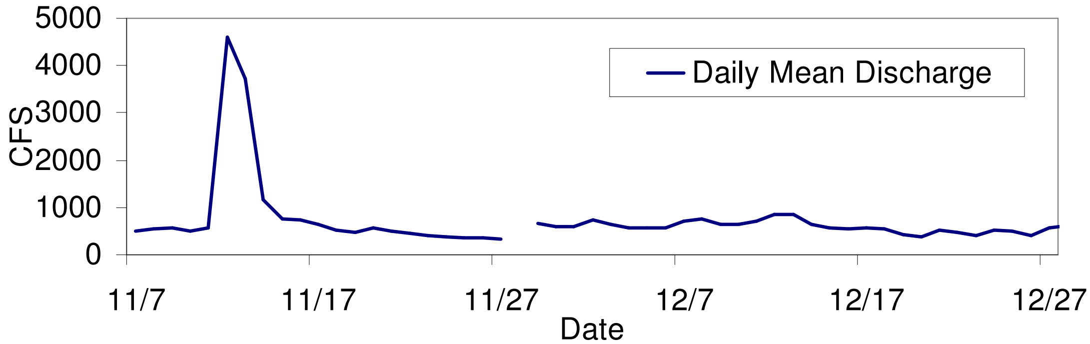


Figure 15 Daily Mean Discharge of the North Fork Toutle River during the coho study period: 7 November to 28 December 2008.

Tagged coho moved within the lower portion of the sediment plain throughout the study period. These movements did not appear to be correlated to increasing flow events. Each of the four tagged coho that traveled beyond the Ecopark to RM 30.0 did so during low and relatively stable flows.

Steelhead

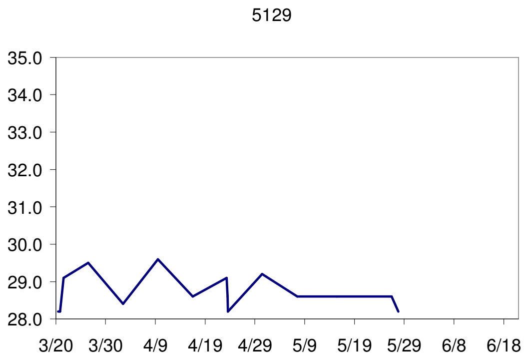
During the 2009 steelhead migration season, a total of 89 fish were captured in the FCF, 21 of which we tagged for one of the two studies described in this report (Table 5 above). For the sediment plain study we tagged and released ten steelhead between 20 March and 1 May 2009 (Table 8). All our study fish were female, and three were fish that had been recaptured in the FCF after being used for the FCF study. The average fork length of our study fish was 69 cm (SE = 1.4 cm).

Table 8 Steelhead tagged for the sediment plain ascension study and a summary of each fish's detection history.

Tag Number	Release Date	Sex	Fork Length	Used in FCF Study	Upstream Extent	Location of Last Detection	Date of Last Detection
5129	03/20/2009	F	64	N	RM 29.6	SRS (RM 28.2)	05/27/09
20083	03/20/2009	F	64	Y	RM 29.8	Ecopark (RM 29.1)	06/15/09
3010	03/27/2009	F	78	Y	RM 29.2	RM 28.4	05/26/09
3023	04/03/2009	F	71	N	RM 31.5	Ecopark (RM 29.1)	06/20/09
3025	04/10/2009	F	73	N	RM 35.0	RM 35.0	05/26/09
5114	04/10/2009	F	67	Y	RM 30.5	Green River (RM 26.5)	04/24/09
20087	04/10/2009	F	66	N	RM 30.5	Alder Creek (RM 29.9)	06/06/09
20082	04/17/2009	F	73	N	RM 29.5	RM 28.8	05/26/09
20079	04/24/2009	F	69	N	RM 33.0	Alder Creek (RM 29.9)	06/06/09
20078	05/01/2009	F	67	N	RM 30.0	Alder Creek (RM 29.9)	06/06/09

All 10 tagged steelhead were able to navigate the sediment plain to locations past the Ecopark site; five were detected upstream of RM 30.0; and two were detected above RM 32.0. The furthest upstream that we detected any tagged steelhead was RM 35.0 near the confluence with Hoffstadt Creek. Nine fish were last detected downstream of their respective highest upstream locations, with one passing back down the spillway and being detected at the Green River site (Figure 16). Between the two upstream fixed sites, which were located on opposite banks of the sediment plain, we detected only one fish at both the Alder Creek and Ecopark Resort sites, suggesting that tagged steelhead chose to migrate up one side or another. Four fish were detected exclusively at the Alder Creek site, four fish were detected exclusively at the Ecopark site, and one fish was detected at neither of these two sites.

The proportion of tagged steelhead that were able to ascend the sediment plain was at least 20 percent. If we assume that the two tagged fish that were last detected at the Alder Creek site successfully ascended into Alder Creek, then the proportion is 40 percent; however, the location of these fish within the tributary was never confirmed, so we cannot validate this assumption.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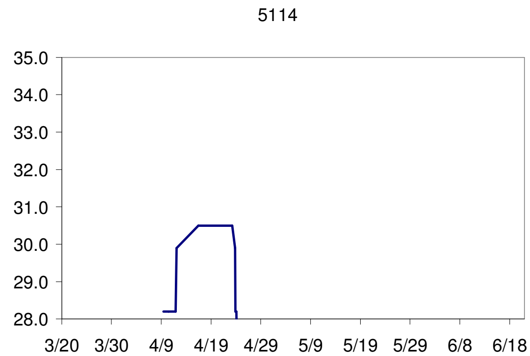
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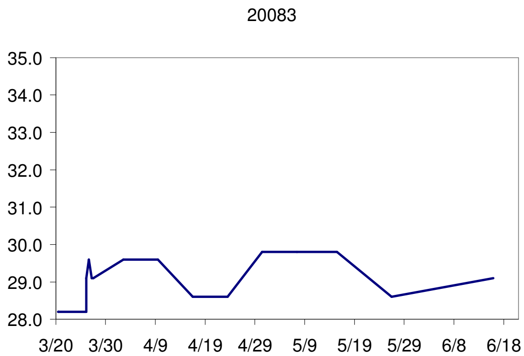
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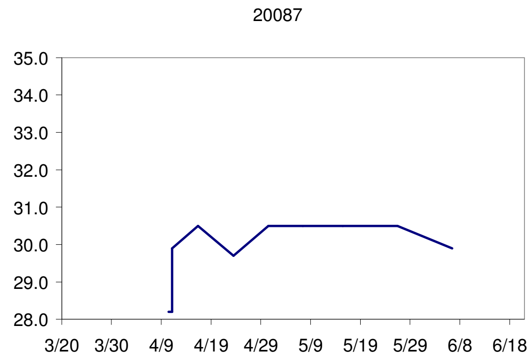
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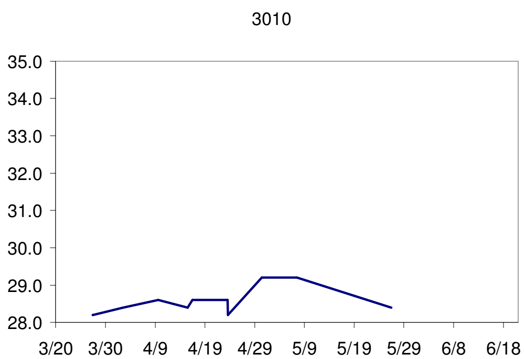
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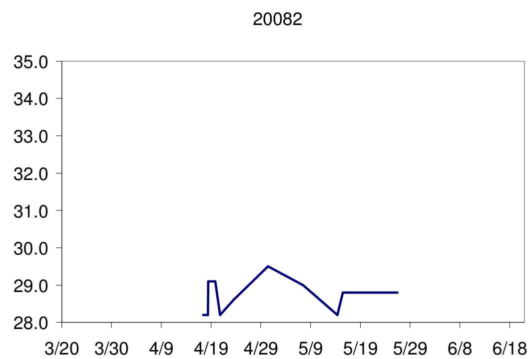
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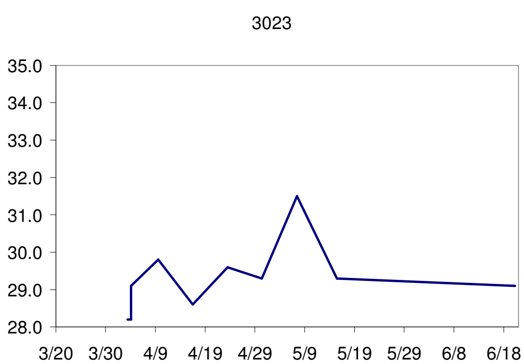
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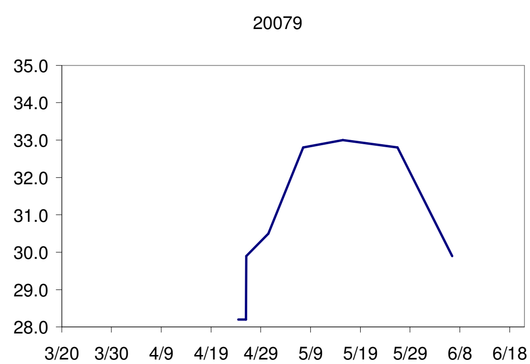
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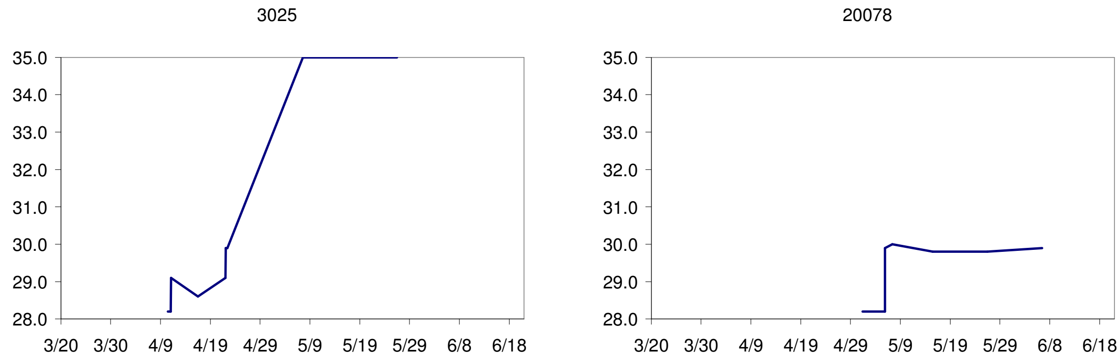

Figure 16 Movement over time of tagged steelhead released above the SRS. River mile location shown on the y-axis; date shown on the x-axis.

During the steelhead study period (20 March to 20 June 2009), daily mean discharge for the North Fork Toutle River averaged 763 cfs, slightly less than the long-term average for this time of year of 875 cfs. The minimum and maximum daily mean discharge during the steelhead study period was 372 cfs and 1,540 cfs, respectively. Flows during this time period generally increased, with repeated spikes in the hydrograph on a period of approximately 4-5 days (Figure 17).

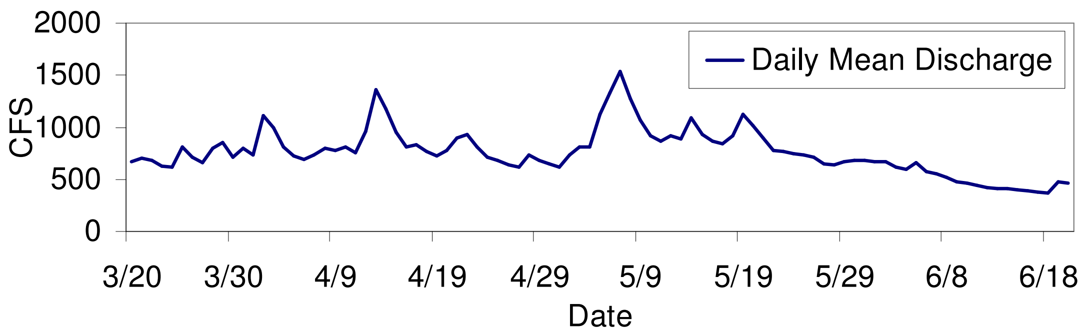

Figure 17 Daily Mean Discharge of the North Fork Toutle River during the steelhead study Period: 20 March to 20 June 2009.

DISCUSSION

This study had similar constraints to the FCF study (Chapter 2), such as potential tag effects and selection of fish that were able to ascend the FCF ladder; however, in this study all fish were naïve to the "challenge" of ascending the sediment plain. Other confounding variables may have included differences in flows and differences in channel morphology. Because of these variables and the small sample sizes, we encourage a cautious approach when attempting to extrapolate these results to the population level.

Coho

The observed behavior of tagged coho above the SRS indicates that they were able to navigate within the sediment plain but were not able to ascend past it: eighty percent of coho reached the Ecopark at RM 29.1, and 40 percent reached RM 30.0, but ultimately none migrated beyond RM 32.0, resulting in an ascension rate of zero percent. We were unable to calculate a confidence interval for a proportion of zero using Student's t-distribution. An alternative Bayesian approach that utilizes the Beta-distribution results in a 95 percent confidence interval between zero and 28 percent (Jaynes 1976). In other words, we can be over 95 percent sure that less than a third of released coho would have successfully ascended the sediment plain during the 2008 season.

We observed a high degree of movement back and forth between the fixed sites, perhaps reflecting fish exploring and retreating from dead ends. We caution that the distance a fish needs to move in order to swim between the detection areas of each fixed site is less than the distance between the site locations as measured in river miles due to the radius of detection (about 0.3 miles). Therefore, the distances of fish movement back and forth within the sediment plain as represented in Figures 14 and 16 are likely overstated.

Under the flow conditions and channel morphology present at the time of this study, it appears that some type of barrier to coho migration was present at approximately RM 30.0. While the Alder Creek telemetry site was not used for the coho study, mobile tracking in this area did not detect any coho moving up into Alder Creek. Coho salmon die after spawning and therefore, tags would be expected to remain in the watershed following a spawning event for a tagged fish. We detected tagged fish moving back downstream from their furthest upstream extent, suggesting that either the fish were not able to locate suitable spawning habitat, or the carcasses were drifting back downstream with the current.

One of the primary concerns regarding fish passage in the sediment plain is the lack of a defined channel during low flow. Low-flow conditions on the sediment plain result in dynamic, typically shallow, warm, or blind-ended channels. Fish negotiating this area are prone to exhaustion as they explore channels that may not be passable, especially under low-flow conditions. If fish are delayed due to these migration challenges, their probability of finding appropriate habitat and having sufficient energy reserves to spawn are reduced. The average daily flow during the coho study was 67 percent of normal; however, we were not able to evaluate the significance of this difference on channel morphology. Further research is needed to understand the relationship between daily flow and the creation of challenging fish passage conditions described above.

Steelhead

Steelhead appeared to have greater success than coho in navigating and ascending the sediment plain and mainstem of the North Fork Toutle River. Forty percent of our tagged fish either ascended the mainstem past RM 32.0 or were last detected near the mouth of Alder Creek, and thus were considered successful. The small sample size results in a wide margin of error and limits the precision to which we can estimate the population's success rate: the 95 percent confidence intervals using Student's t-distribution range from five to 75 percent success.

We were unable to verify whether the fish detected at Alder Creek ascended into the tributary spawning habitat. Mobile tracking efforts on 30 April, and 7, 15, 26 May did not detect any tagged fish in Alder Creek. In general, steelhead are known to be stronger swimmers than coho and may have been able to ascend some of the features that posed challenges for coho. The higher success rate of steelhead could also be attributed to higher flows during the steelhead season, and/or different channel morphology or temperatures on the sediment plain.

In certain instances, steelhead do not die after spawning and will migrate back downstream to the ocean. We noted one steelhead that moved back down through the spillway and was detected at the Green River confluence below the FCF, but we could not verify whether it had spawned. Although it is possible that the detection of this tag at the Green River site was simply the fish carcass drifting downstream, the distance over which it traveled makes this outcome unlikely.

SUMMARY

Our results provide evidence that upstream migration by anadromous fishes is impaired by the sediment plain, especially for coho salmon. The plan by the Corps to modify the SRS spillway to allow for volitional fish passage is commendable, but will not be sufficient to allow returning coho salmon and steelhead consistent access to spawning habitat. While steelhead appear to be less hindered by the sediment plain than coho, it is difficult to determine whether this is because they are stronger swimmers or if the flow conditions in the spring make the sediment plain more passable. Furthermore, our sample sizes were most likely insufficient to account for potential differences in individual fitness between fish and differences across a range of flow rates.

If in fact volitional passage is restored up to the sediment plain, we recommend at minimum an analysis of the sediment plain near RM 30.0 on the mainstem and in the lower portion of Alder Creek near the confluence to identify barriers to fish passage, particularly in the late fall during the coho migration season. However, because the morphology of the sediment plain is known to be highly dynamic (see Chapter 4 below), we recommend a longer term approach. The results of our tagging study, coupled with the geomorphic analysis presented below, suggest that channel stabilization measures across a broad area of the sediment plain would ultimately have a higher likelihood of success than focusing on specific barrier removal. The goal of such measures should be the creation of a consistent, defined low flow channel that would establish a clear route to tributary spawning habitat, utilize hydraulic forces to maintain unobstructed access to tributaries, and reduce the number of blind-ended channels. We believe the channel stabilization measures, as described in the next chapter, would greatly improve the passage success rate and should be considered in concert with the spillway modification plan. In the meantime, the trap-and-haul operation should continue to ensure that coho salmon and steelhead are reaching the spawning grounds.

4.0 CONCEPTUAL SOLUTIONS TO IMPROVE FISH PASSAGE

OVERVIEW

The third major goal of this project phase was to identify and characterize fish passage problems associated with the FCF, the SRS, and the sediment plain that extends upstream from the SRS on the North Fork Toutle River. We also identified and prioritized measures that would enable anadromous fish to more easily navigate these structures during their upstream migrations. This approach complements the investigative, field-based research on fish movement that was described in prior chapters by providing a broader context for analyzing the results, and by addressing components of the system that could not be studied directly. Assessment of fish passage problem areas, both in the FCF and the sediment plain, were informed by the preliminary results from our radiotelemetry studies.

We begin with the FCF, the structure designed and built by the Corps shortly after the SRS was constructed to intercept returning fish, and divert them into a short fish ladder and holding pool where they could be trapped, transported and released in streams above the SRS. Our primary objective was to recommend modifications, repairs and changes in operation that would improve the function of the FCF under short-, intermediate- and long-term management scenarios. Short-term solutions are generally low-cost actions needed immediately to help prevent further decline and extirpation of fish populations. Intermediate-term solutions are more substantial actions that will make measurable progress toward long-term solutions. These are generally more expensive but longer lasting improvements that help bridge the gap between the current situation and the ultimate goal. Intermediate-term solutions might involve fundamental changes to the design or process, rather than simply patching the existing system. Long-term recommendations reflect the steps and actions we consider necessary in order to achieve the ideal combination of fish and sediment management. These scenarios and the actions necessary to achieve them include cost estimates and conceptual design details.

We next turn to the SRS spillway. Our assessment of the problems and potential solutions related to fish passage through the spillway focuses primarily on the fish channel that the Corps is proposing to build, as described in their draft report, entitled “Mount St. Helens Sediment Retention Structure Volitional Fish Passage Design Documentation Report” (USACE 2008) and depicted in the 90 percent engineering level design drawings (USACE 2009).

In the third section of this chapter, we present the results of a reconnaissance level assessment of opportunities for stabilizing the sediment plain, along with a discussion of the challenges they pose to achieving the long-term goal of volitional fish passage through this part of the North Fork Toutle River system.

Greater collection efficiency at the FCF and improved fish passage through the SRS and sediment plain would be expected to result in higher survival and increased production of salmon and steelhead from the upper watershed.

Effect of Uncertainty

At this time, the feasibility and likelihood that various measures, intended to improve fish collection at the FCF and fish passage through the SRS spillway and sediment plain will be implemented, hinges on the Corps' sediment control plans for the North Fork Toutle River. As discussed in Chapter 1, the Corps has proposed two alternatives that would increase the amount of sediment stored in the North Fork Toutle River. One alternative is to raise the height of the SRS to increase the storage capacity behind the dam. The other alternative is to construct a series of grade-building structures (i.e., GeoTubes) in the sediment plain to create sediment terraces and promote the formation of a stable, single-thread channel. The Corps recently announced its intention to conduct a pilot study in 2010 to test the latter option, which is discussed in more detail below.

Both alternatives would significantly affect fish passage conditions in the SRS spillway and in the sediment plain. It is unclear whether either alternative would preclude the establishment of volitional fish passage. For example, raising the elevation of the SRS by 25 ft would require that the spillway be steepened to maintain the existing gradient, unless its length can be increased in proportion to the gain in height. If the spillway length is held constant, its average gradient would increase to 8 percent, which might still allow for the construction of a volitional fishway. However, it is unlikely that the adjustment in elevation would be distributed evenly along the entire length of the spillway. Given the costs involved, it is more reasonable to assume that the upper section of the spillway would be steepened, while the mid- and lower sections would remain unchanged. Under this scenario, there is no guarantee that fish passage could be assured.

Similarly, the installation of a series of GeoTubes upstream of the SRS would alter the longitudinal profile of the sediment plain, creating a drop of up to 6 ft at each structure. Given the highly dynamic and unstable environment of the sediment plain, it would be very difficult to construct reliable fish passage structures to circumvent the GeoTubes.

Both sediment control alternatives, if successful, would cause the sediment plain to grow in size, running the risk of destroying spawning habitat and cutting off access by fish to the lower ends of tributaries that enter the lower North Fork Toutle River.

If the Corps decides not to pursue either sediment control alternative, then it is reasonable to assume that it will abide by its commitment to construct the spillway fish channel as it is currently conceived. If the spillway modifications prove successful at enabling volitional upstream fish passage, then focus would shift to stabilizing the sediment plain in order to create and maintain a low-flow channel that is more conducive to fish passage and navigation to the tributaries. Once the fish channel in the spillway is constructed and it is determined that fish can safely navigate both it and the sediment plain over the normal range of flow conditions, then the importance of the FCF is reduced and decommissioning or alternatives can be considered. In the foreseeable future, however, the FCF will continue to serve as the primary means of ensuring that adult salmon and trout are able to access tributaries and other spawning areas upstream of the SRS. For this reason, it is important to consider what can be done in the near-term to ensure that the FCF functions satisfactorily and is capable of sustaining the local fish populations.

Considering the uncertainty of continued political support, future funding, and the functional effectiveness of proposed solutions, it is impossible to generate an ideal, integrated and comprehensive set of solutions for the watershed at this time. The value of prioritizing a list of potential alternatives is limited since the order of implementation would change significantly under the different sediment management scenarios. Short-term solutions are comparatively easy to identify and the timetable for implementing them is somewhat predictable, so we can be reasonably certain about the validity of the assumptions upon which they are based. Conversely, the value and probable outcome of implementing our intermediate and long-term solutions are less certain because they are based on assumptions that have not been tested and goals that have not yet been defined. For the purposes of this analysis, we first postulate our vision for the ideal management of the North Fork Toutle River and base our prioritization of alternatives on achieving that vision. Although we have sought to balance sediment and fish passage concerns, there is no guarantee that this vision is shared by the other groups and planners.

