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Memorandum

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Subject: Fish Access to Hotelling Gulch from the South Fork Salmon River

Purpose of Memorandum

This Technical Memorandum (TM) summarizes analysis and findings for an assessment of fish accessibility to Hotelling Gulch from the South Fork Salmon River. This assessment is part of a larger feasibility study examining alternatives to improve access for salmonids to desirable habitat within Hotelling Gulch. The findings presented in this TM are intended to assist in guiding the selection of a preferred alternative for the site.

Background

Hotelling Gulch is a tributary to the South Fork (SF) Salmon River, located in the Klamath National Forest, Siskiyou County, California (Figure 1). A culvert on the Siskiyou County-maintained Cecilville Road crosses Hotelling Gulch approximately 200 feet upstream from its confluence with the SF Salmon River. This culvert was identified by Ross Taylor & Associates (2002) as an upstream migration barrier for all life stages of salmonids. The crossing blocks fish passage to approximately 1.4 miles of stream habitat, which contains perennial pools that hold cool water in the summer and has adjacent dense riparian canopy. Mr. Toz Soto, fisheries biologist with the Karuk Tribe Department of Natural Resources Fisheries Department, has indicated that fish access into Hotelling Gulch would be desirable to provide spawning areas for adult salmonids (Personal Communication, 2011). Hotelling Gulch could also provide slow water refugia for non-natal juvenile coho during periods of high water velocities in the river and thermal refugia during late summer when temperatures are elevated in the SF Salmon River.

Based on field evidence presented in the 2002 barrier assessment RTA suggested that the channel had been moved approximately 200-feet towards the east, to its current-day location, thereby abandoning the historical location of the mouth. The 2002 assessment suggested investigating the feasibility of relocating the channel back into its historical alignment. Relocating the channel would move the location of the Cecilville Road crossing and the stream's confluence with the river. The report noted that the historical confluence was located at a pool in the SF Salmon River, making this location better suited for fish attempting to enter Hotelling Gulch.

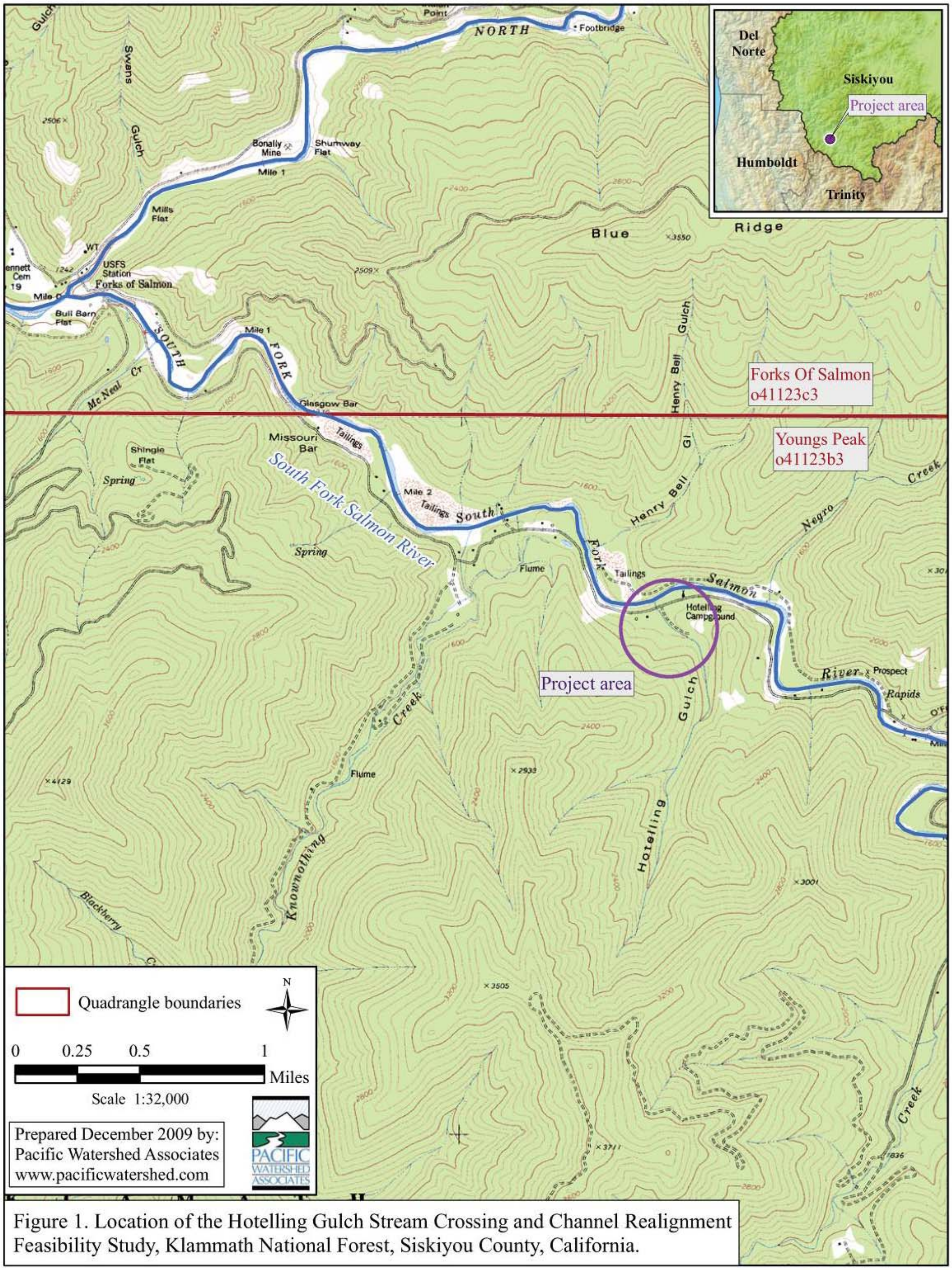


Figure 1. Location of the Hotelling Gulch Stream Crossing and Channel Realignment Feasibility Study, Klammath National Forest, Siskiyou County, California.

Figure 1. Map of Hotelling Gulch confluence with the South Fork Salmon River *(from PWA, 2010).*

The Salmon River Restoration Council (SRRC) had Pacific Watershed Associates (PWA) investigated the feasibility of replacing the Cecilville road-stream crossing. As part of this study (PWA, 2010), they examined the geomorphic and geological feasibility of relocating the channel and crossing to the historical (western) alignment. Field activities included conducting a detailed topographic survey and digging test pits to locate depth to bedrock and groundwater levels along the two alignments.

Through field investigations and aerial photograph analysis, PWA characterized lower Hotelling Gulch as flowing over a broad alluvial fan and is prone to channel avulsion and shifting alignments. Analysis of the aerial photographs verified that Hotelling Gulch flowed along the historical western channel alignment as recently as 1964. Evidence of the historical channel persists, including a culvert crossing at Cecilville Road and a groundwater-fed perennial channel that flows from the culvert inlet to the confluence with SF Salmon River. Because the study area has been highly disturbed through hydraulic mining, the pre-mining alignment of the channel is unknown.

Information from the geologic and geomorphic characterization was used to examine benefits and constraints associated with different channel alignments and road-stream crossing locations. As part of this study, Michael Love & Associates (MLA) assisted PWA with hydraulic analysis of a crossing replacement for the current-day alignment, which included sizing of a replacement bridge. PWA assumed that if the channel were realigned, a similar sized bridge would be needed. The PWA study concluded that restoring the historical alignment is feasible and both the current-day and historical alignments would provide a suitable location for a road-crossing, with differing benefits and limitations associated with each.

The study also highlighted that both the current-day and historical alignments of Hotelling Gulch have mouths characterized by oversteepened channels that cascade into the SF Salmon River at lower flows. Both cascades were described as being made of bedrock and having over 8 feet of fall over 30 to 35 feet of channel length (PWA, 2010). It is apparent that the steep drop at both locations limits fish access from SF Salmon River into Hotelling Gulch at some flows. The PWA study recommended assessing the fish passage conditions at both the current-day and historical mouths of Hotelling Gulch. An assessment would better characterize the range of flow that passage may be provided for adult and juvenile salmonids and determine if one of the channel mouths provides better passage conditions.

