SUPPLEMENTAL INFORMATION FOR FINAL LICENSE APPLICATION RESPONSES TO AGENCY COMMENTS

Lassen Lodge Hydroelectric Project
FERC No. 12496
South Fork Battle Creek
Tehama County, California

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Introduction

On April 21, 2014 Rugraw, LLC (Rugraw) submitted a Final License Application (FLA) to the Federal Energy Regulatory Commission (FERC) for the Lassen Lodge Project (Project) No. 12496 located on South Fork Battle Creek in Tehama County, California. Following a review period, several state and federal agencies provided comments on the FLA including California Department of Fish and Wildlife (CDFW) on June 20, 2014, the National Marine Fisheries Service (NMFS) on June 12, 2014, and the California State Water Resources Control Board (SWRCB) on June 19, 2014.

This Supplemental Information for the FLA has been prepared to address the comments provided by these agencies and provide additional information for the FERC to assess as they prepare a determination if additional studies or information will be needed to support the license application process. Copies of the agency comment letters are provided in Appendix A. Each letter contains a numbering identifier throughout that corresponds to a specific comment and has been used in each chapter below to cross reference the comment to specific responses.

1. FISH HABITAT, MIGRATION AND FISH CAPACITY MODELING

This section presents information to address agency comments on stream habitat, flows, fish, and ESA listed species in the project area.

This Section will address Agency Comments C-9, C-10, C-11, C-12, C-13, C-14, C-15, C-16, N-1, N-2, N-3, and N-4

The term "Project Reach" is used in reference to the stream reach for the water diversion point at RM 23.0 downstream to the powerhouse at RM 20.6. The term "Project Area" includes areas beyond the Project Reach that may be affected by the project.

Both California Department of Fish and Wildlife and the National Marine Fisheries Service have commented that they believe anadromous salmonids will enter and use the project reach from its lower limit (RM 20.6) up to Angel Falls (RM 23), after fish passage improvements are completed at PG&E dams as part of the Battle Creek Salmon and Steelhead Restoration Project. The uppermost of the PG&E dams on the South Fork is named "South Diversion Dam", and is located at RM 14.35, which is 6.25 river miles downstream of the point where all flows diverted by the LLHP will be returned to the stream and 4.55 river miles downstream from the large cold water spring inflows right at and just below Panther Grade. LLHP will be operated as run-of-the-river, possesses no water storage capacity, and will not alter flow at any time below the point of return flow through the powerhouse (RM 20.6).

Project History

The history of the Lassen Lodge Hydro Project (LLHP), and its multiple starts and stops, appears to have led agency reviewers to misunderstand whether their previous criticisms of project impacts are applicable to the revised plan now in process. In particular, their insistence that an appropriate bypass flow should be higher than has empirically determined to be optimal, appears to be linked to requirements that past proposals for projects under this license had been determined by fisheries agencies to require 20 cfs minimum bypass flow. The following summary of the past attempts to license the project describes changes to the project design, and how these changes will alter impacts and their mitigations that were described for past proposals.

Because all roads into the project reach below Angel Falls are accessed only through locked gates, and the lands are private, few people, including fish agency staff, have ever observed habitat within the project reach, and especially not over a range of flows. After exhaustive search, no evidence of measurements of stream habitat have been found in any agency documents for the part of the project reach below Angel Falls (RM 22.3) all the way down to the proposed powerhouse location (RM 20.6), so it appears that agency judgments of habitat capability in the reach may have been derived by assuming similarity to other portions of the

South Fork or to other areas Sierra streams that exhibit markedly better habitat than is found in the Project Reach.

The powerhouse in the first application for a FERC license was proposed to be well downstream of Panther Grade, and in fact, below the Ponderosa Way wooden bridge within the reach where holding and spawning of spring Chinook salmon had been observed in the past. A bypass flow of 20 cfs had already been requested by CDFG when the powerhouse was located in that productive reach, where low season flows substantially exceed those in the presently proposed Project Reach. As reported in Cramer and Ceder (2013), it was discovered in September of 2013 that 13 cfs of cold spring water enters the South Fork below the base of Panther Grade, and composes the majority of flow in the stream at that point during the low flow season. Thus, base flows above Panther Grade are substantially more limiting to fish production than below Panther Grade. In the proposal submitted by Rugraw/Polytech in 1992, the powerhouse was relocated on the South bank of the South Fork of Battle Creek immediately upstream of Panther grade. In letters dated December 1995 and January 1996, the CDFG and USFWS, respectively, affirmed their agreement that this move of the proposed powerhouse to just upstream of Panther Grade (1.7 miles below the present location) would reduce impacts on anadromous salmonids. In spite of the difference in natural flow above Panther Grade (likely not understood at that time), a 1993 letter from CDFG to proponents of the Lassen Lodge Hydro Project, CDFG noted that "*The preceding license required that 20 cfs or the natural flow, whichever is less, be continually released downstream past the project diversion. This mitigation feature should be included.*"

A subsequent plan developed after 2000 again modified the project plan to place the project yet further upstream near its present location 1.7 miles upstream from Panther Grade. The extreme drought continuing in 2014 has caused the entire streambed to go dry from above Angel Falls down to within a few 100 meters of the powerhouse where the first spring flow has been observed in August of 2014 as entering the channel as the only water in the channel at that point. No flow is coming over Angel Falls and the plunge pool at its base is completely dry. By mid August, residual water remained in only four pools between Angel Falls and the power house and they appeared stagnant with dead fish visible. This dry streambed revealed exactly where springs of water entered the channel, and there were none from Angel falls down to a few hundred meters above the proposed powerhouse. Flow has been measured at less than 1 cfs at the powerhouse and appears to accumulate another 1-2 cfs before reaching the top of Panther Grade. The springs below Panther Grade were measured in 2013 to add another 13 cfs. A study to specifically quantify the current "base flow" as defined herein is planned to take place this fall prior to the seasonal rains starting. This unfortunate drought circumstance provides a vivid demonstration that flows above the power house are dependent on surface runoff, and the volume of cool base flow sufficient to support anadromous fish populations emerges predominately between Panther Grade and Panther Creek, about 1.7 miles below the bottom of the project effected reach.

