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Phase 1: Fish Passage Assessment

Evaluation of Salmon and Steelhead Migration after a Landslide on the Sultan River

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EXECUTIVE SUMMARY

The Henry M. Jackson Hydroelectric Project (Project), located on the Sultan River, is currently involved in the Federal Energy Regulatory Commission (FERC) relicensing process. As part of this process, the National Marine Fisheries Services (NMFS) and United States Fish and Wildlife Service (USFWS) requested that the Public Utility District No. 1 of Snohomish County (District) and City of Everett (City) (together, the Co-licensees) investigate the feasibility of constructing fish passage facilities at the Diversion Dam (RM 9.7), which has blocked the migration of anadromous salmonids since its construction for water supply purposes in 1930. The first phase of this assessment was to evaluate fish passage at the Marsh Creek cascade that developed after a large landslide at RM 7.6 on December 11, 2004. The results of the Phase 1 evaluation are reported here. The objectives of this investigation were to evaluate existing and future fish passage at the Marsh Creek cascade using the Powers and Orsborn approach for evaluating salmon passage and observations of adult and juvenile salmonids before and after the landslide. Multiple lines of evidence were used to evaluate fish passage because some fish were known to pass over the cascade.

Characteristics of Marsh Creek cascade changed significantly in response to high flows (up to 3,300 cfs) during November 2006 and March 2007 based on a time series of photographs. These high flow events, which removed large wood and boulders located in the lower portion of the cascade, likely enhanced the potential for fish passage. No redds and no live adult salmonids were observed during regular surveys for steelhead and Chinook salmon prior to these high flow events. A hatchery summer steelhead carcass and very small numbers of coho fry were observed during supplemental observations.

Characteristics of Marsh Creek cascade were measured on September 5, 2007, while flows were approximately 107 cfs at the cascade. This assessment reflects the existing cascade after previous high flow events that altered the cascade. Marsh Creek cascade rose approximately 10.5 ft over a distance of approximately 51 ft (21% gradient). The primary potential impediment to upstream fish migration consisted of a turbulent two-step chute/small pool/falls. Here, the cascade rose 7.3 ft over a distance of 16 ft (46% gradient) and channel width was approximately 10 to 20 ft. Average water velocity in the primary cascade ranged from approximately 5.2 to 8.7 feet per second (fps). Observations of staff gages placed above and below the primary cascade indicated that the height of the cascade increased with greater flows.

Steelhead, Chinook, and coho salmon could potentially swim through the existing cascade (fall 2007) when flows were near minimum levels (107 cfs), based on the Powers and Orsborn approach. Pink and chum salmon would not likely gain passage over the cascade. Steelhead and Chinook salmon may potentially leap over the lower portion of the cascade during low flows, assuming no reduction in performance caused by turbulence and air entrainment. Coho salmon may successfully leap over the lower portion of the cascade if they land correctly and immediately swim upstream from the

crest. Leaping success of salmonids would have been less likely if performance was reduced by 25%.

Summer run steelhead have the greatest opportunity for gaining passage at the Marsh Creek cascade because they encounter the full range of available flows in the Sultan River and because they have long residence in the river prior to spawning. We observed four summer steelhead upstream of the cascade in 2007. This quantity is likely significant given the small population of summer steelhead. Although the cascade may hinder summer steelhead migration, it is likely that most are able to eventually negotiate the cascade in its present configuration. Observations of modest numbers of juvenile trout above the cascade (104 trout per survey) versus below the cascade (217 trout per survey) in 2007 support this conclusion.

Winter steelhead have slightly less ability for negotiating cascades compared with summer steelhead because their gonads are more developed as they migrate up river. Many winter steelhead are still likely able to negotiate the cascade (see aforementioned juvenile trout counts), but additional observations of spawning steelhead during spring are important for further evaluating this statement.

Evaluation of Chinook swimming and leaping ability at the cascade during low flow (107 cfs) when Chinook were present suggested Chinook potentially could have gained passage. However, only one adult Chinook salmon and two redds were observed upstream of the cascade from early September through November 2, 2007. Chinook salmon immediately below the cascade were relatively numerous, suggesting that the Marsh Creek cascade impeded the migration of most Chinook salmon that may have attempted to gain access. Presumably, the behavior of migrating Chinook salmon was influenced by the cascade since the swimming and leaping analyses indicated Chinook could have negotiated the cascade. Counts of juvenile Chinook salmon above and below the cascade suggested more juveniles were present downstream, but juvenile Chinook counts were very low in all areas. The present configuration of Marsh Creek cascade appears to block the migration of most Chinook salmon even though Chinook are present when flows were low to moderate (105 to 165 cfs and above).

Numerous coho attempted to leap over the cascade when flow was 255 cfs (October 21, 2007) but these fish fell short of reaching the lower falls because velocity and turbulence were high in the pool below the cascade. The rate of leaping coho salmon probably approached one fish per minute, on average, during the 20 minute period of observation (see photographs). Coho salmon stopped leaping when flow was 875 cfs and the river channel was highly turbulent. Nevertheless, 7 coho salmon redds were observed upstream of the cascade in early November. Based on the observations of leaping coho salmon falling short of the cascade at 255 cfs, it is likely that these coho gained access when flows were below 200 cfs. Markedly fewer juvenile coho salmon were observed above the cascade compared with counts below the cascade in 2007 (< 1 coho vs. 130 coho per survey). The high count of coho redds above the cascade relative to Chinook salmon likely reflects the presumably large population of coho salmon in the Sultan River based on the typically large coho run to the Snohomish watershed. Based on these observations, it is likely that the Marsh Creek cascade is a modest impediment to coho salmon, but some coho gain access above the cascade.

Observations in this study suggest that salmon and steelhead migration is more likely when flows are less than 250 cfs. Leaping coho salmon fell short of the cascade when flows were 255 cfs, then stopped leaping when flows rapidly reached approximately 875 cfs on October 21, 2007. At 255 cfs, many of the coho initiated their leap from the right bank portion of the channel (next to an eddy), which was farther away from the migration path leading through the cascade. Flows greater than 250 cfs probably block the migration of most if not all steelhead and salmon.

The longevity of the existing Marsh Creek cascade was evaluated. Photographs show that significant changes occurred following high flow events up to 3,300 cfs. Additional change is possible but it will likely require flows exceeding 3,500 cfs because the remaining substrate consisted of large boulders wedged between the rock wall on the left and the active slide on the right. During the past 25 years, flows at the Diversion Dam exceeded 3,500 cfs on 16 days during six years, whereas flows exceeded 6,000 cfs on seven days in four years. Maximum flow during the past 25 years was 16,600 cfs.

The right bank cliff above Marsh Creek cascade, which rises vertically approximately 200 ft, remains highly unstable. Rock debris along the right bank indicated small landslides have continued since 2004. It is highly likely that another large landslide will occur and that fish migration will be affected until high flows remove soil, boulders, and large wood. The high probability of another landslide is supported by the observation of a large landslide and several smaller landslides in the bypass reach during early 2007.

1.0 STUDY OBJECTIVES AND DESCRIPTION

The Henry M. Jackson Hydroelectric Project (Project), located on the Sultan River, is licensed by the Federal Energy Regulatory Commission (FERC) to Public Utility District No. 1 of Snohomish County (District) and City of Everett, Washington (City) (together, the Co-licensees). The Project is currently involved in the FERC Integrated Licensing Process. As part of this process, the Licensees and stakeholders developed a study plan for fish and water resources in order to further evaluate the Project.

The National Marine Fisheries Services (NMFS) and United States Fish and Wildlife Service (USFWS) requested that the Licensees investigate the feasibility of constructing fish passage facilities at the Diversion Dam (RM 9.7), which has blocked the migration of anadromous salmonids since its construction for water supply purposes in 1930. Passage at the Diversion Dam might allow access up to RM 16.3 where steep cascades would block further upstream migration (Ruggerone 2006). This request led to the development of Study Plan 20: Fish Passage Feasibility. The first phase of this evaluation was to assess fish passage at a cascade at RM 7.6 formed by a landslide on December 11, 2004 (Figs. 1 and 2). This landslide occurred approximately 100 m below Marsh Creek; therefore it is often referred to the Marsh Creek landslide or the Marsh Creek cascade.

The objectives of this investigation were to evaluate existing and future fish passage at the Marsh Creek cascade. This information is relevant to the evaluation of potential benefits and costs associated with a feasibility determination for a fish passage facility at the Diversion Dam.

2.0 BACKGROUND INFORMATION

Until recently, the Diversion Dam defined the upstream extent of anadromous fish use in the Sultan River. However, on December 11, 2004, a major landslide occurred along the Sultan River immediately below the confluence with Marsh Creek (RM 7.6), restricting anadromous and resident fish access to habitats upstream. Twenty-two adult fish surveys (8 salmon surveys in fall and 14 steelhead surveys in spring) were conducted in the reach upstream of the landslide between December 2004 and fall 2006 but no redds and no live adult salmonids were observed. However, a hatchery summer steelhead carcass was observed near the Diversion Dam during June 2006. Additionally, coho fry were observed upstream of the slide in very low numbers (less than 30 fish).

Prior to the landslide in December 2004, summer and winter-run steelhead, Chinook salmon, and coho salmon utilized the entire Sultan River area downstream of the Diversion Dam (PUD & City of Everett 2005). Steelhead and Chinook salmon redds were regularly observed near the Diversion Dam during annual surveys. Regular surveys are not conducted for coho salmon, which enter the river during late fall and winter when flows are typically higher and water clarity is reduced. Chum and pink salmon spawn primarily in the lower three miles of the Sultan River; however, pink salmon have been observed upstream to RM 7.5, i.e., the area just below the Marsh Creek cascade. Bull trout (*Salvelinus confluentus*) have not been observed spawning in the Sultan River; however, they are known to use the lower river as rearing/foraging habitat especially during odd-numbered years when pink salmon eggs are prevalent.

3.0 METHODS

The assessment of fish passage at the Marsh Creek cascade was based on several lines of evidence. First, the potential for salmon and steelhead to negotiate the cascade was evaluated using the methodology described by Powers and Orsborn (1985) and physical measurements of the cascade. The Powers and Orsborn approach considers the ability of salmonids to leap over and/or swim through a cascade. The second approach utilized observations of salmonids upstream of the cascade before and after the December 11, 2004 landslide. The third approach involved documentation of changes in cascade characteristics from December 2004 to October 2007 in an effort to evaluate whether the cascade will continue to impede the migration of salmonids, as indicated during the initial period after the landslide.