Following review of the PWA (2010) report, the US Forest Service and Siskiyou County Department of Public Works requested that an evaluation of fish passage at both the current-day and historical mouths of Hotelling Gulch be conducted.

Scope of Study

MLA was retained by the SRRC to perform a fish passage assessment for the mouth of Hotelling Gulch in its current-day and historical locations. This assessment was conducted with funding from a grant with the US Fish and Wildlife Service (USFWS).

The fish passage assessment evaluated passage conditions for adult anadromous and juvenile life stages of coho salmon and steelhead trout. Factors considered in the assessment included (1) timing of fish movement and corresponding hydrologic conditions in the SF Salmon River and Hotelling Gulch, (2) hydraulic conditions in the river in the vicinity of the confluence with Hotelling Gulch, (3) hydraulic conditions at the mouth of Hotelling Gulch, (4) the swimming and leaping abilities of the target fish species, and (5) fish behavior. Findings from this evaluation, combined with previous work by PWA, were used to make recommendations for additional steps to advance the goal of improving fish access into Hotelling Gulch.

Field Activities

A hydraulic model was prepared to estimate water surface elevations in the SF Salmon River at the current-day and historical confluences of Hotelling Gulch. To develop the model it was necessary to obtain river cross sections and water surface profiles of the SF Salmon River through the study reach. Cross section data was used to develop the model geometry and the measured water surface elevations were used to calibrate the working model.

MLA performed a limited topographic survey of the SF Salmon River that extended approximately 254 feet upstream of the current-day confluence of Hotelling Gulch and approximately 628 feet downstream of the historical mouth, for a total distance of 1,080 feet. The survey was tied to temporary benchmarks established by PWA, which used an arbitrary horizontal and vertical datum.

A survey conducted on September 16, 2011 included a thalweg profile of the river, seven cross sections at hydraulic control points (riffles and pools), water surface profile, and high water marks. The survey included additional profile and cross section surveys at the mouth of the historical alignment, which had recently been cleared of brush, allowing greatly improved access. Another survey was conducted on June 7, 2011 to obtain a water surface profile of the SF Salmon River during elevated flows associated with a spring snowmelt runoff event. Water surface elevations were collected along 530 feet of the south (left) riverbank.

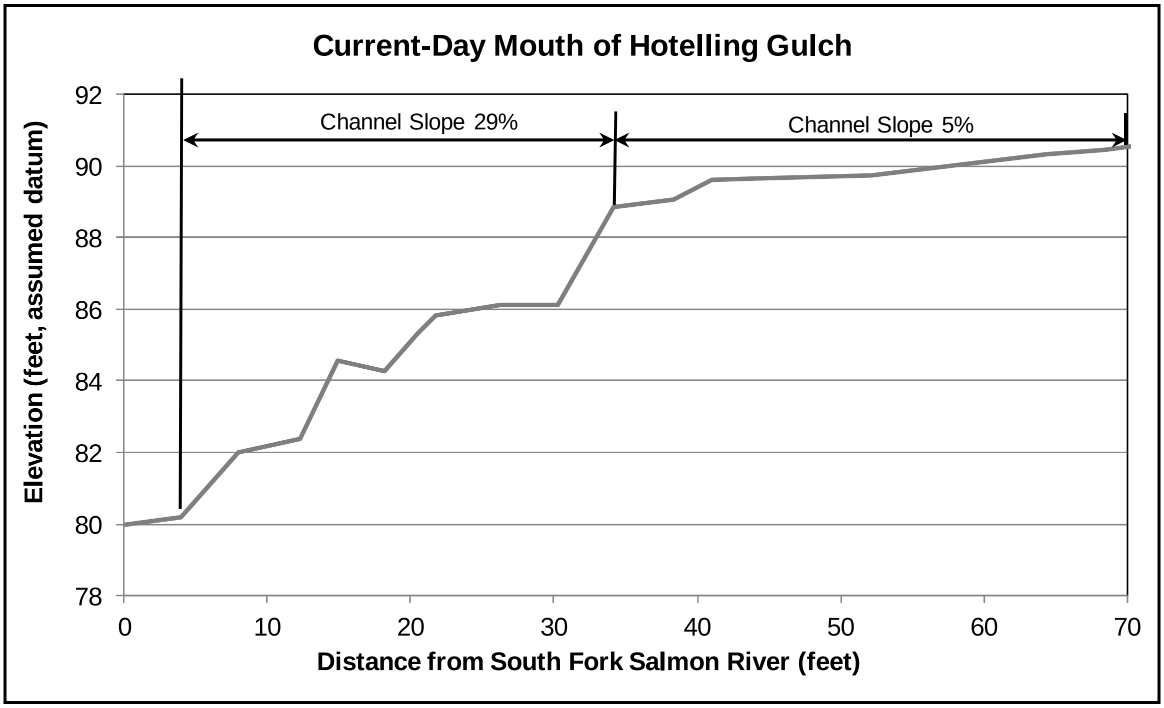
Description of Current-Day and Historical Mouths of Hotelling Gulch

Current-Day Mouth

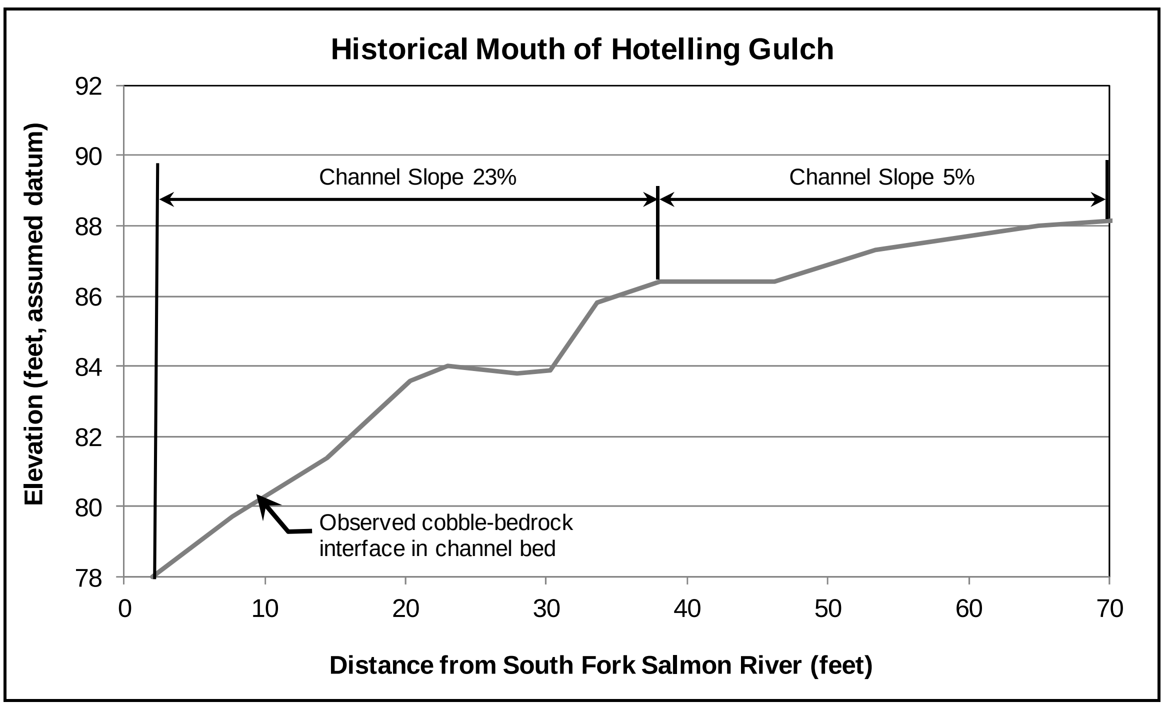
The SF Salmon River, at the confluence with the current-day mouth of Hotelling Gulch, consists of a riffle on a northeast trending transverse bar. Water velocities in this location of the river are swift and depths are shallow. The mouth of Hotelling Gulch is characterized as a bedrock cascade that falls more than 8 feet over a distance of 30 feet, creating an average channel slope of 29 percent (Figure 2a). The channel is located in a narrow notch in the bedrock that appears to be man-made, potentially for use as a sluiceway by miners. In the bedrock notch, there are no resting areas for fish traversing the mouth. Flows within the cascade are rapid and shallow with few discrete drops. Upstream of this cascade, the channel slope drops to approximately 5 percent until reaching the Cecilville Road crossing. Upstream of the crossing the channel slope increases to approximately 6%.