Prior info requests by CDFG now fulfilled

In past licensing efforts, the fisheries agencies have commented on the information they need to judge the project impacts. Although fisheries agencies have offered only criticism of the current application, the information that has been provided fulfills many of the requests from the past licensing efforts. For example, CDFG noted that because habitat conditions were variable within the project reach, they recommended habitat mapping and a sufficient range of study sites to represent the range of habitats. CDFG (2002) states,

> *"From preliminary information provided by the Applicant, we understand that important habitat features such as cold (and warm) water springs and spawning gravels have a "patchy' distribution within the Project. Given this physical habitat heterogeneity, we recommend aquatic habitat mapping throughout the entire Project to provide a basis for extrapolating site-specific impacts…. Given the diversity of habitat provided by South Pork Battle Creek, study sites will have to be selected carefully to accurately capture the range of potential Project impacts on both existing and reasonably foreseeable future aquatic communities."*

In the same letter, CDFG (2002) also notes that PHABSIM results are of uncertain accuracy, and therefore should be validated by fish sampling. CDFG (2002) states,

> *"As a general comment on traditional instream flow models, the resulting weighted usable area (WUA) curves provide only theoretically derived starting points. The Department recommends correlating such predictions of fish habitat utilization with actual field observations and literature findings. Given the limitations of model predictions, we recommend validation of any WUA curves proposed for use in the APEA through snorkeling surveys over a range of flows, a range of habitats (run, riffle, pool), and seasons. Of course, the current absence of anadrornaus species within the Project area will limit the range of fish suitability criteria which can be empirically validated at this time."*

In the present application, measurements have been provided of the length, width, depth, velocity and substrate for every channel unit in the project reach, and these measurements have been applied to a more data intensive simulation than previous PHABSIM studies from the studies completed in 2013. This fulfills the request for detailed habitat mapping. Further, the accuracy of this approach for predicting rearing capacity has been corroborated and published in the peer-reviewed literature (Cramer and Ackerman 2009). Fish sampling was done to confirm presence of rainbow trout areas the habitat was determined highly suitable. Although sampling permits were unable to be obtained (due to ESA concerns), snorkel studies of nine pools with maximum depth ≥1 m were done. Those snorkel studies confirmed that all contained good numbers of resident rainbow trout, as the Unit Characteristic Method (UCM) would have predicted (Sellheim and Cramer 2013; Table 10). Sellheim and Cramer (2013) present size distributions of the fish observed, and those distributions indicate that multiple age classes were present. Because these pools had depths of at least 1 m, the value beyond which the UMC scalar remains constant at its maximum, fish densities decrease at depths < 1 m could not be confirmed.

Key Habitat Elements

Opportunity for Reliable Access Above Panther Grade

The lower limit of the LLHP project reach is 1.7miles upstream of the formidable migration barrier of Panther Grade Falls at RM 18.9. As described, there are several substantial changes in stream conditions beginning at Panther Grade that alter the suitability of stream habitat above that point to support salmon and steelhead. Among these changes are a severe bottleneck to upstream access at Panther Grade, a sharp drop in summer low flows above the grade, and an increase in peak temperatures. This response will address the restriction of upstream access next, and later in this response the flow and temperature issues will be addressed.

Differences in professional opinion have been offered over the years as to the ability of fish to pass Panther Grade Falls. Salmon were historically observed above Inskip Dam (RM 8.02) and South Diversion Dam (RM 14.39) on South Fork Battle Creek. The farthest observation upstream ever documented is near Panther Creek, just downstream of Panther Grade Falls (RM 19.07) (Tehama County 1983 cited in TRPA 1991). The Battle Creek Salmon and Steelhead Restoration Plan project limit is the “natural barrier” on the South Fork at RM 18.90-Panther Grade Falls.

Panther Grade was determined to be impassable by Tom Payne (1983), who wrote in a letter to A.E.Naylor, CDFG Regional Manager, Aug 30, 1983. “*A ten-foot-high falls, located about 1/4 mile upstream of the Ponderosa Way road crossing and the Battle Creek Rod and Gun Club was identified as a complete blockage to anadromous fish upstream migration*.” However, over a decade later, CDFG issued an opinion that Panther Grade may be passable during extreme flow events. The opinion was based on visual observations by agency personnel; however, no quantification was performed to support this conclusion. CDFG issued the following statement in 2001, “*The Department does not consider Panther Grade to be a total barrier to fish* (see April 10 and May 21, 2001, comment letters).” Subsequently, during the period of ESA listings and recovery planning, the upper limits of critical habitat for ESA listed steelhead and spring run Chinook were designated to extend above Panther Grade into the Project Reach.

However, in 2012 a quantitative study of potential for fish at Panther Grade was completed by Douglas Parkinson and Associates (DPA 2012). Passage conditions were assessed based on the jump height required and the depth of the jump pool at the base of each of the four possible passage routes over the falls. The measurements were completed at three flows: 180 cfs (May 5, 2011), 100 cfs (May 11, 2012), and 24 cfs (November 22, 2011). Jump heights and pool depths confirmed that the falls were impassable beyond question at all three flows surveyed. At each flow, the depths of the jump pools were substantially less than necessary for fish to jump the height over the falls. This remained true even if a pool depth needed was reduced from 1.5 times to 1.25 times the jump height of the falls. The full reports of Douglas Parkinson and Associates (2012a and 2012b) have been included as Appendices D-1 and D-2 respectively. The fraction of the required jump that could be achieved, given jump pool depth, was greater at 100 and 180 cfs than at 24 cfs, but decreases slightly as flow increased from 100 to 180 cfs. At 24cfs, the fraction of jump height achieved through the best of four routes over the falls remained at 0.0 (jump height was least at 4.5 ft), because the falls spilled on top of rocks (no pool depth). At 100 cfs, the jump pool depths increased up to 3 ft in the best route, and provided the ability for jumps up to only 34% of the 7 ft height needed. At 180 cfs, the jump pool depths increased up to 3.8 ft in the best route, but only provided the ability for jumps up to 28% of the 11 ft height needed. The 180 cfs exceeds the highest mean monthly flow of 146 cfs for May, but even at that flow, there is no indication that the opportunity for passage would improve with higher flow (there was no improvement between 100 and 180 cfs). Thus, standard measurements employed in fish passage assessments have now determined that the barrier is impassable across a wide range of flows.

Although it is conceivable that very large boulders can move at extreme flows, no change was apparent at the barrier following the extreme flood of 1997. Douglas Parkinson and Associates (2012) reports, "*Many visits to the Panther Grade barrier site since the mid-1990's have not been able to detect any visible physical evidence of changes that would affect the current status of the barrier*." These visits included observations both before and after the 1997 peak flow event.

The USFWS (Earley 2014) has also begun a recent effort to evaluate the fish passage barriers in Battle Creek that previously identified in the study by Tom Payne (TRPA 1998). That study is employing similar quantitative methods as those used by DPA (2012). Earley (2014) is using assumptions of swimming and jumping capabilities referenced from Powers and Osborn (1985), which were also used in both TRPA (1991; 1998) and Newton and Brown (2004). Additionally, it was assumed that for a successful jump, the jump pool depth needed to be ≥ 1.25 times the vertical height or > 8 ft. (Earley cites Reiser and Peacock 1985; cited in Newton and Brown 2004). The USFWS has used redd counts, carcass counts and juvenile fish sampling above the putative barriers to confirm that they restricting passage of anadromous fish.

Earley (2014) reports on the completion of a pilot study to assess barriers near Eagle Canyon Dam on North Fork Battle Creek. The purpose of this pilot study was to determine the feasibility of barrier assessments and to refine the methodologies for measuring the barriers. Earley (2014) measured two Barriers previously reported by TRPA (1998), but measured the barriers at slightly different flows than TRPA. In both cases, the assessments of passability reached similar conclusions to those of TRPA concerning flows at which passage would become possible or not possible. This comparison, suggests that these methods, which were also employed by DPA (2012) at Panther Grade Falls, are reliable and repeatable.