3.1 Powers and Orsborn Approach

The Powers and Orsborn (1985) approach to evaluating fish passage is largely based on the swimming and leaping performance of fish in relation to physical characteristics of the impediment, including water flow. This approach also utilized observations by other researchers (Orsborn 1983, Aaserude and Orsborn 1985). Information on the swimming speed, swimming performance, and leaping ability of salmon and steelhead is briefly described below.

Burst swimming speed of adult salmon and steelhead is key to their ability to negotiate impediments. The upper limit of burst swimming speeds (~6 sec duration), as reported by Bell (1973) and Powers and Orsborn (1985)[1], is shown in the following chart:

	Fish Speed (fps)		
Species	Sustained	Prolonged	Burst
Steelhead	0-4.6	4.6-13.7	13.7-26.5
Chinook	0-3.4	3.4-10.8	10.8-22.4
Coho	0-3.4	3.4-10.6	10.6-21.5
Sockeye	0-3.2	3.2-10.2	10.2-20.6
Pink & Chum	0-2.6	2.6-7.7	7.7-15.0

These values represent fish that are in optimum condition and that occupy water with little air entrainment and depth that covers the entire fish. Air entrainment and exposure of the fish to air in shallow water reduces swimming performance. Water temperature may influence fish swimming speeds. Rapid acceleration may be somewhat greater at warmer temperatures within 5-15°C (Domenici and Blake 1997).

Maximum burst speed decreases as fish condition declines in response to the lack of feeding in freshwater (Paulik and DeLacy 1958). Powers and Orsborn (1985) assumed a 25% reduction in burst swimming capacity for a fish described as “good condition, in the river for a short time, spawning colors partially developed, and still migrating upriver.” For example, when evaluating passage of salmon at a culvert located 35 miles from the ocean, Powers and Orsborn assumed burst swimming speed of salmon was reduced by 25%. For a fish in “poor” condition, they assumed fish burst swimming capacity to be reduced by 50%, i.e., the upper limit of prolonged swimming speed. I assumed that salmon and steelhead in the Sultan River were considered to be in “good’ condition, as defined by Powers and Orsborn, because fish approaching the Marsh Creek cascade are approximately 42 miles from Puget Sound.

Salmon length influences burst swimming speed. Longer fish have the potential to swim faster, but the swim speed in terms of fish lengths per second declines rapidly with greater size. For example, Webb (1995) reported that maximum swim speed of salmonids increased from 16 ft per second (fps; or 9.7 lengths per second) to 20 fps (7 lengths per second) as body length increased from 50 cm to 90 cm.

[1] Prolonged swimming speed was defined to include activities that led to fatigue within 15 seconds to 200 minutes. Burst speeds were defined as speeds leading to fatigue within 15-20 seconds or less.

Swimming performance or distance traveled by fish through high velocity chutes considers the duration that can be maintained by fish at burst swimming speeds. High-end burst speeds reportedly could be sustained for approximately 6 seconds, whereas speeds at the lower end of the range could be sustained for up to 15 seconds (Orsborn 1983). Webb (1995) reported that fatigue occurred more quickly (within 5 seconds) when swimming at 7 lengths per second, decreasing to <1 second when swimming at 10 lengths per second. The upper burst speed values used in this study meet or exceed the upper range of burst speed values reported by a variety of investigations (see Ruggerone 2006). Maximum distances traveled by salmon and steelhead ("good" condition) in relation to water velocity are shown in Fig. 3. These distances assume maximum burst speeds for 5 seconds (i.e., ideal conditions), as suggested by Powers and Orsborn (1985).

Leaping is more efficient than swimming when water velocity reaches approximately 9 fps (Powers and Orsborn 1985). Maximum leaping trajectories for salmon and steelhead are shown in Fig. 4, assuming maximum burst speed and optimum fish condition. Steelhead have the greatest leaping ability (max. height: 10.9 ft at 90° trajectory), followed by Chinook (7.8 ft), coho (7.2 ft), sockeye (6.6 ft), pink and chum salmon (3.5 ft). Maximum leaping height declines as the horizontal distances needed to achieve success increases. For steelhead, the maximum horizontal leaping distance is approximately 21.8 ft when take-off angle is 45°, but the maximum height of this jump is only 5.5 ft (Fig. 5). Thus, leaping success of fish is related to both the height and horizontal distance of the migration impediment.

Aaserude and Orsborn (1985) stated that the aforementioned leaping curves may underestimate leaping height of fish because they do not consider continued burst swimming as the fish leaves the water. They estimated that this additional swimming effort may increase maximum leaping height by the addition of fish length. Thus, they noted that maximum leap heights of steelhead and Chinook salmon may be up to 13.9 ft and 10.1 ft, respectively. These heights assume that the fish are able to achieve maximum thrust as they exit the water, i.e., little effect of turbulence and air entrainment on leaping. For the Marsh Creek cascade analysis, length of fish was added to the leaping profile equations (Powers and Orsborn 1985) while adjusting for the angle of fish leaving the water. Assumed lengths were 32 inches for steelhead, 36 inches for Chinook, and 28 inches for coho salmon.

The addition of fish length to leaping profiles has implications for burst swim speeds estimated from observed leaping heights of fish. Aaserude and Orsborn (1985) noted that burst swim speeds were overestimated when back-calculated from leaping height because these estimates did not consider fish length as the fish exited the water. The overestimation of burst swim speeds based on observations of leap heights was first noted by Paulik and DeLacy (1957).

A number of physical factors of a waterfall or cascade affect the ability of fish to pass in addition to the size of the impediment. Table 1 summarizes the effects of these factors. Fish typically initiate their leap from the standing wave, which can have upwelling currents (caused by air bubbles) that provide an extra boost to the leaping fish. Launching pool characteristics that influence salmon leaping ability in the launching pool include pool depth, location of the standing wave, water turbulence, air entrainment, and orientation of water flow entering the pool. Success at the landing site is influenced by water velocity, orientation and plane of the landing fish, distance to the nearest pool or velocity refuge, and overhanging rock. Higher impediments lead to greater failure rates, which in turn can lead to reduced condition and swimming performance as the fish attempts to leap again. Salmon are attracted to water momentum (flow x velocity), which can impede salmon migration if multiple paths are available and the more difficult path has considerably higher momentum. Turbulent flow (or white water) with surges, boils, and eddies make it difficult for fish to orient themselves and make full use of their swimming power (J. Orsborn, pers. comm.).

3.2 Characteristics of Marsh Creek Cascade

Characteristics of Marsh Creek cascade were documented on September 5, 2007, while flows at the Diversion Dam were approximately 102 cfs, and approximately 107 cfs at the cascade. Four river cross sections were established for measurements based on water elevation change. Photographs of the survey area and transects are shown in Figs. 6-11. Substrate and water surface elevations were measured with a stadia rod and Leica auto-level (Model NA 720) to the nearest 0.01 inch. The auto-level was positioned at a fixed location along the right bank. Measurements were taken at 2 ft intervals across the channel. Additional water surface and substrate measurements were taken between cross sections to document the cascade profile. All substrate and water surface measurements were relative to water surface elevation in the pool immediately below the primary chute/falls (0 ft elevation). Distance between cross-sections was measured. Average water velocity was estimated at potential fish migration routes with a Swoffer current velocity meter positioned approximately 60% of maximum depth. Characteristics of the substrate and large woody debris were noted.

Cross-sectional surveys of the river channel at the cascade were not possible when flows exceeded approximately 145 cfs beginning in mid-September. Therefore staff gages (height 3.3 ft; 0.01 inch increments) were bolted to the rock wall along the left bank so that change in height of the cascade in response to flow could be remotely documented. Staff gages were placed at the pool immediately above the cascade, in the riffle immediately above the primary chute/falls, and in the pool immediately below the cascade. The zero mark on each gage was positioned at the water surface when flow from the Diversion Dam was 107 cfs at the cascade. Gages were monitored from the top of the cliff using 10x binoculars and a Canon digital SLR camera with a 300 mm zoom lens.

3.3 Fish Surveys

Juvenile and adult salmon and steelhead data were obtained from District biologist, Keith Binkley in order to further evaluate passage of salmonids through the Marsh Creek cascade. Steelhead and Chinook salmon redds have been enumerated at three index sites below the cascade (RM 0-2.9, 4.5-5.2, 7.2-7.5) and one site above the cascade (RM 9.2-9.7) since the early 1990s. Observations of live and dead Chinook salmon at the index sites have been recorded since 2003.

Juvenile fish snorkel surveys were conducted during early summer and fall 2007 (as part of the relicensing process; Study Plan 5). Counts of salmonids in a mainstem area above the Marsh Creek cascade (RM 8.7) were compared with counts near the Powerhouse (RM 4.3) and the old USGS gage (RM 5.4). Each location was sampled on the same day during four periods. The area surveyed in each location was constant (E. Jeanes, R2 Resource Consultants, pers. comm.).

During the September 5, 2007 survey of Marsh Creek cascade, we observed a number of Chinook and pink salmon immediately below the cascade. This provided an opportunity to document whether fish migrated over the cascade. Therefore, on September 11, Ruggerone and K. Binkley surveyed the entire reach between the cascade (RM 7.5) and the Diversion Dam (RM 9.7). Water clarity was approximately 5 ft and the sun was bright. One surveyor snorkeled the river and attempted to spook fish from deeper holes immediately below turbulent cascades while the other surveyor with polarized sunglasses stood on large boulders and searched for spooked adults. The survey included the index reach (RM 9.2-9.7).

We planned a second "ground" survey after flows exceeded 145 cfs, however, water clarity declined to zero following heavy rain on September 30 and extreme turbidity originating upstream of the Diversion Dam. Instead, a helicopter survey was conducted by K. Binkley on November 2, 2007 when water clarity was good. This survey is normally conducted to document Chinook salmon redds in both index and non-index areas throughout the 9.7 miles below the Diversion Dam. In 2007, coho salmon redds were also counted above the Marsh Creek cascade. Identification of coho redds was based on gravel size, redd size, redd location, and the presence of spawning adults.

3.4 Cascade Longevity

Longevity of the Marsh Creek cascade was evaluated by compiling and comparing photographs taken immediately after the slide in December 2004 followed by photographs taken in July 2006 and September 2007. Changes in cascade characteristics, including the presence of large wood, were compared with the frequency of flows exceeding 500 cfs at the Diversion Dam (http://waterdata.usgs.gov).