Historical Mouth

The SF Salmon River, at the confluence with the historical mouth, consists of a deep pool forced by a bedrock outcrop immediately downstream. The historical mouth of Hotelling



(a)



(b)

Figure 2. Channel profile of Hotelling Gulch at the confluence with the South Fork Salmon River for (a) the current-day mouth and (b) the historical mouth.

Gulch is characterized as a cascade with a fall exceeding 8 feet over a distance of 36 feet, creating a channel slope of 23 percent (Figure 2b). The channel banks consist of angular bedrock throughout the length of the cascade. It is unclear if this bedrock was notched as part of mining activities. The bed of the cascade is also bedrock near the confluence with the SF Salmon River, but field observations during the September 16, 2011 survey indicate the presence of a cobble-bedrock interface at a low elevation in the cascade (Figure 2b). Upstream of this interface the channel bed is comprised of coarse alluvium to an unknown depth.

Similar to the current-day mouth of Hotelling Gulch, flows within the channel are rapid and shallow, with few discrete drops and no resting areas. Upstream of the cascade, the historical channel slope decreases to approximately 5% until reaching the Cecilville Road crossing. Upstream of the crossing the channel slope increases to approximately 6% (PWA, 2010).

Target Fish Species and Lifestages of Interest

Passage conditions were evaluated for the adult anadromous and juvenile life stages of coho salmon (*Oncorhynchus kisutch*) and steelhead trout (*Oncorhynchus mykiss*), and for adult resident rainbow trout. Mr. Toz Soto provided information on likely timing of fish movement from South Fork Salmon River into small tributaries, such as Hotelling Gulch for spawning and non-natal rearing (Personal Communication, 2012). He also provided size-ranges for the fish (Table 1). Although adult pacific lamprey (*Lampetra tridentata*) may migrate into Hotelling Gulch to spawn, passage for these fish is not believed to be limited by existing conditions at either of the mouths of Hotelling Gulch. Their ability to suck onto to rocks allows them to navigate through steep channel sections with shallow water depths. Therefore, passage for adult pacific lamprey was not analyzed.

Table 1. Anticipated salmonid size ranges and timing of movement from the South Fork Salmon River into small tributaries for spawning or non-natal rearing.

Salmonid Species and Age Class	Movement into Small Tributaries	Range of Fish Lengths
Coho Salmon		
Adult Anadromous Spawning	Nov 15 - Dec 31	400-750 mm (16”- 29”)
Juvenile Non-Natal Rearing	May 15 – Jul 31	65-90 mm (2.6”-3.5”)
Steelhead/Rainbow Trout		
Adult Anadromous Spawning	Feb 15 – Apr 31	400-750 mm (16”- 29”)
Adult Resident Spawning	Feb 15 – Apr 31	200- 300 mm (8”-12”)*
Juvenile Non-Natal Rearing	May 15 – Jul 31	65-250 mm (2.6”-9.8”)

* *Based on literature values.*

Hydrology

Assessment of fish access into Hotelling Gulch required estimating magnitude and frequency of flows in the study area for both the SF Salmon River and Hotelling Gulch. This involved estimating peak flows of specific recurrence intervals and developing flow duration curves.

At the confluence of Hotelling Gulch with the SF Salmon River the drainage area of Hotelling Gulch is 1.18 square miles and the drainage are of SF Salmon River is 260 square miles.

The following summarizes the hydrologic analysis and findings. **Attachment 1** presents more detailed information on the hydrologic analyses.

Peak Flow Frequency

South Fork Salmon River

SF Salmon River flows were gaged by the USGS between 1953 and 1977 (Station No. 11522300 South Fork Salmon near Forks of Salmon). The USGS gage was located downstream of the confluence with Methodist Creek, approximately two river miles upstream of the Hotelling Gulch confluence, and had a contributing drainage area of 252 square miles. The gaging data was used to estimate the magnitude and frequency of the more frequently occurring peak flows in the SF Salmon River using statistical methods presented in Bulletin 17B (USGS, 1982). The predicted flows were scaled to the drainage area at the Hotelling Gulch confluence. Peak flows in the SF Salmon River at Hotelling Gulch are presented in Figure 3.

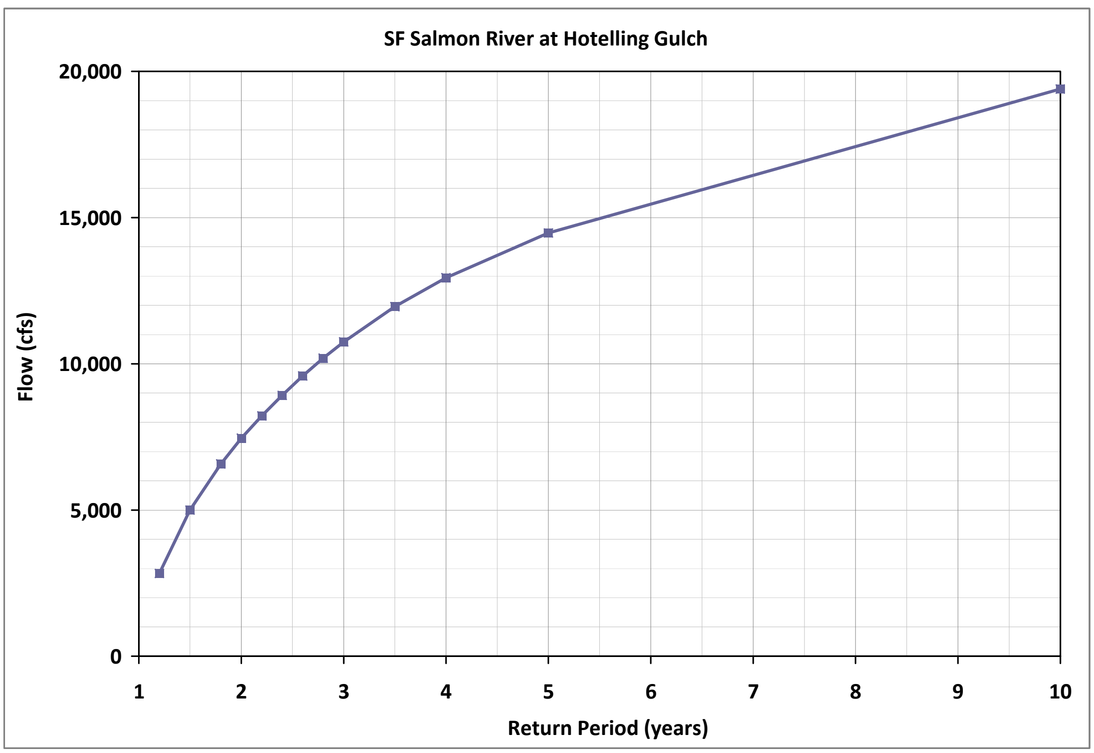


Figure 3. Predicted peak flows and associated return periods for the SF Salmon River at Hotelling Gulch.

Hotelling Gulch

Hotelling Gulch is not gaged, necessitating prediction of flows using indirect methods. Peak flows were estimated using two methods. The first used USGS peak flow data for the SF Salmon River near Forks of Salmon to develop a flow frequency distribution that was scaled to the drainage area of Hotelling Gulch. Peak flows were also estimated using the Siskiyou County drainage manual (Siskiyou County Department of Public Works, 1974), which is based on regional frequency analyses of USGS stream gages. For the methods in the Siskiyou County Drainage manual, flows were computed using graphs from the *Zone 1B Hydrologic Region and Flows* and a mean annual rainfall depth of 50 inches for the watershed (PRISM, 2007).