Drought resistant springs

Plans for recovering ESA-listed runs of winter-run and spring-run Chinook in the Sacramento Basin have emphasized that the life history of these fish, with extended adult holding periods in fresh water, historically relied on consistent sources of cold water that were supplied by springs. Battle Creek is cited as a stream with abundant spring inflows that are capable of supporting winter and spring run Chinook. For example , the final EIS/EIR for the Battle Creek Salmon and Steelhead Restoration Plan (Jones and Stokes 2005) states,

> "*The timely restoration of a drought-resistant, spring-fed system like Battle Creek is especially important to species such as winter-run and spring-run Chinook salmon and steelhead, which are dependent on cool water stream habitats. Winter-run Chinook salmon is actually obligated to habitats like Battle Creek that have reaches kept constantly cool year-round by springs."…" Because it is inevitable that serious drought conditions will again affect Shasta Lake, it is necessary to have drought resistant refugia available in the upper Sacramento River system for populations sensitive to drought conditions like winter-run and spring-run Chinook salmon.*"

This same theme is echoed in the Fish and Wildlife Coordination Act evaluation prepared by the USFWS (2005): **"***Spring water releases on Battle Creek could provide drought resistant refugia and spread the risk of reproductive failures of the Sacramento River winter-run population.*" As described by Cramer and Ceder (2013) and further reported here, it has recently been learned that cold spring inflows and the drought-resistant refugia they supply are absent in the Project Reach, but are present at Panther Grade and below. Thus, the Battle Creek Salmon and Steelhead Restoration Project - which involved all fisheries agencies and many interest groups - identified a key habitat feature that spring and winter run Chinook need, and it has now been determined unequivocally that this feature is absent in the South Fork Battle Creek above Panther Grade.

There have been some doubts expressed prior to the recent field studies, about the quality of habitat in the South Fork. Jones and Stokes (2005) states, "*South Fork Battle Creek is considered less desirable during drought to winter-run and spring-run Chinook salmon that are natal to the North Fork. North Fork Battle Creek has higher resistance to drought conditions, and it may be important to maintain the fidelity of the fish natal to this fork to ensure survival of the population during adverse conditions affecting streams elsewhere in the Sacramento River drainage."*

The US Fish and Wildlife Service (Newton and Brown 2003) surveyed the South Fork to Panther Grade between July 11 and October 10, 2001, another drought year. They reported that flows in the reach below Panther Grade were 12 cfs. This is nearly equal to the amount of spring inflow that enters near Panther Grade, and confirms that inflow from those springs in critical to suitability of the stream for fish life in low water years. This drought resistant supply of water is not present in the project reach, and this year the stream bed went completely dry, killing all fish in the reach that did not migrate down below this reach before it dried up. There is no option to migrate up the reach due to the location of the undisputed absolute barrier Angel Falls located at RM 22.30 upstream.

Gradient and Spawning Gravels

Stream gradient is a key geomorphic feature that has strong influence on channel morphology, and thus on fish habitat. Many have made the mistake of assuming gradients in the project reach were similar to productive reaches in the Mt Lassen area, such as Deer and Mill Creek. However, the evidence shows that gradients in the project area of the South Fork are steeper than other stream reaches know to be productive for Chinook salmon. Gradients in the South Fork generally increase with distance upstream, and reach 4% above South Diversion Dam (Figure 1-1). Gradients average over 5% above Panther Creek and exceed 15% in the upper portion of the reach near Angel Falls (Sellheim and Cramer 2013). The correct comparison to Deer or Mill Creek should be from lower gradient reaches lower on the South Fork. Jones and Stokes (2005) make the appropriate comparison: "*Gradients upstream of Eagle Canyon Diversion Dam in North Fork Battle Creek and upstream of Inskip Diversion Dam in South Fork Battle Creek are similar to portions of Deer and Mill Creeks between 2,000 and 4,300 feet in elevation.*"

Comments by the fish agencies suggest that Chinook should spawn successfully in gravel patches associated with boulders, just like the Chinook do in Deer Creek. However, the watershed assessment for Deer Creek by Armentrout et al. (1998) suggests the important spawning areas in Deer Creek are not similar to the project reach. Armentrout et al. (1998) report for Deer Creek, "*the lower gradient mainstem reaches appear to be very important in terms of fish habitat, as they support nearly all of the spawning and holding habitat for spring run salmon. They are more depositional in nature than the steeper mainstem reaches, and may be sensitive to sediment increases (resulting in pool filling and fines accumulation in pool tail substrate).*" Armentrout et al. (1998) goes on to specify, "*Main stem Mill Creek is predominantly bedrock and boulder dominated, with slopes near 2% for most of the reach within the Lassen Forest*." Thus, Chinook may spawn on gravel patches near boulders in Deer Creek; those reaches do not have the hydraulic forces of ≥ 5% gradient that will frequently mobilize gravel patches perched in front or behind boulders.

The work of Kondolf to survey spawning habitat in the South Fork of Battle Creek confirmed that within Battle Creek, just as elsewhere, concentration and types of gravel deposits are directly correlated to stream gradient.