4.0 RESULTS

4.1 Characteristics of the Cascade

Marsh Creek cascade rose approximately 10.5 ft over a distance of approximately 51 ft (21% gradient) when flow at the Diversion Dam was 102 cfs and approximately 107 cfs at the cascade (Figs. 12 and 13). These measurements extended from the base of the lower pool upstream to the fourth step of the cascade. The primary potential impediment to upstream fish migration consisted of a turbulent two-step chute/small pool/falls. Here, the cascade rose 7.3 ft over a distance of 16 ft (46% gradient). The upper chute (2.7 ft high; ~3 ft wide) flowed into a shallow turbulent pool (3.3 ft deep) that fed the entire flow into a narrow falls (4.6 ft high; 4 ft wide). The falls fell into a shallow bed rock pool (2.3 ft deep); pool depth increased to 4.3-7.2 ft approximately 20 ft downstream.

Average water velocity 20 ft downstream from the falls was approximately 6.3 fps, increasing to approximately 7 fps six ft below the falls (Fig. 12). Average water velocity was approximately 8.7 fps near the middle of the falls and in the chute. Water velocity near the top of the chute was 5.2 fps.

A 15 ft glide extended upstream from the chute, leading to a 1.7 ft rise, another 16 ft glide and a 1.5 ft rise. Water velocity varied considerably across the channel at the two small rises and was equal to or less than 6.8 fps (Fig. 13). Velocity within each glide was less than 6.8 fps. Large boulders (4-6 ft diameter) rising above the surface and submerged boulders reduced water velocity. A large deep pool (>50 m long, 8 ft deep) extended upstream from the cascade area.

Detailed measurements within the cascade were not possible when flows exceeded the minimum flow of 145 cfs that began on September 15, 2007. However, staff gages installed above and below the cascade indicated the vertical height of the cascade increased with greater discharge. Vertical height increased by 0.34 ft when discharge at the cascade increased from approximately 107 cfs to 210 cfs. Vertical height increased by 0.4 ft (total) at approximately 255 cfs, 1.2 ft at 600 cfs, 1.3 ft at 875 ft, and by more than 1.6 ft at 1,080 cfs. Water velocity and turbulence increased with greater discharge.

The presence of large wood in the cascade decreased over time. The landside contained numerous large fir trees that became embedded in the lower cascade in 2004 (Fig. 2). Large wood was still present in the lower cascade during July 2006 (Fig. 14). However, large wood and large boulders surrounding the large wood were gone when we surveyed the cascade in September 2007 (Fig. 14). This area was located at the downstream end of the pool below the primary cascade. The high flows during November 2006 and March 2007 likely flushed the large wood and some large boulders downstream. Thus, the lower portion of the cascade is no longer a potential factor affecting fish passage.

4.2 Application of Powers & Orsborn Method

A relatively deep pool below the cascade provides a resting area for fish at most flows. Water depth along the cascade at 107 cfs was adequate for migrating salmon (Fig. 12). The small rises and associated glides in the upper part of the cascade would not have inhibited fish migration, therefore the analysis focused on the primary chute/small pool/falls.

Peak measured water velocity was 8.7 fps in the primary cascade (Fig. 12), indicating swimming against the current was possible at 107 cfs. Water velocity may have been slightly higher in locations beyond our reach with the velocity instrument. Assuming an average velocity of 8.7 fps in the primary cascade, “good” fish condition, maximum burst speed (5 seconds), and no air entrainment, then the maximum distance traveled against the current may be approximately 56 ft for steelhead, 41 ft for Chinook, 37 feet for coho, and 13 ft for pink and chum salmon. Travel distance across the primary cascade was approximately 17 ft within the area of high velocity (~8.7 fps) or 37 ft when including the moderate velocity area extending 20 ft below the falls (6.3-7 fps; Fig. 12).

These data suggest that the cascade was a migration barrier to pink and chum salmon, a finding that is consistent with fish observations described below. The data suggest that steelhead, Chinook, and coho salmon could potentially swim through the cascade when flows are near 107 cfs. This analysis does not directly consider the effect of air entrainment and turbulence on swimming performance and behavior. These factors could have reduced the ability of salmon and steelhead to migrate over the cascade (Powers and Orsborn 1985).

Salmon and steelhead may have attempted to leap over the primary cascade. The area of leap initiation likely would have been approximately 3 ft below the lower falls where water boils to the surface. Assuming fish were in "good" condition, maximum burst speed, and optimum leaping angle, steelhead and Chinook salmon would have been able to leap into the shallow pool between the falls and chute, whereas coho salmon would have hit the crest of the falls (Fig. 15). The take-off area below the cascade is not ideal because the area is shallow, turbulent and entrained with air, all of which would reduce leaping ability. If burst speed was reduced by 25% in response to these factors, then steelhead would have approached the crest, whereas Chinook and coho would have fallen short of the crest. These fish may have gained access to the shallow pool between the falls and chute if they landed such that they could immediately swim the remaining distance.

If fish gained access to the shallow pool between the falls and chute, they would need to swim or leap over the chute. As noted previously, steelhead, Chinook, and coho probably could swim through the chute when flows are near 107 cfs. Leaping over the chute may have been more difficult than swimming because turbulence was high and multiple pathways may have caused disorientation.

The above analysis was based on observations made when instream flows released from the Diversion Dam were near the minimum allowed (95 cfs). Minimum instream flows increase to 145 cfs and 155 cfs in mid- to late September in order to enhance salmon migration in the Sultan River, especially in relatively shallow areas. Staff gages at the Marsh Creek cascade indicated that the vertical height of the cascade increased by approximately 0.34 ft when flows at the cascade increased from 107 cfs to 210 cfs. The increase in vertical height indicates swimming and leaping over the cascade would have been slightly more difficult at 210 cfs.

4.3 Observations of Leaping Coho salmon

Coho salmon attempting to leap over the cascade were observed on October 21, 2007. Discharge was 168 cfs at the Diversion Dam or approximately 255 cfs at the cascade in response to heavy rain and inflow from Marsh Creek (K. Binkley, pers. comm.).

Numerous coho salmon were observed and photographed during a 20 min period, probably at a rate approaching one fish per minute on average (Fig 16). Coho salmon initiated their leap approximately 15- 20 ft below the cascade. High velocity and turbulence immediately below the falls were likely too great to allow fish to initiate their leap closer to the falls. Coho initiated their leaps from a variety of locations but most tended to leap from near a right bank boulder which provided some refuge from high velocity and where fish were likely attracted to the flow produced by the chute angling across from the left bank. One fish was photographed while leaping from the edge of the white water and clear water eddy, well below the primary cascade (Fig. 16). All observed fish landed short of the lower falls of the cascade. No fish were observed swimming through the relatively shallow water (substrate visible) at the pool tailout immediately above the cascade.

While observing the leaping salmon, discharge increased from 255 cfs to approximately 875 cfs within approximately 15 min (785 cfs at the Diversion Dam) in response to flow releases for the whitewater recreation study (Revised Study Plan 14: Flow Recreation Study) conducted that day (K. Binkley, pers. comm.). Velocity and turbulence increased substantially and no salmon attempted to leap over the cascade within the next 20 minutes. The area of high velocity and turbulence extended further downstream and likely inhibited salmon from further leaping attempts.

4.3 Chinook and Steelhead Redds

Total Chinook salmon redds observed in all index areas of the Sultan River averaged 119 ± 11 (SE) redds prior to the landslide (1991-2004) and 105 ± 18 redds after the landslide (2005-2007). Total steelhead redds observed in all index areas of the Sultan River during spring averaged 160 ± 24 redds prior to the landslide (1993-2004) and 67 ± 19 redds after the landslide (2005-2006). Steelhead redds were not counted during spring 2007 because turbidity was too high.

Annual percentages of Chinook and steelhead redds observed in the index area above the slide versus the total index area counts are shown in Fig. 17. Prior to the landslide, 15.3 ± 2.4% of Chinook and 7.2 ± 1.1% of steelhead redds were observed above the cascade area. After the landslide, the percentage of total redds above the cascade declined to 0.4 ± 0.4% for Chinook and 0% for steelhead. Zero Chinook salmon redds were observed in the index area during 2005 and 2006 when the cascade contained more large wood than in 2007. Two Chinook salmon redds were observed during surveys extending from early September through November 2, 2007 (5 ground surveys, 1 helicopter survey).

A two factor ANOVA (period, species) indicated that the percentage of redds (arcsin transformed proportions) was significantly less after the slide (2005-2007) compared with years prior to the slide (1991-2004) ($df = 1, 26$; $F = 42.60$, $P < 0.001$). The ANOVA interaction term was non-significant ($P = 0.567$), indicating this pattern was consistent for both Chinook and steelhead during all years of available data. The species effect was non-significant ($P = 0.154$) indicting the response by Chinook and steelhead was not different.

A single factor ANOVA (period) was performed with Chinook salmon in order to compare the proportion of Chinook salmon redds above the cascade prior to the landslide with the proportion of redds during 2007 only. Redd counts during 2005 and 2006 were excluded because it appeared that passage conditions had improved in early 2007. The percentage of redds above the cascade was significantly less after the slide (2007 only) compared with years prior to the slide (1991-2004) (df = 1, 13; $F = 4.705$, $P = 0.049$).

On November 2, 2007, a helicopter survey of Chinook salmon redds along the entire Sultan River downstream of the Diversion Dam was conducted by K. Binkley. Visibility was good. A total of 40 redds were observed along the 9.7 miles of river below the Diversion Dam. Chinook redd density average 3.1 redds per mile in the river below the powerhouse (RM 0 to 4.5), 8 redds per mile from RM 4.5 to RM 7.5, and 1 redd per mile upstream of the Marsh Creek cascade (RM 7.6 to 9.7).

Coho salmon redds were counted upstream of the Marsh Creek cascade because numerous coho were observed attempting to leap over the cascade on October 21 when flow was approximately 255 cfs at the cascade. A total of 7 coho salmon redds were observed above the cascade (3.3 redds per mile). Two coho redds (4 redds per mile) and one adult coho salmon (2 adult coho per mile) were observed in the index reach above the cascade. Coho redds were not counted downstream of the cascade but 5 adult coho salmon were observed in the index reach below the cascade (16.7 adult coho per mile).