Peak flows in Hotelling Gulch are presented in Table 2. Flows estimated using the two different methods were nearly identical. Therefore, the flood frequency distribution generated using the scaled flows from the USGS gage were used to estimate a return period associated with any given flow.

Table 2. Summary of peak flows in Hotelling Gulch using two methods of flow estimation.

Method of Peak Flow Estimation	Flow Frequency				
	1.5-Year	1.8-Year	2-Year	2.33-Year	5-Year
Peak Flow Record from Historical SF Salmon River Gage Scaled to Drainage Area at Hotelling Gulch	23 cfs	30 cfs	34 cfs	39 cfs	66 cfs
Siskiyou County Drainage Manual	-	-	-	38 cfs	66 cfs

Flow Duration Curves

A flow duration curve (FDC) describes the percent of days that a flow is equaled or exceeded within a given period. Daily average flows were recorded at the USGS gage at the SF Salmon near Forks (Station No. 11522300) between 1958 and 1965, a shorter period than the peak flow records. This record was used to construct flow duration curves (FDCs) for both SF Salmon River (Figure 4) and Hotelling Gulch (Figure 5) at their confluence by scaling flows to their drainage areas. Both annual and seasonal FDCs were constructed. The seasonal periods coincide with the periods of potential upstream movement into Hotelling Gulch for the different fish species and life stages of interest.

Flows for Hydraulic Model Calibration

Flows in the SF Salmon River coinciding with the surveyed water surface profiles were estimated using a correlation between measured flows at the currently active USGS Salmon River at Somes Bar gage (Station No. 11522500) and flows in the SF of the Salmon River at the bridge crossing near Forks of the Salmon (Dreamflows.com, 2011). The estimated flows provided by Dreamflows were then scaled to the drainage area of the SF Salmon at Hotelling Gulch.

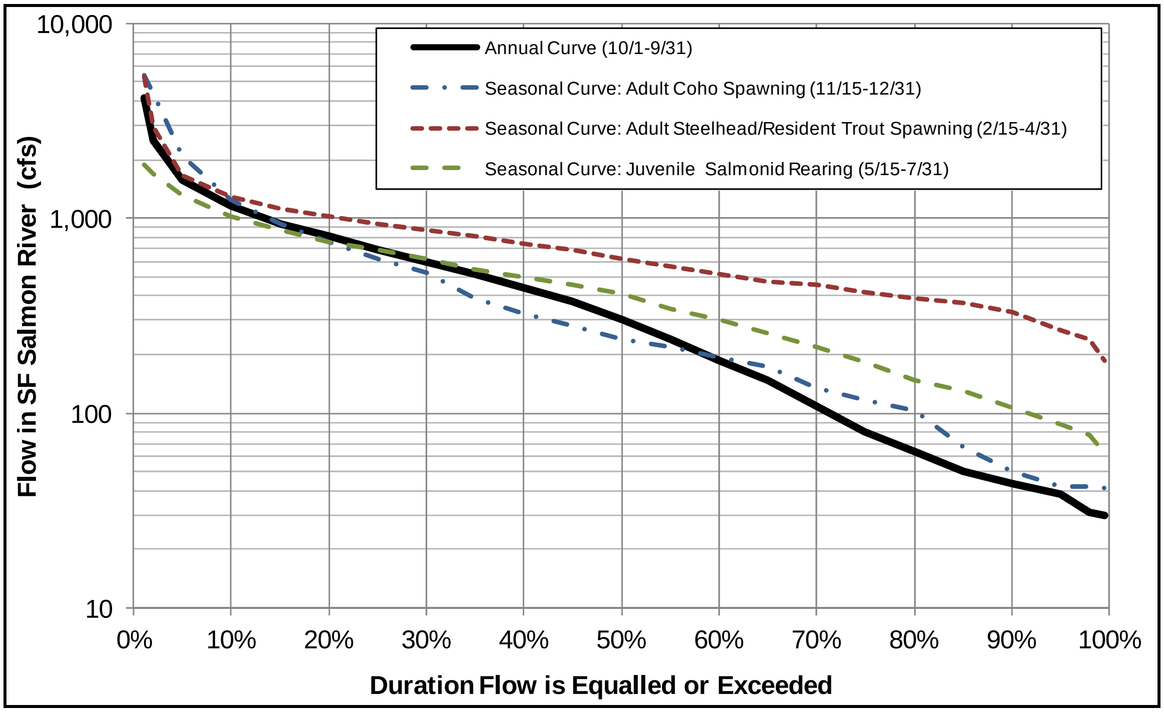


Figure 4. Daily average flow duration curves for South Fork Salmon River at Hotelling Gulch for annual and select periods of anticipated fish movement into Hotelling Gulch.

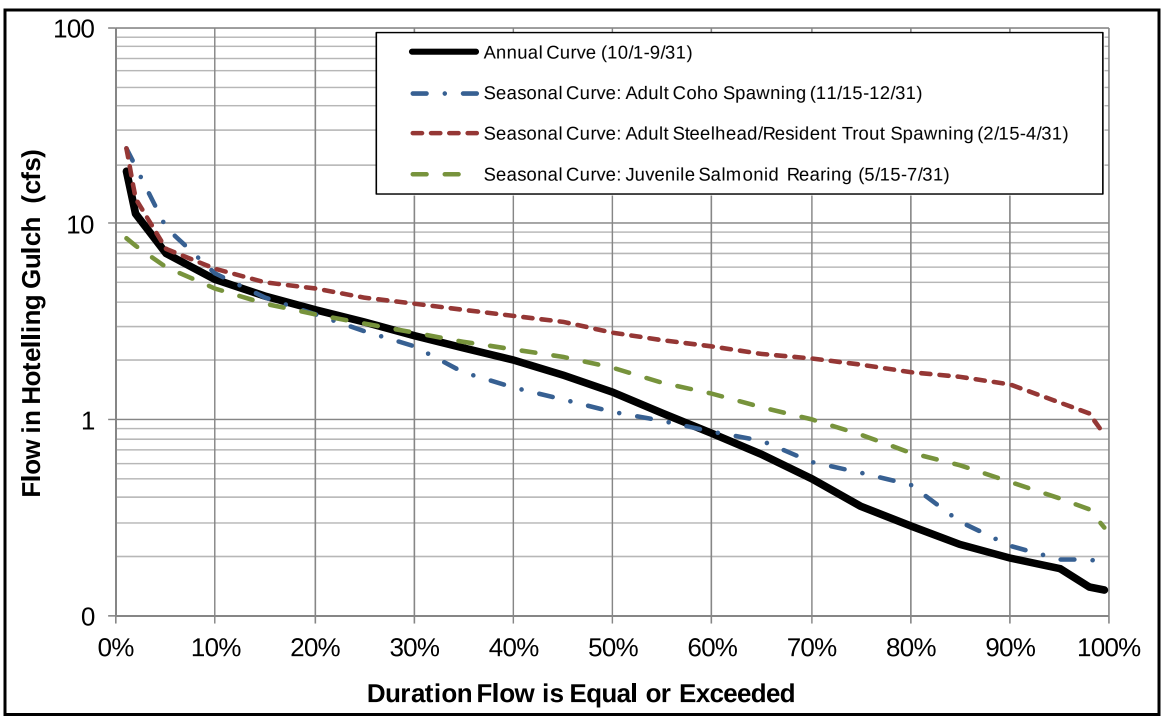


Figure 5. Daily average flow duration curves for Hotelling Gulch at confluence with South Fork Salmon River for annual and select periods of anticipated fish movement into Hotelling Gulch.

Dreamflows predicted that the flow on June 7,2011 in the SF Salmon River at Hotelling Gulch was 1,615 cfs, with a 90% confidence range of 1,301 cfs to 1,965 cfs. Based on the annual FDC in Figure 4, a flow of 1,615 cfs in the SF Salmon River has an annual exceedance probability of approximately 5 percent, indicating that flows at this location in the river exceed 1,615 cfs on average 18 days per year.