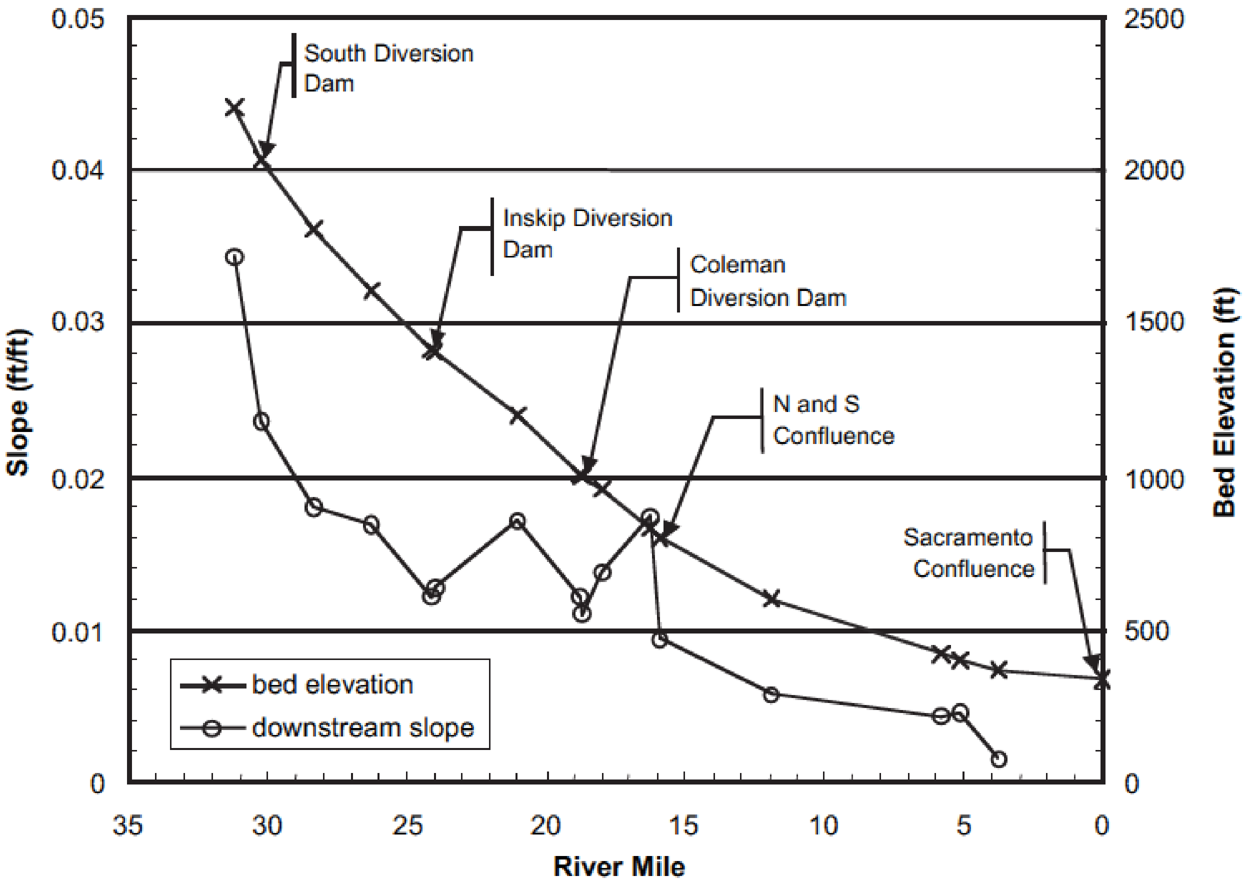

Figure 1-1 Elevation profile and gradient of South Fork Battle Creek from its confluence up to South Diversion Dam. From (Jones and Stokes 2005)

Tom Payne (1983) also reported from his PHABSIM study in the South Fork just above Panther Grade the reaches suitable for spawning were rare or absent, other than the one stretch he surveyed. Payne reports, "*One study reach containing five transects was located on the South Fork about 1/4 mile above the falls. This reach is believed to be the lowest gradient, most flow-sensitive area of the project bypass*. [Note: This study refers to the old project power house site downstream of Panther Grade which included this section of the stream at that time in the then effected project reach. This section of the South Fork of Battle Creek is about 1.5 RM below the current proposed power house location and, therefore, well below the current Project Reach.] *A second survey of several miles of the bypass by foot, and a third by helicopter, both along with your staff, did not reveal any more areas where transect placement was believed to be necessary*." In that case, he was searching for a suitable spawning area to measure, and he found none.

Kondolf and Katzel (1994) found from the study of spawning gravel in Battle Creek, that "*In general, lower gradient reaches tended to have higher gravel concentrations.*" Further,"*The higher gravel concentrations (Appendix E) tend to be associated with gradients lower than 2%, while reaches with* *higher gradients tend to have lower concentrations*." Finally, Kondolf and Katzel conclude, "*From our review of surveyed gradients, most spawning gravels were associated with local gradients of less than 1.5%. Gravels in higher gradient reaches were located in association with large boulders. Deposition upstream and downstream of these boulders probably occurs during the receding limb of the hydrograph; particles may be entrained at high flow by secondary circulations around boulders*." Thus, Kondolf and Katzel conclude that fish spawning in gravel patches around boulders in a 5% gradient are at high risk of having their redds scoured.

Findings in the Sacramento Basin that spawning gravels tend to be most abundant in channels with less than 3% gradient is also true for salmon streams elsewhere. Buffington et al. (2004) report, "*alluvial channels with slopes greater than 3% tend to be composed of boulder-sized substrate (step–pool and cascade morphologies) that are generally inhospitable for spawning salmonids. Although salmonids (particularly resident species) do spawn in gravel and cobble patches that occur in local backwater areas and low shear-stress environments in these steep channels* (Kondolf et al. 1991*), salmonids typically prefer lower gradient, plane-bed and pool–riffle channels* (Inoue et al. 1997; Montgomery et al. 1999)."

Kondolf and Katzel (1994) also completed a study of gravel scouring by placing painted tracer rocks in potential spawning gravels to observe flows at which they were mobilized (scoured). They found, "*The bed material in general, and the spawning gravels in particular, were clearly mobilized during the 1989 flows on Battle Creek. The peak flow occurred in March, and had a recurrence interval of 2.4 years as an annual maximum*." Further, at the sites the studied in the South Fork, they found, "*All tracers were mobilized and none recovered. Thus, flows in March 1989 were ssufficient in most instances to mobilize spawning gravels*."

The patchy and sparse distribution of gravel observed in the project reach of South Fork Battle Creek is similar to that which Kondolf et al. (1991) report for steep boulder-bed streams of the eastern Sierra Nevada. Kondolf et al. report that deposits of suitable spawning gravels were scarce, and were usually in sub-reaches with gradients of 4-11%. Just as in South Fork Battle Creek (Kondolf and Katzle 1994), the gravels occurred mostly as isolated pockets behind boulders or upstream of natural hydraulic controls. These are the same conditions as reported by Cramer and Sellheim (2013) for South Fork Battle Creek, where gradients generally averaged 5% but were as high as 27%. In demonstration of the importance of gradient to the abundance of gravels composing stream substrate, Kondolf et al. (1991) report that gravels were abundant in lower-gradient reaches, both upstream and downstream of the steep reaches they studied. They found that tracer gravels placed in nine gravel patches on four boulder-bed study streams were completely swept away following high flows in 1986, but none were swept away in 1987, a dryer year. They conclude, "*The contrasting experiences of 1986 (complete washout of gravels) and 1987 (stability) demonstrate that the study streams are periodically, but not annually, subject to major scour and channel modification*."

Montgomery et al. (1996) studied survival of eggs deposited by chum salmon in two different streams and found that bank-full flow events in these pool riffle streams (gradient < 1%) scoured the eggs from about 40% of redds. In sharp contrast, 100% of eggs were scoured during high flows in the high gradient streams studied by Kondolf et al (1991). The study of Kondolf et al. (1991) is particularly relevant the LLHP project reach, because their study is one of very few that addresses streams were in the Sierra Nevada with gradient and channel form similar to that in South Fork Battle Creek.

Frequent occurrences of scour can be tolerated better by the population dynamics of resident trout than steelhead. Resident trout have a substantially higher fraction of mature fish that spawn in multiple years before they die. Whereas a 100% scour event would eliminate an entire cohort of steelhead or salmon, a high fraction of resident parents would remain alive to contribute to multiple cohorts. With a high frequency of scour events in gravel pockets behind boulders, failed reproduction will periodically extend for successive years. Rearing capacity is often the limiting factor to population size in small streams, so the preceding and following cohorts of resident trout have the potential to benefit to some degree from the reduced completion following a failed cohort.