Long-Range Management Goals

In general, our goal is to create and maintain conditions that promote natural processes that sustain healthy, natural populations of coho and steelhead, including the unrestricted movements of fish within the system, and that also reduce the risk of flooding downstream communities to acceptable levels. In the ideal world, returning salmonids would be able to migrate volitionally upstream without delay or undue stress, and be able to access high-quality spawning habitats in their natal tributary streams in the upper North Fork Toutle River watershed. A long-term solution would entail the construction of a fishway through the SRS spillway. Under this scenario, trap-and-haul operations would no longer be necessary and the existing FCF would either be removed or made passable by replacing the velocity barrier with a fishway or a restored, natural stream channel.

There are certain advantages to maintaining a facility that would allow fisheries managers to intercept and remove fish from the North Fork Toutle River. A trap-and-haul facility would provide insurance against the possibility of a catastrophic failure of the fish channel in the spillway, or a blockage in the sediment plain. It would also allow managers to enumerate and identify fish to origin. The steelhead and coho salmon returning to the North Fork comprise both natural and hatchery-origin fish; the latter having strayed into the system. Because effective fisheries management requires maintaining acceptable proportions of both natural and hatchery fish in naturally spawning and hatchery populations, it is advantageous to have the capability of culling fish as they return to the North Fork Toutle River. For this reason, we recommend that the existing FCF eventually be replaced by a smaller trap-and-haul facility built into the bottom of the spillway. The facility would be designed to handle high sediment loads and would only trap fish when appropriate staff levels were available. At all other times, fish would be able to swim freely up through the fishway.

Assuming it is technically feasible and can be integrated with sediment control actions taken by the Corps, it would likely take over a decade and several million dollars to achieve this ideal outcome. In the meantime, we provide short-term alternatives meant to have an immediate, positive impact that will allow more time to study and plan these long-term changes. A separate list of intermediate measures is proposed to bridge the gap between short- and long-term scenarios.

FISH COLLECTION FACILITY

The FCF is in severe need of immediate measures to keep the current situation from getting worse. However, these measures should also facilitate progress toward the long-term goal. This section describes the problems and possible solutions to improving the effectiveness of the FCF based on what we have learned during the course of this study. First, we list the deficiencies of the current FCF. Then we describe our vision of how a collection facility fits into the best long-term solution for the watershed, considering both sediment and fishery management objectives. This long-term goal is important to establish, even with the gaps in knowledge and inherent uncertainty about the effectiveness of our actions and the future behavior of the system. Having a clearly defined goal provides the context that enables us to prioritize solutions.

We proceed to describe the most important short-term measures that need to be taken to temporarily halt or slow down the ongoing deterioration of conditions. The proposed short-term solutions are meant to be cost-effective, stop-gap measures. Implementing them will help ensure that fish populations persist into the future while we work on making the changes necessary to achieve our long-term goal. Finally, we describe intermediate-term solutions that would help to move the system from the state that results from our short-term actions to one that approximates our long-term vision.

Problems with the FCF

AMEC's hydraulic engineer and fish passage expert inspected the FCF to assess the ability of returning salmonids to enter and ascend the fish ladder and be captured in the trap. The likelihood that fish detect and enter the fish ladder and their behavior as they approach and ascend the FCF, (described in Chapter 2) was used as a starting point to direct the engineer's assessment. A list of problems with the current facility, both relating to design, maintenance, and operations, was presented to WDFW in a technical memorandum dated 14 September 2009 (Appendix B). The most critical problems associated with design, current condition, and operation of the FCF are summarized below:

- The FCF has not performed as well as originally intended, largely due to the high rates of sediment carried by the river and its debilitating effect on virtually every component of the FCF. Sediment has blocked openings and clogged orifices, holding pools, and moveable parts of the SRS, necessitating frequent and time consuming cleaning and maintenance activities. The additional effort required to remove excess sediment and keep the FCF in working condition has significantly reduced the amount of time spent trapping fish. As a result, fewer fish have been collected and transported than expected.

This problem has grown particularly acute since the re-routing of all river flow through the SRS spillway in 1998 and the high-water event of November 2006.

- The lack of adequate resources to maintain and repair the facility has led to a significant decline in the general physical condition of the FCF over time.
- In response to the problems caused by the sediment and the lack of maintenance, the way the FCF has been operated has changed significantly over time. Work-around solutions have achieved limited improvements in the trap's effectiveness, but not enough to avoid significant impacts to returning fish.
- Design elements that either do not work or are inappropriate under the current conditions include the lack of a headgate at the intake to the weir box; an undersized weir box; lack of a sediment flushing mechanism within the weir box; an undersized sediment sluice; and the sill of the stop-log bay in the diversion dam which is 2 ft higher than the intake sill. All these elements promote sediment build up in the weir box, which in turn decreases the likelihood that sediment will settle out before the water is routed through the fishway as originally intended.
- The rate of flow of water through the fishway must be restricted in order to prevent large amounts of sediment from accumulating within the FCF. This reduces attraction flow and velocities through the ladder, thereby limiting its effectiveness.
- Low flows in the fishway in the FCF reduce passage efficiency because fish are forced to swim through baffle orifices rather than by leaping over the top of the weirs. Orifice flows are not conducive to passage due to sediment accumulations, orifice size, and locally high velocities.
- Despite these problems, some proportion of coho salmon and steelhead are successful in navigating the fishway; some fish have been observed traveling both directions in the ladder.
- The automated crowder and collection system is inoperable, due to a combination of both sediment and maintenance issues. The procedure currently used to manually collect and transfer fish to holding tanks on fish transport trucks is undoubtedly stressful on the fish and is inefficient. The effect of the trap-and-haul experience on the reproductive success of released fish is unknown.
- The degraded downstream river channel and lip of the stilling pool has lowered the elevation of the tailwater. This creates a partial fish barrier (to coho in particular) immediately below the stilling pool, directs fish away from the fishway entrance, and creates shallow depths in the fishway entrance area, particularly during low-flow conditions.
- Turbidity and flow levels influence the behavior of fish and may affect trap efficiency. High-turbidity levels in the river likely discourage significant numbers of fish from entering the North Fork Toutle River or from entering the FCF fishway entrance.

These problems are significant both individually and in aggregate. The interrelated nature of these deficiencies and their causes makes it virtually impossible to separate the component parts in a manner that allows for a convenient cost-benefit analysis. Ideally, a distinct action and its associated cost would result in a distinct benefit measured in the additional number of fish captured. However, too much is unknown to attempt such an evaluation. For example, altering fishway weirs will not help pass more fish if they can not reach the fishway entrance. Without a cost-benefit basis, prioritization of potential improvements is difficult and must rely on alternative metrics or logic. In general, however, measures that exclude or flush sediment from the FCF, and that help fish orient and move in the upstream direction provides some basis for mitigation action prioritization.

Solutions to Known or Potential Problems

Long-term Plan

Watershed managers should continue to stress sediment control as the primary means of addressing system-wide problems. Ecological restoration and the recovery of salmon and trout populations in the North Fork Toutle River can only be achieved if the problems associated with sediment are overcome. Sediment yield from the basin and its conveyance downstream must be returned to more normal conditions before meaningful progress and permanent results can be achieved in regards to restoring volitional fish passage. This is true for fish passage through all the components of the watershed, including the FCF, the SRS spillway (as discussed in the following sections) and the sediment plain.

The long-term goal that serves as the premise of this report is to reestablish volitional upstream fish passage to spawning habitat in the North Fork Toutle River. Whether this long-term goal includes some type of fish trapping facility is still to be determined. The FCF in its current state is ineffective, under-staffed and detrimental to fish over the long run; for this reason it should be removed and replaced with a functioning facility.

Although removing the FCF is recommended, it should be done only if volitional passage measures have been implemented and shown to be successful. Achieving this goal will take time, especially considering the amount of resources that will be needed to implement and evaluate the proposed solutions. Accordingly, it would be prudent to continue the practice of trapping and hauling fish, both in the interim and possibly as a tool to manage fish populations over the long term in the watershed. The WDFW has clearly indicated their desire for a trap-and-haul facility that allows for population monitoring and culling of hatchery strays.

The uncertainty surrounding the type and effectiveness of the sediment control measures recently proposed for the North Fork Toutle River by the Corps argues for maintaining a trap-and-haul capability, either by continuing to operate the FCF, provided it can be maintained in properly functioning condition, or by replacing it with another facility. As a man-made structure in a highly unstable environment, the proposed spillway fish ladder will be subject to an unknown probability of failure. The FCF or its replacement would serve as a back-up in the event of failure. Given the unpredictability of the outcome of the Corps' actions, we recommend rehabilitating the FCF to the point where it can function adequately while various sediment control and fish passage options related to the SRS are being considered and implemented. The immediate objective is to reduce sediment accumulations that would impair the functionality of the refurbished FCF or a similar facility.

Short-term Plan

In the near future, the FCF will need to remain in operation for the foreseeable future while the sediment situation is further mitigated and may be necessary on a longer time scale under a number of adaptive management strategies. Unfortunately, effectiveness of the trap-and-haul process continues to decline, putting fish populations at risk of extinction. It does not appear that the facility can be easily repaired in a meaningful way that will measurably improve its effectiveness. Rather, it is clear that continuing to rely on the FCF to conserve threatened fish populations requires major rehabilitation and improvements. These major improvements are described in the intermediate term plan and are considered necessary to improve fish collection and trapping efficiency in a sustainable manner.

In the meantime, major rehabilitation efforts will require some lead time to collect critical information, determine feasibility, develop the specific design and identify funding. During this time, interim measures will be needed to prevent the FCF physical condition and ability to collect fish from further deteriorating. These interim measures comprise the short-term plan and emphasize straight-forward improvements that can be implemented quickly and at a modest cost.

The short-term plan is an initial three year period (calendar years 2010 through 2013) during which continued planning, continued studies, design of intermediate-term improvements and construction of these improvements is expected to occur. To address information gaps, continued studies should address the following objectives:

- Further define the limiting factors associated with upstream fish movement at the FCF; i.e., fish behavior, ladder navigation, and the relative influence of each factor;
- Characterize and quantify attraction flow;
- Determine the degree to which the tailwater degradation acts as a fish barrier;
- Determine the furthest upstream extent of migrating adult salmonids in terms of the proportion of each species per run;
- If the FCF needs to remain in place indefinitely, where should it be located and what features should it have;
- Monitor success of the sediment mitigation actions;
- Monitor effectiveness of the ongoing trap-and-haul program; and
- Improve knowledge and control over the factors that determine trap efficiency.

Without more well-defined limiting factors, and with a high level of uncertainty regarding cause and effect, attempts at problem solving are restricted to essentially a trial-and-error process, which can only coincidently result in an effective end result. In addition, any attempted fixes that are implemented in isolation are highly unlikely to translate into an acceptable solution.

Operation of the FCF during this short-term period will continue much as it has during the most recent years, but it is expected that several improvements can actually be implemented during this time, beginning immediately. These might include FCF maintenance/repair items that will remain in place after major rehabilitation has occurred, downstream gradient control and other easily feasible, separable and implementable items that can be quickly identified and characterized in more detail.

Some of the more immediate and implementable improvements remain to be clearly identified; however, they include the following actions listed in order of their relative importance (construction costs in parenthesis):

1. Stoplog bay (fish barrier notch) sill revisions to enable sweeping flow and sediment past the water intake (Figure 18) and to avoid debris accumulation/removal ($30,000) – More specifically this would consist of leaving both concrete stop logs out of the notch, removing the 4-inch diameter steel mounts (Figure 19), re-shaping the concrete and constructing a debris deflecting boom or similar structure in the approach to the notch.

2. Removing the debris/sediment blockage from the existing sediment sluice that leads from the weir box to the stilling basin ($15,000) – This will restore the ability to flush sediment back to the river from the weir box, thereby excluding some of the sediment from the internal workings of the FCF.

3. Construct and install an operable gate at the water intake so that sediment can not enter the weir box except when water is actually being directed into the FCF ($50,000).

4. Repair or replace the gates and gate lifts (3) at the fishway entrance pool openings (Figures 20 and 21) ($30,000) and/or outfitting the entrance pool openings with side constricting orifice inserts to enhance the velocity and concentration of attraction flow ($30,000) – The specifics of this depends on further evaluation considering the current reduced tailwater level, the available head for the orifices and configuring the gates, orifices and channel to minimize sediment accumulation (Figure 22) ($20,000).

5. Replace the collection pool finger gate (Figure 23) with a fixed more robust structure that does not require mechanical/electrical operation ($20,000) – This is to more effectively contain fish within the collection pool.

6. Repair/replace/purchase new wash-down and sediment removal equipment ($15,000).

7. Replace diffuser screens and complete other unlisted yet to be identified improvements ($100,000).

8. Provision of the minimum miscellaneous safety and maintenance equipment ($20,000) – This does not directly enhance fish collection, however, it will undoubtedly be required to continue to collect fish in the current method of practice which is in conflict with normal safety standards.

These interim improvements amount to approximately $330,000. Including an allowance for unidentified items (10%) and contingency (30%), approximately $460,000 should be budgeted for these improvements.

Figure 18 Suspended sediment and re-suspension of sediment accumulated in front of the intake being pulled into the intake.

Figure 19 Existing stoplog bay obstructed by debris accumulating on opening and stoplog supports.

Figure 20 Two of the three gates: the existing single-functional gate and the currently blocked off gate to its right.

Figure 21 Marginally functional gate lifts and chain cans.

Figure 22 Sediment accumulation in the channel and the third gate at the channel edge.

Figure 23 Collection Pool Finger Gate

It should be noted that re-establishing the FCF tailwater and arresting the river degradation is a separate high-priority improvement that can be accomplished under any of the three levels of plans, but is not included in the Short-term Plan due to its cost.

Dedication of additional funds and manpower for a level of operation and maintenance consistent with the suggested interim improvements is also needed.

Intermediate-Term Plan

After three years of carrying out the necessary studies and stop-gap measures outlined in the short-term plan, more significant improvements to the FCF should be initiated. Actions under the intermediate-term plan should address three primary elements of the FCF: flow diversion into the FCF; the internal components of the FCF; and the FCF tailwater elevation. These elements, and respective potential conceptual level improvements (Figure 24), are described below.

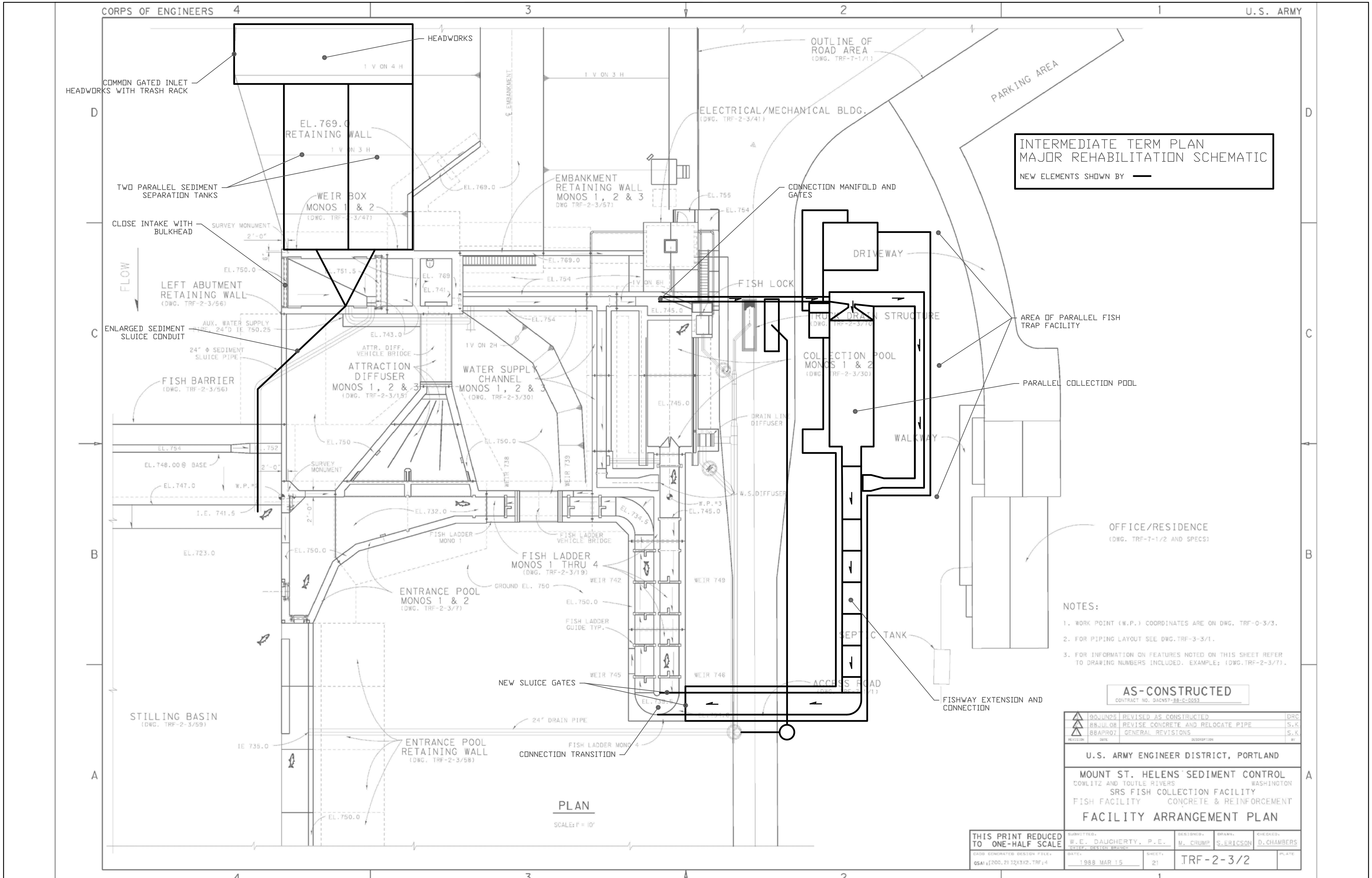

Figure 24 FCF Plan View with Overlay of Parallel System.

In addition to the structural elements, the intermediate-term plan will need to address operational issues. Finally, a summary of conceptual cost estimates is provided.

Flow Intake

Sediment exclusion from the FCF should be the highest priority objective in the intermediate term plan. Reducing the amount of sediment passing through the fishway is a fundamental step to improving the effectiveness of the existing structure at trapping adult fish. While some reduction in the river's sediment load might be achieved by actions upstream in the sediment plain (see subsequent section on sediment plain), there is a high degree of uncertainty regarding how much sediment will be reduced, when the sediment stabilization actions will be implemented, and when to expect results. Therefore, we recommend several measures to be enacted at the FCF to accomplish this objective.

- Modify the hydraulic conditions in the river immediately outside the diversion intake and at the fish barrier dam to sluice as much sediment past the new intake as possible. This might include the addition of an underflow sluice gate at the crest of the dam in addition to the previously described short-term improvements.
- Construct a new river intake that is gated so that it can be closed during periods when the trap is not operating, and can split flow into two new, larger sediment removal basins (Figure 24).
- Construct two new sediment settling basins in parallel, each larger than the existing basin and designed to handle the full, originally designed diversion flow rate (attraction flow rate) so that either can be taken out of service for cleaning and/or maintenance while the other remains operational (Figure 24).
- Install new, much higher capacity sediment sluices back to the river from both new sediment basins, and manifold into a common main sluice.

Internal Components

Within the FCF itself the objective should be to keep any sediment that enters the FCF moving through and out of the FCF. Re-design of the internal components and fish handling process should be done in conjunction with the ideal future operations process and take into consideration what we have learned about fish behavior, movement abilities, and the characteristics of sediment in this situation. We suggest several modifications and/or additions to internal components of the FCF.

- The construction of a parallel fish collection pool and crowder system designed to handle the full fish ladder flow rate so that either system could be taken out of service for cleaning/maintenance while the other remains operational (Figure 24).
- The construction of a parallel fish lock and fish delivery system for the second pool/crowder or a revised design for delivering fish to the transportation vehicle (Figure 24).

- Revision of the crowder design to avoid sediment issues and eliminate direct handling of fish – possibly using a revised concept of fish collection (collection, crowding, and transfer) integral with the ladder itself.
- Revisions to the design of the fishway panels to include more orifice area (as it appears most fish use the orifices due to the shallow weir flow), balancing the head and tailwater to be similar at each panel and resetting the panels closer to that originally intended.
- Once the sediment is better controlled, increasing the flow rate through the FCF and fishway can be considered.
- Revisions to the plan orientation of the fishway to enable feeding water to either of the collection pool/crowder pairs and to bypass either (Figure 24).

River Tailwater

The aforementioned improvements to the functionality of the FCF will only be effective if fish are able to ascend to the holding pool and enter into the FCF. Based on our observations of the holding pool and downstream channel (Appendix B), along with results from the fish behavior study (Chapter 2), this ability appears to be limited. Tailwater degradation due to downstream erosion and failure of the holding pool sill needs to be arrested to ensure that the approach to the FCF remains passable to fish (Figures 25 and 26). In addition, the tailwater control needs to be at least partially restored by approximately 2 ft to create a minimum tailwater level on the fishway to both enhance fish access and protect the fish barrier infrastructure from undermining. Constructing a stabilized tailwater gradient and weir-pool type fishway with six to eight steps through the tailwater riffle is likely necessary (Figure 27).

Figure 25 Photographs of original construction (5/89) (top) (Source: USACE) and current conditions (6/09) show the tailwater feature from the upstream side.

Figure 26 Photographs of the original construction (6/89) (top) (source: USACE) and of current conditions (6/09) show the tailwater feature from the downstream side. These pictures show very graphically the downstream sill degradation and breach of the right end and the lower resulting tailwater.