Dreamflows predicted that the flow on September 16, 2011 in the SF Salmon River at Hotelling Gulch was 160 cfs. A flow of 160 cfs in the SF Salmon River at Hotelling Gulch has an estimated annual exceedance probability of approximately 63 percent.

Hydraulic Analysis

A hydraulic model was developed for the SF Salmon River to estimate water surface elevations at the current-day and historical mouths of Hotelling Gulch for various flows in the river. This model was used to estimate extent and frequency of backwatering and inundation of the mouths of Hotelling Gulch by high flows in the river. Separate hydraulic models were also developed for the steep cascades comprising the current-day and historical mouths of Hotelling Gulch. These two models were used to characterize water depths, water velocities, and fish passage conditions within the cascades at various flows in Hotelling Gulch and SF Salmon River.

Hydraulic Model Development

Hydraulic modeling of the SF Salmon and the two alignments of the Hotelling Gulch mouth was conducted using the Army Corps of Engineers Hydrologic Engineering Center's River Analysis System (HEC-RAS), a one-dimensional steady-state open channel flow model (ACOE, 2010).

SF Salmon River

Model Geometry

The modeled reach of the SF Salmon River was 1,082 feet in length, extending downstream and upstream of the current-day and historical confluences of Hotelling Gulch. Hydraulic model geometry was developed from the cross section data surveyed by MLA on September 16, 2011. Cross sections were spaced from 88 to 200 feet apart, and located at hydraulic controls (i.e. riffle crests) and pools. Cross section numbering was based on centerline stationing of the SF Salmon River. The current-day mouth of Hotelling Gulch is located at Station 10+75 along the SF Salmon River, and the historical mouth is located at Station 8+35.

Model Calibration

The water surface profile surveyed on June 7, 2011 and the associated flow estimate was used to back-calculate the hydraulic roughness (Manning's n) through the project reach. Both the upstream and downstream boundary conditions were set to normal depth, with a channel slope of 0.006 feet/feet, which was the overall slope of the surveyed water surface profile.

A model simulation using the June 7, 2011 estimated flow of 1,615 cfs and a channel roughness value of 0.035 yielded a water surface profile that had good agreement with the surveyed water surfaces. The maximum difference between the model and measured water surface elevations was 0.26 feet, except at one cross section. The one cross section where the discrepancy between modeled and measured water surface elevations was greater was located on a long northeast trending transverse riffle. The difference was 0.86 feet, which is a result of the hydraulic complexity of the river across the bar that is not reflected in the modeling.

The calibrated model predicted within 0.1 feet the measured water surface elevation at the current-day confluence with Hotelling Gulch. At the historical confluence with Hotelling Gulch the predicted water surface elevations was 0.26 feet grater than measured.

After calibration, the model simulations were conducted for a range of flows up to 14,475 cfs, the 5-year flow event. **Attachment 2** presents the hydraulic model results for the SF Salmon River.

Hotelling Gulch

Individual hydraulic models were prepared for the current-day and historical alignments of the Hotelling Gulch channel mouths. For each alignment, the hydraulic analysis extended from the confluence with the SF Salmon River upstream through the steep cascade and into the more gently sloping section of channel, for an overall length of channel exceeding 100 feet. Model geometry was based on a combination of cross sections from the MLA survey and from the digital terrain model prepared by PWA as part of the previous study (PWA, 2010). Cross section numbering followed alignment stationing, with station zero located at confluence with the SF Salmon River.

For both alignments, cross sections within the steep reach of the channel mouth were located at hydraulic control points and were spaced at a maximum distance of 10 feet apart. Cross sections were interpolated between known cross sections at a maximum distance of 5-foot spacing to achieve the model resolution desired for the fish passage analysis. Cross sections within the more gently sloping reach of the channel were spaced 20 to 60 feet apart and were located at hydraulic control points. Cross sections were then interpolated at spacing ranging between 5 and 18-feet.

A Manning's roughness coefficient, *n,* of 0.08 was estimated for the channel based on channel morphology. Left and right overbank roughness values of 0.1 for the current-day alignment and 0.15 for the historical alignment were based on visual observations of the channel margins and floodplain. The upstream boundary condition of each model was set to critical depth. The downstream boundary condition was set at a constant water surface elevation reflecting the surveyed June 7, 2011 water surface elevations at each of the mouths. A constant water level was selected to simplify the analysis, and the June 7th level is a relatively common water surface elevation in SF Salmon River during fish migration periods.

Model simulations were conducted for each alignment of Hotelling Gulch for a range of flows from 1 cfs to the 2-year return period flow of 34 cfs.

Attachments 3 and 4 present hydraulic model results for current-day and historical mouths of Hotelling Gulch.

Fish Passage Assessment

Backwatering from South Fork Salmon River

As water levels rise in the SF Salmon River, the river begins to inundate the current-day and historical mouths of Hotelling Gulch. Depending on the water level in the river, the cascades at the two mouths may be partially or completely backwatered, potentially improving fish access into Hotelling Gulch. Figure 6 present the extent of backwatering from the river into the (a) current-day and (b) historical mouths of Hotelling Gulch. For each water surface elevation, the corresponding flow in the river is provided along with its annual exceedance or return period.

At both locations, a flow event in the SF Salmon River with a 3-year return period would fully submerge the steep cascade reaches of Hotelling Gulch, allowing unimpeded fish access to the lower-sloped reaches of the channels. However, at this flow cross sectional averaged water velocities in the river are over 10 feet per second, which may make it difficult for fish to swim upstream to the Hotelling Gulch mouth.

Fish Access to Hotelling Gulch Based on Swimming Ability

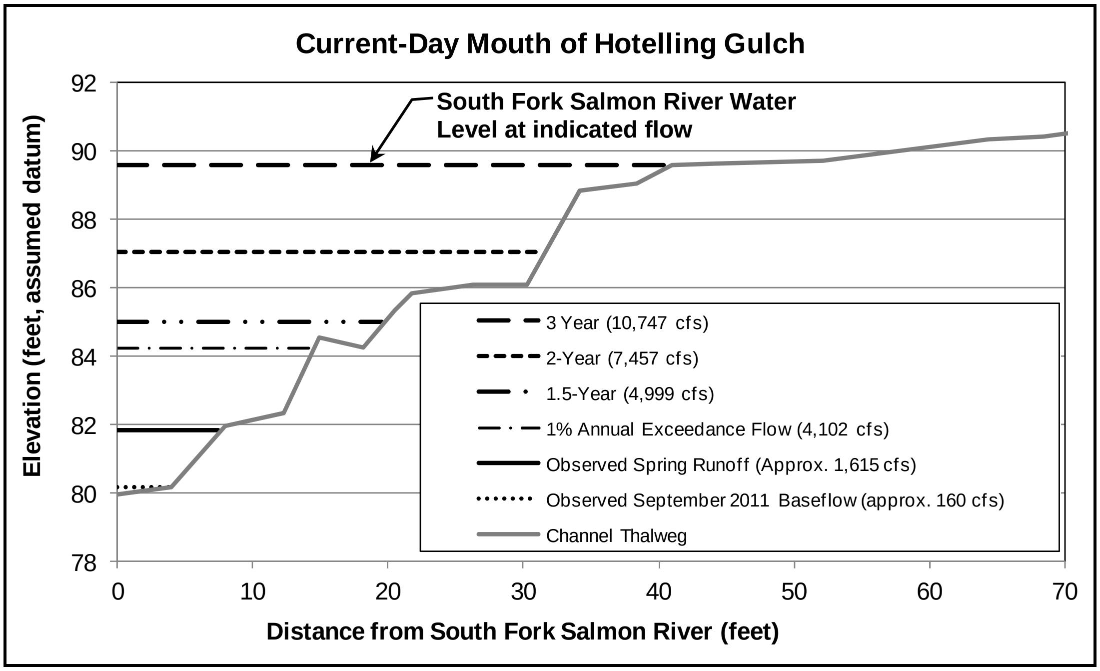
River-caused backwatering of the cascades in the current-day and historical mouths of Hotelling Gulch is an infrequent event and does not contribute substantially to providing fish access into Hotelling Gulch. Therefore, fish access to Hotelling Gulch is predominately dependent on fish negotiating the swift and shallow flows within the current-day or historical mouth, when minimal backwatering is provided by the river.