Holding pools

Spring and winter-run Chinook spend several months holding in freshwater before they spawn, and during this time they seek out pools, generally deeper than 6 ft, where they can hold undisturbed in cool water. Armentrout et al. (1998) reports that observations of adult Chinook holding in Mill Creek and Deer Creek indicate a preference for deeper pools. Limited studies in Mill Creek, Deer Creek and Antelope Creek (Sato and Moyle 1989; Grimes 1983 and Airola 1983) document holding adult salmon prefer pools with maximum depths 6.0 feet or greater. Using the 6 ft depth criterion to define holding pools, Newton and Brown (2003) found in the South Fork Battle Creek that the greatest number of holding were found in four reaches, which included the first two reaches continuing downstream 1.5 miles and the next 3.2 miles below Panther Grade, respectively. This is an important finding for understanding the potential to support steelhead and Chinook in the South Fork. Newton and Brown found that the best spawning opportunities were immediately downstream from Panther Grade, and Cramer and Sellheim (2013) found the drought resistant spring flows enter the South Fork near the base of Panther Grade. Further, Cramer and Sellheim found there were only three pools greater than 6ft deep in the project reach, and all of those have dried up in 2014. If spring Chinook would have been present in the reach, there would have been 100% mortality.

Gravel Patch Size for Spawning

Territory sizes for spawning salmonids were used as reported in the published literature of the modeling of spawning capacity for salmon and steelhead. As reported by Burner (1957) and confirmed by Keeley and Slaney, 20.7 m^2 for the area a Chinook salmon would defend was used. The fisheries agencies responded that Chinook will spawn in patch only large enough to fit a red. The possibility that individual pairs of spring Chinook would choose to spawn on smaller patches of gravel than the typical area they would defend (20.7m^2) in the presence of other spawners was examined. The area that spawning Chinook will defend was derived from measurements of Chinook redds in intensively spawned areas where the average size of Chinook was reported 80 cm (see **Error! Reference source not found.**), which is near the median length of spring-run Chinook in Battle Creek (Stafford and Newton 2010). A review of the published literature on habitat requirements for Chinook spawning suggests that Chinook avoid spawning on patches that support few spawners, and seek large patches that accommodate multiple spawning pairs. A relevant example comes from Spring Chinook redds counted by helicopter in the Middle Fork Basin Salmon River during 1995-2004, for which Isaak et al. (2007) analyzed the relationship of redd counts to on-the-ground measurements of stream habitat features. These counts in a wilderness area provide a unique opportunity to evaluate the consistency between years of where and in what habitat fish choose to spawn, especially given that redd counts spanned a wide range from only 10 redds up to 1,326, across years. Isaak and Thurow (2006) report, *"As abundances increased, fish expanded into portions of the stream network that had recently been unoccupied. Even at the highest escapements, however, distributions remained clustered, and a limited portion of the network contained the majority of redds."* They further report, "*Preferred areas typically consisted of low-gradient, pool–riffle channels that flowed through wide, alleviated valleys, a finding which others have documented for this species* (Vronskiy 1972; Montgomery et al. 1999; Burnett 2001*)."* Isaak and Thurow (2006) noted that few fish spawned in the main stem of the Middle Fork Salmon River where much of the channel flows through narrow, V-shaped valleys. Isaak et al. (2007) found that many suitable patches were rarely used, including those in the main stem. Like the Middle Fork Salmon River, the South Fork Battle Creek flows through a narrow, V-shaped valley.

Isaak et al. (2007) were struck by the strong and consistent tendency of Chinook to choose areas where they could spawn in aggregate together. Isaak et al. (2007) draws the following conclusions: "*Our results … indicate that 8–12 ha of spawning habitat are needed to ensure 50% occurrence probabilities when populations and connectivity levels are low… Our results suggest that altering habitat quality will not be a panacea and that spatial considerations will occasionally supersede the importance of local habitat conditions."* This evidence suggests that Chinook are unlikely to consistently spawn as solitary pairs on gravel patches smaller than they would defend in preferred spawning areas. More likely, spawners would vacate the area in search of more suitable spawning habitat, which eventually would lead them back downstream below Panther Grade where higher flows should provide better opportunities for spawning.

Fit of Stream Habitat in Project Area to Anadromous Runs

Extent of project area

Direct alteration of flow in Battle Creek will extend downstream only to the powerhouse location. Any alteration of stream temperature, if present at all, could extend down to Panther Grade. No effect on stream temperature is expected below Panther Grade, where the entry of cold spring water becomes the dominant portion of flow during summer and fall, and re-sets summer water temperatures. This was vividly demonstrated during the summer of 2014 when the entire stream channel went dry from above Angel Falls down to about 200 m above the Powerhouse location. All flow in the South Fork below that point to the inflow of Panther Creek was supplied by springs and the inflow locations and temperatures have been documented.

The assessment of habitat suitability for anadromous salmonids is limited to the stream above Panther Grade, because no detectable effect of the project on flow or temperature will be present below Panther Grade. It appears from comments by NMFS and CDFW that they did not comprehend the dramatic change in stream flow and temperature that sampling has revealed to occur right at and just below Panther Grade.

Three lines of evidence will be described that can be used to evaluate habitat suitability for anadromous salmonids:

(1) opportunity for reliable access to the area,

(2) holding habitat to support prespwaning survival

(3) temperature regime to support egg incubation.

Winter-run

The final EIS/EIR for the Battle Creek Salmon and Steelhead Restoration Plan (Jones and Stokes 2005) states, "*The timely restoration of a drought-resistant, spring-fed system like Battle Creek is especially important to species such as winter-run and spring-run Chinook salmon and steelhead, which are dependent on cool water stream habitats. Winter-run Chinook salmon is actually obligated to habitats like Battle Creek that have reaches kept constantly cool year-round by springs*."…" *Because it is inevitable that serious drought conditions will again affect Shasta Lake, it is necessary to have drought resistant refugia available in the upper Sacramento River system for populations sensitive to drought conditions like winter-run and spring-run Chinook salmon.*" As already discussed, there is no such refugia in the project reach area.

Further, the temperature and flow regimes are not appropriate to the timing of event in the winter-run life history. The Sacramento Winter and Spring-run Recovery Plan issued in 2014 points out, "*winter-run Chinook salmon are immature when upstream migration begins, and need to hold in suitable habitat for several months prior to spawning*." NMFS (2014) further states, "*Winter-*

run Chinook salmon are unique because they spawn during summer months when air temperatures usually approach their yearly maximum. As a result, winter-run Chinook salmon require stream reaches with cold water sources that will protect embryos and juveniles from the warm ambient conditions in summer". Such conditions are inconsistently available in the project reach.

Temperatures reach 60 about by late May in the project reach, and they can reach 70 by early July as they did in 2013 (Sellheim and Cramer 2013). Such temperatures in early summer would be lethal to winter-run eggs, which are usually deposited from late April through mid-August (Vogel and Marine 1991).

One of the primary causes of decline for winter-run Chinook in the Sacramento River was the released of water at temperatures from Shasta Dam that were too warm for egg incubation. As a result, new water temperature objectives for the Sacramento River were adopted by the State Water Resources Control Board, and the US Bureau of Reclamation installed the Shasta Temperature Control Device in order to meet those objectives (NMFS 2005). Jones and Stokes (2005) summarize, "*Based on a literature review, conditions supporting adult Chinook salmon migration are reported to deteriorate as temperature warms between 54ºF and 70ºF* (Hallock 1970 as cited in McCullough 1999). *For Chinook salmon eggs and larvae, survival during incubation is assumed to decline with warming temperature between 54ºF and 63ºF* (Myrick and Cech 2001; Seymour 1956). (Myrick and Cech 2001; Rich 1997)."