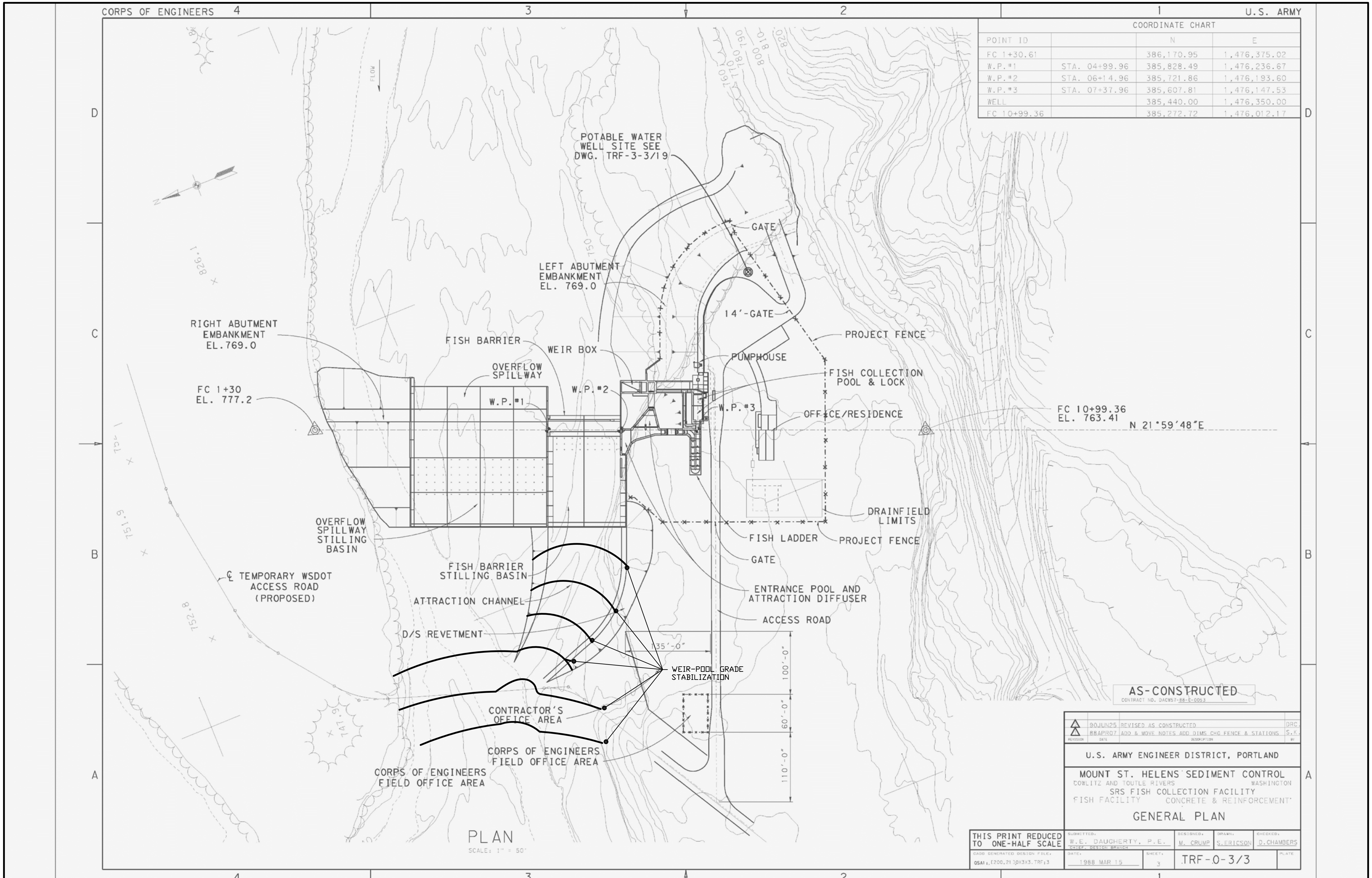

Figure 27 The approximate schematic location of a stabilized tailwater gradient and weir-pool type fishway with six to eight steps through the tailwater riffle

Optional Mitigation

Several optional components of the intermediate-term plan should also be considered during the short-term time frame, and further investigated as preferable options. These include:

- The current fishway could be extended to the upstream headwater in order to allow for the possibility of an integrally designed volitional fishway that fully bypasses the collection portion of the FCF. The implementation of this option depends on the long-term plan.
- The extensive list of proposed solutions for flow intake and internal components could be reduced if a separate source of clear water (free from unnaturally high sediment, but not from natal homing cues) can be identified and developed to supply the collection facility and fish ladder.

Operations

As described more completely in the technical memorandum (Appendix B), the FCF operations are limited not only by a lack of adequate physical facilities and proper maintenance, but by the limited human resources and material to properly operate it in order to achieve the desired results. It is difficult to describe specifically what operational improvements are necessary or preferred given the uncertain results of functional improvements, but we suggest at minimum the following considerations:

- Develop a more well-controlled procedure for no-touch fish collection and transfer (supported by the previously described physical facilities);
- Acquire, and have available, multi-purpose equipment such as a mobile crane for tasks such as fish brail lifting, fishway panel movement, and sediment removal assistance, and a small loader to assist with sediment removal from limited access areas;
- A higher number of personnel to improve the number of fish that can be moved and to provide for a more intensive sediment maintenance effort; and
- Develop a process for sediment removal and disposal (versus return of sediment to the river).

The current facility operation, which has evolved to adapt to the limited resources and a physically dysfunctional facility, must be improved in tandem with any efforts to improve structural elements. This can be accomplished by setting performance standards, having more completely defined operation and maintenance procedures and having routine expert advice to optimize the benefit of the renovated trap-and-haul process.

Costs

The costs outlined below represent first order estimates based on professional opinion. Developing these figures to more detail relies upon more information of the physical conditions that each element would be required to handle, and subsequently further computation of necessary size, materials, and labor needs. Nevertheless these estimates are provided to frame the scale of resources that will be needed to accomplish the type of improvements listed in this report.

Once a project reaches a point where its size and location have been tentatively located and initial investigations associated with that project configuration have been completed, a cost estimate can be prepared. At a conceptual level, such as is the case with the intermediate-term plan, the cost estimate is at the most flexible level of accuracy. The estimate should be expected to change as the project becomes more well defined, becoming more comprehensive, more detailed and based on progressively more reliable information. While the construction cost is the primary component of the total cost, there are other significant costs associated with implementing the proposed project. Only the construction cost is addressed herein. We have identified the major items of construction; however, there is still a need to allow for items which are not identified or included in the project at this time in order to have a more complete estimate of total project cost. Accordingly, unlisted items and contingency items are also included in the construction cost estimate. As the project becomes more defined, the listed items become more comprehensive and reliable, and construction commencement moves closer, these allowances become smaller. Forward pricing has not been used and the reference date for costs is October 2009. Costs are provided in thousands of dollars and rounded to the nearest ten thousand dollars. Costs have not been listed for the optional elements such as development of a supplemental clear water source or for a full length fishway bypassing the FCF.

Construction

The construction cost summary provided herein is based on line items for the major components of construction, conceptual level evaluation supported by only minimal design sizing, and estimated quantities of items lumped together. The subtotal of the major component line items was used as the basis for a construction cost estimate. A line item for mobilization/demobilization was also added to the estimate.

Since a conceptual cost estimate is based on major items of construction, a 10 percent allowance of the major component line items subtotal is made for unlisted items reflecting those items which are too small individually to be listed, but when considered together, constitute a significant enough cost to be included. A conceptual cost estimate also must allow for unknowns. On this project contingency includes allowance for modest changes in project scope, refinement of material quantities, unknown conditions, uncertainty in unit prices and similar details, which become better known as design and construction proceeds. To provide for this, a 30 percent contingency on the major component line items sub-total is added.

The construction items described under the intermediate term plan amount to $2.5 M for the FCF flow intake, $3.3 M for the FCF internal components, and $2.1 M for the FCF tailwater, for a total of $7.9 M, including the allowances for unlisted items and contingency. These estimates are more specifically described in Table 9.

Table 9 Construction cost estimates for the three main items of the intermediate-term plan (in thousands of dollars).

Intake Renovation		
Mobilization & Demobilization		80
Bulkhead current headworks and modify weir box		20
New upstream headworks		250
Two new sediment settling tanks in parallel		700
Replumbing of headworks / weir box		100
Rebuild sediment sluice / manifold		300
Modify dam crest to contain gated sediment sluice		150
Demolition, water handling and connections		150
Unlisted items (10%)		180
Contingency (30%)		520
	Subtotal	2,450
Internal Renovation		
Mobilization & Demobilization		110
Replumbing of collection, crowding, lock and delivery		200
Parallel collection pool and crowder		500
Parallel lock and delivery		500
Site work, water handling, demolition and connections		200
Parallel fishway extension along split route		500
Fishway weirs new and replacement		110
Misc. repair, replace and upgrade components		250
Unlisted items (10%)		240
Contingency (30%)		710
	Subtotal	3,320
Tailwater Renovation		
Mobilization & Demobilization		70
Access and clearing and grubbing		50
Water handling		100
Demolition		50
Six weir-pool instream steps		1,200
Restoration		50
Unlisted items (10%)		150
Contingency (30%)		460
	Subtotal	2,130

Operation and Maintenance

In order to provide for adequate personnel and direct costs to operate and maintain the renovated FCF, it is estimated that $300,000 per year will be needed. This breaks down into approximately $120,000 for 1.5 FTE (which actually consists of eight people, none of which are truly full time) and $180,000 for repair, replacement, routine operating expenses, and sediment hauling and disposal. A sinking fund for facility reconstruction or replacement in the future is not included in the annual cost.

SPILLWAY

As mentioned previously, the Corps has considered the possibility of constructing a fish channel within the SRS spillway that would accommodate upstream passage of returning salmonids. In the initial design process, the Corps evaluated several alternative configurations and developed the preferred alternative to the 90 percent completion stage. AMEC reviewed the design and provided feedback to the Corps as a technical memorandum (1 July 2009; Appendix A). Construction of the preferred alternative was originally scheduled for the summer of 2010; however, there is no guarantee that these modifications will be feasible given the other Corps activities in the watershed, or that funding will be available. The plan is currently on hold until broader basin-wide plans have been developed (J. Britton, USACE, personal communication). Our critique of the preferred alternative as presented in the tech memo is summarized here.

The preferred alternative was to make improvements to the spillway that would direct and confine flow to a fish passage channel within the spillway chute in order to minimize the opportunity for false passage routes; reduce the height of the falls and cascades to a series of vertical drops measuring no more than 3 ft in height; and add thalweg pools to the channel so that fish are able to rest and orient themselves for leaping or swimming upstream. The designed channel would be superimposed on the most pronounced existing low-flow channel to minimize rock excavation. The river would be drawn into the channel a short distance upstream of the crest, then pass the crest through a new notch excavated in the rolled compacted concrete (RCC) steps. The channel would follow a central route through the spillway until passing through the existing notch in the RCC at station 30+00, after which it would shift to the left and travel along the south side to the bottom of the spillway. Along the route, two falls (one being the falls at the bottom) would remain in the channel but would be reduced in height for fish passage. The intent of this alternative is to convey the river through this channel for flows up to a design maximum flow rate, excluding water from other routes that may be impassable to fish.

The “jumps and pools” channel design resembles a conventional “pool and weir” configuration, except that it requires fish to leap greater heights at certain locations than is normally the case in a pool and weir-type fish ladder. The fishway entrance appears to meet criteria for sufficient attraction flows (4 to 8 ft per second); however, not enough detail is available to determine whether the plunge pool depth below the first jump meets depth requirements (4 ft minimum; recommended 6 ft). The fish channel runs in the Corps’ design are shown to be a minimum of 0.6-ft deep, rather than the recommended minimum depth of 1 foot, although hydraulic modeling shows that the one foot depth may be achieved anyway. More importantly, the prolonged, relatively steep gradient of the channel (6%) is likely passable by fish at burst speed, but a sufficient number of well designed pools will be critical to allow resting.

The pool dimensions in the Corps' plan are unconventional, but from a plan view perspective meet the minimum criteria. Pools that do not produce a stilling or eddying effect on the flow will have relatively low value as resting and jump staging areas. The originally proposed pool depth of 1 ft has been increased to 3 ft, which is a definite improvement, but it is still lower than the desired minimum depth of 4 ft. Lacking adequate depth, a pool may not provide the hydraulic conditions a fish needs to leap over the drop at the head of the pool, even if the height of the drop is within the leaping ability of the target species of fish.

Further design detail is needed as to how the fish channel exit is to be configured to exclude sediment while at the same time effectively directing flow into the fishway and guiding fish upstream. A compromise must be achieved between locating the fishway exit too much into the sediment plain, where the channel is actively moving and could close off the spillway exit, and too close to the spillway lip, where fallback might occur.

Significantly more detail regarding the Corps' preferred alternative, and our suggestions for enhancing the preferred alternative can be found in the technical memorandum "North Fork Toutle River Fish Passage at the Sediment Retention Structure: Comments on the Design Documentation Report and 90 percent Stage Drawings for Spillway Modifications" (Appendix A).

SEDIMENT PLAIN

Background

Volcanic eruptions typically disturb fluxes of water and sediment in a river basin, and can result in sediment yields that exceed pre-eruption sediment yields by many orders of magnitude. The catastrophic eruption of Mount St. Helens in 1980 affected some basins more than others. Basins to the north of the volcano, including the Toutle River basin, underwent the most severe disturbance and the greatest accretion of loose sediment from deposition by a 2.5 km^3 debris avalanche and a following direct blast (Pierson and Scott 1985), which covered the landscape with gravelly to silty sand tephra (<1 cm - >1 m) and flattened forest across approximately 600 km^2 of craggy terrain (Smith and Swanson 1987; McEwen and Malin 1989) (Figure 28). The avalanche deposit buried 60 km^2 of the valley to a mean depth of 45 m and severed surface drainage between the lower and upper North Fork Toutle River watershed.

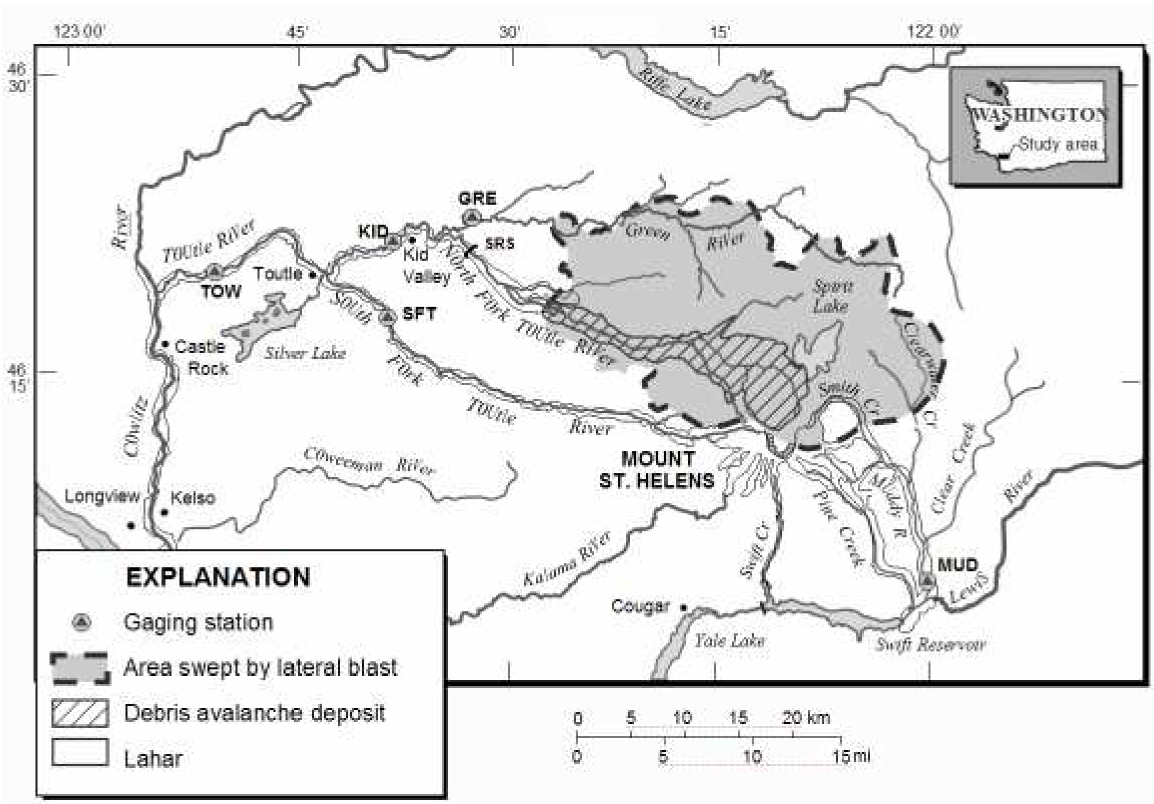

Figure 28 Effects of Mount St. Helens 1980 eruption and location of gaging stations. Stations: TOW—lower Toutle River, KID—lower North Fork Toutle River, SFT—South Fork Toutle River, MUD—Muddy River, GRE—Green River. SRS—Sediment Retention Structure (From: Major, Pierson, et al. 2000).

The Toutle River basin has thus been dramatically altered by the eruption of Mount St. Helens. Measures were quite rapidly implemented to protect the public from flood, a hazard that continues to be exacerbated by changes to basin hydrology and reduced channel capacities as a vastly increased volume of sediment moves through the system. The Mount St. Helens (MSH) Project was designed to control the transport of large amounts of sediment downstream from the debris avalanche. The *Sediment Retention Structure* (*SRS* – Figure 28 above) of the MSH was constructed on the North Fork Toutle River in 1987, and has since provided a significant reduction in sediment volumes moving downstream and into the Cowlitz River. Operated as a reservoir, the SRS from 1987 to 1998 trapped over 100 million cubic yards of sand and silt eroded from the debris avalanche, this material now stored behind the SRS as a large sediment plain (Figure 29).

Figure 29 North Fork Toutle River Sediment Plain storing over 100 million cubic yards of sediment.

In maintaining a congressionally authorized level of flood protection along the lower Cowlitz River, the SRS has itself presented a significant, anthropogenic, alteration to the North Fork Toutle River basin. The river now meanders through the lower four miles of the sediment-filled reservoir pool, exiting through a spillway and rock ramp (Figure 30).

Figure 30 Spillway (note fractured concrete apron) and rock ramp at SRS.

While stream systems around Mount St. Helens are slowly recovering, elevated sediment loads, channel widening, and a lack of vegetation cover and large woody debris in the North Fork Toutle River all remain serious problems today. Fish gaining access to the sediment plain are currently faced with a complex system of meandering and often braided channels that frequently do not have sufficient depth and/or cover to facilitate safe passage to spawning tributaries. An additional challenge for fish is that while the sediment plain continues to aggrade, entrances to tributary systems are increasingly plugged (Figure 31).

Figure 31 Evolution of the sediment plain has restricted fish access to tributary channels.

Stabilization of the sediment plain to facilitate development of a single and stable main channel could improve opportunities for fish passage by providing an established stream with somewhat stable, vegetated banks and sufficient water depth even at low flows to support fish access. Similarly, sediment plain stabilization may also create opportunities to reestablish mainstem-tributary connections that are sufficiently stable to enable safe fish passage from a mainstem channel to spawning tributaries. Many agencies have considered and continue to deliberate about the challenge of restoring the sediment plain to mitigate for reduced fish access resulting from construction of the SRS, while balancing this need against ongoing flood control requirements. In particular the Corps has conducted a restoration reconnaissance of the sediment plain (USACE 2007) and is currently undertaking an ongoing sediment monitoring and analysis project which includes development of a system-wide sediment transport model. This is part of a long-term plan development that will be an addendum to a 1985 Decision Document outlining cost effective actions to maintain levels of flood protection through 2035, including mitigation for fish passage at the SRS and associated FCF. A draft of long-term alternatives (combination of measures) is expected from USACE in December 2009. Potential USACE activities linked with sediment plain stabilization are discussed in more detail below.

The aim of this report was to conduct a reconnaissance level assessment of opportunities for stabilizing the sediment plain, and challenges to these. The assessment is based on a project orientation and field trip to the SRS and sediment plain, meetings with the Corps Portland Office and Cowlitz Indian Tribe, and a review of related reports and scientific literature.

North Fork Toutle River Basin Post-eruption Geomorphology and Hydrology

The Mount St. Helens eruption covered the landscape with a blanket of tephra and killed the forest tree cover in a 550 km^2 area. Following the eruption, rates of sheetwash, rill erosion, and plant cover were measured on tephra-covered hillslopes which had previously been subject to grass seeding and salvage logging (Collins and Dunne 1988). On rapidly-eroding hillslopes subject to grass seeding, plant cover was established only after erosion declined sharply. Logging of trees downed by the eruption and scarification of previously logged surfaces was found to have slowed erosion, although the effect was small because erosion rates had already slowed substantially by the time these two practices were implemented. Grass seeding has not been very effective at slowing erosion. Collins and Dunne (1988) also identified that even without deliberate conservation measures, processes which mechanically disturb a surface layer of low hydraulic conductivity (e.g., frost-action) can radically reduce runoff and erosion before revegetation has an important effect. Post-eruption adjustment of channel networks and their roughness characteristics together with the strong seasonal variability in regional climate have hindered a consistent or persistent shift in peak discharges. Vegetation recovery has also played a role.

Hydrologic modeling studies conducted shortly after the eruption concluded that runoff peaks and volumes would increase (e.g., Lettenmaier and Burgess 1981). Predicted peak discharges of post-eruption unit hydrographs were found to be 50 percent greater and had rise times that were approximately 25 percent faster than pre-eruption unit hydrographs and magnitudes of floods of given frequencies were predicted to increase by 20–60 percent (Lettenmaier and Burgess 1981), with changes greatest for small to moderate-magnitude events. Hillslope storage and subsurface flow are generally the dominant components of forest hydrology in the Pacific Northwest. Post-eruption vegetation loss and greatly reduced infiltration have thus radically modified the amount of precipitation reaching the surface, and also the evaporative and infiltration losses, hillslope storage, subsurface flow, and the dynamics of snow accumulation and melt (which direct substantially more rainfall and snow melt to overland flow). These spatially complex basin disturbances have shaped a variety of potentially compensating effects that have interacted with and influenced hydrological responses. Major and Mark (2006) note that changes to water transfer on hillslopes and to flow storage and routing along channels have both enhanced and retarded runoff. For example, enhanced depression storage owing to accumulations of downed trees and other surface irregularities has partly counteracted landscape changes that have enhanced runoff.

Following the 1980 eruption, the destructive North Fork Toutle River debris flow (Pierson and Scott 1985) scoured riparian corridors while straightening and smoothing the river channel and transforming it from a sinuous, gravel-bedded, pool-riffle system to a streamlined, sand-bedded system. These channel changes have had variable hydrologic and hydraulic impacts.

Straightening and smoothing of channels enhanced flow efficiency by reducing hydraulic roughness. In contrast, disruption of the upper North Fork Toutle River temporarily diminished channel flow (Major and Mark 2006). The debris-avalanche deposit blocked several channels tributary to the North Fork Toutle River (Janda, Scott, et al. 1981), and because of its irregular surface of mounds (Figure 32) and closed depressions it disrupted through-flow (Simon 1999). Development of channels on the debris-avalanche deposit began shortly after its deposition with the breach of ponds formed in depressions. This process was enhanced by water pumped from Spirit Lake and controlled releases from other lakes, by subsequent meltwater floods and debris flows from the crater, and by runoff erosion (Simon 1999). It took nearly three years to fully integrate a new drainage network across the deposit (Janda, Scott, et al. 1981).

Figure 32 Incised lahar mound on the North Fork Toutle River (note Pile-Dike sediment stabilization structures to left, and tree plantings to right).

Across the debris-avalanche deposit fledgling channels were initially affected by large debris flows. Ultimately the broad sediment plain has formed and channel response has followed complex cycles of incision, followed by substantial channel widening and bed aggradation, then further widening with little net change in bed elevation (Major, Pierson, et al. 2000; Major and Mark 2006). Steeper upstream reaches were incised and widened during the first year after the eruption, then have principally aggraded. Reaches downstream on gentler slopes initially aggraded and widened, and later became incised. Changes in post-eruption channel geometries have thus varied based on position in the valley, and the nature of disturbance processes.

Time scales of landscape evolution processes such as channel incision and drainage-network development are greatly reduced following catastrophic disturbances such as the eruption of Mount. St. Helens. The eruption, resulting debris flows, and deposition of sediment have created enormous imbalances between upstream sediment delivery and available transporting power. Renewal of fluvial networks by channel incision typically leads to further network development and an increase in drainage density as gullies migrate into previously non-incised surfaces. These imbalances create a significant challenge to implementing approaches to stabilize the sediment plain because the process dynamics are in many cases unpredictable, thus management measures will contain large performance uncertainties.

However, attaining a stable 'quasi equlibrium' channel (Darby and Simon 1999) on the North Fork of the Toutle River seems to be a worthy pursuit despite these challenges. As discussed previously, a stable channel that has incised and then widened to achieve some equilibrium would offer greater possibilities for fish attempting to reach spawning tributaries upstream. Simon and Thorne (1996) attempted to predict stable channel geometries for the North Fork Toutle River using the minimum stream power approach (Chang 1984) and found this method to be unsuccessful (compared to measured 1991-2 channel geometries and bed material characteristics) because study reaches were found to be too unstable. Reaches of the North Fork Toutle River are not in regime, and movement towards a dynamic equilibrium will not be attained until a new floodplain has been formed by renewed channel incision, full retreat of lahar mounds (still abundant on the sediment plain - see Figure 32), and establishment of riparian vegetation and integration of large woody debris to limit the destabilizing effects of large floods (e.g., Simon and Thorne 1996).