Neither of the channel mouths at Hotelling Gulch have discrete drops or deep pools. Instead, the flows are more characteristic of conditions that salmonids attempt to swim-through rather than leap over. The water depths and velocities the fish must swim through and the size and swimming abilities of the fish will determine passage success.

Swimming Abilities and Minimum Water Depths

CDFG (2002) and NOAA Fisheries (2001) fish passage design criteria prescribe maximum water velocities and minimum water depths for salmonids of different life stages and life histories. These criteria are widely recognized as being conservative, with the intent of providing passage for the weakest individuals in the population with a factor-of-safety included. These criteria are intended for engineered fish passage structures and generally not applied to assessment of natural passage impediments. Instead, passage conditions at natural features are generally assessed using documented swimming abilities of individual fish and the size distribution of the population. Using this approach, the assessment results describe the proportion of the fish population likely blocked by the feature at a specific flow.

Salmonids have three distinct modes of swimming: sustained, prolonged, and burst (Beamish, 1978). Sustained swimming is a completely aerobic activity that can be maintained indefinitely. Prolonged swimming is a combination of aerobic and anaerobic metabolic activity that can be maintained for between 20 seconds and 60 minutes before the fish becomes fatigued. Burst is the fastest mode of swimming and uses anaerobic muscles almost exclusively. Burst can only be maintained for between 1 and 20 seconds before the fish becomes fatigued.



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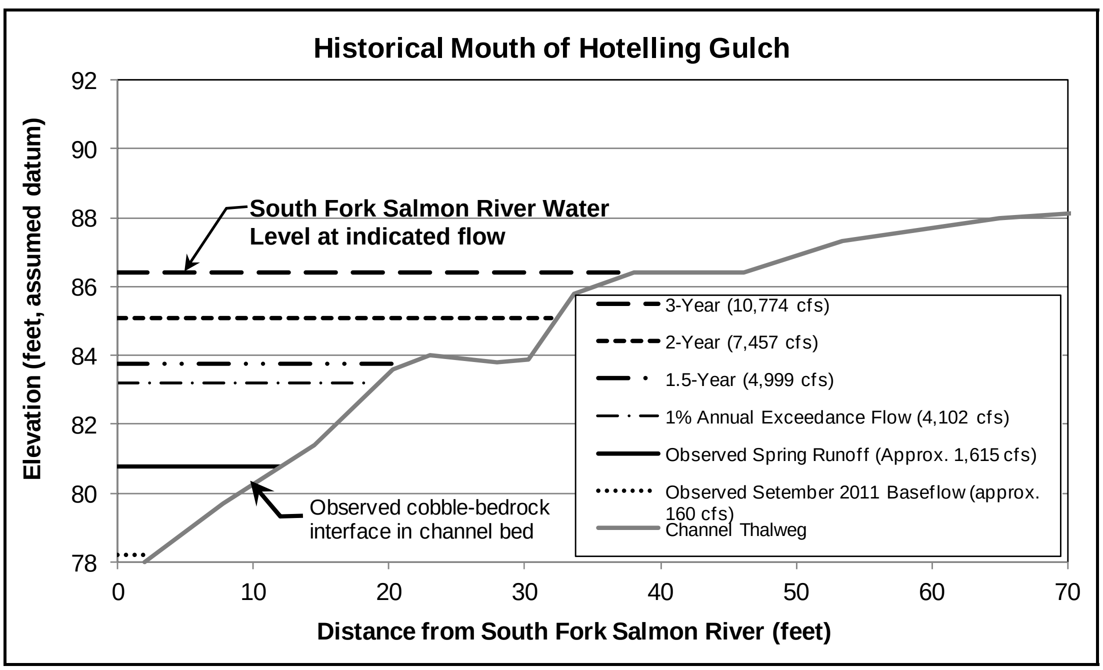

(b)

Figure 6. Extents of backwater from the South Fork Salmon River into the (a) current-day and (b) historical mouths of Hotelling Gulch. Levels based on observed and modeled water surface elevations in the SF Salmon River.

Because of the steepness of the channel mouths at Hotelling Gulch and resultant high velocities, salmonids would likely ascend the channel in burst mode. The speed that a fish can swim in burst before becoming fatigued is dependent on the species and the body length of the fish and the duration of time spent swimming in burst mode.

Hunter and Mayor (1986) developed swim speed-fatigue time relationships for various salmonid species including coho salmon, and steelhead/rainbow trout. These relationships were derived from published and unpublished data and allow computation of the burst swim speed based on their total body length and duration spent swimming in burst mode. Burst swim speed increases with fish length and decreases with duration spent in burst mode. For this passage assessment, the fish size ranges provided in Table 1 were used for each listed group and a duration in burst mode of 5 seconds was used (Table 3). Using 5 seconds as the time-to-fatigue typically resulted in the best passage performance of the fish.

For this assessment, water depth within the channel should be sufficient to permit the fish to swim freely. This includes full submergence of the fish's body. When swimming partially submerged, the fish's tail fails to provide full thrust and its gills may by partially exposed to the air, reducing respiratory function. Under these conditions, the swimming speed-fatigue time relationships are not valid. For this analysis if water depth does not fully submerge the fish, depth was considered insufficient for passage.

The Hotelling Gulch fish passage assessment used a minimum water depth equal to the body depth of the fish. A relationship of body depth to fish length for salmonids, published by Carlander (1969 and 1977), was applied to each evaluated fish species and size (Table 3).

Table 3. Burst swim speeds for various sizes of salmonids computed using Hunter and Mayor (1986) with a swim time to fatigue of 5 seconds. Water depth to submerge the fish was computed using body depth to length ratios developed by Carlander (1969 and 1977).

Fish Species	Fish Size (Total Length)	Burst Swim Speed	Water Depth to Submerge Fish
Coho Salmon	3.5 inch	2.4 fps	Not Calculated
	16 inch	9.6 fps	0.32 feet
	20 inch	10.8 fps	0.40 feet
	24 inch	11.9 fps	0.48 feet
	29 inch	13.1 fps	0.58 feet
Steelhead/ Rainbow Trout	10 inch	3.9 fps	0.18 feet
	12 inch	4.5 fps	0.22 feet
	16 inch	10.2 fps	0.29 feet
	20 inch	11.7 fps	0.37 feet
	24 inch	13.1 fps	0.44 feet
	29 inch	14.7 fps	0.53 feet

Assessment Methods

The fish passage assessment was performed for a range of streamflows by comparing the swimming abilities and water depth requirements of the target fish to the cross-sectional average water velocities and maximum depths at each HEC-RAS computed cross section. The assessment was prepared for both the current-day and historical mouths of Hotelling Gulch. Passage was considered unsuccessful if one or more of the following conditions occurred:

a. Water depth was insufficient at two or more adjacent cross sections. A 0.1 foot leeway was allowed for insufficient water depth.
b. Channel water velocities exceeded the burst speed of the fish, sweeping the fish downstream.
c. A fish was unable to navigate the full length of the steep channel reach in the 5 seconds, becoming fatigued before traversing the cascade.

The fish passage assessment was performed only for the cascade reaches of the current-day and historical Hotelling Gulch channel alignments, which are 33 feet and 36 feet in length, respectively. Computations were performed using the SF Salmon River water surface set at the levels surveyed during the June 2011 spring runoff event. Assessed flows in Hotelling Gulch ranged from 1 cfs to 34 cfs, the predicted 2-year peak flow.