The Biological Opinion prepared by NMFS (2005) for ESA listed Winter-run Chinook, Spring-run Chinook, and Steelhead points out that spawning of winter-run Chinook in Battle Creek did not simply translate into a viable population of winter-run Chinook in Battle Creek. NMFS (2005) states, "*Monitoring information derived from the methods described above, have indicated that hatchery origin winter-run Chinook salmon from past artificial propagation efforts at the CNFH* (FWS 1995a, 1996) *have returned to Battle Creek…. Although extensive monitoring for both adult and juvenile winter-run Chinook salmon has been consistently conducted in Battle Creek since 2000, no evidence of adult spawning or natal juvenile rearing has been detected* (FWS, unpublished data). *Therefore, it is likely that there is no longer a viable, naturally-reproducing population of winter-run Chinook salmon in Battle Creek*." Thus, the presence of winter-run spawners in Battle Creek during 1995 and 1996 does not necessarily indicate the presence of a viable population in the area. The occasional observation of spawning fish does not validate that a stream is suitable to sustain a population of those fish. Only the consistent observations of spawners across years with return rates greater than one recruit per spawner confirms suitability to support that population.

Spring Run Chinook:

Several of the points made for winter run apply for spring run as well. CDFG (2002) reported, "*Given the headwater nature of the stream between Panther Grade and Angel Falls, this reach is largely steelhead trout habitat. However, it is reasonably foreseeable that spring-run chinook could also occur* *within the Project area based on observations of spring-run in headwaters of nearby streams (ie., Mill Creek)."* The important differences between reaches of Mill Creek that support spring-run and the conditions in the project reach have already been reviewed. Data does not support the contention that these reaches are comparable.

Since spring-run Chinook must hold in freshwater through the summer, any attempt to hold in the project reach would likely lead to frequent high levels of prespawning mortality. The USFWS (2005) noted, "*Release of cold spring water into the natural stream channels provides cool water habitat refugia for winter- and springrun Chinook salmon holding in the creek during spring and summer. Elevated summer water temperature in holding areas of Battle Creek causes mortality of spring-run chinook salmon* (USFWS 1996)". As described, reliable cool water exists below Panther Grade, but not in the project reach. High levels of prespawning mortality would be likely in low water years. Jones and Stokes (2005; Appendix R, p. R-12) report from an analysis of stream temperatures, "*South Fork Battle Creek temperatures at South Diversion Dam are always warmer than North Fork Battle Creek temperatures at Feeder Dam* (see Figures R-2 to R-11). *The Feeder Dam temperatures range from 55 to 58ºF during the warmest months* (July and August). *The South Diversion Dam temperatures are about 5ºF warmer than the Feeder Dam temperatures in these months. Temperatures are slightly cooler in June and September, with a difference of about 3ºF between dams.*" As already reviewed by Cramer and Ceder (2013), prespawning mortality has already been a serious problem for spring Chinook in the lower South Fork, and the problem has been related to low flow and warm temperatures. Conditions that caused their mortalities also occur during low flow years in the project reach.

Another key attribute of the project reach that does not fit the needs of spring Chinook is the low flows that occur in September and October when spring-run Chinook salmon spawn. Flows at that time are below 8 cfs in the project reach during most years, and reduce to no flow in some years.

Finally, analysis of spawning habitat indicates there was a paucity of gravel patches large enough to support spring Chinook (Cramer and Sellheim (2013). Under most conditions in the spawning season, only 2-3 redds could be supported.

Fall run Chinook

At present, the USFWS (2005, p. 39) reports, "*fall-run Chinook salmon were not modeled because current management objectives at CNFH include blocking fall-run at the hatchery's barrier weir.*",, "*Fall-run Chinook salmon have been intentionally restricted from entering the project area since 1989 because of potential problems that excessive numbers of fall-run pose to the small number of spring-run Chinook salmon* ." Further (USFWS 2005P 6-16) explains, "*Currently the Coleman National Fish Hatchery operates a barrier weir to congregate and collect brood stock for the hatchery. The upstream fish ladder at the barrier weir is closed from August 1 through early March. The barrier weir also serves purposes unrelated to fish propagation at Coleman National Fish Hatchery, including monitoring fish movement into the Battle Creek watershed, temporally and spatially separating spring-run and fall-run* *salmon to maintain or manipulate stock identity"*.

The threats that fall-run Chinook pose to the genetic integrity of spring-run Chinook salmon was identified as a serious concern to the species when it was listed in 1999 (63 FR 11482, March 9, 1998; Myers *et al*. 1998). The lack of reproductive isolation between spring and fall run following dam construction throughout the Central Valley was a key factor in this concern. Given that there suitable habitat for spring-run below Panther Grade, fall–run would have to pass through that area in order to enter the LLHP project reach. There is no known data to suggest that fall Chinook do not spawn upstream of spring Chinook in any known river system. Therefore, the conditions that cause spring run to spawn below Panther Grade would also cause fall-run to spawn below that point. Such conditions are believed to be temperature and the inability to pass upstream of Panther Grade. Stream temperatures in October have dropped substantially from their season high in South Fork Battle Creek, and would promote fall Chinook spawning far downstream from Panther Grade where the fish first begin to encounter temperatures in the mid 50's. The spatial segregation of spawning for Chinook races is a function of the difference in temperatures regimes during the period of spawning**.**

The timing of fall Chinook migration would require that they pass Panther Grade Falls during the lowest flows of the year at which the barrier has been found impassable (Douglas Parkinson and Associates 2012). If circumstances should arise in which some fall Chinook did pass Panther Grade, they would most likely find no gravel patches of sufficient area, depth and velocity for spawning.

Late-Fall run

The late fall run would find almost no suitable habitat for spawning, and their eggs would be subject to desiccation as flows drop rapidly in many years after May. There is no expectation in the Battle Creek Salmon and Steelhead Restoration Plan that late fall Chinook are suited to the project area.

Substantiate Reliability of Fish Capacity Modeling (CFS)

The comments by CDFG ask why the past PHABSIM results from Tom Payne (1983) were not used in the recommendation of minimum bypass flows. Tom Payne was asked how he would respond to that question, and responded with the email contained in Attachment 1. He lists several strong reasons that the 1983 is not**,** "*even remotely applicable to assessing the potential aquatic habitat impacts of the current South Fork Battle Creek project*." These begin with the fact the study site was more than 1.5 miles downstream of the present project, and the unique features of that site were washed out in the 1997 flood. Please read Tom Payne's email in Exhibit 1 - It speaks for itself.