Channel adjustments are spatially and temporally organized and thus allow for reconnaissance-level interpretation of past, present, and future channel processes, providing a tool for planning. The continuum of channel change can be segmented into stages, each described by controlling processes of adjustment. The foundation for a scheme to describe this is based on the notion that channel evolution is usually triggered by excess stream power relative to the upstream sediment load. Changes in channel evolution phase correspond to the crossing of geomorphic thresholds and associated processes. The Simon and Hupp (1986) channel-evolution model (Figure 33), identifies the equilibrium channel as an initial, pre-eruption stage (I), and the disrupted channel as an instantaneous condition (stage II). Rapid channel degradation of the channel bed ensues as the channel begins to adjust (stage III). Degradation lessens channel gradient and available stream power for a given flow over time at the same time as bank heights are increased and bank angles steepened by undercutting, and pore-water pressure induced failure near the base of the bank (Simon and Hupp 1986).

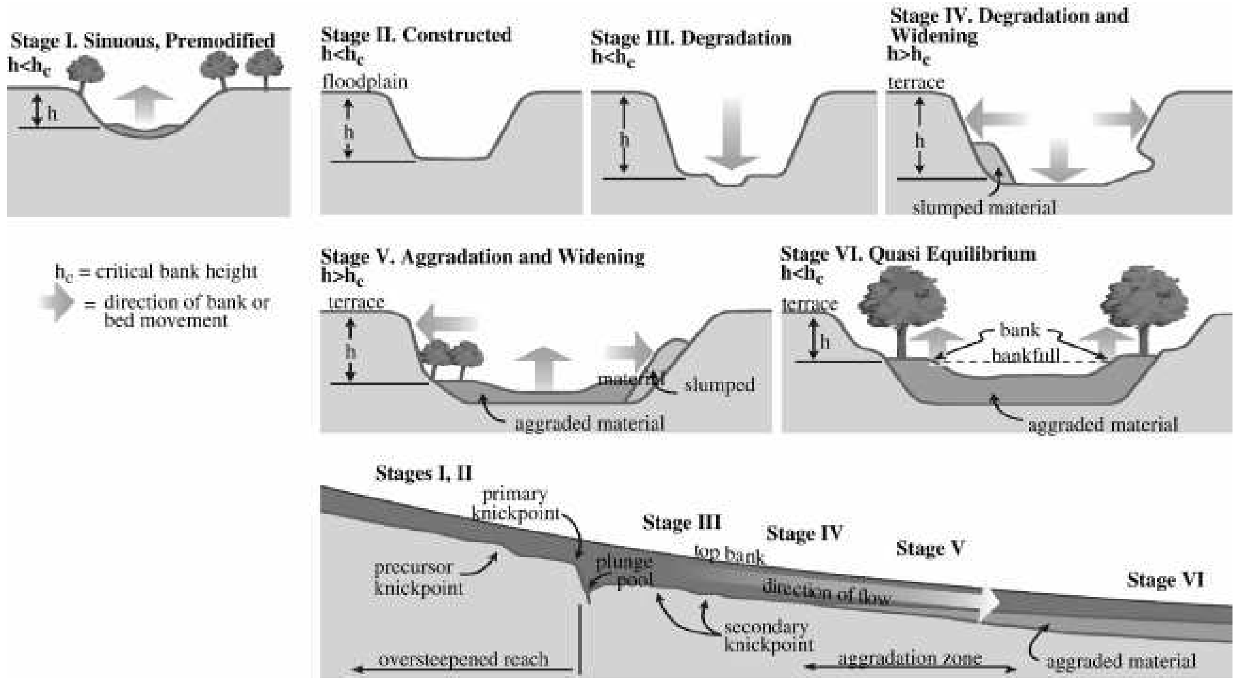

Figure 33 Stages of channel evolution (modified from Simon and Hupp, 1986).

The degradation stage (III) is directly related to destabilization of the channel banks and leads to channel widening by mass-wasting processes (stage IV) once bank heights and angles exceed conditions of critical shear-strength of the bank material. The aggradation stage (V) becomes the dominant trend in previously degraded downstream sites as degradation migrates further upstream because the flatter gradient at the degraded site cannot transport the increased sediment loads emanating from degrading reaches upstream. This secondary aggradation occurs at rates roughly 60 percent less than the associated degradation rate (Simon 1992). Riparian vegetation becomes established on bank surfaces during this stage and serves as a positive feedback mechanism by providing roughness that enhances further deposition. These milder aggradation rates indicate that recovery of the bed will not be complete and that attainment of a new dynamic equilibrium (stage VI) will take place through further (1) bank widening and the consequent flattening of bank slopes, (2) the establishment and proliferation of riparian vegetation that adds roughness elements, enhances bank accretion, and reduces the stream power for given discharges, and (3) further gradient reduction by meander extension and elongation. Vertical adjustments, such as upstream degradation and downstream aggradation, represent the reduction in channel gradients with time (Simon and Hupp 1986).

Recommendations

- Participants in sediment plain restoration activities should recognize that the North Fork Toutle River is quite obviously not in regime, and that movement towards a more dynamic equilibrium and stable channel(s) will not likely be attained until renewed, significant channel incision occurs in association with establishment of riparian vegetation and integration of large woody debris to limit the destabilizing effects of large floods. This process should be encouraged with 'soft' engineering solutions (discussed below) to maintain a consistent channel over time and to facilitate vegetation processes. Currently the existing 'main' channel has a tendency to avulse broadly across the sediment plain.

- Adoption of an appropriate channel evolution model could provide a framework for planning and monitoring sediment plain stabilization activities.
- The record of storms and associated flows that have occurred since the 1980 eruption provides a range of events that likely does not include expected extreme events with low frequencies of occurrence that could occur within the current planning horizon (i.e., before 2035). Assessments (including scenario modeling described below) should thus account for the magnitude and geomorphic effectiveness of more extreme events.

Sediment Budget and Hydrologic/Hydraulic Modeling

Understanding past and future rates of sediment supply and distribution to the sediment plain is critical for restoration efforts, providing a framework for identifying, screening and evaluating potential stabilization alternatives. Recent work conducted by a consultant to the Corps (Biedenharn 2009) has developed a DRAFT sediment budget (reviewed for this report) that attempts to identify the existing watershed sediment sources, pathways and sinks contributing the transport of the massive sediment load of Mount St. Helens 1980 eruption.

The Biedenharn (2009) sediment budget estimates the volumes and transport rates of sediments in the Toutle watershed and the near and long-term range of possible effects on the Cowlitz and Columbia Rivers. The Corps' Sediment Impact Analysis Method (SIAM) and HEC-RAS computer models were used, directed by the Portland USACE District, to develop an existing conditions sediment budget. SIAM is a first-approximation screening tool that provides relatively quick estimates of the without- project conditions and similar estimates for a number of suggested management alternatives. SIAM treats a stream network as a series of user-defined sediment reaches. Sediment reaches are delineated based on observed locations of significant geomorphic change such as tributary locations, changes in channel gradient, planform and geometry, and shifts in sediment composition. Computations of sediment supply and transport are conducted on a reach-by-reach basis and are representative of the average annual conditions for each reach.

SIAM outputs consist of local bed material balance, average annual transport capacities, bed material and wash material supplies, and local sediment supply totals for each sediment reach. Local bed material balance is defined as the difference in the bed material supply and the average annual transport capacity for a sediment reach. A negative local balance indicates excess transport capacity and thus erosion potential for a reach, whereas a positive local balance indicates excess supply and potential for deposition. For the Toutle River project, SIAM was implemented with HEC-RAS allowing for integration of sediment continuity concepts into stream rehabilitation, and providing a tool for assessing sediment continuity for a single, defined (scenario) condition. Because channel geometry was not updated based on erosion or deposition, the results of this study are only indicative of a single channel configuration for the entire period of record being analyzed. This is a significant limitation. Since SIAM is a reach-based model that uses reach-averaged parameters and produces reach-averaged results, information on specific locations of erosion/deposition cannot be determined.

The primary SIAM output is a local (reach) sediment balance, which reports magnitude of the average annual tendency of a reach to fill or scour. The local bed material balance plot for two alternatives, reported by reach, is depicted in Figure 34 and 35.

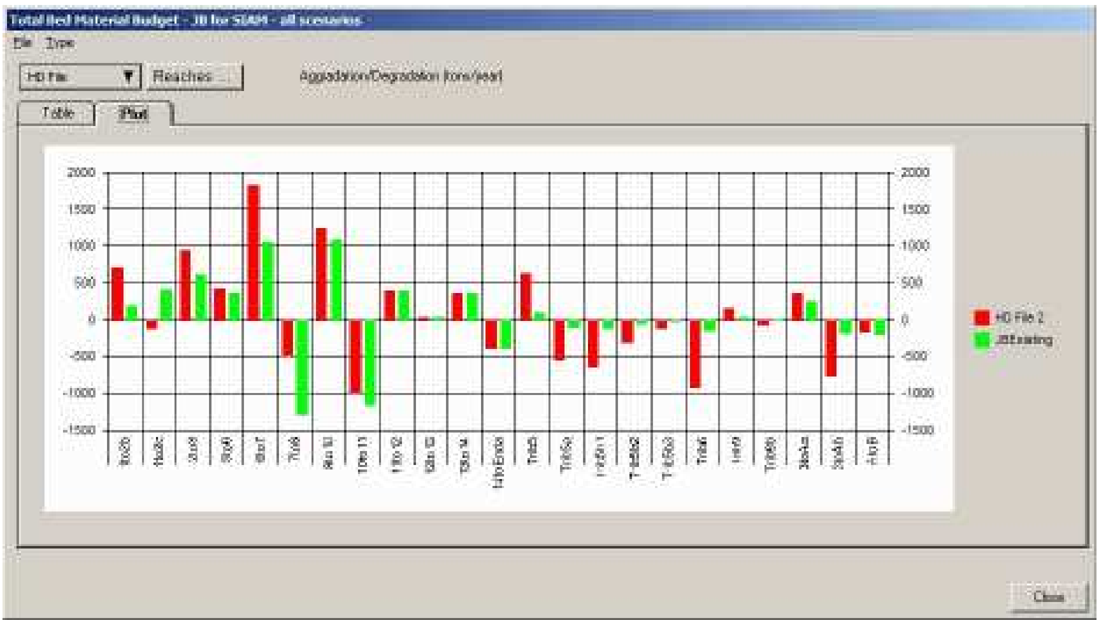

Figure 34 SIAM output: Local bed material balance (green=fill; red=scour).

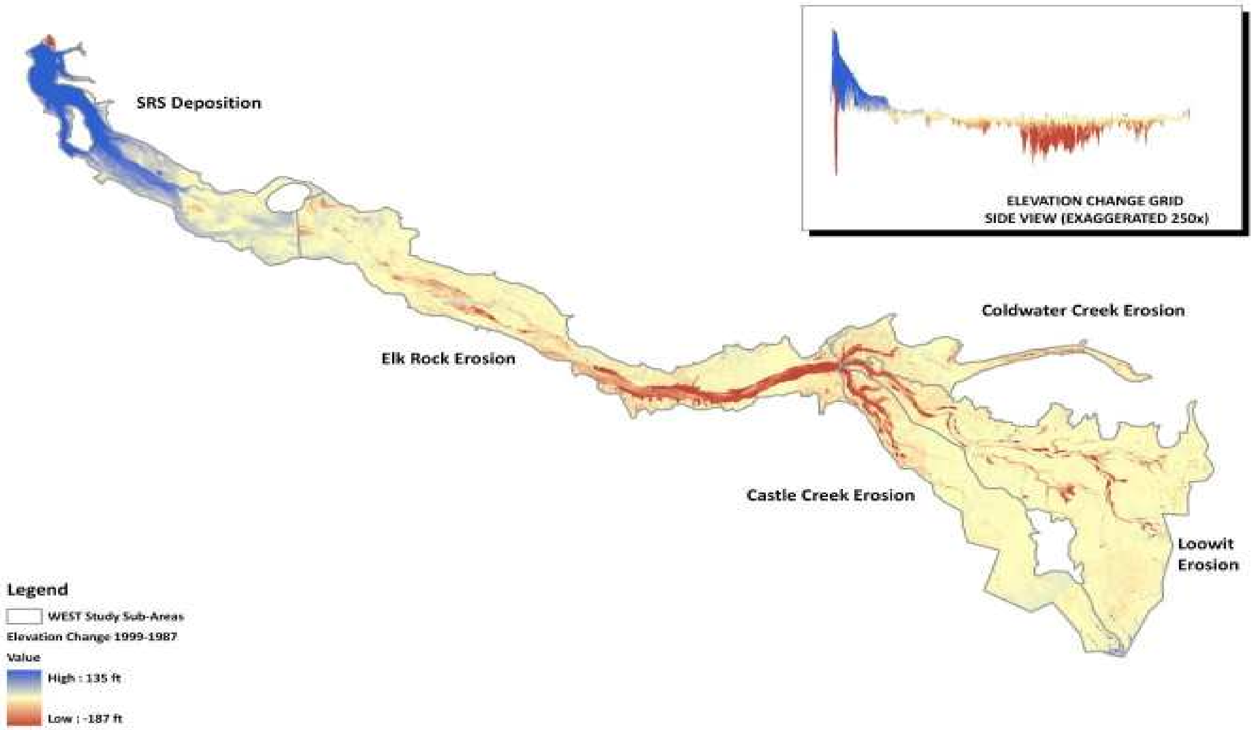

Figure 35 SIAM output: Local bed material balance - color-coded contours of elevation change: blue depicts aggradation and brown depicts degradation.

SIAM appears to provide a useful screening tool for evaluating the sediment budget of the Toutle River Drainage basin. However, such an off-the-shelf model may have limited utility for modeling the dynamics of long-term landform evolution. Detailed hydrological representation is important, but in the case of the Toutle River basin it seems that representation of topographic change (involving sediment mobilization and redeposition), is very important for developing a sound sediment plain stabilization plan. Such a modeling approach should also be able to consider the consequences for hydrological behavior involving feedbacks with topography.

Geomorphologists have successfully used a modeling approach called Cellular Automata (CA) (e.g., Murray and Paola 1994; Coulthard, Lewin, et al. 2005). Wolfram (1984) identifies the five key factors that characterize CA models: (i) they consist of a discrete lattice of cells; (ii) they evolve in discrete time-steps; (iii) each cell takes on a finite set of possible variables; (iv) the value of each cell evolves according to the same deterministic laws; and (v) the laws for the cell's evolution depend only on the local neighborhood of cells around it. Coulthard, Kirkby, et al. (1999) have used this approach to combine numerous processes including the previous inherited channel geometry, vegetation, lithology, sediment supply, slope channel coupling, and the flashiness and shape of the flood hydrograph. This was achieved within a high-resolution spatial framework and was designed to simulate the dynamic response of an upland catchment and channels to a series of flood events.

Recommendations:

- The Biedenharn Report (2009) authors note that channel geometry is not updated based on erosion or deposition, so the results are only indicative of a single channel configuration for the entire period of record being analyzed. However, the LiDAR DEM could be adjusted to reflect modeled/potential erosion or deposition and channel geometry extracted from these scenario configurations providing opportunities to conduct more varied assessments of sedimentation on the sediment plain.
- Analysis of time-series and adjusted architecture hydraulic geometry data extracted from LiDAR data could be expanded to further evaluate serial trends in erosion/deposition via hydraulic and sediment transport modeling. It could also be used as a surface boundary condition for scenario assessments of geomorphic work and potential incision pathways on the sediment plain under various management plans.
- Tighter coupling of the sediment volume behind the SRS with that eroded from the debris avalanche would provide useful calibration and validation data.
- Develop a reach-by reach time series map sequence of locales for sediment aggradation, degradation, or transfer related to reach hydrology would provide a powerful management tool to assess dynamic versus stable reaches, etc.
- Consider using alternative modeling approaches (e.g., a CA model). Modeling can be expensive but the outcomes of long-term modeling (both screening level and higher resolution modeling) will provide a more rigorous framework for sediment management operations. A sediment plain restoration needs to be viewed as a long-term project, thus a goal should be sustainable management action and planning which can be enhanced by long-term scenario modeling. Such a strategy requires a careful data collection plan.

Climate Change and Sediment Plain Stabilization

There are a number of different types of climate impacts on fluvial systems (Vandenberghe and Maddy 2001). These include direct climatic forcing (e.g., peak precipitation) and indirect forcing (e.g., permafrost). Vegetation, or lack of, can be considered a related forcing and should also be considered because it is generally the primary cause of fluvial incision or deposition during temperate or cold periods. Because climate change has implications for sediment management beyond the 2035 USACE management term for the sediment plain and SRS, it should be assessed so that any management decisions based on process modeling build in this risk element. Climate change models can be applied in ensemble or scenario fashion for strategic planning of future sediment and flood risk management.

Recommendations:

- Climate forcings for the Pacific Northwest, and how they relate to sediment plain processes, need to be specified in more detail;
- The role of other external controlling factors that are only indirectly or partially determined by climate should also be estimated, particularly the relationship between vegetation and channel stability;
- Non-climatic factors also have to be considered.

Sediment Plain Restoration Opportunities

In the past year a number of sediment plain stabilization ideas and possibilities have evolved. The Corps has recently contemplated a number of concepts for floodplain stabilization and related flood hazard reduction for Cowlitz River communities threatened by reduction in channel capacity resulting from sedimentation. One of these is to dredge out part of the sediment storage area behind the existing SRS, creating a sump to catch more sediment and re-establish some of the dam's sediment-catching ability. This might have few obvious environmental effects, but it is recognized that a major flow event could engulf the sump in a similar manner as the 1981 flood that damaged the original (pre-SRS) sediment retaining N-1 dam, eroding sediment from the sump back into the river.

Another possible solution is to raise the spillway of the existing SRS, increasing sediment-storage area behind the dam. However, the maximum the spillway can be raised without endangering the SRS itself is 20 ft. This option doesn't gain much sediment-control unless the entire SRS is raised to increase sediment-storage capacity. Raising the SRS could be effective for sediment control but has little flexibility if sediment transport to the SRS ends up being lower than forecasted using sediment transport and sediment budget modeling. It would also result in reduced fish access by enhancing inundation of tributary streams behind the SRS. Watershed-wide debris avalanche deposit stabilization by grading, seeding and riverbank protection has great potential value, but needs to be conducted in coordination with other long-term restoration efforts to be successful, including sediment plain and North Fork Toutle River stabilization.

The concept that currently appears to hold the greatest currency with the Corps is construction of a series of small (10 to 20-foot tall) dams upstream of the SRS. The approach would be to terrace the valley to create a series of permanent sediment storage traps that could be added or raised to adjust to the flow of sediment. One approach might be to use earthen dams, while a 'soft' (i.e., not concrete or rock-based) engineering strategy called GeoTubes has also been considered. GeoTubes are essentially long, fat (e.g., 6-ft diameter) synthetic tubes that are filled (pumped) onsite with a slurry of sediment and water (Figure 36). The tube then dewaters to leave a stable structure that is also quite easily removed (compared to concrete structures) if the application does not work or when the project is complete.

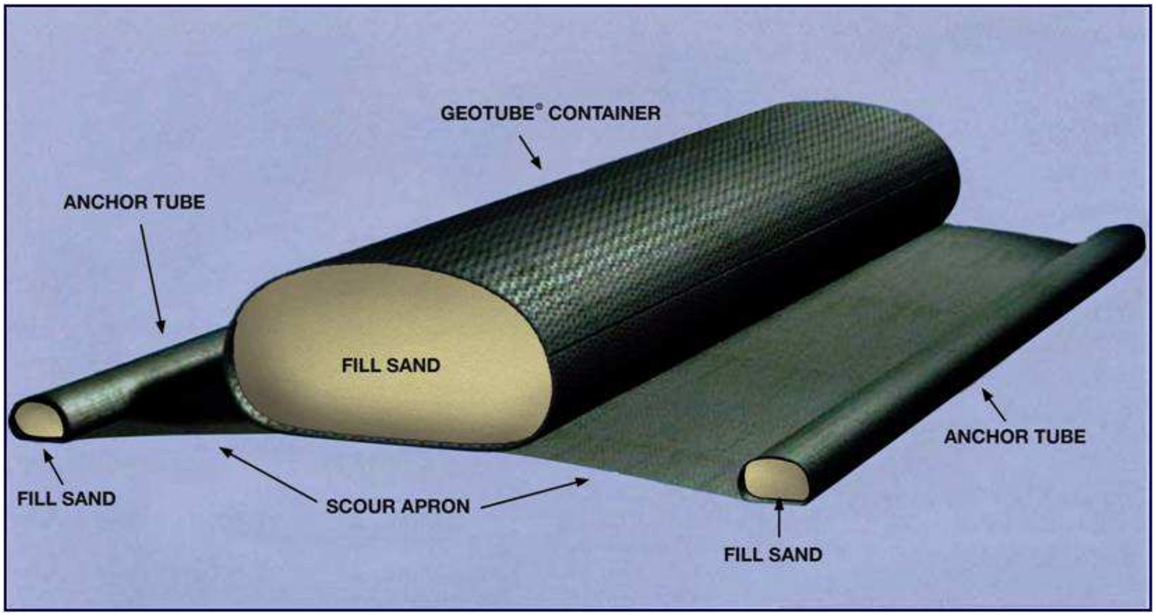

Figure 36 GeoTube grade control structure proposed by the Corps to promote sediment deposition in the North Fork Toutle River upstream of the SRS.

The Corps has assessed this technology to provide a potentially low risk, adaptive management-based approach to building small scale sediment retaining structures for floodplain terracing. Low height structures would be built each year, as needed, to provide up to 8 mcy of shallow pools for sediment deposition for the following year. Figure 37 illustrates a suggested layout for this implementation, with the GeoTube terraces extending over much of the floodplain. This concept has merit from the perspective of sediment plain stabilization, though a major concern is that more sediment aggradation above the existing SRS would further block fish passage to tributaries. In addition, a major flow event could likely breach these structures in the same manner as the original N-1 dam was breached. The potential for sediment mixes to become hyporheic during high flows is strong, and such an erosive flow would seemingly cut through a synthetic fabric material quite readily, creating a significant maintenance concern.