4.4 2007 Adult Salmon and Steelhead Observations

A survey was conducted on September 10 and 11, 2007 to determine whether salmon and steelhead had passed over the Marsh Creek cascade when flows were approximately 102 cfs at the Diversion Dam. The survey was conducted from the Diversion Dam to approximately 0.4 miles below the slide (i.e., including the Gold Camp Index area (RM 7.2-7.5) where Chinook salmon and steelhead redds are routinely monitored). The upper area was surveyed by snorkeling and by observing from relatively high rocks using polarized sunglasses. In pool areas immediately below cascades, one biologist snorkeled through the turbulence and into the calmer pool area while the other biologist searched for adult salmonids that might be startled by the activity. Redds (Chinook only at this time period) and adult fish were counted by species. The Gold Camp Index Area was surveyed by K. Binkley using the standard walking method.

A total of four summer steelhead and one large Chinook salmon were observed in the 2.1 mile reach between the Marsh Creek cascade and the Diversion Dam. The Chinook salmon and one summer steelhead were observed in the pool below the Diversion Dam. Two other summer steelhead (identification based on long slender body) were observed within 0.4 miles of the Diversion Dam. One summer steelhead was observed in the pool above Marsh Creek. During the survey, we encountered a gold miner who had been camping and fishing along the river for the past month or so. He noted that he had captured 8-12” trout in the area, but did not see or capture adult salmon or steelhead.

In the pool immediately downstream of the Marsh Creek cascade, 7 pink salmon and two Chinook salmon were observed. There was no spawning habitat in this area (the pool tail out was very large cobble from the slide). It appeared that these fish would have migrated over the cascade if they were capable. In the tailout area of the next downstream pool, a pair of Chinook salmon were holding near a redd. Thus, a total of 4 Chinook and 7 pink salmon were observed within the 0.1 mile reach immediately below the cascade. A total of 8 Chinook redds were counted within 0.4 miles downstream of the Marsh Creek Cascade.

Although we did not attempt to enumerate juvenile salmonids, we observed relatively few while snorkeling and walking through boulder patches and deep pools in the canyon between the Marsh Creek cascade and the Diversion Dam. Abundances of juvenile trout and coho salmon were noticeably greater in the two pools immediately downstream of the cascade.

4.5 2007 Juvenile Salmon and Steelhead Observations

No juvenile Chinook salmon were observed above the slide compared with 1.4 Chinook salmon per survey below the slide. On average, 0.6 coho salmon per survey were observed above the slide compared with 130 coho salmon below the slide. Juvenile trout counts averaged 104 fish per survey above the slide compared with 217 trout below. All Chinook and coho salmon were likely young-of-the-year fish (based on size), whereas trout included young-of-the-year and older fish. The trout could have been produced by anadromous and/or resident trout. Adult Chinook that produced these fry likely spawned prior to the high river flows in mid-November 2006, whereas many coho and all trout (and steelhead) spawned after the high flows that probably altered the Marsh Creek cascade.

4.6 Cascade Longevity

Photographs of the Marsh Creek cascade show considerable change from December 2004 to September 2007. In late July 2006, a large log jam was present immediately below the primary chute/falls. This log jam apparent washed away during high flows during November 2006 and March 2007 (Fig. 14, Table 2). Maximum flow during this period was 3,300 cfs at the Diversion Dam.

The Marsh Creek cascade is presently formed by large boulders (approximately 4-6 ft diameter) pressed between the rock wall along the left bank and landslide debris along the right bank. The existing cascade is stable within flows that are typically released from the Diversion Dam. Changes in the slide apparently occurred when flows reached 3,300 cfs during March 2007, and it is possible that flows exceeding this level could cause additional change. During the past 25 years, flows at the Diversion Dam exceeded 3,500 cfs on 16 days during six years, whereas flows exceeded 6,000 cfs on seven days in four years. Maximum flow during the past 25 years was 16,600 cfs. It is probable that exceptionally high flows could alter characteristics of the cascade. Although is seems plausible that such an event might reduce the significance of the cascade, it is also possible that unforeseen alterations could cause fish passage to become more difficult, e.g., shifting of large boulders or accumulation of large wood.

The canyon wall rises abruptly approximately 200 ft above the right bank of the cascade. Although the top of the canyon is forested, the canyon wall is vertical and has no vegetation. The wall along the right bank is highly unstable. Small angular rocks and soil along the right bank indicate small landslides have continued to occur in recent months. Unstable soil originates from glacial deposits, which also contribute to landslides along other parts of the Sultan River (GeoEngineers 1984). Small and possibly large landslides are likely to occur in the future. A large landslide could block salmon and steelhead migration, at least temporarily.

5.0 DISCUSSION AND CONCLUSIONS

The Powers and Orsborn approach to evaluating salmon passage at cascades and observations of adult and juvenile salmonids were used to evaluate the ability of salmonids to migrate over the Marsh Creek cascade. Multiple lines of evidence were used to evaluate fish passage because some fish were known to pass over the cascade.

Steelhead, Chinook, and coho salmon could potentially swim through the cascade when flows were near minimum levels (107 cfs), based on the Powers and Orsborn approach. Pink and chum salmon would not likely gain passage over the cascade because their performance is much less than that of other salmonids. Steelhead and Chinook salmon may potentially leap over the lower portion of the cascade during low flows, assuming no reduction in performance caused by turbulence and air entrainment. Coho salmon may successfully leap over the lower portion of the cascade if they land correctly and immediately swim upstream from the crest. Leaping success of salmonids would have been less likely if performance was reduced by 25%.

Height of the cascade increased with greater discharge suggesting that swimming and leaping over the cascade would be more difficult when flows exceed approximately 145 cfs, typically beginning in mid-September. Turbulence, air entrainment, and orientation of the cascade can inhibit fish passage, therefore observations of fish passage provide key information for this evaluation.

Steelhead have the greatest ability for negotiating cascades such as Marsh Creek cascade. Summer run steelhead have the greatest opportunity for gaining passage at the cascade because they encounter the full range of available flows in the Sultan River and because they have long residence in the river prior to spawning. We observed four summer steelhead upstream of the cascade in 2007. This quantity is likely significant given the small overall population of summer steelhead, but there are no comparable data for previous years. Although the cascade may hinder summer steelhead migration, it is likely that most are able to eventually negotiate the cascade in its present configuration. Observations of modest numbers of juvenile trout above the cascade (104 trout per survey) versus below the cascade (217 trout per survey) in 2007 support this conclusion.

Winter steelhead have slightly less ability for negotiating cascades compared with summer steelhead because their gonads are more developed as they migrate up river and because they may encounter a narrower range in flows. Winter steelhead would typically encounter flows in the Sultan River of approximately 100-200 cfs, which appear to be most conducive for migrating salmonids at the cascade. Winter steelhead would also encounter much higher flows but observations of coho salmon leaping when flow was 255 cfs suggests flows exceeding 250 cfs are less conducive for fish passage. Many winter steelhead are likely able to negotiate the cascade (see aforementioned juvenile trout counts), but additional observations of spawning steelhead during spring are important for further evaluating this statement. Unfortunately, water clarity was too low during spring 2007 to enable counts of spawning steelhead.

Evaluation of Chinook swimming and leaping ability at the cascade during low flow (107 cfs) when Chinook were present indicated Chinook potentially could have gained passage. However, only one adult Chinook salmon and two redds were observed upstream of the cascade from early September through November 2, 2007. Chinook salmon immediately below the cascade were relatively numerous, suggesting that the Marsh Creek cascade impeded the migration of most Chinook salmon that may have attempted to gain access. Presumably, the behavior of migrating Chinook salmon was influenced by the cascade since the swimming and leaping analyses indicated Chinook could have negotiated the cascade. Counts of juvenile Chinook salmon above and below the cascade suggested more juveniles were present downstream, but total juvenile Chinook counts were very low, presumably because many Chinook emigrated from the river before surveys began in early July. The present configuration of Marsh Creek cascade appears to block the migration of most Chinook salmon even though Chinook are present when flows were low to moderate (105 to 165 cfs and above). Based on the observations of leaping coho salmon, it is likely that flows exceeding 250 cfs are less conducive to migrating Chinook salmon.

Numerous coho attempted to leap over the cascade when flow was 255 cfs but these fish fell short of reaching the lower falls because velocity and turbulence were high in the pool below the cascade. Coho salmon stopped leaping when flow was 875 cfs and the river channel was highly turbulent. Nevertheless, 7 coho salmon redds were observed upstream of the cascade in early November 2007. Based on the observations of leaping coho salmon falling short of the cascade at 255 cfs, it is likely that these coho gained access when flows were below 200 cfs. Markedly fewer juvenile coho salmon were observed above the cascade compared with counts below the cascade in 2007 (< 1 coho vs. 130 coho per survey). The high count of coho redds above the cascade relative to Chinook salmon likely reflects the presumably large population of coho salmon in the Sultan River based on the typically large coho run to the Snohomish watershed. Few observations and counts of adult coho salmon are available for the Sultan River. Based on these observations, it is likely that the Marsh Creek cascade is a modest impediment to coho salmon.

Observations in this study suggest that salmon and steelhead migration is more likely when flows are less than 250 cfs. Leaping coho salmon fell short of the cascade when flows were 255 cfs, then stopped leaping when flows rapidly reached approximately 875 cfs on October 21, 2007. At 255 cfs, many of the coho initiated their leap from the right bank portion of the channel (next to an eddy), which was farther away from the migration path leading through the cascade. Measurements of water elevation above and below the cascade suggested that the height of the cascade increased as flows increased. Flows greater than 250 cfs probably block the migration of most if not all steelhead and salmon.

Characteristics of the cascade have changed significantly since the landslide on December 11, 2004. Exceptionally high flows (3,300 cfs) during November 2006 and March 2007 removed large wood and some large boulders in the lower portion of the cascade. Additional change is possible but it will likely require flows exceeding 3,500 cfs.

The right bank cliff above Marsh Creek cascade remains highly unstable. The vertical cliff extends approximately 200 ft above the river. Rock debris along the right bank indicated small landslides have continued since 2004. It is highly likely that another large landslide will occur, possibly within five or 10 years, and that fish migration will be affected until high flows remove soil, boulders, and large wood. The high probability of another landslide is supported by the observation of a large landslide and several smaller landslides in the bypass reach during early 2007 (K. Binkley, pers. comm.) and by previous accounts of landslides in the watershed (1984).