The USFWS (2005; Table 4) reports that the recommended minimum instream flow below South Diversion Dam was established based on the PHABSIM analysis of Tom Payne (1991), and was 30 cfs during Dec-Apr and 20 cfs May-Nov. South Dam is at RM 14.4 and has watershed area of 66 square miles in contrast to the proposed power house at RM 20.6 with a watershed area of 33 square miles. Further, the key springs in the watershed enter below the project and above South Diversion Dam. Given these circumstances, a minimum flow of 20 cfs at South Dam should equate to something far less for the LLHP reach. The proposal that 13cfs be retained in the project reach seems generous in comparison to the recommendation for South Diversion Dam and the substantial year-round spring water and Panther Creek inflows that are now known to exist between the project reach and the South Diversion Dam.

The agency comments point out that the hydraulic geometry application to the UCM is not the traditional approach. The following comparison of PHABSIM and UCM approaches demonstrate why the UCM approach is appropriate for the purpose it was used in evaluating this proposed project. PHABSIM varies from the UCM in a number of ways (Table 1). One important distinction between the two methods is that PHABSIM assumes stream carrying capacity is a function of habitat preferences at the microhabitat scale (e.g. stream cross section), whereas the UCM assumes carrying capacity is a function of the suite of habitat choices available at the mesohabitat scale (i.e. pool, riffle, glide). The microhabitat preferences used in PHABSIM are based on daytime measures of fish location, and do not account for changes in habitat preference that occur between times of feeding and resting or between day and night. As far as anyone knows, the bias associated with daytime measures of habitat preferences in PHABSIM has not been specifically evaluated. In the UCM, because fish preference is measured at the habitat unit scale, it takes into account that fish preferences vary throughout the day within habitat units.

Despite their differences, the two models take into consideration similar attributes known to be important for fish production, including depth, cover, and substrate conditions. Although velocity is not specifically measured as part of the UCM, velocity is a function of the habitat unit type and therefore ambient velocity conditions are implicit in the model. Alkalinity, embeddedness, and turbidity are used in the UCM as survival modifiers, which increment or decrement the fish capacity values.

PHABSIM has a longer track record and has historically been widely recognized and utilized model for addressing instream flow issues, whereas the UCM is newer and has received less evaluation. Mesohabitat-scale capacity models such as UCM, however, are receiving more and more attention as agency managers come to realize the greater biological realism provided by such approaches. Mesohabitat-scale modeling tools were developed to overcome some of the shortcomings of PHABSIM. Although these newer tools are perhaps less familiar to the reviewing agencies, their results more closely align with the specific habitat preferences of fish.

Table 1. Matrix comparing attributes of PHABSIM and UCM.

Attribute		**PHABSIM**	**UCM**
Model type		Relative Capacity	Total Capacity
Measurement scale		Microhabitat (cross-section)	Mesohabitat (habitat unit)
Output		Weighted Useable Area	Numbers of parr/area
Can be used to assess habitat suitability at a range of flows?		Yes	Yes
Habitat features considered	Depth	Yes	Yes
	Velocity	Yes	Indirect via unit type
	Substrate	Yes	Yes
	Cover	Yes	Yes
	Alkalinity	No	Yes
	Embeddedness	No	Yes
	Turbidity	No	Yes
	Surface area	Yes	Yes
Life stages considered		Can be applied to any lifestage	Parr rearing, Also useful for spawning
Habitat preference assumption		Daytime velocity, depth, cover, & substrate conditions	Habitat unit type and condition

Compare Assumptions and Calculation Process PHABSIM vs. UCM

The agency comments state that the UCM is too simplistic, and a more traditional approach would be superior. How data and calculations proceed, in order to demonstrate the adequacy of the UCM approach was compared. First, note that the PHABSIM model does not reliably predict the complex depth and velocity patterns found in high gradient channels. Tom Payne commented in his criticism (Attachment 1) of his own 1986 PHABSIM analysis of the South Fork Battle Creek at Panther Grade that the site *"is now high gradient (about 6%) like the rest of the project area, flows on the opposite (northern) side of the canyon, and contains habitat features (e.g. stepped pools, cascades) that are not readily compatible with standard one-dimensional transect hydraulic modeling methods."* In this statement, Tom Payne is pointing out that much of the project reach with averages >5% gradient, is not conducive to the modeling approach of PHABSIM. Kondolf et al. (2000) affirm this conclusion about complex hydraulics, as they state,

> *"We also consider some implications of the limitations of hydraulic modeling for describing fish habitat and assessing instream flows. Highly accurate hydraulic modeling seems infeasible for streams with complex channel geometry, and in any event practical hydraulic modeling cannot resolve flow patterns at the short length scales at which fish often respond to the hydraulic environment. Information on depth, velocity, and substrate is important for assessing instream flows, but information from hydraulic models should be treated with great caution and is not a substitute for biological understanding."*

Although such hydraulics are not predicted well by PHABSIM, the project reach contains an abundance of pocket water created by boulder filled riffles, and the fish densities assigned in the UCM for such channel units are based on fish density data specifically for such boulder-filled riffles.

UCM Analysis of Sensitivity to Bank-full flow estimate

The comments by NMFS correctly noted that the estimate of bank-full flow provided had high uncertainty, and they reasoned this would render the entire method unreliable. In order to test that hypothesis, a sensitivity analysis was completed on how the carrying capacity is affected by the estimate flow at bank-full flow. The primary conclusions of the response of salmon carrying capacity to changes in flow, as presented by Cramer and Ceder (2013) remain unchanged across a range of bank-full flow values from 200 to 600 cfs. Those conclusions are: (1) rearing capacity for steelhead is governed by the seasonal low flow and is far more limiting to steelhead production than spawning, and (2) both spawning and rearing capacity for spring Chinook are strongly limited by low flows that occur when the project will not be operating. Figure 1-2 below, shows how the predicted rearing and spawning capacities change with differing assumptions of what the flow is from the active channel mark on the stream banks. Cramer and

Ceder (2013) assumed that flow was equivalent to the 2-year flood event estimated at 600 cfs. The simulations of carrying capacity at incremental increases in the assumed bank full-flow from 200 cfs to 600 cfs were re-run. The results show almost no discernible change for the estimated rearing capacity, which were estimated at the median value of 8 cfs for the lowest monthly flow of the year. The hydro project would not be operating during those low flow time periods. Spawning capacity for steelhead is the one outcome the shows modest response to the assumed value of bank-full flow. The assumed bank-full flow has no effect on predicted spawning capacity for steelhead for flow from 10 to 30 cfs, and the predictions diverge for flows from 25 to 50 cfs. At 50 cfs during spawning, the predicted spawning capacity for steelhead increases from about 21,000 parr equivalents up to about 24,000 parr equivalents as the value used for bank-full flow decreases from 600 cfs down to 200 cfs. For Chinook salmon, there is no meaningful change in rearing capacity across spawning flows from 10 to 50 cfs. As explained by Cramer and Ceder (2013) there are very few patches of gravel that meet the preferred areas used by a single pair of spawning Chinook.