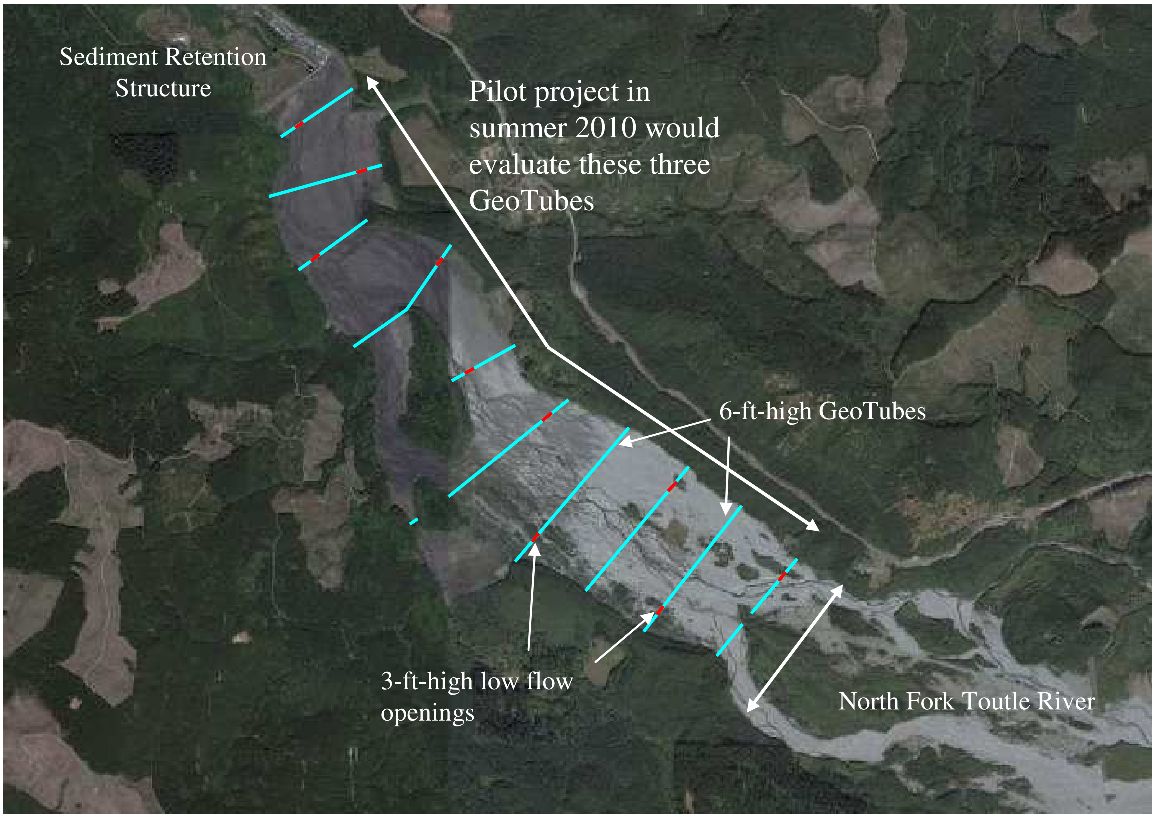

Figure 37 Possible deployment of low head sediment retaining dams using GeoTube Technology (Source: U.S. Army Corps of Engineers, Portland).

A suggested alternative to sediment plain-wide spanning retention structures is the use of an assemblage of structures including Pile-Dikes, GeoTubes and engineered large woody debris (ELWD) structures to encourage and enhance existing preferential flow paths that would be determined prior to deployment using detailed hydraulic modeling and estimates of spatially distributed stream power under scenario flow conditions (Aggett and McColl 2008; Aggett and Wilson 2009). The goal would be to direct low-moderate flows into a main channel flow 'zone', to encourage establishment of a well formed and potentially stable bank structures via some sediment retention and an aggressive revegetation planting program that will strengthen banks while enhancing roughness elements to reduce stream power in moderate-high flows.

The 'assemblage' strategy recognizes the sediment plain dynamic is complex and that a 'one size fits all solution' is unlikely to be sufficient. It also provides an opportunity to monitor the performance and interrelationship between several structures understanding that one might be more effective than another for a specific flow, or that certain combinations, spacing and orientation of each may have quite different impacts in an aggrading reach, versus a reach that is eroding or transporting sediment. Figure 38 provides a conceptual design for this assemblage deployment.

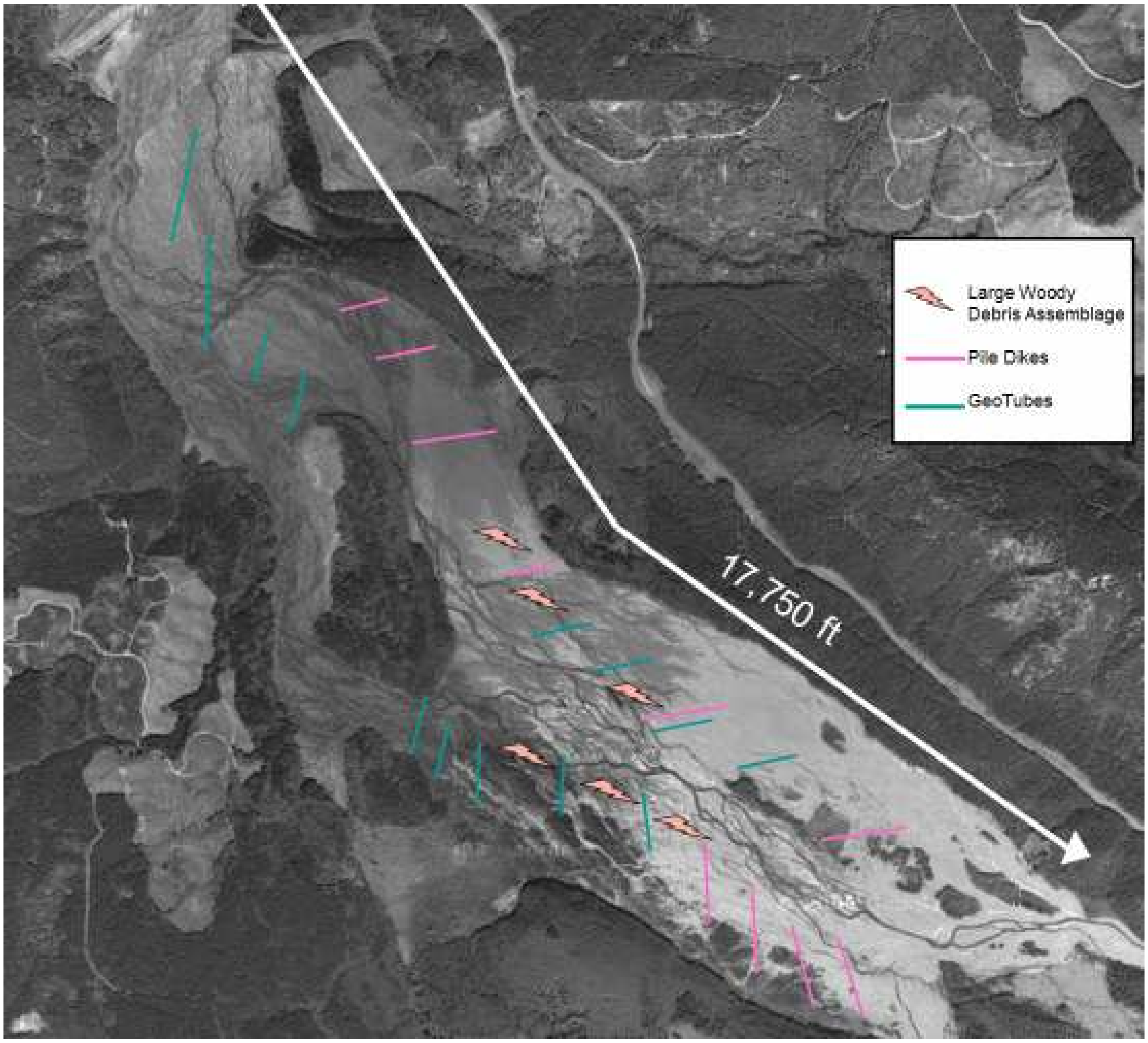

Figure 38 Conceptual design for deployment of mixed channel stabilization assemblage.

Recommendations:

- Develop/adapt a conceptual model of channel evolution to use as framework for planning sediment plain stabilization;
- Conduct hydraulic and sediment transport modeling to determine reach dynamics; Adjust conceptual channel evolution model to a spatial framework;
- Deploy assemblages of Pile-Dikes, GeoTubes, and ELWD structures, supported after some time by aggressive revegetation; and
- Continue modeling and monitoring of assemblage performance, identify what is working, and use an adaptive approach.

Use of GeoTubes in Proximity to the SRS Spillway to Trap Sediment

A locally based retired engineer with experience working on the sediment plain, Lou Reebs, has provided useful recommendations for utilizing GeoTubes or similar technologies to capture sediment in the proximity of the SRS spillway (Figure 39). Specifically, use of GeoTubes to develop a channel local to the SRS would permit more ready access to fish immediately accessing the sediment plain. By developing and providing water of sufficient depth, in a single channel, to enable fish to begin their journey in the right direction, this design could help mitigate the potential for fish to almost immediately get stranded by taking a smaller channel that is ultimately impassable.

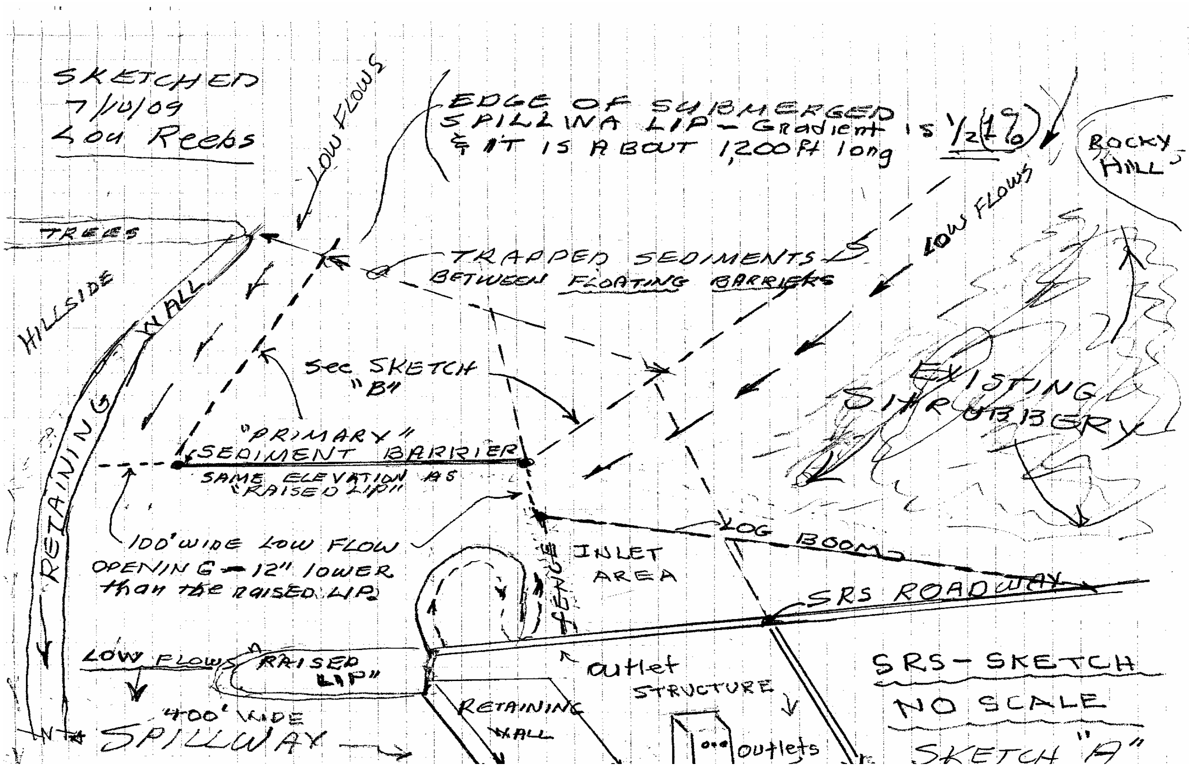

Figure 39 Conceptual design sketch of low-flow channelization approach at SRS spillway (*Source*: Lou Reebs).

The recommendations included in this chapter call for a substantial amount of effort on the part of the several agencies involved in this watershed. The next steps will involve not only committing to a plan of action, but also identifying sources of funding.

5.0 CONCLUSIONS AND RECOMMENDATIONS

The North Fork Toutle River has been characterized as one of the most sediment-laden rivers in the world, transporting as much sediment in one week of high flows as other rivers do over an entire year. Avalanches, landslides and lahars triggered by the 1980 eruption of Mount St. Helens introduced enormous quantities of sediment, rocks and wood into the upper 14 miles of the North Fork Toutle River valley. The Corps sought to prevent this material from being transported downstream by constructing a large, earthen dam across the lower North Fork Toutle River. The Sediment Retention Structure, finished in 1989, was designed to impound water and slow velocities sufficiently for bedload and suspended sediment to settle out behind the dam. The SRS functioned more-or-less as intended during the ensuing decade, but its trapping efficiency decreased significantly in the years following 1998 when flows were permanently diverted over the spillway. The North Fork Toutle River continues to erode and transport large quantities of sediment downstream, where much of it settles out in low gradient reaches of the Toutle, Cowlitz and Columbia Rivers.

The risk of downstream flooding has increased in recent years due to higher-than-expected rates of sedimentation in the lower Cowlitz River. Beginning in 2007, the Corps began dredging the lower Cowlitz River to reduce the threat over the short-term. Because dredging alone would not provide an adequate level of flood protection for downriver communities, the Corps is also developing a long-term sediment management strategy for the Cowlitz watershed (Kuhn 2009). Several sediment control alternatives are being considered (Table 1 above). Some of these are directed at removing previously deposited sediment, mainly in the lower reaches of the Toutle and Cowlitz Rivers; others seek to intercept and sequester sediment higher up in the watershed before it can be mobilized and transported downstream. Two alternatives in particular – raising the elevation of the SRS and spillway to increase its storage capacity, and deploying a series of grade control structures (GeoTubes®) in the sediment plain to encourage sediment deposition and channel incision – have the potential to significantly affect local fish passage conditions. For example, the first option would increase the gradient and/or length of the spillway, and the second option would increase the river gradient if the GeoTubes are successful at building the grade and straightening the river channel. Both of these options would need to be carefully designed, evaluated and, if necessary, modified to ensure that local populations of anadromous fish are not adversely affected.

When the Corps constructed the SRS, no provision was made for volitional fish passage through the spillway. Corps engineers recently developed plans to construct a fish channel in the SRS spillway to enable volitional passage of fish through the structure (Corps 2009); these plans have been temporarily put on hold while the Corps evaluates its sediment control options. The Corps must consider the technical feasibility, cost and ability to reduce the risk of flooding downstream of the different sediment control alternatives in light of their potential to negatively impact the environment, in particular threatened and endangered species of fish and wildlife.

The alternatives under consideration would directly affect fish passage conditions within spillway and sediment plain, and might potentially block access to the lower reaches of Alder, Hoffstadt, Deer and Bear Creeks. Because these streams contain some of the best remaining spawning and rearing tributary habitat in the upper watershed, their accessibility and quality would exert a strong effect on the abundance and distribution of local fish populations.

Fisheries Management Issues

Although the number of fish returning to the North Fork Toutle River has been declining for over 60 years; the downward trend has accelerated during the post-eruption era. Recent surveys suggest that the coho and steelhead populations in the North Fork are approaching critically low levels, and that drastic measures are required to stave off extinction. Because both species are protected under the Endangered Species Act, the Corps must ensure that any actions they take to control sediment do not jeopardize their continued existence or adversely modify their critical habitat. The FCF and SRS, as they are currently configured and operated, as well as any future measures to control sediment in the vicinity of the SRS, are subject to the requirements of the ESA. Notwithstanding the importance of reducing the threat of flooding downstream, sediment control measures will need to avoid doing further harm to local coho and steelhead populations. The provision of safe and effective fish passage, either indirectly via collection and transport, or directly through the creation of natural channels or artificial fishways, is critical to the long-term persistence of these populations.

Although coho salmon and steelhead trout have been the focus of salmon recovery efforts in the North Fork subbasin, anadromous cutthroat trout, chum salmon and spring and fall Chinook salmon historically returned in significant numbers to the system and are therefore also worthy of attention. It is also likely that Pacific lamprey returned to the basin; the historical and present status and distribution of this species is unknown. If present, all actions taken to protect and reintroduce salmonids to the North Fork Toutle River subbasin should also consider the needs of Pacific lamprey.

Chum salmon were reported to have spawned in the Toutle River prior to the eruption of Mount St. Helen (Groot and Margolis 1991), but few have returned since. There is no evidence to suggest that chum salmon spawned the North Fork Toutle River; what little is known of their historical distribution suggests that the majority of chum salmon spawned lower down in the system. Few chum salmon currently return to the Cowlitz River basin. For these reasons, we do not recommend that resources be expended at this time on the reintroduction of chum salmon to the North Fork Toutle River.

Fisheries biologists from Weyerhaeuser Corporation and the Cowlitz Indian Tribe have found relatively high densities of cutthroat trout in North Fork tributaries, particularly in areas above known barriers to upstream passage. The number of adult cutthroat captured at the FCF has declined dramatically in recent years, suggesting that local populations comprise mostly resident fish. Anadromy confers distinct evolutionary benefits on trout populations, and is widespread among cutthroat trout populations in western Washington.

Populations of resident trout retain the capacity to express anadromy for many generations, even if fish that express the anadromous life history form are no longer present. However, the anadromous life history type is seldom regenerated once it is lost from a population (Bilby et al. 2005). Because anadromous cutthroat were prevalent in the historical North Fork Toutle River populations, and because there is a low probability that anadromy, once lost, would be reestablished, we recommend that all adult cutthroat trout captured at the FCF be transported and released above the SRS. The design of the proposed fish fishway in the SRS spillway should be reviewed and revised, if necessary, to facilitate the upstream passage of cutthroat trout. Fish passage success should be monitored and, if cutthroat trout appear to have trouble ascending the fishway, the structure should be modified.

Both races of Chinook were also historically present in the North Fork Toutle River – fall Chinook, for example, were reported to spawn as far upstream as Coldwater Creek (Myers et al. 2003). From 1964 through 1979, an estimated 3,250 fall Chinook spawned the North Fork River above the Green River (WDFW 1992). Like chum salmon, spring and fall Chinook are no longer extant in the North Fork subbasin. However, the Lower Columbia Salmon Recovery and Fish and Wildlife Subbasin Plan (LCFRB 2004) identifies reaches upstream of the SRS as having the highest restorative potential for spring Chinook of any reach in the Toutle River system.

Given the precarious status of the Lower Columbia River Chinook Salmon ESU, and the historical importance and present potential for Chinook production in the upper North Fork, fisheries managers should make their reintroduction into the Toutle River basin a high priority. Fall and spring Chinook from the Cowlitz Salmon Hatchery could serve as donor stocks; both are derived from populations that historically spawned throughout the Cowlitz River system, including the Toutle River. Adult spring and fall Chinook from the Cowlitz Salmon Hatchery are currently released into the Cispus and upper Cowlitz Rivers above Cowlitz Falls Dam. The majority of these fish appear to spawn successfully, as evidenced by the redd counts and the number of naturally produced Chinook smolts that are captured each year at the dam. A similar reintroduction program could be initiated in the Toutle River basin. Wild Chinook adults from the upper Cowlitz River or hatchery-produced fish (in excess of hatchery broodstock needs) could be captured at the hatchery and transported and released into areas of the Toutle River basin that historically supported Chinook salmon, including tributaries to the North Fork. The use of fish captured at the Cowlitz Salmon Hatchery would be scaled back over time as natural escapement to the basin increased. We recommend that fall and spring Chinook salmon be introduced into the North Fork Toutle River concurrent with implementation of measures taken to restore volitional passage in the system.

Efforts to supplement natural production and improve fish passage in the North Fork Toutle River should be undertaken in conjunction with a program designed to restore and enhance spawning and rearing habitat in the basin. Recent stream surveys have documented salmonid production in Alder, Deer, Hoffstadt, Bear, Coldwater and other tributaries to the lower North Fork upstream of the SRS. However, no systematic assessment of the production potential of existing habitat has been undertaken, nor have opportunities to improve habitat conditions and expand salmonid production in the upper basin been systematically evaluated. A subbasin-wide assessment should be conducted to determine the extent and quality of anadromous fish habitat present above the SRS, and to identify opportunities and evaluate the feasibility of restoring access to suitable habitat and improving existing habitat within the mainstem North Fork and its tributaries. This work should proceed without delay so that efforts to control sediment and restore fish passage and habitat can be coordinated and implemented concurrently.

Fish Collection Facility

The FCF was constructed a short distance below the SRS in 1989 so that returning adult salmonids could be trapped, transported around the facility, and release into streams in the upper North Fork Toutle River subbasin. Although the FCF continues to be operated for this purpose, the facility has not fared well over time due to wear and tear caused by heavy sediment accumulations, and a lack of funding for operation and maintenance. Biologists were concerned that the FCF, because it could not be adequately maintained or operated as intended, was preventing the successful collection of fish and was therefore a contributor to the observed declines in fish numbers.

The findings of the present study corroborate these views.

Although small sample sizes prevent us from making definitive statements, our telemetry data suggest that fewer than half of the coho salmon and steelhead trout that arrive at the FCF subsequently enter the facility and are captured and transported above the SRS. A partial explanation is that the facility functions for only part of the time that salmon and trout are migrating upstream; we estimate that the FCF is not operational – either because there is no one there to operate it (e.g., on weekends) or because it is rendered inoperable by sediment accumulations – for almost 60 percent of time during the migration season. The data suggest that some fish elect not to enter the facility and return downstream to spawn in other areas. A significant number of tagged steelhead that entered the FCF were observed to swim up the ladder and into the holding vault, but then swam out of the vault, down the fish ladder, and back out the entrance. This behavior graphically illustrates some of the shortcomings of the facility.

We documented several structural and operational problems that, if not addressed in the near future, will eventually lead to complete failure of the FCF. Until such time that volitional fish passage has been implemented and shown to be effective, the ability to capture fish at the FCF and transport them above the SRS and other known fish barriers will need to be improved. To meet this need, we have recommended several modifications to the existing facility, as well as a number of operational changes that can be made over the short, intermediate and long-term.

Short-term improvements to the FCF assume a three to five year time horizon, during which the most critical problems affecting the facility's performance would be addressed. Chief among these are the replacement of certain FCF components, implementing measures that would reduce the amount of sediment that enters and remains within the facility, and improving hydraulic conditions associated with the fish ladder entrance and within the fish ladder and fish collection pools. Implementing these measures would cost approximately $0.5 M. This cost does not include further monitoring and research, nor the planning and design of additional improvements to the FCF that we recommend be conducted over the next few years.

Exactly what should be done to ensure that the FCF operates satisfactorily over a longer period - that is, until the long-range vision of full volitional passage is fulfilled - cannot be specified due to uncertainty surrounding funding and management decisions. Nevertheless, assuming that the Corps will carry out its plans to enable safe, volitional passage by fish of the SRS spillway and sediment plain, we recommend several "intermediate-term" actions. These include further modifications to the structure to eliminate sediment problems; construction of another fish holding pool to increase capacity and allow operators to continue working while other parts of the facility are being cleaned; restoring the grade of the FCF tailwater pool to ensure that fish can access the fishway entrance; and improving FCF operations by increasing staff levels, acquiring additional equipment, and formalizing the operations process. We estimate that it will cost up to $8.0 M to implement these recommendations.

For fisheries managers, the explicit goal for the North Fork Toutle River is to reverse the decline in salmonid escapements to the subbasin, and to create the conditions necessary to sustain viable populations of fish and a healthy ecosystem over the long-term, subject to the constraints imposed by the harsh physical setting and the imperative that sediment inputs to the lower Cowlitz River be reduced. The long-range vision calls for implementing actions that would result in greater retention of sediment in the North Fork Toutle River channel upstream of the SRS, while at the same time facilitating the safe, unimpeded passage of anadromous fish in both up- and downstream directions. These are not mutually exclusive goals. However, if they are to be achieved simultaneously, managers must take care to identify and address potential problems before, rather than after, final decisions are made and irreversible actions are taken. If steps are taken to accommodate the interests of all parties, there is a good chance that recent declines in fish numbers can be reversed.

The FCF will not be needed if volitional passage is restored throughout the North Fork Toutle River. By enabling salmon and trout to move under their own power at times and under conditions of their choosing, we are allowing the expression of adaptive traits that have evolved to maximize survival in dynamic riverine environments. Replacing the existing trap-and-haul system with a volitional passage system will reduce the stress and injury and delay associated with FCF operations. It will also increase the probability that fish will spawn successfully. At present, fish that elect to not enter the FCF and are forced to spawn in suboptimal areas downstream, and fish that are captured and transported to non-natal streams in the upper watershed probably experience lower reproductive success.