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Table 1. Characteristics of falls and cascades that influence passage by salmon and steelhead. Sources: Stuart (1962), Orsborn (1983), Powers and Orsborn (1985).

Characteristic	Comment
Launching pool	Depth of pool should be greater than length of fish for maximum propulsion; a good takeoff pool is essential if fish are to leap to any reasonable height; adequate pool conditions needed so that fish's orientation and propulsive power are unimpaired.
	Depth of falling water penetration should be less than depth of plunge pool; if not turbulence disorients fish & standing wave reduced and shifted downstream from where falling water strikes bed of pool.
	Fish approach to leap is usually made downstream of standing wave with the body at an angle between 20° an 30° to pool surface and head pointed downward; often tail broke surface of water (Stuart 1962).
	Pool depth should be 1.25 times that of falls height to maximize standing wave effect (Stuart 1962). This was verified hydraulically at WSU (J. Orsborn, pers. comm.).
Light & shade	High contrast between crest of falls and background (sky or trees) is needed for fish orientation. Leaping stops at dusk and heavy overcast (Stuart 1962).
Standing wave	Fish typically hold in and leap from standing wave to gain momentum and additional elevation; without a standing wave the fish will attempt to swim over the obstruction (Stuart 1962). A standing wave produced from vertical falls will be closer to the falls and will produce conditions more conducive of successful passage compared with a wave produced by a chute (Stuart 1962).
Turbulence	Burst speed and jumping height reduced by excessive turbulence and air entrainment; unstable pools disorient and reduce fish's leap trajectory.
Falls height	Maximum leaping height (steelhead) is 10.9 ft, thus "falls exceeding 11 ft water surface elevation are total barrier"; however, Aaserude suggests fish length should be added to height. Maximum height only possible at vertical falls.
Splash rocks	Water may strike rock as it cascades over falls or as it plunges into pool. Splash rocks affect horizontal and vertical angle of attraction flow by modifying the standing wave, which fish use to judge their angle of leaping at the falls. This signal is key to successful leaping of salmon and it is the most critical factor affecting leaping success if height is within reach (Orsborn 1983, J. Orsborn, pers. comm.).
Falls horizontal distance	Height of passable falls is reduce to extent horizontal distance increases, e.g. maximum height of steelhead reached at horizontal distance of 4 ft when leaping at 80° angle. Thus, high gradient chutes can be difficult to leap over.
	If the standing wave is located distant from the crest of the fall beyond the visual range of the fish, as is found below a chute or long sloping weir, the leaps may not be oriented and passage may be unsuccessful (Stuart 1962).

Table 1. Continued.

Characteristic	Comment
Horizontal angle of falls	In plan view of cascade, the horizontal angle of falls relative to the upstream landing area is important to leaping success. If inadequate, fish may miss the upper pool or strike their heads on an overhang or land on shore where they may not be able return to the stream.
Landing site	A landing site having high velocity and turbulence will reduce leaping success. Optimal when crest of falls enters deep, calm pool.
Orientation	The fish's angle of approach to the crest must be aligned with the flow or the fish will be swept back.
Water velocity	For more energetically capable salmonids, such as steelhead and Chinook, leaping is more energetically efficient than swimming when drop reaches approximately 1.25 ft or 9 fps. Less capable species, such as chum salmon, will attempt to swim through the drop.
	Velocity at or near the landing site should be within the range of the sustained swimming speed for the species (e.g., steelhead: less than 4.6 ft/s; Chinook & coho: 3.4 ft/s; sockeye: 3.2 ft/s); greater velocities will reduce success depending on distance to refuge.
	Because of the violence and air entrainment in turbulent flow and the effect it has of reducing fish capabilities, Powers and Orsborn (1985) assumed that "any waterfall that is steep enough to accelerate the flow into violent turbulent white water is a total barrier to all fish species attempting to swim up the barrier. Fish can only pass if they leap and clear the area of turbulence before landing."
Fish condition	Fish condition can have a significant impact on leaping ability. Fish traveling relatively long distances and holding in freshwater for prolonged periods will have reduced leaping ability compared with "fresh" fish that recently left the sea (Powers and Orsborn 1985).

Table 2. Mean daily flows that exceeded 500 cfs after the December 11, 2004 landslide and presence of Large woody debris (LWD). Discharge exceeding 600 cfs were based on transducer-based flows rather than the Diversion Dam gage (K. Binkley, pers. comm.). Discharge data source: http://waterdata.usgs.gov/wa/nwis.

Date	Flow (cfs)	Significant LWD?
11-Dec-04	484	Yes (landslide)
15-Dec-04	142	Yes (photos)
18-Jan-05	539	Yes
12-Dec-05	638	Yes
13-Dec-05	669	Yes
14-Dec-05	549	Yes
21-Jul-06	99	Yes (photos)
6-Nov-06	1400	?
7-Nov-06	847	?
16-Nov-06	968	?
17-Nov-06	1260	?
30-Nov-06	2070	?
1-Dec-06	970	?
24-Mar-07	1160	?
25-Mar-07	3300	?
26-Mar-07	1630	?
5-Sep-07	101	No LWD (photos)

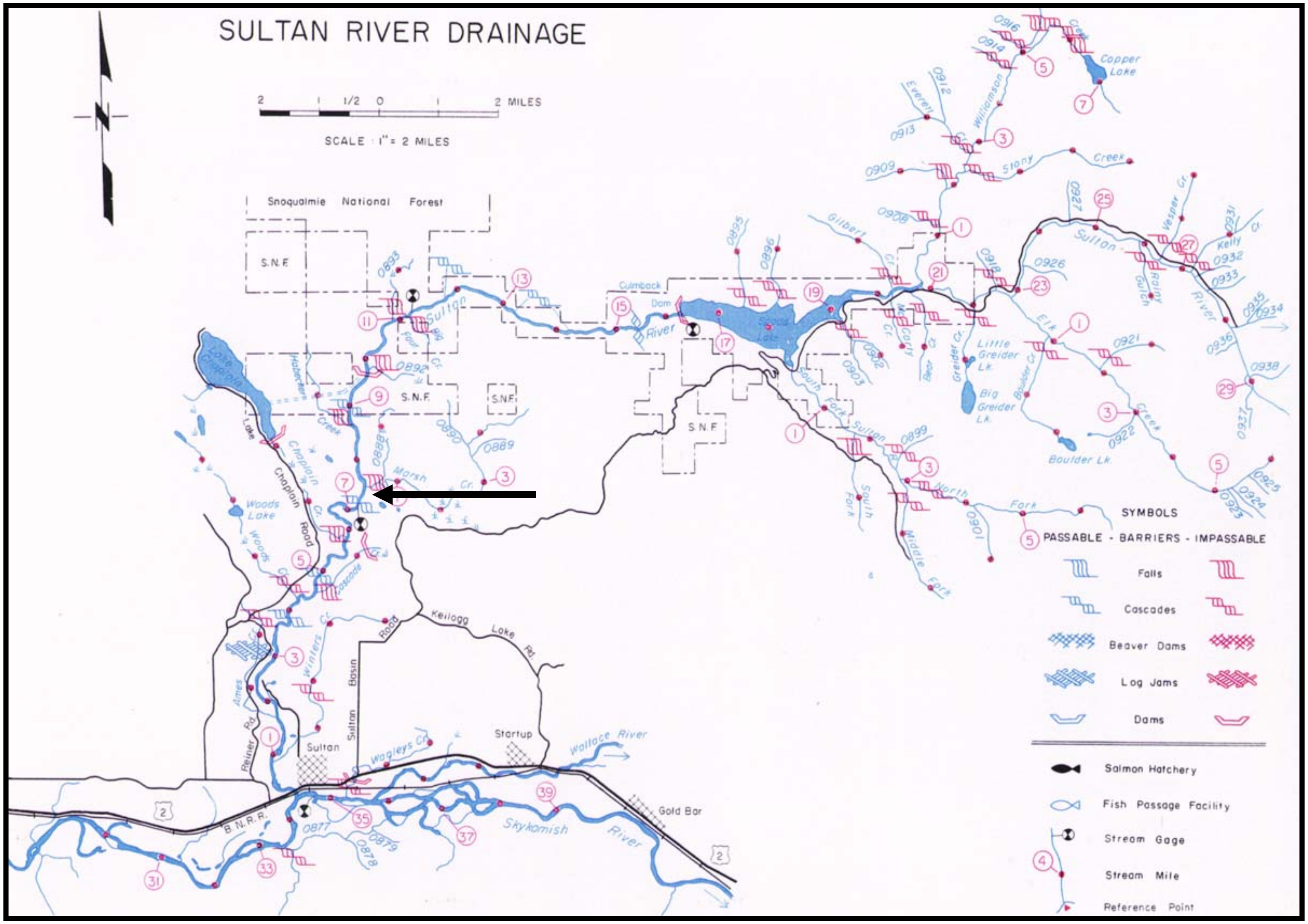

Fig. 1. **Fisheries map (WDF 1975) of the Sultan River drainage showing the location of the Marsh Creek cascade (arrow).**

Fig. 2. **Photographs of Marsh Creek cascade four days after the landslide on December 11, 2004. Photographs provided by K. Binkley. A video of the landslide is available at http://www.kayakingsucks.com/sultan/sultan.html.**