Fish Passage Results

The results of the fish passage assessment for both the current-day and historical mouths of Hotelling Gulch are summarized in Figure 7 (a) and (b). Fish passage conditions are similar at both mouths. The 24-inch to 29-inch, stronger swimming species of steelhead and coho salmon are capable of traversing the steep cascade at burst speed when water depths are sufficient. At lower flows, shallow water depths limit passage. Passage of smaller steelhead and coho is limited at to lower flows. Higher flows create high water velocities that sweep fish downstream or result in ascent failure due to exhaustion.

Access into Hotelling Gulch for the entire size range of adult resident rainbow trout is limited by excessive water velocities. Computations showed that channel velocities often exceeded rainbow trout burst speeds, sweeping them downstream. Based on these results, smaller juvenile salmonids would also be blocked by the high water velocities, unable to access Hotelling Gulch from the SF Salmon River regardless of the location of the mouth.

At elevated river levels, smaller adult steelhead and coho salmon may be able to traverse the shortened length of cascade in both mouths due to backwatering from the river. However, the water velocities in both of mouths exceed the burst swim speeds of adult rainbow trout and juveniles salmonids, making it unlikely that they could access upstream habitat when the cascades are partially submerged.

Fish Passage Assumptions and Limitations

The passage assessment relied on a number of assumptions and limitations that should be considered when applying these results. The hydraulic model employed in the assessment provides one-dimensional cross-sectional averaged hydraulic conditions, and is not capable of identifying smaller pathways of slower water and adequate depth that may occur along the channel margins within the cascades.

Current-Day Mouth	Flow, cfs (Exceedance Probability or Annual Return Period)														
Target Fish Species and Size	1 (90%)	2 (40%)	3 (25%)	4 (15%)	5 (10%)	6 (8%)	7 (5%)	8 (4%)	9 (3%)	10 (2%)	13 (1.5%)	19 (1%)	23 (1.5-Yr)	30 (1.8 Yr)	34 (2-Yr)
16" Coho	—	—	E	E	E	E	E	E	E	E	E	E	E	V	V
20" Coho	D	—	—	—	—	—	E	E	E	E	E	E	E	E	E
24" Coho	D	D	—	—	—	—	—	—	—	—	—	V	E	E	E
29" Coho	D	D	D	D	—	—	—	—	—	—	—	—	—	—	—
16" Steelhead	—	—	—	E	E	E	E	E	E	E	E	E	E	E	E
20" Steelhead	D	—	—	—	—	—	—	—	—	—	—	V	E	E	E
24" Steelhead	D	—	—	—	—	—	—	—	—	—	—	—	—	—	—
29" Steelhead	D	D	D	D	—	—	—	—	—	—	—	—	—	—	—
10" Rainbow	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V
12" Rainbow	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V

Historical Mouth	Flow, cfs (Exceedance Probability or Annual Return Period)														
Target Fish Species and Size	1 (90%)	2 (40%)	3 (25%)	4 (15%)	5 (10%)	6 (8%)	7 (5%)	8 (4%)	9 (3%)	10 (2%)	13 (1.5%)	19 (1%)	23 (1.5-Yr)	30 (1.8 Yr)	34 (2-Yr)
16" Coho	—	E	E	E	E	E	E	E	E	E	E	E	E	V	V
20" Coho	D	—	—	—	—	E	E	E	E	E	E	E	E	E	E
24" Coho	D	—	—	—	—	—	—	—	—	—	E	E	E	E	E
29" Coho	D	D	—	—	—	—	—	—	—	—	—	—	—	E	E
16" Steelhead	—	—	—	E	E	E	E	E	E	E	E	E	E	V	V
20" Steelhead	—	—	—	—	—	—	—	—	—	—	E	E	E	E	E
24" Steelhead	D	—	—	—	—	—	—	—	—	—	—	—	—	E	E
29" Steelhead	D	D	D	—	—	—	—	—	—	—	—	—	—	—	—
10" Rainbow Trout	E	V	V	V	V	V	V	V	V	V	V	V	V	V	V
12" Rainbow Trout	E	V	V	V	V	V	V	V	V	V	V	V	V	V	V

Figure 7. Summary of fish passage conditions through the steep cascade in the (a) current-day and (b) historical channel mouth of Hotelling Gulch. Solid line indicates suitable water depth and velocities for passage at the specified flow. Insufficient water depths are indicated by *D*. Excessive water velocities that sweep fish downstream are indicated by *V*. Passage failure due to exhaustion is indicated by *E*.

The passage analysis through the current-day and historical mouths of Hotelling Gulch was simplified by using a constant river level for the downstream boundary condition. During higher river stages than modeled, part of the cascades in the mouths would be backwatered, reducing the distance the fish would have to swim in burst mode. This may increase the predicted range of flows that the adult steelhead and coho would be capable of negotiating both mouths. However, it would not affect passage efficiency for the smaller fish because the water velocities exceed their swim speeds.

The swim speeds used are averages for the specific fish species and size evaluated. Individual fish may have more or less speed and/or endurance than predicted. It is not unusual to observe an individual fish either under- or out-performing in comparison to the predicted outcome.

Fish Passage Assessment Conclusions

In conclusion, fish passage conditions through the current-day and historical mouths of Hotelling Gulch are similar for both mouths. Elevated flows in the SF Salmon River sufficient to backwater the steep cascades at the mouths of both alignments, allowing adult and juvenile salmonids to swim unchallenged into Hotelling Gulch, occur infrequently. Instead, most of the time fish must swim through the cascade at the mouth to access upstream habitat. Conditions at both mouth locations would likely preclude use of the upstream habitat by juvenile non-natal coho salmon for rearing. Only adult steelhead and coho salmon are likely to successfully navigate the steep mouths present in both channel alignments of Hotelling Gulch, obtaining access to spawning areas upstream.

Additional Findings, Discussion and Next Steps

Observed Cobble/Bedrock Elevation

The historical channel mouth of Hotelling Gulch was brushed by volunteers prior to the September 2011 topographic survey, allowing for a close inspection of the channel morphology. Observations indicated that the banks are comprised of bedrock, but the channel bed appears to be cobble. The channel bed transitioned from cobble to bedrock just above the water surface in the river, at an elevation of 80.1 feet. This is substantially lower than the bedrock elevations depicted in the profile presented in the PWA (2010) report (Figure 8). This profile, which is associated with Alternative IIb in PWA (2010), follows the presumed alignment of the historical channel. The 2010 bedrock elevations shown on the profile near the confluence with the river were based on mapping of bedrock in off-channel test pits rather than direct observations from the channel bed. The mapped bedrock elevations appear to be higher than observed in the channel and may coincide more closely to the elevation of bedrock observed in the channel banks rather than the channel bed.

Although speculative, an estimate of the historical channel profile was made assuming that the bedrock near the confluence is deeper than depicted in Figure 8. The estimated profile was derived by drawing a constant-sloped line between the bedrock/cobble interface and the current-day channel bed at the location where it diverges from the historical alignment. This results in a slope of approximately 7.0 percent for a length 550 feet. Though steep, the channel slope is similar to the overall slope along the current-day channel alignment and within the range of channel slopes that steelhead/rainbow trout reside in

Reoccupying Historical Channel Alignment

The surveyed bedrock /cobble interface is located at a lower elevation than the June 2011 water level associated with a typical spring runoff event on the SF Salmon River. If bedrock is not forming the cascade at the mouth of the historical channel, it may be feasible and desirable to re-establish the historical alignment of Hotelling Gulch and regrade the cascade to improve fish access.

Other reasons that re-establishment of the historical alignment of Hotelling Gulch may be beneficial include:

1. The mouth is located at a pool on the side of the SF Salmon River, creating better entrance conditions for fish accessing Hotelling Gulch than from the riffle at the current-day mouth of Hotelling Gulch.
2. The more uniform slope of the channel would result in substantially improved sediment transport conditions than the current-day channel, which has a break in the channel slope at the crossing that causes persistent sediment aggradation.

3. The stream and road crossing along the historical alignment is at the lowest point across the alluvial fan, making it a more stable location to place a road-stream crossing.
4. The lower elevation of the channel at the historical crossing would require substantially less roadway improvements associated with a replacement crossing than replacing the crossing over the current-day alignment.