SRS Spillway

In response to the difficulties encountered at the FCF, the USGS, with assistance from AMEC and the Cowlitz Indian Tribe, undertook a series of radio-telemetry studies between 2005 and 2007 to, among other things, determine the degree to which the SRS spillway posed a barrier to migrating adult salmonids. The findings confirmed that adult coho salmon are unable to ascend the spillway, and that fewer than 1 in 3 (27 percent) steelhead that arrive at the base of the spillway are able to successfully navigate it (Kock et al 2007; USACE 2008).

In 2007 the Corps announced that it would address the need for volitional passage through the SRS spillway under its existing project authority. The draft "Mount St. Helens Sediment

Retention Structure Volitional Fish Passage Design Documentation Report" and a 90% engineering level design of the preferred fishway alternative identified in that report were published in 2008 and 2009 (USACE 2008, 2009). The Corps' decision to undertake this analysis, although welcomed, obliged us to shift the focus of our study away from further telemetry studies of fish movements through the spillway to a critique of the Corps plans and design drawings of the proposed fish passage channel.

Based on our assessment of historical, existing and desired future conditions in the North Fork Toutle River as they relate to salmonid production, we fully support the Corps' proposal to construct a fish passage channel in the SRS spillway. We believe that the SRS spillway can be structurally modified to enable adult fish to volitionally navigate the spillway over the range of flows that typically occur during the salmon migration season. The new fish passage channel can be constructed over the next 2-3 years at a reasonable cost, without need for mitigation, and without affecting the SRS' ability to continue to retain sediment.

In our comments we noted that the Corps' design called for slightly shallower run and pool depths than are normally specified for fish passage, and that fish would be required to swim at burst speed over extended distances, but concluded that adult coho salmon and steelhead trout should still be able to ascend the fishway without undue difficulty. We also noted that the orientation and location of the entrance and exit of the fish passage channel were critical to its performance. To increase stability, the fishway entrance should be located near the left bank of the spillway. It would be desirable to create a hydraulic barrier across the base of the spillway that induced fish to swim into the entrance of the fishway. The exit of the fish passage channel should be located close enough to the spillway crest to minimize the possibility of being cut off from the North Fork channel, yet far enough away so that fish are unlikely to fall back down the spillway once they exit the fish passage channel.

The existing gradient of the SRS spillway is 6.4 percent. The spillway drops 140 feet over a distance of 2,200 feet. If the Corps decides that, in order to be able to retain more sediment behind the dam, the SRS and spillway should be raised an additional 25 feet, the average gradient will increase to 7.5 percent, assuming the length of the spillway is left unchanged. Although the adults of most species of salmonids can navigate channels with slopes of 8 percent or less, it is important to point out that elevating the spillway along its entire length to achieve an average gradient of this magnitude would be impractical. If the Corps decides to raise the height of the spillway crest, it is much more likely that the gain in elevation would be achieved by steepening the spillway over a relatively short distance at its upper end.

It is unreasonable to expect that adequate fish passage conditions can be maintained if the spillway gradient exceeds 8 percent, even if the jumps and other height discontinuities are eliminated. For this reason, we recommend that the proposal to raise the height of the SRS and spillway be rejected unless volitional fish passage can be accommodated.

The Corps apparently did not consider the possibility of integrating a structure for trapping fish in the fish passage channel they are proposing to build in the spillway. After speaking with WDFW and Cowlitz Indian Tribe personnel, we understand that the ability to trap, enumerate, and if necessary, transport adult salmon to upstream areas is critical to the long-term viability of coho salmon and steelhead populatons in the North Fork Toutle watershed. There will be a continued need to trap and haul fish around the SRS until the new volitional fish passage channel has been demonstrated to be effective. A long-term backup system is needed in the event that the proposed volitional upstream passage system fails, or barriers form in the sediment plain. The new facility would have the added advantage of enabling WDFW and tribal biologists to selectively remove hatchery fish from the returning assemblage of fish. Maintaining the genetic purity of indigenous salmonid populations is a key tenet of salmon recovery.

Based on the foregoing arguments, we recommend that the Corps explore the feasibility of incorporating a short section of conventional fish ladder and an in-ladder adult fish trap at the downstream end of the fish channel. The downstream end of the fish ladder would serve as the entrance to the fish passage channel; the fish ladder would bypass the falls at the base of the spillway; and the entire structure would be anchored to the spillway's south wall. The fish ladder would extend upstream only as far as is necessary to accommodate the fish trap and connect with a pool excavated in the fish passage channel. A vertical slot fish ladder is recommended since it can accommodate a wide range of water surface elevation fluctuations. To ensure that sediment does not build up in low velocity areas in the pools, and that the entire structure will be self-cleaning, the lower edges of the ladder baffles and weirs would be elevated several inches off the bottom of the ladder.

The trap structure should be designed so that fish are able to migrate through it unimpeded it unless removable gates or pickets are intentionally put in place to create a trap. It will be necessary to devise a mechanism for temporarily dewatering the holding pool and reducing velocities to acceptable levels in order to be able to remove the fish. A lift on the back of a truck would be used to load netted fish into a live tank for transport.

We believe that constructing a fish ladder and trap as part of the fish passage channel offers a practical and far less expensive alternative to rehabilitating and operating the existing FCF facility. If this option is pursued, we advise against deconstructing the FCF until the new fish ladder, trap and fish passage channel have been fully tested.

Sediment Plain

Another prerequisite for constructing a volitional fish passage channel in the SRS spillway is that fish are able to successfully navigate the sediment plain. The sediment plain is a highly variable environment that changes rapidly in response to episodic, flow-mediated sediment fluxes. The North Fork Toutle River responds to the continual interaction of flow, sediment and channel slope by forming a meandering and, especially in the upper reaches of the sediment plain, a braided channel pattern. The multiple channel threads and braid bars move around, often rapidly during flood events, but also progressively under non-flood conditions due to the lack of stable banks and incised channels within the sediment plain. Even the "main" North Fork channel is prone to extensive lateral migration across the valley floor.

The braided channels that traverse the sediment plain each convey a relatively small portion of the total flow and are wide relative to their depth, which is typically shallow. Fish are often prevented from migrating upstream, especially under low flow conditions when channels split, flows go subsurface and depths become impassable. One of the objectives of the telemetry studies was to determine whether coho and steelhead could successfully migrate to spawning areas in tributaries and upper reaches of the North Fork Toutle River. If radio-tagged fish were not able to pass through the sediment plain, we wanted to pinpoint the locations where they encountered problems. Coho salmon were not detected above RM 30.0, presumably due to a barrier that existed at this location under the conditions that prevailed at the time of this study. Steelhead appeared to have greater success than coho in navigating and ascending the sediment plain and upper reaches of the North Fork Toutle River. Their success might be attributable to their greater swimming prowess, or to higher flows that prevailed during the steelhead migration period.

We inferred from these observations that the sediment plain poses significant challenges for upstream migrating coho and steelhead. Since our sample sizes were too small to support a definitive conclusion, we encourage the collection of additional fish movement data before a commitment is made to modify the SRS spillway to allow for volitional fish passage. In particular, more detailed measurements and modeling are needed to identify potential barriers to fish passage, particularly in low gradient areas and near tributary mouths.

The sediment plain evaluation also sought to identify opportunities to improve hydraulic conditions within the North Fork Toutle River so that adult salmonids are able to rapidly migrate to tributaries and mainstem areas upstream. If the Corps proceeds with its plan to construct a series of small dams (e.g., GeoTubes) upstream of the SRS to promote sediment deposition, the structures should be positioned to force low flows into a single channel that is sufficiently deep to enable fish to access tributaries and the upper reaches of the North Fork Toutle River under a range of flow conditions. Habitat restoration (i.e., large wood placement and riparian vegetation planting) should be implemented concurrently to further stabilize and define the channel, and provide the hydraulic conditions that coho and steelhead require to reach their spawning grounds.

We believe that GeoTubes and large wood can be used to promote the channel incision and widening necessary to achieve a single dominant channel that is in ‘quasi equilibrium’ (sensu Darby and Simon 1999) under expected flow and sediment regimes. Further benefits will be secured if bars and terraces form that are stable enough for vegetation to flourish. A stable channel with a well established riparian system would make it easier for fish to navigate the sediment plain and access spawning areas upstream.

In spite of the generally favorable impression imparted by the Geotubes concept, we have several concerns with the proposed approach. One is that fish will have difficulty passing through the notches in the structures, especially after sediment has accumulated and caused the bed to aggrade. If the GeoTubes function as planned, the North Fork Toutle River will traverse a series of low gradient terraces separated by short, steep channel sections that fish are likely to find difficult to negotiate. Moreover, additional sediment deposition may eliminate important spawning habitat in the lower reaches of tributaries that enter the sediment plain. And finally, a major flow event is likely to breach these structures in the same manner as the original N-1 dam was breached.

It may be possible to address these uncertainties and improve the GeoTubes concept through research, modeling and monitoring. Understanding past and future rates of sediment supply and distribution to the sediment plain is critical for restoration efforts. To better our understanding, and increase the probability that our actions will have the desired effect, we recommend the following adaptive, modeling-based framework:

- Develop/adapt a conceptual model of channel evolution to use as a framework for planning sediment plain stabilization;
- Conduct hydraulic and sediment transport modeling to determine reach dynamics;
- Adjust the conceptual channel evolution model to a spatial framework;
- Deploy assemblages of "soft" structures (e.g., GeoTubes, Pile-Dikes, and large wood) in the sediment plain to promote sediment deposition and encourage the formation of a stable low-flow channel;
- Further stabilize the system by aggressively planting newly formed terraces to limit the destabilizing effects of large floods; and
- Continue modeling and monitoring system performance, identify what works and what doesn't, and adjust efforts accordingly.

The draft report by Biedenharn (2009) identifies sediment sources, pathways and sinks contributing to the transport of sediment to the Cowlitz and Columbia Rivers, including estimates of the volume and transport rate of sediment generated by the Toutle River. Computations were conducted on a reach-by-reach basis. The authors note that they did not update channel geometry based on erosion or deposition, so the results are based on a single channel configuration for the entire period of record being analyzed. This represents a serious limitation of the model. To overcome it and allow for a more realistic assessment of the effects of modifying the sediment plain, we recommend adjusting the LiDAR DEM to reflect potential erosion, deposition and channel geometry under various restoration scenarios. Adjusted architecture hydraulic geometry data extracted from LiDAR data could be expanded to further evaluate temporal trends in erosion/deposition via hydraulic and sediment transport modeling. It could also be used as a surface boundary condition for assessments of geomorphic work and potential incision pathways on the sediment plain under various management scenarios. A time series analysis of sediment aggradation, degradation, or transfer related to reach hydrology would provide a powerful, spatially explicit, management tool to evaluate sediment control alternatives and fish passage conditions.

Sediment plain restoration requires a long-term commitment to data collection and analysis. The potential effects of climate change and other factors affecting the water and sediment regime in the North Fork Toutle River need to be analyzed in greater detail. In the meantime, it is necessary to implement immediate actions to prevent the situation from becoming worse. The current system involving the FCF, SRS and sediment plain is only marginally functional, and wholesale improvements are needed to create a sustainable system that meets the multiple objectives of the watershed.

Next Steps

The conclusions and recommendations included in this report build upon an extraordinary amount of effort by agencies and other entities involved in the management of the North Fork Toutle River watershed and its resources. The field research component of this project was conceived and implemented with the goal of gathering information on the behavior and fate of upstream migrating salmon and trout, as it is affected by conditions at or in the FCF, the SRS spillway, and the sediment plain. Radio-telemetry techniques were used to monitor fish behavior and identify passage problems associated with the FCF and the sediment plain upstream of the SRS. This information was analyzed and applied in an engineering feasibility-level assessment of the structural and functional characteristics of the FCF, SRS spillway, and sediment plain, so that conceptual level solutions for improving fish passage at these facilities and locations could be identified. Due to the large degree of uncertainty inherent in the proposed actions, we recommend that a formal monitoring and adaptive management program be developed and implemented in conjunction with the engineering solutions discussed above. Assuming that safe fish passage is absolutely essential to the long-term persistence of local fish populations, the recommended course of action is deemed reasonable and prudent.

The next steps will involve not only committing to a course of action, but also identifying sources of funding and the roles and responsibilities of various parties. We recommend that representatives of the Corps, WDFW, Cowlitz Indian Tribe, Lower Columbia Fish Recovery Board, and other interested parties meet soon to define short- and long-term actions, develop a long-range budget and fundraising strategy, and agree on respective duties. Ideally, the plans to reduce flooding risks and recover fish populations will be developed together. We are hopeful that common solutions can be found that will achieve efficiencies while meeting multiple goals. It is clear that a single-focus or small-scale approach will be unsuccessful if not coordinated with other management efforts in the basin.

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APPENDIX A

SRS Memorandum

MEMORANDUM

TO: United States Army Corps of Engineers, Portland District
333 SW 1st Avenue, #200
Portland, OR 97204
Attn: Jeremy Britton

FROM: AMEC Earth & Environmental, Inc.
3500 188th St SW, Suite 600
Lynnwood, WA 98037
Contact: Tad Schwager (tad.schwager@amec.com)

DATE: 1 July 2009

RE: North Fork Toutle River Fish Passage at the Sediment Retention Structure: Comments on the Design Documentation Report and 90% Stage Drawings for Spillway Modifications

cc: Lower Columbia Fish Recovery Board
2127 8th Avenue,
Longview, WA 98632
Attn: Jeff Breckel

Introduction

The Lower Columbia Fish Recovery Board (LCFRB) received grant funding in 2007 from the Washington State Salmon Recovery Funding Board to investigate several issues relating to the upstream passage of adult salmonids in the North Fork Toutle River. Coho salmon and winter-run steelhead are the primary species of interest in the North Fork Toutle River watershed. Both are currently listed as threatened under the Endangered Species Act. Formerly abundant spring chinook salmon have been extirpated in the watershed. The ecology and management status of these species are described elsewhere (LCFRB 2004; COE August 2008), and will not be repeated here.

AMEC Earth & Environmental, Inc. (AMEC), as a sub-recipient of the grant, has lead the fish passage study. One objective of the study was to investigate adult fish behavior and migratory movements in the immediate vicinity of the Fish Collection Facility (FCF), the Sediment Retention Structure (SRS), and the sediment plain above the SRS. Previous radio-telemetry studies conducted by fisheries biologists from AMEC, the U.S. Geological Survey and the Cowlitz Indian Tribe determined that the SRS spillway is a complete barrier to upstream migrating coho salmon and that only a fraction of the steelhead that arrive at the base of the spillway are able to ascend it successfully (Kock et al 2007).

A second objective of the study was to conduct an independent engineering review to determine what actions can be taken to (1) enable volitional fish passage through the SRS spillway, and (2) improve the performance of the FCF. The overarching goal was to identify measures that would increase the probability that wild coho salmon and steelhead trout would successfully spawn in areas upstream of the SRS.

There has been a steady decline in recent years in the number of adult coho and steelhead trapped at the FCF by Washington Department of Fish and Wildlife personnel[1] and transported to tributaries above the SRS. The situation has reached critical levels: last year, roughly 100 fish of each species were trapped and released above the SRS. Much of the decline may be attributed to ongoing impacts on the quality and accessibility of fish habitat in the upper NF Toutle watershed caused by the continuing erosion and deposition of massive quantities of sediment. However, it is also likely that the FCF is contributing to the decline since the facility suffers from disrepair, is understaffed, and can be rendered inoperable by sediment for much of the time the two species are migrating. Radiotracking data suggest that a significant portion of the fish that approach the FCF do not enter it and subsequently return to areas downstream to spawn.

Responding in part to these concerns, the United States Army Corps of Engineers (Corps) initiated an engineering study in 2008 to evaluate alternative configurations that would enable adult salmon and steelhead to pass volitionally upstream through the SRS spillway. The Corps recently updated their design documentation report and associated 90% stage drawings (COE April 2009).

The Corps' decision to modify the spillway to facilitate fish passage required AMEC to alter its original scope of work. Instead of investigating adult fish movements in relation to the SRS spillway and exploring various fish passage options, as was called for in the original grant proposal, AMEC proposed to review and comment on the Corps' preferred fish passage alternative. The intent of this memorandum is to evaluate the modifications proposed by the Corps to facilitate the safe passage of fish through the SRS spillway. Our observations and recommendations are based on several field trips to the SRS site, a thorough review of available information, and discussions with Corps personnel. We have also met with representatives from other agencies in order to better understand the flooding and fisheries management issues that affect decisions related to the SRS and FCF.

[1] WDFW is assisted by members of the Cowlitz Indian Tribe and citizen volunteers.

AMEC is also preparing a second technical memorandum that evaluates the structural and operational aspects of the FCF and recommends improvements that would facilitate the collection and transport of adult salmon and steelhead into the upper NF Toutle watershed. Preliminary findings indicate that the FCF is in a serious state of disrepair and can be expected to break down completely in the next 5 years unless significant resources are invested in its repair and maintenance. Assuming that the extirpation of coho and steelhead populations above the SRS is not an option, and that a fish trapping facility is necessary to ensure the desired level of genetic purity (i.e., by enabling managers to cull hatchery fish from returning runs), we encourage the Corps to explore the feasibility of incorporating a fish ladder with an adult trap built into it at the base of the SRS spillway as part of their preferred design. As discussed further below, the addition of a fish ladder and trap to the proposed Corps' "full length channel improvement" design would pose significant technical challenges. Nevertheless, we believe it offers a practical and less expensive alternative to rehabilitating and operating the existing FCF facility.

Background

The Corps of Engineers' draft "Mount St. Helens Sediment Retention Structure Volitional Fish Passage Design Documentation Report" (COE August 2008) provides an excellent summary of the effects of the eruption of Mount St. Helens on May 18, 1980 on the natural environment, and subsequent attempts by the agency and others to limit the potential for flooding in the Toutle and Cowlitz River drainages. Several preventative measures were implemented, including levee raising, dredging, bank hardening, and construction of structures designed to facilitate the deposition and storage of sediment within the active river channel. One such structure is a 549-m wide, 56-m high dam built in 1989 across the lower North Fork Toutle River. The Sediment Retention Structure (SRS), as it is known, functioned admirably in trapping sediment during the decades following its construction; however, faster-than-expected deposition of sediments behind the dam has filled the forebay to the existing spillway level and created a 6-km long, unstable sediment plain upstream. Resuspension of these previously deposited sediments is a major source of material transported through the SRS and hence downstream. Aggradation of the Cowlitz River near its mouth has increased the risk of flooding, which has prompted in turn an increased frequency of dredging in the lower river by the Corps.

The SRS was constructed in 1989 with concrete outlet works and a rough bed spillway. The spillway had a 7% gradient and measured approximately 670 m long and 122 m wide at its crest. No special provision for enabling upstream fish passage through the spillway was made at the time of construction.

Between 1989 and 1998, NF Toutle River flows passed the SRS primarily via the outlet works. High flow events were handled by a combination of outlet works discharge and spillway overflow. As the SRS filled with sediment, more and more water was diverted over the spillway. The spillway was damaged by high flows in 1996 and prompted the Corps to make minor structural repairs to the spillway and construct a weir 305 m downstream of its crest to prevent downcutting. In 1998, the top row of outlet pipes was closed off; from then on, all water passed the SRS via the spillway. Under normal flow conditions, hydraulic conditions in the spillway consist of high velocity cascades interspersed with areas of shallow, turbulent flow. The spillway terminates at its lower end in a vertical drop of approximately 3 m.

At the same time that the SRS was constructed, the Corps built a fish collection facility (FCF) approximately 1.5 km downstream of the SRS and 0.2 km upstream of the Green River confluence. The FCF consists of a 23 ft-high concrete barrier dam that spans the entire NF Toutle River channel, a short fish ladder, and terminal trap. Fish are prevented from passing upstream in the river by the barrier and volitionally enter the fishway and trap. Trapped fish are netted, transferred to a tank of oxygenated water on the back of a flatbed truck, and transported to either Alder or Hoffstadt Creek, located 11 and 24 river km, respectively, upstream of the SRS. Along with the mainstem NF Toutle River, these two streams contain the primary spawning and rearing habitat in the upper watershed.

For several years following its construction, the FCF functioned as designed. However, after the SRS outlet structure was closed off and flows were diverted through the spillway, increasing amounts of sediment were conveyed through the SRS sediment plain and thence downstream. Operators of the FCF had to contend with higher sediment loads, which during high flow events routinely overwhelmed the capacity of the FCF to purge sediment and maintain the hydraulic features necessary to successfully attract, trap and collect returning adult salmon and steelhead. Due to excessive sediment accumulations and a reduced budget, the FCF trap facility is now operated for only a couple of days each week.

In response to the difficulties encountered at the FCF, AMEC, U.S. Geological Survey, and Cowlitz Indian Tribe fisheries biologists undertook several radiotracking studies between 2005 and 2007 to determine the degree to which the SRS spillway posed a barrier to migrating adult salmonids. The findings confirmed that adult coho salmon are unable to ascend the spillway, and that fewer than 1 in 3 (27 percent) steelhead that arrive at the base of the spillway are able to successfully navigate it (Kock et al 2007; COE August 2008).

In 2007 the Corps announced that it would address the need for volitional passage through the SRS spillway under its existing project authority. Since then, the Corps released the draft “Mount St. Helens Sediment Retention Structure Volitional Fish Passage Design Documentation Report” (COE August 2008) and completed a 90% engineering level design (COE March 2009) of the preferred fishway alternative identified in that report. The following comments address each of three alternatives considered by the Corps, but focus primarily on the preferred alternative; the reader is referred to the design document report for further detail.

Physical Characteristics of the Spillway

The SRS was initially constructed with a spillway at the right end (looking downstream) of the structure. The spillway is not the short, steep slide typical of most dams; rather, it is a 670-m long, moderately sloped (7 percent grade) chute cut into existing bedrock. The spillway is roughly trapezoidal in cross-section, ranging in width from 60 m to 122 m. There is a 3- to 4-m high cascade located roughly two-thirds the distance down the spillway, and another 3-m high falls at the downstream end. The rest of the spillway has an irregular bottom of rock and concrete, containing numerous channels, small pools, local smaller drops and areas exposed at low flow. Concrete was added in places to achieve the desired slope and stabilize the bed.

Now that the SRS outlet works have been closed, all NF Toutle River flows pass through the spillway. The flows and associated hydraulic characteristics that exist in the spillway at times when coho and steelhead are likely to be migrating upstream have been thoroughly described by the Corps (COE August 2008). These descriptions are accepted at face value for use herein.

Upstream Fish Passage through the Spillway

The SRS spillway currently presents several types of barriers to upstream migrating fish, including:

1. The 3-m falls at the downstream end of the spillway;
2. The 3-4 m cascade approximately 1/3 the distance up the spillway;
3. The numerous secondary channels that exist at low-to-moderate flows, and that become impassable as flow attenuates in the upstream direction; and
4. The cumulative stress on fish of having to navigate a long, steep and energetically challenging section of spillway with little opportunity to rest between sustained bouts of vigorous swimming and leaping.

Fish that successfully ascend the spillway must also cope with additional fish passage problems associated with the sediment plain immediately upstream of the SRS[2].

Alternatives Considered

The Corps described three fish passage alternatives in their 2008 report, as follows:

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[2] Fish passage through the sediment plain will be discussed in a separate memorandum.