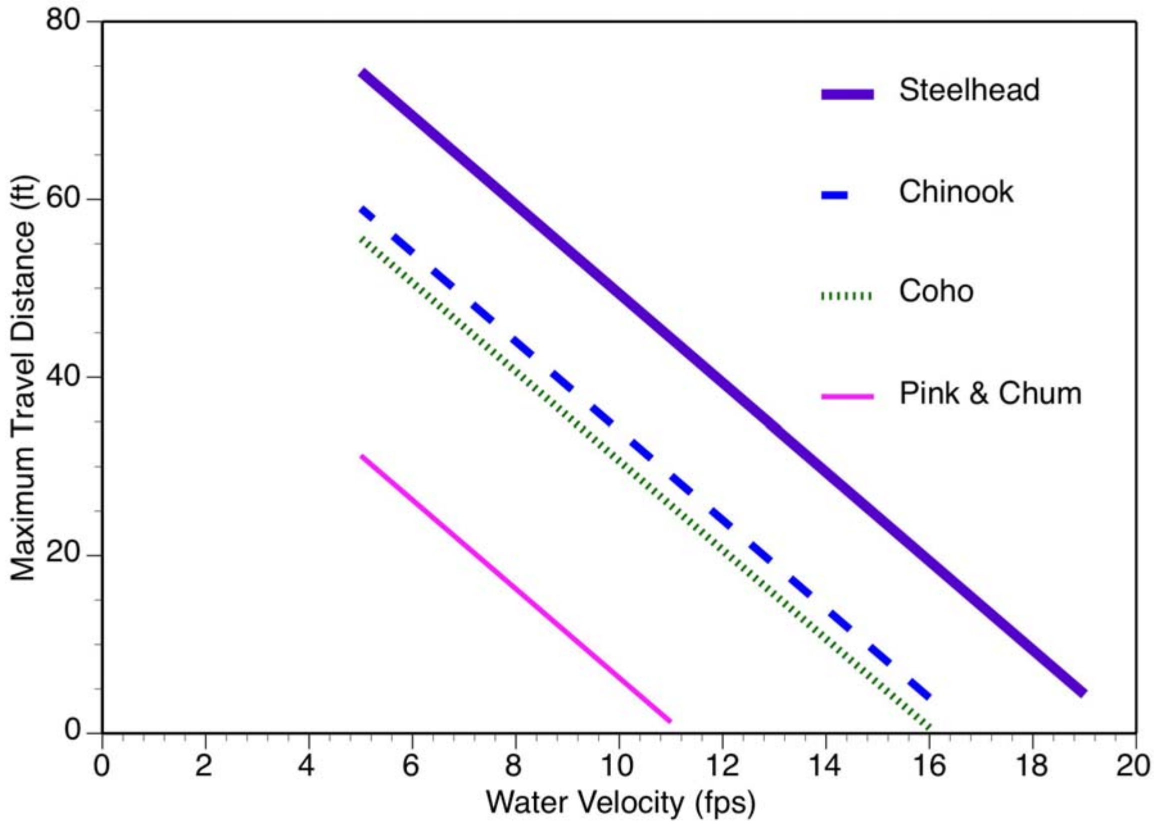

Fig. 3. Maximum travel distance of salmon and steelhead in relation to water velocity, assuming maximum burst speed of fish in good condition for 5 second duration. Values based on Powers and Orsborn (1985).

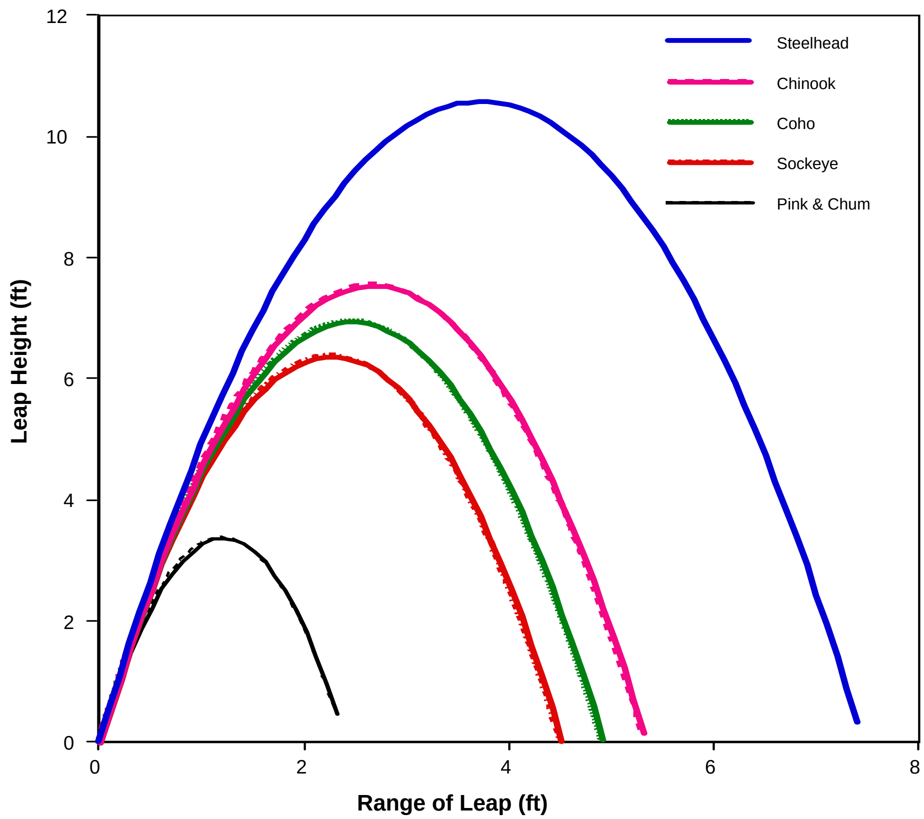

Fig. 4. Maximum salmon and steelhead leaping abilities assuming 80° leaping angle, maximum burst speed, and maximum body condition. Data Source: Powers and Orsborn (1985).

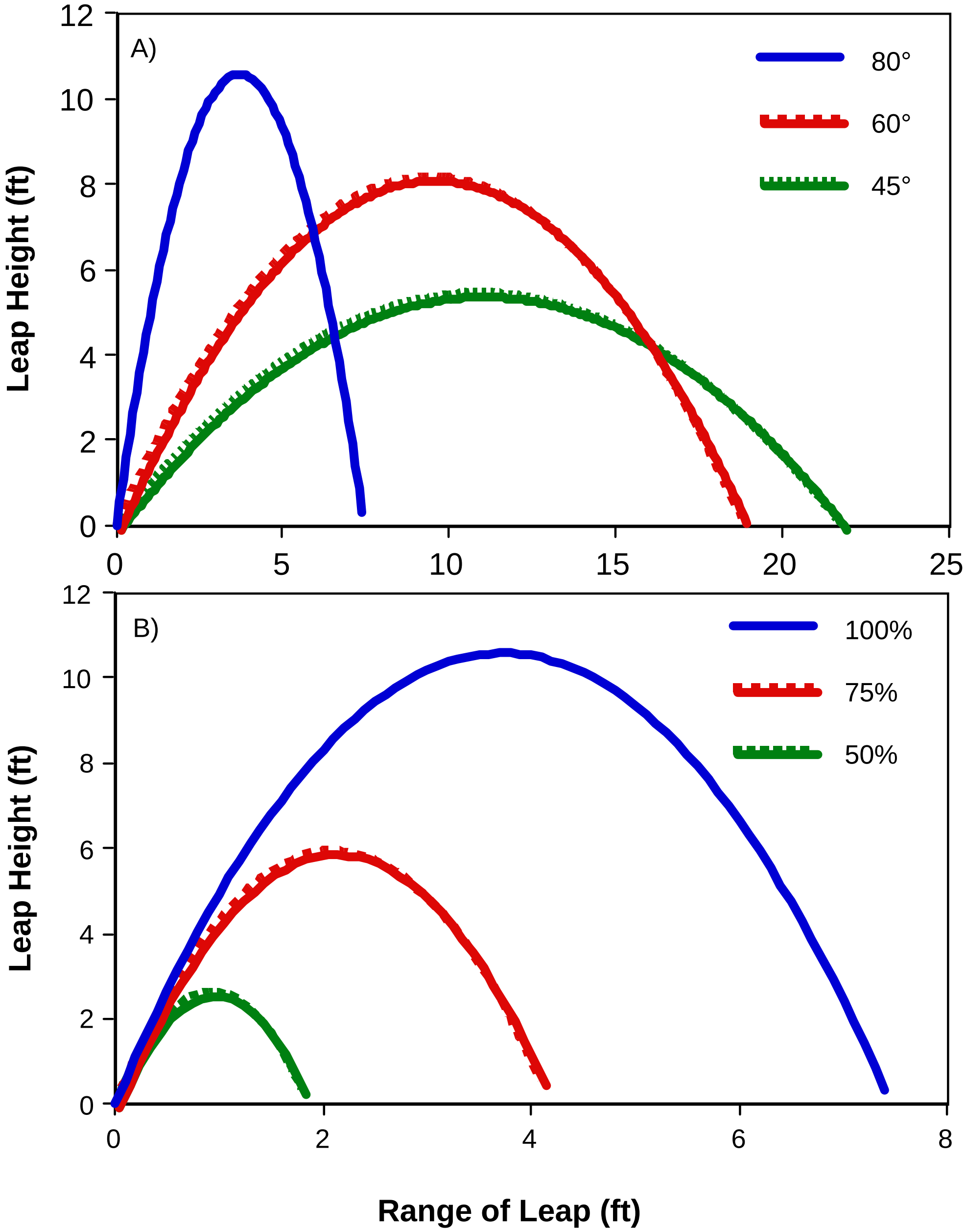

Fig. 5. Steelhead leaping ability assuming maximum burst speed (26.5 ft/s) and 100% swimming efficiency (A), and steelhead leaping ability assuming 80° leap angle and varying degrees of fish condition (B), which is influenced by distance from and elevation above Puget Sound. Data source: Powers and Orsborn 1985.

Fig. 6. **Survey transects where substrate and water surface elevations and water velocity were measured across the channel.**

Fig. 7. **Measuring velocity in the lower falls within the primary cascade. Left bank chute and turbulent pool are above the lower falls.**

Fig. 8. **Measuring velocity and depth in chute (upper portion of primary cascade).**

Fig. 9. **Looking downstream from the top of the primary drop. Line shows the location of Transect C.**

Fig. 10. View of Transect B.

Fig. 11. View of Transect A (upper most) and staff gage in large deep pool.