Re-occupation of the historical alignment of Hotelling Gulch also has some drawbacks. It would be necessary to restore approximately 550 feet of stream channel, rather than the approximately 150 feet recommended for a crossing replace along the current-day alignment. Additionally, construction access to the mouth of the historical alignment would necessitate removal of several large alder trees and disturbance to a mature riparian area. Though the channel avulsion potential at Cecilville Road would be reduced with re-occupation of the historical channel, there is still a risk of channel avulsion in the upper portion of the alluvial fan, as evidenced from the past.

Next Steps

Because of the potential benefits of re-occupying the historical alignment of Hotelling Gulch, MLA recommends that additional geologic and geomorphic investigations be performed at the historical mouth of Hotelling Gulch to identify the depth of bedrock under the stream channel. If additional field investigations identify that the bedrock elevation is substantially lower than currently mapped, and construction of a channel with a profile similar to that shown in Figure 8 is deemed feasible, MLA recommends that the PWA Alternative IIb be considered for the crossing replacement and channel restoration of Hotelling Gulch. Alignment IIb more closely follows the slope of the alluvial fan than Alignment IIa.

In the event that bedrock is found to be situated such that regrading the mouth of the historical channel is infeasible/undesirable, road-crossing improvements on Cecilville Road should focus on roadway and geomorphic stability rather than fish passage. Based on the PWA (2010) report and field observations by MLA engineers, we would recommend relocating the Hotelling Gulch to its historic alignment and moving the road-crossing to the western location.

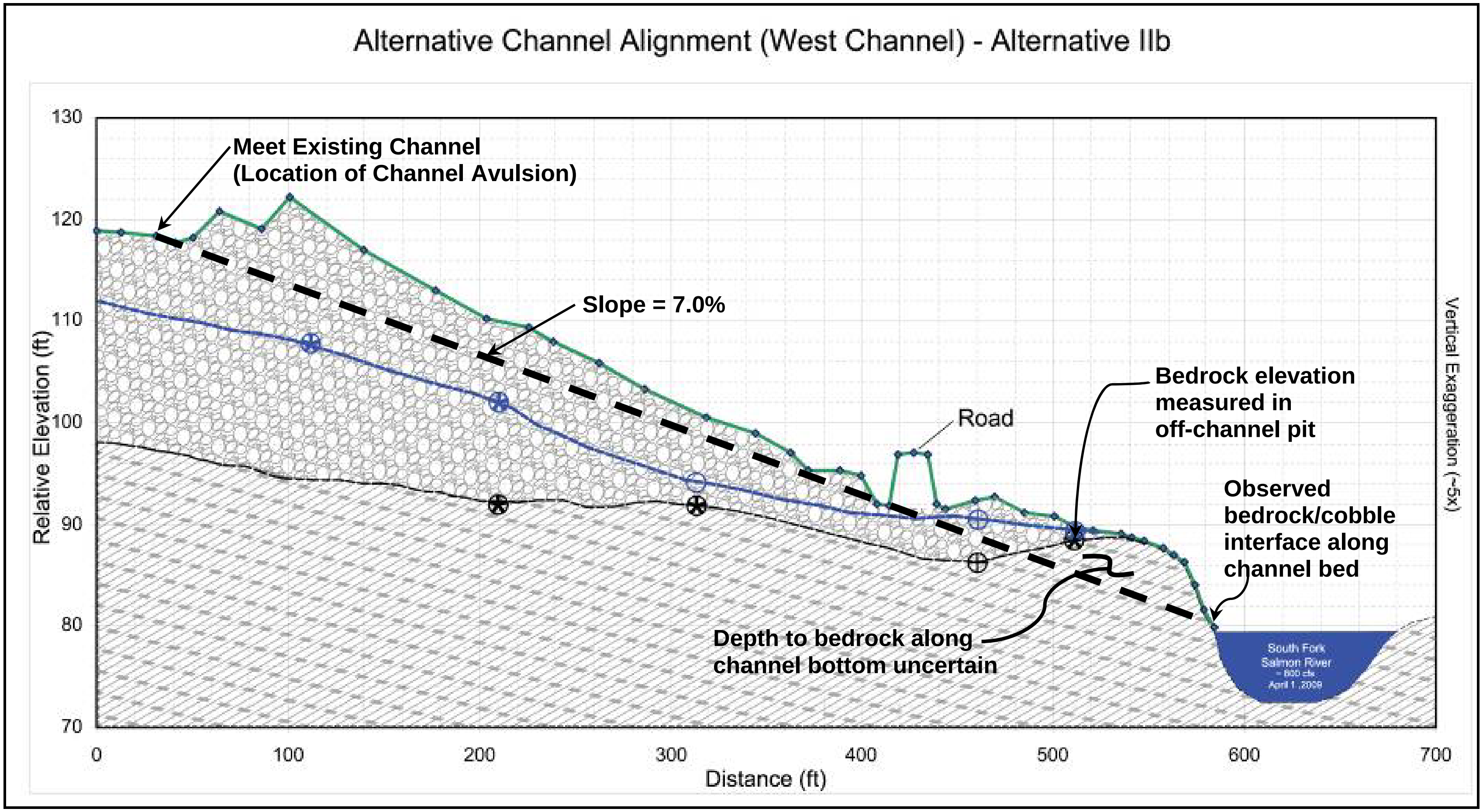

Figure 8. Profile along the historical mouth showing groundwater (blue) and bedrock elevations mapped by PWA (2010). September 2011 observations of a cobble bedded channel near the confluence suggest bedrock may be deeper than shown. Drawing a constant-slope line from the bedrock/cobble interface to the current-day channel results in a slope of 7.0% for approximately 550 feet (Profile adapted from PWA, 2010).

References

ACOE. 2010. *HEC-RAS River Analysis System Version 4.1.0*. U.S. Army Corps of Engineers Hydrologic Engineering Center. Davis, California.

Beamish, F. W. H. 1978. Swimming Capacity. Pages 101-187 in Fish Physiology, volume 7. Academic Press Inc.

CDFG. 2002. Culvert criteria for fish passage. Appendix A in California Salmonid Stream Habitat Restoration Manual 3rd edition. California Department of Fish and Game.

Carlander, K. 1969. Handbook of Freshwater Fishery Biology. Volume 1. Iowa State University Press, Ames, Iowa.

Carlander, K.D. 1977. Handbook of Freshwater Fishery Biology. Vol. 2. Iowa State University Press, Ames, Iowa.

Hunter, L. and L. Mayor. 1986. Analysis of fish swimming performance data. North-South Consultants and City Lights Engineering Consultants. Prepared for the Department of Fisheries and Oceans and the Alberta Department of Transportation. Winnepeg, Manitoba.

NOAA. 2001. Guidelines for salmonid passage at stream crossings. NOAA Fisheries, NMFS SW Region.

Pacific Watershed Associates. 2010. Hotelling Gulch Stream Crossing and Channel Realignment Feasibility Study. Prepared for Salmon River Restoration Council and U.S. Department of the Interior, Bureau of Reclamation.

PRISM. 2007. Parameter-elevation Regressions on Independent Slopes Model. Oregon State University.

Ross Taylor and Associates, 2002, Final report: Siskiyou County culvert inventory and fish passage evaluation. Report for the California Department of Fish and Game.

Siskiyou County Department of Public Works. 1974. Siskiyou County Drainage Manual.

Soto, Toz Personal Communication 2011, 2012, fisheries biologist with the Karuk Tribe Department of Natural Resources Fisheries Department

USGS. 1982. Guidelines for determining flood flow frequency. Bulletin #17B of the Hydrology Subcommittee. Interagency Advisory Committee on Water Data, US Dept. of Interior, Geological Survey, Virginia.

Attachments

Attachment 1: Hydrologic Analysis

Attachment 2: HEC-RAS Results for SF Salmon River

Attachment 3: HEC-RAS Results for Current-Day Mouth of Hotelling Gulch

Attachment 4: HEC-RAS Results for Historical Mouth of Hotelling Gulch