1. Bottom falls removal and spot improvements to one existing low-flow channel: This alternative was described in the Mount St. Helens Ecosystem Restoration General Reevaluation Study Reconnaissance Report (July 2007). The work involves 1) removing the falls at the bottom of the spillway (estimated at 1,000 cubic yards of rock excavation) and 2) creating a small number of lateral connections and holding/resting pools on the spillway (the "spot improvements," estimated at 500 cubic yards of rock excavation total). The intent of this alternative was to remove the salient fish barrier—the falls at the bottom—and construct a minimum number of local improvements—lateral trenches for connectivity of the multiple low-flow channels and holding/resting pools for use during high flows.

2. Full length channel improvements: This alternative involves the design of a channel that would run the length of the spillway. The designed channel would be superimposed on the most pronounced existing low-flow channel to minimize rock excavation. The river would be drawn into the channel a short distance upstream of the crest, then pass the crest through a new notch excavated in the rolled compacted concrete (RCC) steps. The channel would follow a central route through the spillway until passing through the existing notch in the RCC at station 30+00, after which it would shift to the left and travel along the south side of the spillway to the bottom of the spillway. Along the route, two falls (one being the falls at the bottom) would remain in the channel but would be reduced in height for fish passage. The intent of this alternative is to convey the river through this channel for flows up to a design maximum flow rate, excluding water from other routes that may be impassable to fish. Several pools would be constructed along the channel for resting areas. This alternative is described in more detail below as the preferred alternative.

3. Fishway constructed in spillway: either pool-and-weir or slot-type: This alternative involves construction of a fishway within the spillway. Two types were considered: pool-and-weir and slot. The approximate volume of RCC needed to construct the roughly 150 weirs is 500 cubic yards. Pools would be excavated in the rock below each weir. The approximate volume of rock removal is 1,800 cubic yards. The pool-and-weir fishway would cover about 33,000 square feet of the spillway. A rectangular channel approximately 15 ft wide by 5 ft deep by 2,200 ft long (volume = 6,100 cubic yards) would be excavated in the spillway for the slot type fishway. The area of spillway disturbed would be 33,000 square feet. The estimated total volume of reinforced concrete required to construct the slots in the fishway is 2,500 cubic yards. The wall running parallel to the fishway, built to keep high flows out of the fishway, is initially estimated to be 3 ft high, 10 ft wide at the base, 5 ft wide at the top, and constructed using RCC. The volume of the wall would be approximately 1,800 cubic yards. With a base width of 10 ft, the area of spillway disturbed by the wall would be 22,000 square feet.

Preferred Alternative

The three alternatives require progressively greater inputs of effort and material to achieve the goal of volitional fish passage. Judgment needs to be applied to the characteristics of each in order to reach a rational conclusion on which alternative best meets the needs for fish passage at a reasonable cost, while at the same time allowing for the desired conveyance of water, sediment and large wood through the spillway.

An important consideration at this site is the durability and the need for long-term maintenance of the fish passage structure. Since the spillway is the primary route by which water, sediment and large organic material travel around the SRS, it is important that the selected alternative is capable of accommodating high flows and expected sediment and wood loads. Each of the Corps' alternatives contain features that would result in temporary accretions of sediment. Large trees will pose problems if they become lodged in the spillway and modify local hydraulic conditions.

Ideally, a normalizing characteristic, such as the cost associated with passage of one fish, could be used as a basis for selecting an alternative. This, however, does not accurately reflect the high value of passing a minimum number of fish, with a declining return thereafter; the non-cost value of passing threatened or endangered fishes; and other considerations. The absence of accurate knowledge of fish numbers, prospective passage success, confidence in cost estimates and related factors largely prohibits a quantitative basis for making a selection. Understandably, the Corps used a more qualitative process for comparing alternatives to make a selection of a preferred alternative. That process led them to select Alternative 2 as their preferred alternative. Alternative 2 is presented (COE August 2008) at a preliminary engineering level of detail, but with a limited amount of design specifics. Accordingly, the following review is consistent with that level of detail.

Conformance with Fish Passage Criteria

The Corps' preferred alternative consists basically of directing and confining flow to a fish passage channel within the spillway chute in order to minimize the opportunity for false passage routes; reducing the height of the falls and cascades to a series of vertical drops measuring no more than 3 feet in height; and adding and deepening thalweg pools to the channel so that fish are able to rest and orient themselves for leaping or swimming upstream. The Corps avoids calling this alternative a fishway, even though technically it is one, presumably because it does not meet all of the fish passage criteria applied to conventional fishway design. We make no such distinction, referring to the preferred alternative interchangeably as a fishway when the meaning is obvious.

The Corps' preferred alternative – a "jumps and pools" channel design – most closely approximates a conventional "pool and weir" configuration, except that the Corps option requires fish to leap greater heights at certain locations than is normally the case in a pool and weir-type fish ladder. Although the desired 1-ft vertical height criterion could not be consistently accommodated throughout the fish passage channel, the placement of sufficiently deep pools at the base of the steeper drops should provide the hydraulic conditions fish need to propel themselves successfully over all of the obstacles they are likely to encounter.

Downstream Entrance to the Fish Channel

The key objectives at the downstream fishway entrance are to locate the entrance where fish can easily find it, and to ensure that the discharge from the fish channel and associated water velocities (4 to 8 feet per second) are sufficient to induce fish to ascend the spillway along the intended route. The preferred alternative appears to meet these conditions, especially at low to moderate flows when most of the water flowing down the spillway will be discharged from the fish passage channel. At all but the highest flows, fish should have no trouble achieving proper orientation and entering the fish passage channel.

As conceived by the Corps, upstream passage through the fishway must be initiated by jumping. Therefore, the plunge pool at the entrance should have sufficient volume, depth (4 feet minimum; we recommend 6 feet) and uplift for fish to orient and gain momentum for the jump. There is not enough detail in the Corps' plans to determine whether their preferred alternative meets these criteria. However, it can be assumed from the existing physical conditions and basic design concepts that the desired depth, velocity and attraction flow can all be achieved with minor design refinements at the entrance, without major changes to the basic project configuration.

The lower terminus of the proposed fish way is located in the area where the spillway, which is hardened and resistant to scour, transitions to the natural, erodible river channel. The structures in this area will need to be carefully engineered and located to minimize the risk of scour and lowering of the streambed.

It should be noted that the design of the Corps' preferred alternative can be modified further to incorporate a conventional fish ladder and an in-ladder adult fish trap in a short section of the fish passage channel at its downstream end. The addition of this feature, which would require modifying the preferred alternative to incorporate elements of the Corps' third alternative, should be explicitly considered if it is decided to replace the FCF with a more reliable structure. This option is discussed in further detail below.

Fish Channel Runs

The concentration of water into a well-defined and minimally obstructed channel will provide the environmental cues and conditions necessary for upstream migration. We recommend, however, increasing the target minimum water depth to 1 foot versus the shallower 0.6 foot minimum depth proposed by the Corps. Based on hydraulic modeling results, the Corps' design seems to have essentially accomplished this deeper depth anyway.

Although the Corps attempts to design the runs so fish swim at "preferred speed" as much as possible while ascending the channel, their modeled velocities vary quite a bit at the programmed flow rates and are generally on the high side of those considered suitable for adult salmon. The average 6 percent gradient between drops will force fish to swim at burst speed for a good portion of the distance. This, plus the energy expenditure associated with leaping over obstacles, could result in the buildup of lactic acid, exhaustion and failure to pass. The potential for this to occur highlights the importance of providing frequent pools along the route, siting and dimensioning them so that fish have the opportunity to recover sufficiently before restarting their journey upstream.

Fish Channel Pools

In addition to allowing fish to recover from prolonged exertion, water depth and turbulence in pools help conceal fish from potential predators. Pools are typically located between hydraulic steps where the total grade change is in excess of ten to twelve feet. If designed correctly, they also provide conditions that enable fish to gain momentum to either swim or leap over a cascade at the head of the pool. As such, depth, velocity, pool volume and residency time are important characteristics to consider in sizing pools. It is difficult to determine from the information that is available how the Corps determined their pool sizing criteria. The wide width and minimum 7-foot length of the pools recommended by the Corps are unconventional, but from a plan view perspective meet the minimum criteria. The originally proposed use of side pools has been eliminated and while this was an unconventional feature, it remains unknown what impact this may have on the availability of resting places or alternate passage routes over the range of anticipated flows.

The positioning of some of the pools below unusually high (3-ft) individual drops could potentially result in flows that sweep through the pools with little dissipation of energy, as opposed to pools in which the current is directed tangentially toward the bed or bank, forming eddies. Pools that do not produce a stilling or eddying effect on the flow will have comparatively low value as resting and jump staging areas. The originally proposed pool depth of 1-foot has been increased to 3-ft, which is a definite improvement, but it is still lower than the desired minimum depth of 4-ft. Lacking adequate depth, a pool may not provide the hydraulic conditions a fish needs to leap over the drop at the head of the pool, even if the height of the drop is within the leaping ability of the target species of fish

The recommended pool capacity of 0.2 cubic feet of water per pound of fish seems high, approaching levels found in high-density fish farming operations, but is not expected to be exceeded given the number of returning adults anticipated. Nonetheless, it is recommended that pool volume be increased by increasing the average pool depth, especially in pools located at the base of significant hydraulic drops.

Upstream Exit to the Fish Channel

The two most important characteristics of fishway exits are 1) to locate them far enough upstream in areas of low velocity so that fatigued fish do not inadvertently get swept back downstream before continuing their upstream migration, and 2) to direct and control the volume of water entering the fishway according to the designed conveyance capacity. As with the entrance, insufficient information exists to ascertain whether the current design meets these criteria. However, it can be assumed from the existing physical conditions and basic design concepts that the exit can be positioned and oriented as part of minor, more detailed design refinements at the entrance, without major changes to the basic project configuration. A potential problem at this specific location is that the exit will be located in the highly mobile sediment plain that has developed in the SRS forebay. The position of the main river bed and channels containing depths suitable for fish passage changes constantly in this area in response to high flows and sediment deposition. A happy medium must be met between locating the fishway exit too much into the sediment plain, where the channel is actively moving and could close off the spillway exit, and too close to the spillway lip, where fallback might occur. Clarification is needed as to how the spillway exit is to be configured to exclude sediment while at the same time effectively directing flow into the fishway and guiding fish upstream. A training wall should be considered as a means of controlling hydraulic conditions at the fishway exit and, possibly, intercepting large woody debris before it enters the spillway. The Corps should investigate this and other measures for maintaining a stable channel configuration and preventing sediment buildup immediately upstream of the spillway.

Downstream Fish Passage through the Spillway

Solving the upstream fish passage problem at the SRS will for the most part ensure adequate downstream passage. This is because the downstream passage route will be the same as the upstream route. Refining fish passage entrance and exit details and configuring the pools to provide less turbulent and more quiescent areas will facilitate the safe and rapid downstream passage of NF Toutle salmonids.

The issues that are of greatest concern regarding the downstream passage through the SRS spillway are related to the potential for stranding and subsequent mortality. The primary goal is to direct downstream migrating fish into the fish passage channel at the head of the spillway, and to constrain them to use the channel as their main migratory route so that they experience the most felicitous hydraulic conditions while traveling downstream.

The potential for stranding increases, especially at low flows, when a fish is entrained in water that flows down the spillway outside the boundaries of the fish passage channel.

In this case, there is no guarantee that the fish will encounter adequate flow depths over the entire length of channel. Moreover, if a fish takes up temporary residence in one of the many small pools that pockmark the spillway surface, and the pool becomes isolated or gradually dewaters as flows recede, the fish is at risk of asphyxiation or predation. We recommend that the incidence of fish stranding be monitored following construction of the fish channel. If significant, the offending pools and depressions can either be plugged with concrete or altered so that fish are able to readily vacate them during the descending limb of the hydrograph.

In high energy/high turbidity environments like the NF Toutle River, outmigrating juvenile salmon tend to face upstream and allow themselves to be passively swept downstream by the flow. This behavior leaves them susceptible to abrupt changes in flow direction. Once in the fish channel, the presence of false passages remains a concern, but the primary issue shifts to minimizing hazards related to water turbulence, including impact trauma, de-scaling and fin damage. An additional concern is protecting juveniles from predation while they are concentrated in the artificial fish passage channel, where there is less cover and escape habitat than is found in natural channels.

A significant number of adult winter-run steelhead, on the order of 10-20 percent, survive spawning and migrate downstream afterwards. Females are two to three times as likely to survive as males, presumably due to the extended time and energy males spend on the spawning ground competing for and guarding females. The likelihood that post-spawn steelhead, referred to as kelt, will survive to spawn again the following year depends in part on stresses and hazards associated with downstream migration. Post-spawn emigration of adult steelhead should be explicitly considered when addressing downstream passage at the SRS spillway. Measures devised to protect juvenile fish, as described above, should also be implemented to protect steelhead kelt.

Opportunities for Enhancing the Preferred Alternative

Due the substantial energy demand that will be imposed on adult coho and steelhead as they migrate up the spillway fish channel, one of the most important features of the Corps' preferred design is the pools that will be excavated from the spillway bed. Pool spacing, shape, depth and volume all affect the metabolism and swimming and leaping capabilities of upstream-bound fish. To the extent possible, we recommend that the Corps provide an extra margin of safety and utility, taking into consideration the known preferences of adult coho and steelhead, in the design and configuration of pools.

Understanding how natural scouring and depositional processes impact the effectiveness of the fish passage is extremely important in the sediment rich environment of the NF Toutle River. For example, how quickly will pools fill with sediment and debris and how will this incrementally affect upstream and downstream fish passage for each species? Are there additional structural or operational features that can be included that will prevent sediment from building up in the fishway?

Pools should be designed to maximize their hydraulic self-cleaning properties while providing the depth, velocity and volume conditions necessary for fish passage. In this regard, the pool and chute configuration developed by Bates (AFS 1991) is known to be effective at sluicing sediment and is therefore worth considering.

A range of pool geometries and variations in the plan arrangement of the pools should be considered, and the most promising evaluated using physical modeling. Physical modeling will produce configurations that strike a balance between providing fish passage and minimizing sediment accumulations. The number of pools in the design and their importance in ensuring successful fish passage warrants this level of evaluation and design support.

Limited access to design support information and a general lack of detail on the drawings limits the extent to which specific comments can be made on other details of the preferred alternative. The following general comments are made for consideration in the completion of the design and design documentation.

- A "windrow" or training wall will be constructed along the length of the spillway to physically separate the fish passage channel from the rest of the spillway. The fish passage channel will occupy approximately one-third of the existing spillway. The right side of the windrow is designated to receive excess excavated material, which will reduce the conveyance capacity of the remainder of the spillway. Will the height of the windrow be calibrated to ensure that the entire spillway, including the fish channel, is capable of conveying flood flows? This dual function for the spillway needs to be clarified.
- Details for anchoring the windrow and "crest fills" into the spillway floor should be provided.
- The precise grades for the pools, crests, windrow and related features should be specified.
- The use of sculpted concrete in lieu of grouted rock and precast concrete blocks should be considered.
- Considerably more detail should be shown for the fishway entrance and exit areas – these features are critical to the overall success of the fishway.
- The specifics of how the dam outlet gates are to be opened for construction, how the accumulated sediment upstream of the gates is to be controlled, and the criteria that need to be met by the contractor in designing and operating the diversion channel, need to be more precisely addressed.

- Greater attention should be given to features that are important to spillway operation, dam safety, fish sampling and salvaging, site access, and maintenance issues.

In the process of reviewing the proposed SRS spillway fish passage modifications, several other items of potential interest were noted. Those items are listed below in random order:

- The cost for the Corps alternatives seems to be on the low side, particularly for preferred Alternative 2. A more thorough, itemized engineers' estimate would be more useful and accurate for determining costs. Such an estimate should be based on a quantity takeoff and include itemized components of construction, an allowance for unlisted items, and a higher allowance for contingencies.
- Because the Corps does not have their own criteria for fishway design and construction, they extracted criteria from Reiser et al. (2006) for use in this analysis. It should be noted that there are numerous other sources of information that could prove valuable in providing a more complete set of design criteria.
- In this case, the results of the HEC – RAS 1-D hydraulic model for simulating fish passage facility velocities are difficult to rely upon due to the steep gradient and rapidly varied flow conditions within the channel. The Corps acknowledges this in their report and we mention it here for emphasis. This is another characteristic which supports the use of a design based on physical model testing.
- The existing spillway is currently a significant navigation obstacle and hazard for recreational users, including whitewater boaters and rafters. In its proposed condition the nature and location of the hazards will change but will still exist.

Additional Observations and Recommendations

The fish passage channel that the Corps proposes to construct in the SRS spillway is likely to achieve its stated goal – the successful volitional up- and downstream passage of salmon and steelhead around the SRS. This structure should be constructed, however, only if it is reasonably certain that fish are able to navigate the 6-km long sediment plain upstream of the SRS and reach their spawning grounds in tributaries and mainstem reaches of the upper NF Toutle River. The constantly changing sediment plain, with its highly braided and unstable channels, many of which are unsuitable for upstream passage, poses a particular challenge to fish. Under certain conditions, fish that successfully ascend the spillway will be vulnerable to low-flow stranding and elevated stream temperatures while attempting to navigate the sediment plain. For this reason, we recommend that construction of the fish passage channel be deferred until plans for controlling sediment and channel form in the sediment plain have been finalized. We encourage the Corps to explore the use of artificial berms and other retaining structures to promote off-channel sediment storage and the formation of a single threaded channel upstream of the spillway fish passage channel entrance.

We also encourage the Corps to consider designing and constructing a fishway structure at the lower end of the fish passage channel that would allow for the capture and removal of adult salmon and steelhead. WDFW[3] has argued that the ability to trap, enumerate, and if necessary, transport adult salmon to upstream areas is critical to the recovery of ESA-listed coho salmon and steelhead in the NF Toutle watershed. As will be discussed in a second memorandum[4], the Fish Collection Facility has deteriorated to the point that a major refurbishment and upgrade to the facility would be very costly, and would likely be ineffective in any event. The possibility of building another adult salmon collection facility should be explored before a decision is made to abandon the existing one. Note that if a new facility is built, it will be necessary to determine how best to breach or remove the existing structure.

WDFW makes the additional point, and we concur, that there is a continued need to be able to trap and haul fish around the SRS until the new volitional fish passage channel has been demonstrated to be effective. A backup system is needed in the event that the proposed volitional upstream passage system fails. The new facility would have the added advantage of enabling WDFW biologists to 1) monitor the number of returning salmon and steelhead and determine the success of these efforts to restore volitional passage; 2) efficiently capture and tag fish to study migration behavior and further identify passage bottlenecks; and 3) remove hatchery fish so that they do not interbreed with locally adapted wild fish. Limiting the genetic impacts of hatchery programs on the native gene pool is a key recommendation of the Hatchery Scientific Review Group.

Several trapping systems are worth considering. We recommend designing a new adult collection facility that can be incorporated directly into the Corps' preferred fish passage channel alternative. A short segment of conventional fish ladder with an in-ladder adult collection facility could be constructed at the lower end of the spillway. The lower end of the fish ladder would also serve as the entrance to the fish passage channel. The fish ladder would be physically tied to the existing bedrock on the south side of the spillway and would extend only as far upstream as is necessary to accommodate the adult collection facility and connect with a pool that is excavated in the fish passage channel. The site would be accessible by road, so the transfer of fish to a tanker for delivery upstream would be feasible.

A vertical slot fish ladder is recommended since it can accommodate water surface elevation fluctuations more readily than can other conventional fish ladder designs. The

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[3] Wolfgang Dammers, District Fish Biologist (personal communication, June 26, 2009).

[4] AMEC is currently analyzing the effectiveness of the FCF and recommending measures for its rehabilitation.

overflow weirs between sections should have one or more V-slots (minimum width, one foot) to ensure proper depth and velocity characteristics at different flow levels. A slight (1- 1.5 inch) gap between posts supporting the bottom of the weirs will ensure that sediment does not build up in low velocity areas in the pools, and that the entire structure will be self-cleaning. The number of pool sections required will depend on the total grade differential. Two to three resting pools should be included. The trap structure should be designed so that fish are able to migrate through it unimpeded it unless (removable) gates or pickets are intentionally put in place to create a trap. It will be necessary to devise a mechanism for temporarily dewatering the holding pool and reducing velocities to acceptable levels (< 1.5 fps) in order to be able to net the fish. A lift will be needed to load netted fish into the tanker, if desired.

There are other ways that fish trapping can be accommodated in the Corps design. We recommend that Corps and WDFW personnel sit down together to identify the desired attributes of the fish ladder and collection facility.

Monitoring and Evaluation

The fish passage channel proposed by the Corps is an unconventional yet reasonable approach to enabling fish to pass volitionally through the SRS spillway. The approach does not attempt to achieve a perfectly engineered fishway; nor does it guarantee that desired fish passage criteria are met at all locations. To attempt to do so would be prohibitively expensive. Instead, the Corps' preferred alternative consists of a well-defined channel that concentrates flow and guides fish over a confined area of the spillway to which pools have been added and false passage routes and barriers to upstream passage have been eliminated. It is expected that these objectives will be achieved through careful engineering and construction techniques.

However, given the design uncertainties and dynamic nature of the spillway, it will be important to observe the structural and functional characteristics of the fish passage channel after it is constructed to verify that fish are able to successfully navigate it in both up- and downstream directions without significant delay or injury. With respect to the physical characteristics of the constructed channel, it should be verified through observation that sediment deposition and scour and the accumulation of large woody debris over time do not reduce passage success. We consider it very likely that further modifications will be required after the initial tests are conducted. Careful evaluation of the newly constructed spillway elements will lead to a better understanding of passage effectiveness and the ability to make timely, appropriate adjustments when necessary. This is a situation where an iterative, empirical approach may be both prudent and necessary to reach the desired long-term solution.

A monitoring and evaluation plan should be prepared that ensures the collection of appropriate physical and biological performance data, identifies appropriate performance metrics and objectives, and outlines management responses when those objectives are not met. The plan should describe how these objectives will be measured, and how adaptive management decisions will be made and funded to achieve the objectives. The plan should include, at a minimum, the following performance metrics:

- Upstream adult fish passage success by species;
- Downstream juvenile fish passage success by species;
- Downstream steelhead kelt passage success;
- Sediment and large wood accumulation and remobilization rates;
- Hydraulic characteristics under different flow conditions; and
- Structural integrity of fish passage channel and its components.

We recommend that the movements of different fish species and life stages be monitored under a range of flow conditions for several years following construction. In this respect, radiotelemetry is likely to continue to be the most effective monitoring technique.

Operation and Maintenance

It should be acknowledged up front that this project will require continual monitoring and maintenance to be effective in the long-term. The facility will likely require physical modifications as more is learned about its effectiveness. The causes of poor performance and changes in channel characteristics (e.g., downcutting) should be carefully monitored and, if significant, addressed immediately.

Most fishways are not designed to accommodate high sediment loads – an important consideration at this site. The sediment may quickly fill eddy and low velocity areas of pools, eliminating depth, volume and resting areas. The channel should be inspected after high flows occur to ensure it remains passable. To maintain optimum performance of the fish passage channel, sediment maintenance should be performed annually to remove sediment and debris in the fish passage channel and in vicinity of its entrance and exit. A high level of monitoring and maintenance activity will likely be necessary and adequate funds will need to be allocated to ensure that the project operates at a high level of performance.