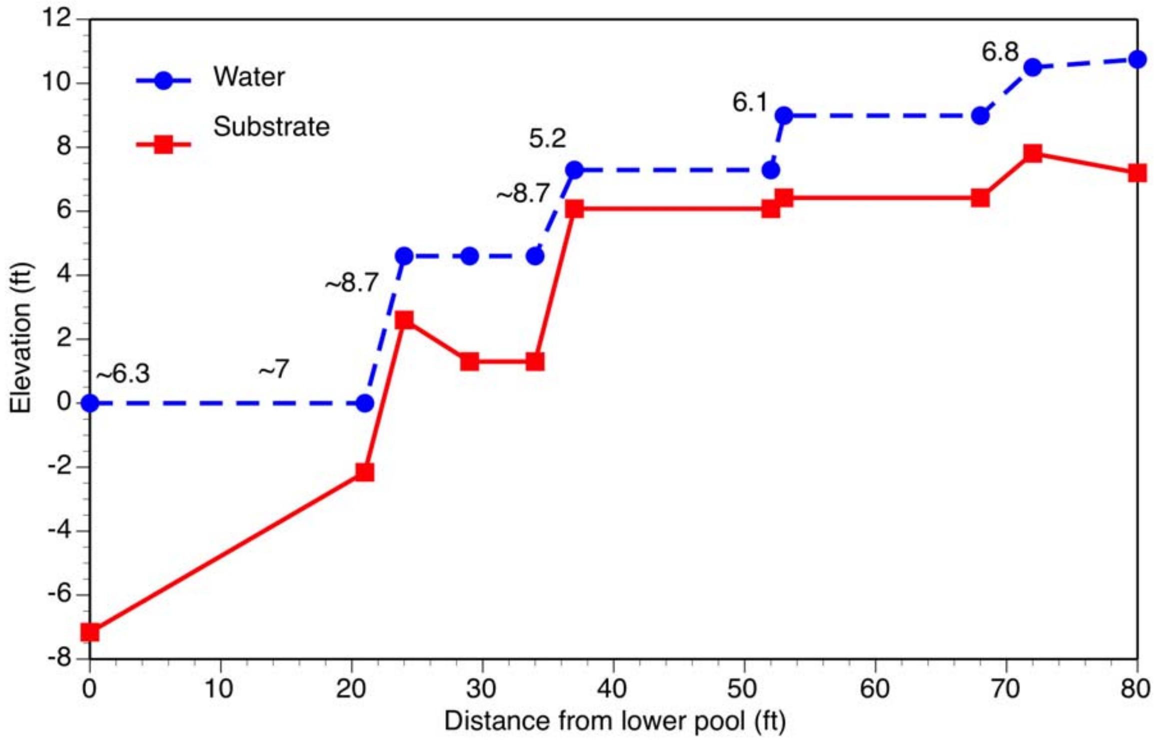

Fig. 12. Profile view of Marsh Creek cascade showing substrate and water surface elevation relative to the lower pool surface. Approximate average water column velocity is shown (feet per second). Discharge was approximately 107 cfs.

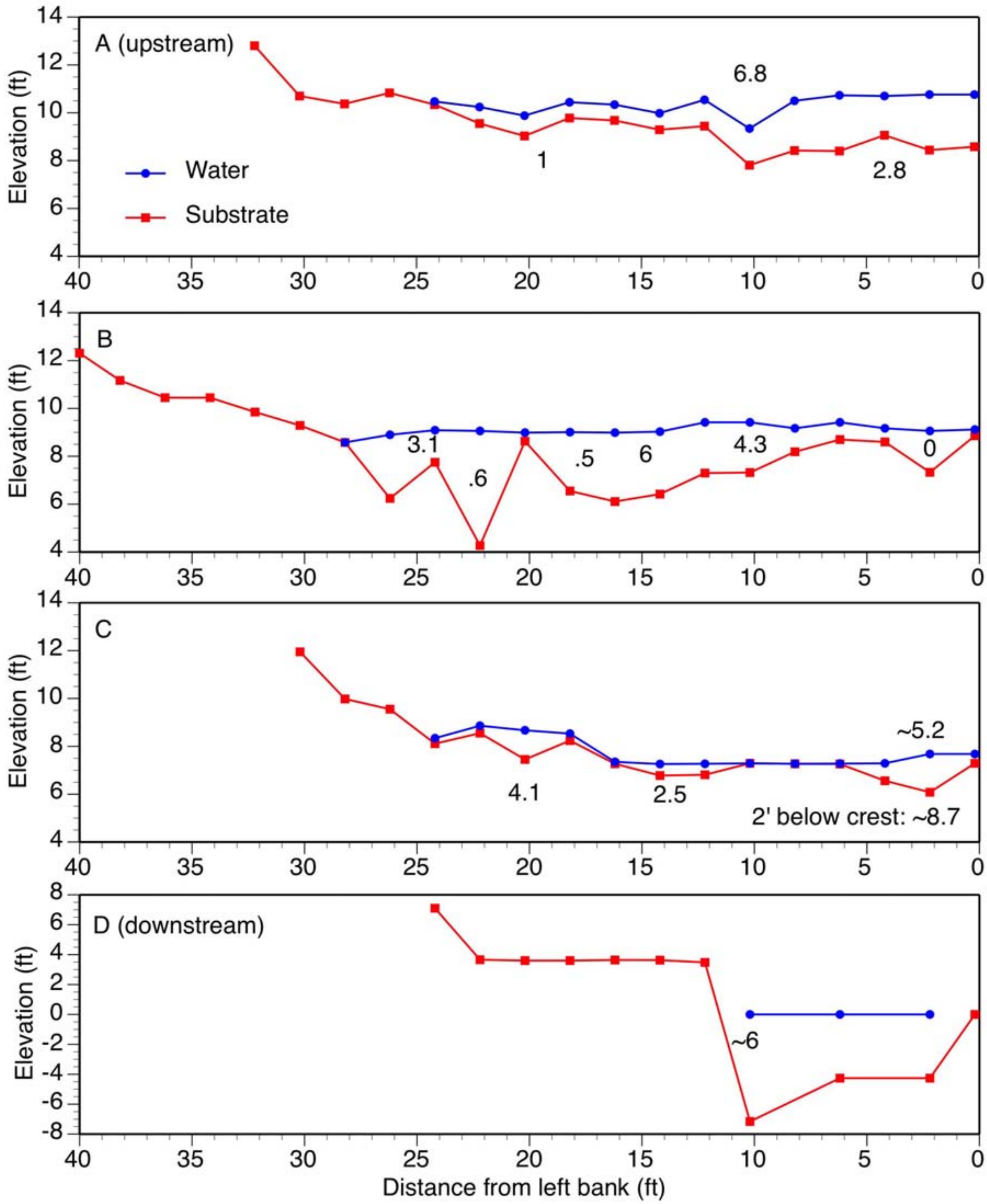

Fig. 13. **Cross-sections of water surface and substrate elevation relative to the lower pool water surface elevation. Approximate average water column velocity is shown (feet per second). Discharge was approximately 107 cfs. The left bank is a vertical rock wall.**

Fig. 14. **Comparison of slide area during July 2006 (upper) and September 2007 (lower). Note loss of large wood in 2007 (circle).**

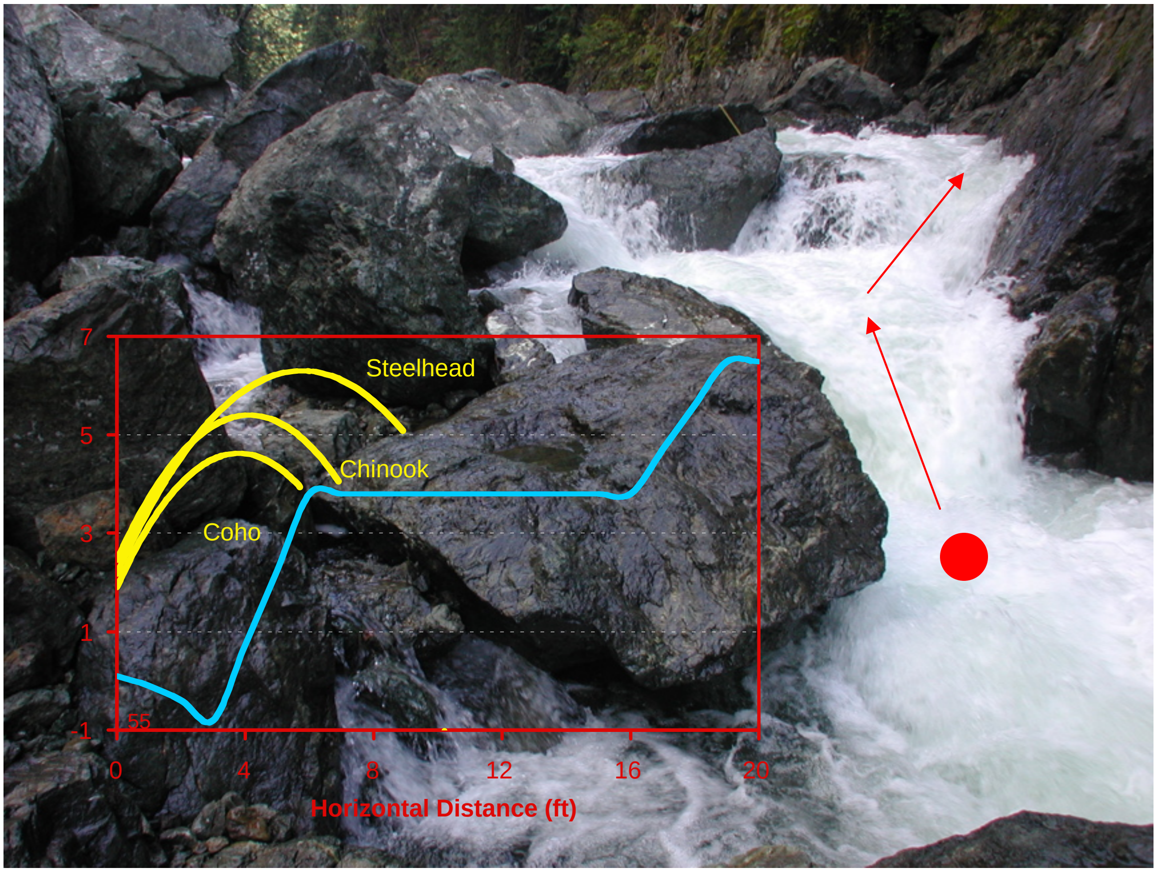

Fig. 15. **Primary Marsh Creek cascade and leaping trajectories of steelhead, Chinook, and coho salmon at 107 cfs. Red dot indicates likely initiation of leap where water surface was slightly higher than surrounding pool. Arrows indicate migration path (left channel too shallow). Leaping performance assumes "good" fish condition, and maximum burst speed, and addition of fish body length to leap height.**