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APPENDIX B

FCF Memorandum

MEMORANDUM

TO: Washington Department of Fish and Wildlife, Region 5
2108 Grand Boulevard
Vancouver, WA 98661
Attn: Patrick Frazier

FROM: AMEC Earth & Environmental, Inc.
3500 188th St SW, Suite 600
Lynnwood, WA 98037
Contact: Tad Schwager (tad.schwager@amec.com)

DATE: 14 September 2009

RE: Effectiveness of the Fish Collection Facility on the North Fork Toutle River

cc: Lower Columbia Fish Recovery Board
2127 8th Avenue,
Longview, WA 98632
Attn: Jeff Breckel

Introduction

The Lower Columbia Fish Recovery Board (LCFRB) received grant funding in 2007 from the Washington State Salmon Recovery Funding Board to investigate several issues relating to the upstream passage of adult salmonids in the North Fork Toutle River. Coho salmon and winter-run steelhead are the primary species of interest in the North Fork Toutle River watershed. Both are currently listed as threatened under the Endangered Species Act. Formerly abundant spring Chinook salmon have been extirpated in the watershed. The ecology and management status of these species are described elsewhere (LCFRB 2004; COE August 2008), and will not be repeated here.

AMEC Earth & Environmental, Inc. (AMEC), as a sub-recipient of the grant, has led the fish passage study. One objective of the study was to investigate adult fish behavior and migratory movements in the immediate vicinity of the Fish Collection Facility (FCF), and through the sediment plain above the Sediment Retention Structure (SRS). Previous radio-telemetry studies conducted by fisheries biologists from AMEC, the U.S. Geological Survey and the Cowlitz Indian Tribe determined that the SRS spillway is a complete barrier to upstream migrating coho salmon and that only a fraction of the steelhead that arrive at the base of the spillway are able to ascend it successfully (Kock et al 2007).

A second objective of the study was to conduct an independent engineering review of (1) the effectiveness of the FCF structure and its operations, and (2) the US Army Corps of Engineers' (Corps) design for modifying the SRS spillway to enable volitional fish passage around the SRS. The overarching goal was to identify measures that would increase the probability that wild coho salmon and steelhead trout would successfully spawn in areas upstream of the SRS. This technical memorandum addresses the first part of the second objective - by providing an evaluation of the FCF and its current performance. The second part of the second objective has been achieved through a similar technical memorandum addressed to the Corps.

There has been a steady decline in recent years in the number of adult coho and steelhead trapped at the FCF by Washington Department of Fish and Wildlife (WDFW) personnel[1] and transported to tributaries above the SRS. The situation has reached critical levels: last year, roughly 100 fish of each species were trapped and released above the SRS. Some of the decline may be attributed to ongoing impacts on the quality and accessibility of fish habitat in the upper NF Toutle watershed caused by the continuing erosion and deposition of massive quantities of sediment. However, it is also likely that the FCF is contributing to the decline by operating in a highly inefficient manner.

We evaluated the current structures and operations of the FCF and found that the facility is in a serious state of disrepair and can be expected to break down completely in the next 5 years unless significant resources are invested in its repair and maintenance. Radio-tracking data, collected as part of the first objective, confirmed that a significant portion of the fish that approach the FCF do not enter it and subsequently return to areas downstream to spawn (see associated report on radio-telemetry results for details).

We present these results with the intention of stimulating discussion and prompting efforts to either improve the efficiency of the FCF, or find an alternative strategy to increase the success of returning salmonids to reach spawning habitat. We have assumed that the extirpation of coho and steelhead populations above the SRS is not an option, and that a fish trapping facility remains necessary to ensure the desired level of genetic purity (i.e., by enabling managers to cull hatchery fish from returning runs). This assessment focuses on the FCF in its current condition, in its current location, and with the current need for this type of facility. Clearly, any decisions regarding repair or replacement will need to consider other activities occurring within the watershed.

[1] WDFW is assisted by members of the Cowlitz Indian Tribe and citizen volunteers.

Background

The eruption of Mount St. Helens on May 18, 1980 heavily impacted the North Fork Toutle River Basin and mobilized massive amounts of ash and debris that smothered the watershed. In 1989 the Corps constructed the SRS to trap sediment flushing downstream and to limit the potential for flooding in the Toutle and Cowlitz River drainages. No special provision for enabling upstream fish passage at the SRS was made at the time of construction. Instead, the Corps built a fish collection facility (FCF) approximately 1.5 km downstream of the SRS and 0.2 km upstream of the Green River confluence. The FCF consists of a 23 ft-high concrete barrier dam that spans the entire NF Toutle River channel, a short fish ladder, and terminal trap. Fish are prevented from passing upstream in the river by the barrier and volitionally enter the fishway and trap. Trapped fish are transferred to a tank of oxygenated water on the back of a flatbed truck, and transported to either Alder or Hoffstadt Creek, located 11 and 24 river km, respectively, upstream of the SRS. Along with the mainstem NF Toutle River, these two streams contain the primary spawning and rearing habitat in the upper watershed.

For several years following its construction, the FCF functioned as designed. However, as the forebay of the SRS filled with deposited sediment, the outlet works were closed off. Once the top row of pipes were reached, flows were diverted through the spillway, and increasing amounts of sediment were conveyed through the SRS sediment plain and thence downstream. Operators of the FCF had to contend with higher sediment loads, which during high flow events routinely overwhelmed the capacity of the FCF to purge sediment and maintain the hydraulic features necessary to successfully attract, trap and collect returning adult salmon and steelhead. Due to excessive sediment accumulations and a reduced budget, the FCF trap facility is now operated for only a couple of days each week.

Recently, the Corps has been developing plans to address the need for volitional fish passage through the North Fork Toutle River by constructing a fishway within the SRS spillway. The final decision to make these modifications depends on the overall watershed strategy to reduce flooding and contain the massive amounts of sediment. Further detail of this plan is available in the Corps' draft "Mount St. Helens Sediment Retention Structure Volitional Fish Passage Design Documentation Report" (COE August 2008) and completed a 90% engineering level design (COE March 2009). If the SRS Spillway is made passable to upstream migrating fish, and the radio-telemetry results show successful ascension through the sediment plain, then it may be possible that the FCF is no longer needed. Until these conditions are met, the FCF or other similar structure will be necessary to ensure that native salmonids return to spawning habitats. Even then, it may still be important to retain the ability to handle fish before allowing them upstream to monitor population sizes and to cull hatchery strays.

This evaluation was undertaken with the assumption that a fish collection facility (FCF) remains necessary in this general area (upstream of the Green River confluence and downstream of the SRS) as part of the overall Mount St. Helens' Sediment Control Project. Should the overall need or configuration of any of the integrally related components of the project (the SRS, FCF, the sediment plain mitigation, etc) be reconsidered, the conclusions of this narrative should also be reconsidered accordingly.

This evaluation was based primarily on site visits made by Douglas Laiho (AMEC) on June 20, 2008 and June 18, 2009. It was also based on review of as-constructed drawings, selected record photos, discussions with Corps personnel, and minutes from an operational site evaluation conducted by the Corps and WDFW on October 27, 2006. Several observations made by AMEC, were also noted in the Corps' site visit minutes. In this report, these similar findings are denoted with an asterisk (*). The level of detail associated with the evaluation was consistent with that conducted by the Corps (2006).

The original design and supporting information was not reviewed, as it was not made available. The comments on facility features that are offered in this memo are based on observation, operator provided information and professional judgment.

The June 18, 2009 site visit was conducted for the purpose of observing the general condition of the facility, the operations being conducted at the time, the operability of selected features, and to discuss how the facility typically operates during fish collection and transfer procedures. The site visit took place over a period of approximately five hours and was conducted independently by Mr. Laiho and jointly with Ms. Julie Henning and the FCF operator Mr. Chris Gleizes, both with the WDFW.

Findings

General

Access to the facility during the site visit was good, and allowed the engineer to observe many of the different components of the FCF while in operation. However, the facility was not being operated to collect and transfer fish at the time of the visit, since no adult salmonids were migrating during this time of the year. River flow levels were low due to the lack of recent rains and snowmelt. Turbidity levels were high, as is common for the North Fork Toutle River. A water/sediment sample taken at the FCF had a measured turbidity of 105 NTU and showed some visible settling within seconds, indicating that fine sand was being carried in suspension. Visibility into the water was limited to approximately two inches.

Sediment Related

The primary characteristic impacting the natural flow regime of the North Fork Toutle River is the eruption material that is being eroded from the watershed and carried away in the form of river bed load and suspended sediment. The FCF was designed with the assumption that the SRS would be in place and functioning to intercept sediment, thereby reducing the amount of sediment reaching the FCF. In addition, it was assumed that the sediment loads in the river would decrease over time and be significantly reduced by now - almost thirty years after the eruption. Instead, the sediment loads in the river below the SRS began to increase again after the storage capacity of the SRS was essentially filled (in 1998) and re-suspended sediment was allowed to flush through the spillway. This increased sediment load now must be handled at the FCF at a level not anticipated in the original design.

While the FCF was designed with the knowledge that it would have to handle large amounts of sediment, the amount, and persistence, of sediment it currently experiences was apparently underestimated. This is evident in several elements of its design, including: the absence of a bulkhead gate that would prevent entry of sediment into the weir box during periods when water was not being diverted; a weir box that is undersized for removing at least sand size materials in suspension; a weir box that has no proactive means of sediment flushing/removal (in the form of a scraper or flushing mechanism); and a sediment sluice that is undersized. Particularly problematic locations for sediment accumulation occur in the weir box, in the attraction diffuser between the wall and the right vane, in the attraction diffuser behind the fish screens and in the fish collection crowder pool.

Sediment accumulates in the weir box continuously, even when the facility is not operating, because it has no headgate or easily placed bulkhead to exclude both normal streamflow sediment as well as more extensive materials of various types carried by flood events. When the facility is readied for operation, one of the first steps is to run water to flush accumulated sediment from the weir box, either out the sediment sluice or at least partly through the system. Since the sediment sluice has not worked for some time, the sediment is alternatively sluiced through the attraction diffuser, where some of it accumulates as described in the previous paragraph. The result of the non-functioning sediment sluice is that the weir box is almost always filled with sediment, which significantly reduces its intended function of removing suspended sediment from diverted water.*

During the 2008 inspection, a trial operation of the weir box demonstrated that sediment accumulated on the river side of the intake trash racks is pulled into the weir box upon initiation of water diversion. This remobilization of sediment at the intake undoubtedly increases the sediment passing through the FCF to levels exceeding that being carried by the river at the time. This condition was partly corrected last year by removing the concrete stop log from the velocity barrier dam crest. The open stop log notch allows a higher sweeping velocity across the diversion entrance and reduces the amount of sediment that accumulates at the inlet to the diversion. Despite the encouraging results, the velocity barrier dam crest without stop logs is two feet higher than the diversion sill, indicating that some sediment accumulation at the face of the diversion sill is still likely to occur. Even in the absence of the stop logs, the stop log notch and stop log mounting posts quickly foul with debris, which must be removed to maintain sweeping velocity. Removal is complicated by the absence of a permanent or mobile facility crane that could be used to move bulkheads, stop logs or debris from this diversion inlet and dam crest area.

Based on experience with the facility, the trap operator has made physical adjustments and adopted modifications to the operational procedures which help to alleviate the problems caused by sediment accumulation within the FCF. The facility now operates at its lowest intended design flow rate, which has several secondary impacts on the fishway. With the assistance of WDFW engineering staff, the operator has altered the design settings of the fishway baffles, intending to adjust for a lower tailwater (separately described), a lower flow rate, and to minimize sediment accumulation. One result of this action is to reduce the amount of flow that passes over the weir portion of the baffles, which limits the extent that fish passage can occur via jumping or swimming past each baffle weir. Instead, fish passage occurs primarily via the baffle orifices. At the low flow rates used, balancing the flow across each baffle takes extra time, which allows sediment to accumulate in the fishway and limits fish movement through the orifices because of the high orifice velocities that result from temporarily unbalanced heads across the baffles. The baffle spacers and the baffles themselves both accumulate sediment, but not to the same degree as at other locations.

Sediments observed at the aforementioned locations apparently accumulate at a higher rate and higher density than originally anticipated. System flushing via gate operation manipulation and pump/hose manual washing is inadequate to evacuate sediment from the FCF. Sediments several feet deep must be removed by hand from the system, in particular from the critical fish collection crowder pool. This is a labor intensive process that takes several hours.* Cleaning is further complicated by the inoperability of the pump/hose water flushing system that was originally intended for this purpose.*

High sediment loads have led to problems throughout the FCF. Major portions of the facility have either seldom or never been used as originally envisioned, including:

- The weir box, which is no longer used to remove sediment from the diverted water.* The weir box is largely ineffective in removing sediment from the water because it is un-gated, contains "resident" sediment, has a small volume, and lacks an effective sediment removal mechanism. In addition, the 24-inch diameter sediment sluiceway pipe is undersized and was non-functional at the time of the inspection.
- The small fish crowder, which is not in place and is not used.*
- The main crowder, which is not used and has unknown operational capability.*
- The entire fish collection system from the main crowder through the small crowder, the fish lock and the fish lift to hopper delivery to a truck, which has

not been used for its purpose for many years. Accordingly, the operability of each individual component was not investigated in detail and is unknown.

- The original collection crowder pool screens, which were replaced by WDFW with screens closer to the head end of the chamber for access and ease of sediment maintenance.

Operations Related

The extensive sediment related issues, both expected and unexpected, make it difficult to distinguish between how much of the current operations of the FCF are directly or indirectly due to this single issue, due to other physical issues, or due to the operator's adaptive management in response to the composite of all the issues. It is also obvious that operations have changed in response to both changed conditions and the personnel involved in operations.

The best available information indicates that operational funds and possibly personnel assistance was provided by the Corps at the time the facility began operation. As-constructed drawings and an original Operation and Maintenance Manual (COE 1990) were easily obtained from the Corps when requested for this assessment; however, some confusion remains as to when these documents were first provided to the State. Ownership and operation responsibility for the FCF was taken over by the Washington Department of Game in 1990, which later became WDFW. The Corps has had little involvement in the FCF operations since 1990 in the form of operational reviews, assisting with operational adjustments or training.

The Operation and Maintenance Manual reflects a basic level document for this type of a facility and it is not known if complimentary manufacturer support literature was provided in a usable form for operator use. The exact amount of documentation and training that were initially made available to the operator can not be easily reconstructed. The lack of good as-constructed electrical information and field installations that are hard to trace have most certainly led to involved repairs, "work around" repairs, or simply the failure to repair electrical problems.* Given the nature of the facility and the Corps' typical project practices it is logical to assume that some meaningful form of facility documentation and operator training occurred around the date of initial operation of the FCF in 1990.

During the time since responsibility was passed to WDFW, the State has used several different facility operators. Operational procedures have been significantly revised from the original procedures for a variety of reasons. The training for subsequent operators has consisted primarily of hands-on instruction and passing of information by word-of-mouth. As a result, the facility operation that occurs now mostly reflects the adaptive management that has evolved over the years. The current operator has a basic knowledge of how the facility was intended to be operated, and is generally aware of as-constructed information, but this for the most part has little relevance as the facility can no longer be run as intended. The resulting facility operation is conducted with the best of intentions by a dedicated and creative operator, but it bears little resemblance to how operation was intended to occur.

The normal fish collection and movement process currently consists of operating the auxiliary water supply through the attraction diffuser channel for about a half hour to flush the sediment out. The fish ladder water supply is then turned on as the attraction water is cut back so that most or all of the water coming into the FCF is going through the water supply channel into the fish collection crowder pool and the fish ladder. Once it is determined that sufficient fish have moved up the ladder into the collection pool, the water supply is turned off and the collection pool drained to approximately one foot deep. Staff wearing waders then enter the pool and manually corral and net fish, transferring them to a ground surface holding tank. Carbon dioxide gas is used to immobilize the fish after which they are sorted, characterized and transported to appropriate release locations. This is an intermittent process and is largely controlled by the simultaneous need to handle the large amount of sediment. It results in one day per week for fish collection and handling with the rest of the week spent in sediment removal, maintenance and idle. This process involves a significantly higher level of labor than originally envisioned. It also greatly increases the amount of fish handling, and consequently increases the risk of fish stress and mortality. In combination, these improvised procedures limit the number of fish that can be effectively collected and moved.

Some other miscellaneous issues relating to facility operations include the following:

- Security is marginal, with at least one gate found latched, but not locked.
- There is no central operator control/monitoring station.
- There is no automated or mechanical trash rack or fish screen cleaning; an unusual oversight for a river with known high debris and sediment loading.

Maintenance and Replacement Related

We observed significant operation and maintenance issues at the FCF stemming from the need to operate under severe conditions, and inadequate routine maintenance. It was clear that proactive maintenance is largely ignored. When some component of the FCF breaks, it is fixed only if necessary; otherwise it is left as is and worked around. For a structure that has been operating under adverse environmental conditions for approximately twenty years, it is logical to expect that replacement of major components would be coming due in order to maintain a minimum level of facility operation. Examples of this include:

- Two of the overhead electric hoists serving the fish entrance bulkhead and screen are non- functional.* The structures they are intended to move have been blocked off or opened semi-permanently.
- Miscellaneous areas of rusted metal at important locations such as at chain boxes, ladders, railings, etc are in use when they should be repaired or replaced.
- General housekeeping is poor with broken, unused, and never used parts lying about (e.g. lifting beams, metal stop logs, cables, fishway baffles and parts, etc.).
- Some maintenance items are simply not addressed unless absolutely necessary due to the lack adequate equipment. One example is the inability to move or adjust many heavy items such as bulkheads, fish ladder baffles, the inlet trash racks, the weir box bulkhead and metal/concrete stoplogs without having to hire a mobile crane.
- Operator ingenuity is apparent throughout the facility to enable things to work in the best manner possible with the minimum cost. This includes the use of cables and hooks as complimentary lifting devices, come-a-longs to hold items in place, plywood, plastic sheets, wood blocks, etc.
- The fish screens at the attraction diffuser are deformed sufficiently to make it difficult for them to slide in their mounting frames. This is likely due to the combination of heavy sediment and debris loading. They should be replaced with stouter, easily cleaned screens.

Other Issues

While the facility was likely designed and constructed to meet the safety standards in effect at the time of its construction, safety upgrades are needed to meet current standards. In addition, operating the facility under the current modified procedures exposes the operators to risks that were not originally envisioned. These issues include, but not are limited to the following:

- An automated system for cleaning sediment and debris from the trash rack and fish screen was not provided in the original design. Screen cleaning is needed frequently and must be accomplished manually; at times from within a confined space.
- Fish removal is not a "hands-off" process as originally envisioned. Instead, manual netting is done by wading within a confined space, exposing netting personnel to other hazards as well.
- Where sediment can not be flushed from the system, especially in the collector crowder and the fish ladder, it is manually removed, exposing workers to unexpected confined space and injury hazards.
- Deteriorating and damaged project components (including railings and ladders) create risk for falls.

- Common safety devices such as hard hats, safety glasses, respirators, etc. are not commonly used, nor did they appear readily available for use.

Downstream of the velocity barrier stilling basin, a separate metal-fiber reinforced concrete sill was constructed to control the stream gradient. Based on conversations with the Corps of Engineers and our observations, we believe the natural alluvial material was re-graded flush with the top of this sill at the time of construction. Subsequent river degradation downstream of the sill has caused the concrete to become exposed and to mostly fail, resulting in a new tailwater level in the structural stilling basin that is 8 ft lower than originally designed.* This condition is clearly not a complete blockage to upstream passage and FCF access - some proportion of both coho and steelhead are able to climb the small rapids that now exist, enter the stilling basin tailwater and ascend into the FCF ladder. However, further degradation of the tailwater control could further drop the tailwater level, expose the stilling basin lip and create an unexpected barrier to the fish entrance. This could also compromise the structural integrity of the stilling basin and its energy dissipation characteristics, which, taken to the extreme, could threaten the FCF facility itself.

The preoccupation with handling high sediment loads, the noted FCF operational issues, the lack of funds to properly operate and maintain the facility, and other factors all lead to much poorer FCF performance than expected. No reliable estimates of the number of fish that try ascending the North Fork Toutle River but are unsuccessful because of the FCF are available. However, it is believed that the trapping efficiency is very low based on radio-telemetry work conducted as an additional component of this project (see upcoming report for details). We do know that only 127 coho and 84 steelhead were collected in the FCF last season. This undoubtedly raises questions about costs versus benefits when considering solutions to the problems identified in this assessment, and a circular argument develops: it is difficult to justify expensive repairs for only 100 fish per season, but it is very likely that the neglect of these repairs is precisely why so few fish return.

Summary

The current condition of the FCF, as described in this memorandum, renders it only marginally functional. This condition is due to a combination of very high sediment levels in the North Fork Toutle River that the facility must handle, design/construction issues, and inadequate routine maintenance/replacement of many of the facility's components. The degraded functionality of the FCF severely compromises its ability to meet the fisheries management goals for which the facility was originally constructed. Without significant rehabilitation, the facility will continue to deteriorate to the point where it is effectually inoperable, possibly within five years.

While no costs have been projected in detail, the estimated cost to repair the existing FCF components in order to optimize current operations (without making improvements) is likely to be over $100,000; significant improvements and repairs are likely to cost over $2 M; complete renovation and improvements are likely to cost over $10M and should not be undertaken without considering the full replacement of the facility. Partial demolition of the facility and construction of a fishway past the FCF is likely to cost over $2 M.

Recommendations

The following recommendations are made with respect to correcting the deficiencies at the FCF.

- A detailed several day inspection that would cover each component of the FCF (each motor, hoist, pump, motor control center, etc) should be made to ascertain its condition, its need, functionality, remaining useful life, cost to repair/replace, etc. This should ideally be accomplished by civil, structural, mechanical and electrical engineering representatives of the original designer. This would provide the basis for providing a relatively detailed cost to repair or replace estimate, an estimate of salvage value and remaining useful life as is appropriate.
- A full day should be dedicated to participating in the facility operation as it is currently conducted, preferably during the annual period of active fish collection and transfer in order to examine first hand how the facility operates in comparison to how it was intended to operate. This should be conducted by the same personnel as suggested in the preceding bullet.
- A report covering the two preceding bullets should be prepared to specifically address 1) the capability of the facility to function as originally intended, 2) the capability of the facility to function in an optimal modified manner considering its current condition and what has been learned through its operational history, 3) the costs to repair and/or replace on-site and if replacement is not feasible on-site, 4) what form the replacement should take.
- The current condition of the FCF tailwater should be studied more thoroughly to determine if gradient re-establishment is necessary to both improve fish passage, and to restore the structural integrity of the FCF.

The results of the preceding bullets should enable WDFW and other relevant parties to make a decision regarding the most appropriate action plan for the FCF. The ultimate goal should be to restore coho and steelhead runs in the North Fork Toutle watershed. To that end, any options for either restoring, repairing or rebuilding the FCF must consider the role of the FCF under any new watershed plans. In particular, the Corps' sediment and flood control plan will determine the fate of the SRS, the SRS spillway, and possibly address habitat restoration and fish passage issues in the upper watershed. Therefore, the continued need for the FCF, as a critical element in the trap-and-haul process, may be reduced if volitional fish passage is restored.

If efforts to restore volitional upstream passage are shown to be successful, yet the need for a sorting and counting facility remains, then we encourage the WDFW and the Corps to explore the feasibility of decommissioning the current FCF structure and incorporating a fish ladder with an adult trap into the base of the SRS spillway as part of the Corps' preferred design for fish passage modifications. This suggestion is discussed in more detail in the technical memorandum entitled: "North Fork Toutle River Fish Passage at the Sediment Retention Structure: Comments on the Design Documentation Report and 90% Stage Drawings for Spillway Modifications," (AMEC 2009). The addition of a fish ladder and trap to the Corps' proposed "full length channel improvement" design would pose significant technical challenges. Nevertheless, we believe it offers a practical and less expensive alternative to rehabilitating and operating the existing FCF facility.

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