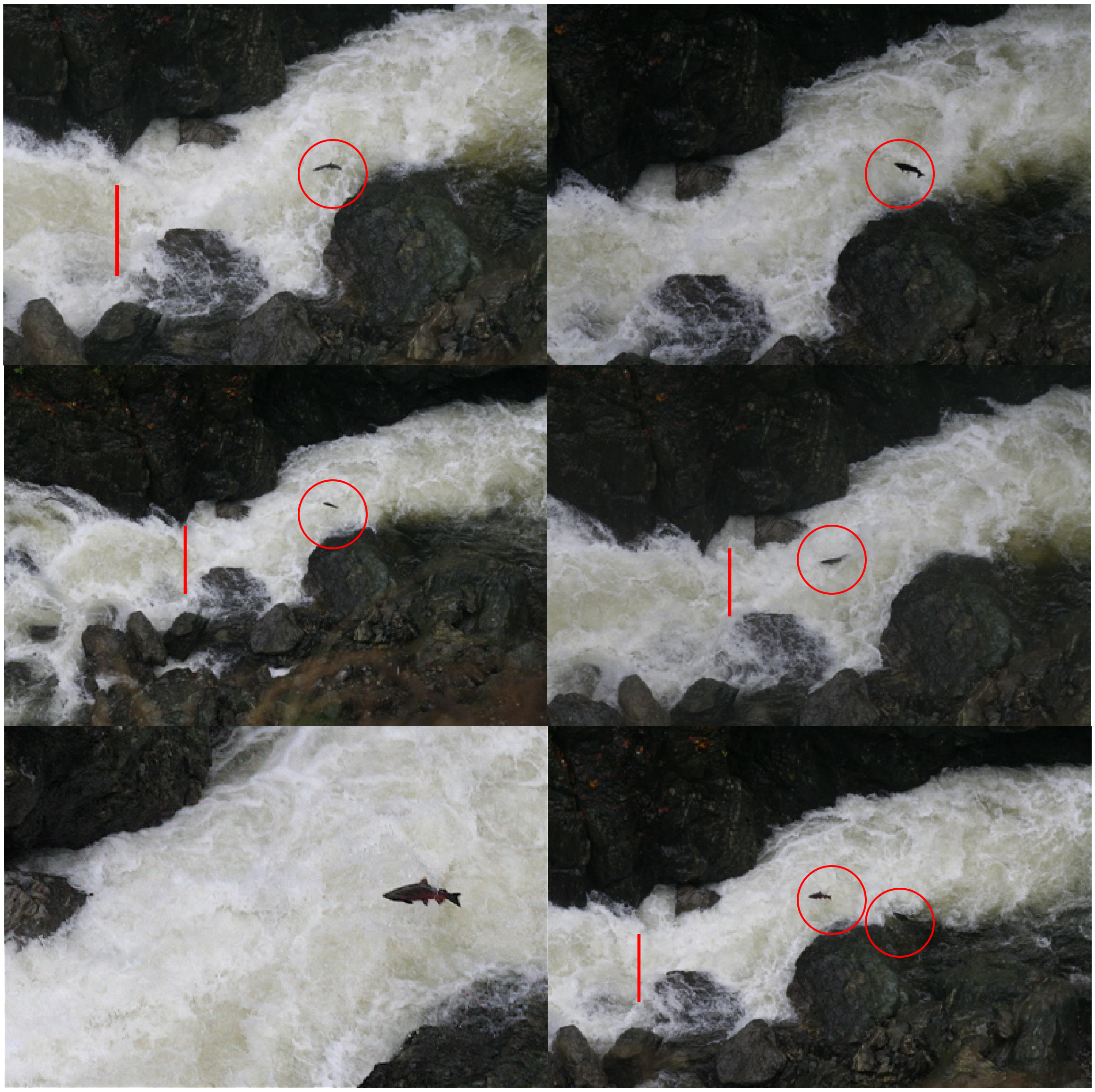

Fig. 16. **Observations of coho salmon (red circle) leaping from the turbulent pool below Marsh Creek cascade on October 21, 2007 when flow was 255 cfs. Fish landed before reaching the lower falls (red line). In the lower right photograph, two salmon were observed leaping; one fish leaped from the boundary of turbulent flow and the clear-water eddy. Leaping stopped when discharge increased to 875 cfs within a 15 minute period.**

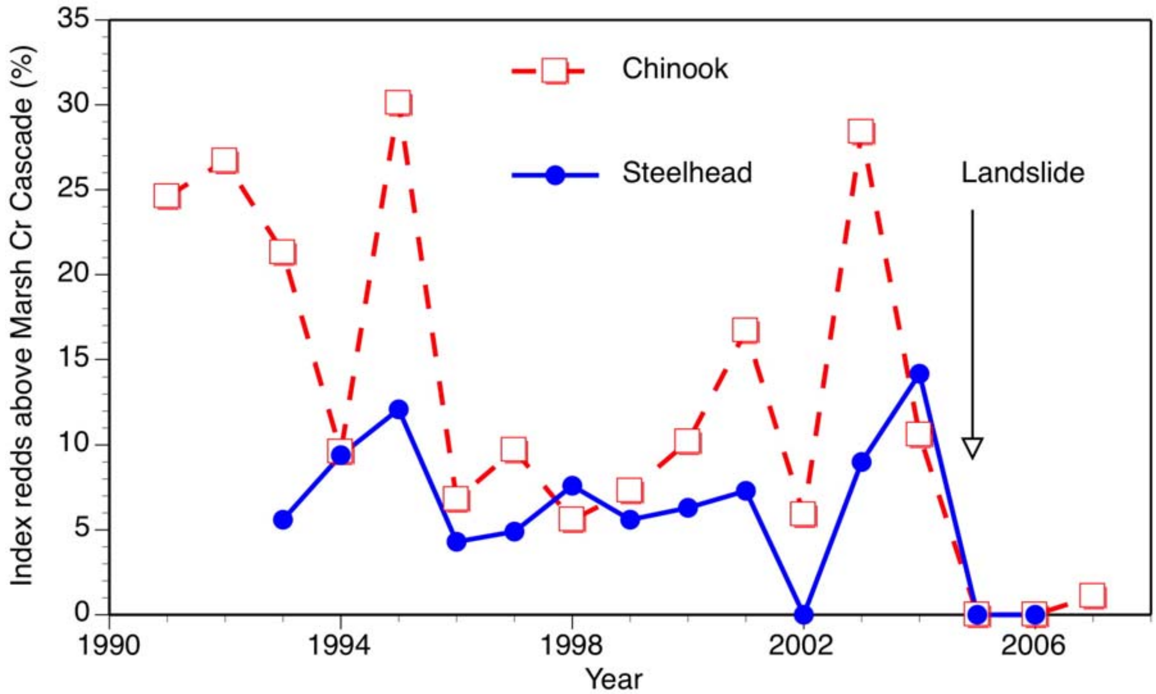

Fig. 17. **Percentages of Chinook salmon and steelhead redds that occurred above the Marsh Creek cascade compared with total redds in the Sultan River, 1991-2007. Steelhead redd counts were not available until 1993 and water was too turbid during spring 2007. Only redds counts during regular index area surveys are shown.**

APPENDIX A

Draft Report Comments from Stakeholders

Presler, Dawn

From:	Karen Chang [kchang@fs.fed.us]
Sent:	Wednesday, January 02, 2008 4:00 PM
To:	Presler, Dawn
Cc:	Eric Ozog; Barry Gall; Karen Chang
Subject:	comments to RSP20: Phase I Fish Passage Assessment

Hi Dawn! I have just a few comments on this:

1) Section 3.3 Cascade Longevity--should be titled Section 3.4
2) Section 4.1 references Figure 13 in paragraph 5, but the reference should be Figure 14. Figure 13 needs to be referenced with the appropriate discussion, or more discussion added.
3) Section 4.4 mentions Gold Camp Index Area, but the report does not include this area on a map, describe it, or discuss its significance. I assume this area is an index area for WDFW spawner surveys?
4) Section 4.5 says "..most trout were young-of-the-year fish." Is this meant to say that most trout were "not" young-of-the-year fish?
5) Section 4.6, last paragraph, talks about how unstable the area is. It would be pertinent to address the underlying geology or soil type of the area, and perhaps also discuss the channel pattern here, to support the unstable nature of the area (adding support beyond noting that landslides have occurred and are likely to continue to occur would be nice).
6) Section 5.0 Discussion and Conclusions--I would have liked to have read about the flow requirements and the trend in flows over the period of record or since the dams were in place in relation to fish use (perhaps this is an information need and the Instream Flow Report will address it all). Also, is there a simple statistical analysis that can be included to show whether the quantity of observed summer steelhead upstream of the cascade in 2007 was significant?

Thank you! Karen

****
Karen Chang, Fish Habitat Biologist
Mt. Baker-Snoqualmie National Forest
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APPENDIX B

Responses to Draft Report Comments

STAKEHOLDER COMMENT	LICENSEE RESPONSE
Karen Chang – US Forest Service – Email dated January 2, 2008	
Section 3.3 Cascade Longevity--should be titled Section 3.4	Fixed.
Section 4.1 references Figure 13 in paragraph 5, but the reference should be Figure 14. Figure 13 needs to be referenced with the appropriate discussion, or more discussion added.	Figure reference corrected.
Section 4.4 mentions Gold Camp Index Area, but the report does not include this area on a map, describe it, or discuss its significance. I assume this area is an index area for WDFW spawner surveys?	Text added to describe location of the Gold Camp Index area and its importance.
Section 4.5 says "..most trout were young-of-the-year fish." Is this meant to say that most trout were "not" young-of-the-year fish?	Text corrected.
Section 4.6, last paragraph, talks about how unstable the area is. It would be pertinent to address the underlying geology or soil type of the area, and perhaps also discuss the channel pattern here, to support the unstable nature of the area (adding support beyond noting that landslides have occurred and are likely to continue to occur would be nice).	Text on glacial deposits, past landslides, and reference were added.
Section 5.0 Discussion and Conclusions--I would have liked to have read about the flow requirements and the trend in flows over the period of record or since the dams were in place in relation to fish use (perhaps this is an information need and the Instream Flow Report will address it all). Also, is there a simple statistical analysis that can be included to show whether the quantity of observed summer steelhead upstream of the cascade in 2007 was significant?	Statistics cannot be used to evaluate whether the observation of four summer steelhead in 2007 was different from past years because visual counts for this entire reach were not available in previous years. Only total steelhead redd counts at index areas were available. Flow requirements (minimum flow/instream flow) are outlined in the Pre-Application Document. These requirements will be revisited as a part of consultation with the Aquatic Resource Working Group; RSP 3: Instream Flow Study will inform these discussions. A detailed statistical analysis of the range of variability of flows is outlined in the technical report for RSP 23: IHA/RVA.