Why are the simulations not more responsive to the assumed value of bank-full flow? First of all because the bank-full flow is so much higher than the low flow of the season, and that predictions at the low end of the flow scale are affected little by changes at the upper end. Second, the values measured during stream surveys for width and depth of each channel unit at the full active channel level do not change, so that leaves only the velocity to change in order to produce the active channel flow. A reduction in the magnitude of active channel flow will then reduce the calculated velocity at the active channel depth and width. At the same time, the channel width and depth must increase more rapidly per flow increase in order to reach the full active channel level if the flow at that level is assumed to be less than the original estimate of 600 cfs. Taken together, this means that if the active channel flow is less than originally assumed, the width and depth must go up faster, but the velocity must go up slower per increase in the simulated flow. It turns out for steelhead that the increased depth and width at 50 cfs, but at lesser velocities, is advantageous to steelhead spawning – it produces more gravel patches that satisfy the minimum depth for steelhead spawning. However, the rearing capacity is unchanged - it remains about one tenth of the capacity for spawning. More spawning without more rearing capacity does not benefit steelhead. It turns out for spring Chinook that the choice of flow for the bank-full channel level has almost no effect on carrying capacity.

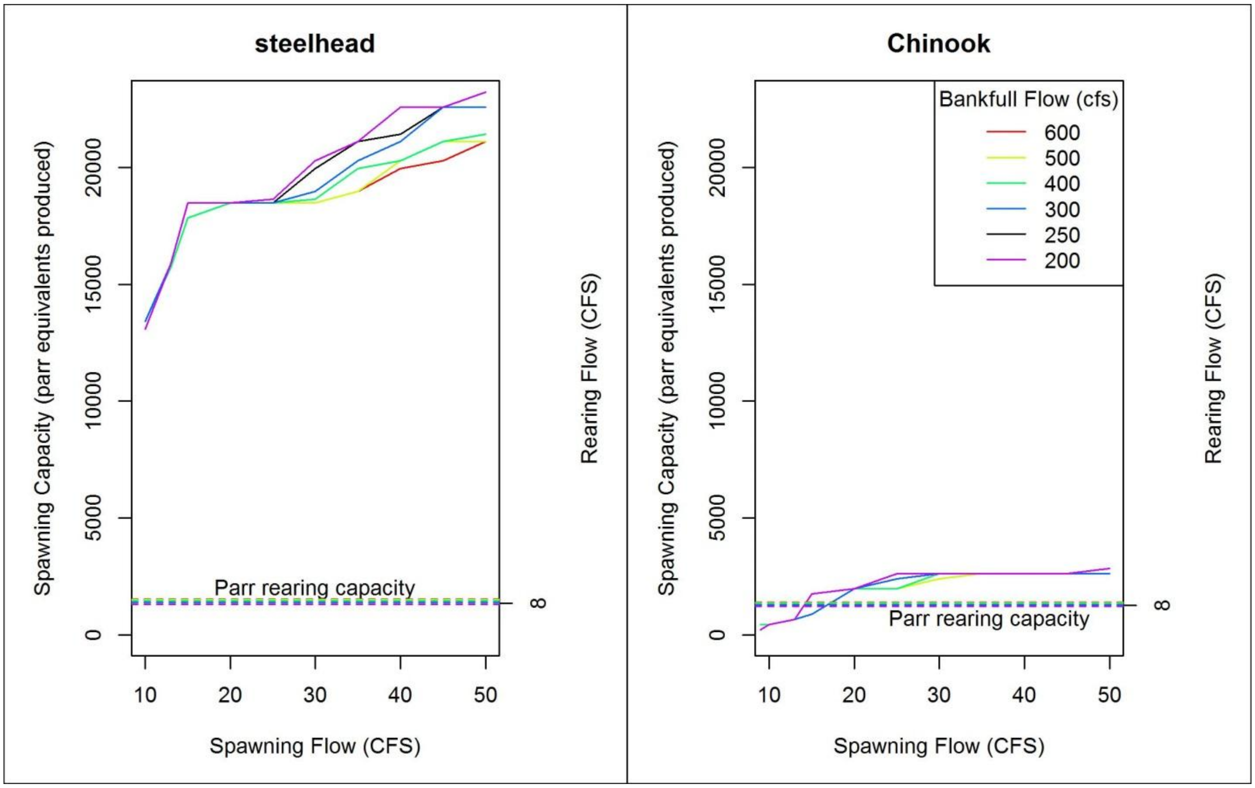

Figure 1-2. Differences in simulated carrying capacity given differing assumptions about the bank-full flow that corresponds to field measurements of channel width and heigth at bankful flow. A bank-full flow estimate of 600 cfs was used by Cramer and Ceder (2013).

Accuracy of Cross-section prediction vs. Channel Unit prediction

Fisheries agencies had participated in the selection of study transects for the PHABSIM analysis completed by Tom Payne (TRPA 1986), and following that study, the agencies had prescribed minimum instream flows of 20 cfs for the project with only that analysis available to assess the relationship of flow to suitable area for salmon and steelhead rearing and spawning. CDFW expressed in their recent comments to FERC that they questioned why that analysis was not used in the current license application. Thus, the fisheries agencies have indicated by their actions and comments that they were comfortable with the TRPA (1986) analysis. The comments by fish agencies on the present application have criticized the estimation of flow effects as too simplistic, and lacking in detailed accounting for the specific stream “cells” that fish might occupy. It appears that commenters misunderstood the methods used for the survey and for the use of data to calculate carrying capacity. In fact, the methods used provide far more detailed coverage of the study reach than in the TRPA (1986) analysis. For that reason, the detail of accounting in the present analysis with that in the PHABSIM analysis of TRPA were compared. Note that Tom Payne himself, who conducted the study, now states emphatically that the 1986 study was based on and inadequate level of sampling to be representative of the

Project Reach.

The TRPA analysis addressed a single study site over a total distance of 232 feet with five transects and three measurements across each transect, for a total of 15 point estimates of flow, depth and velocity. In contrast, the current estimate of suitable rearing habitat area was made by measuring width, depth, length and velocity in every one of the 51 channel units in the project reach. Widths and velocities were measured at three points across a representative cross section of every channel unit. This is a total 153 measurements of depth and velocity spaced throughout the 1.5 length of the project reach below Angel Falls, and is 10 times the number of measurements as used in the TRPA (1986) analysis. The three widths and velocities for each channel unit were averaged for each channel unit in the analysis, and a subsequent paragraph will describe why that averaging had negligible effect on the calculation of usable area. In addition to the measurements of rearing area, a full additional set of measurements were also made for every suitable patch of spawning gravel. In all, 54 suitable patches of gravel were measured, of which 33 were submerged in water. In those 33 patches, the length, width, and midpoint depth and velocity were measured. For those patches above the water, the height above the water surface, patch length, and patch width were measured.

In the expansion of these measurements to estimate carrying capacity, all measurements in each channel unit to compute the carrying capacity for each unit were used. Separate expansion factor for each unit is dependent on its dimensions. The value of calculating separate rates of response to flow for each channel unit can be seen by the wide range in dimensions between channel units. Active channel width ranged over 3-fold from 15 m to 45 m (Figure 1-3) while active channel height ranged almost 5-fold from 1 m to 5 m (Figure 1-4). Dimensions at the low-flow water level also varied widely, and combined variation at low flow and high flow resulted in important differences in the predicted rate that a change in flow would affect width, depth, and velocity in each channel unit. The same was true for the rate of change in depth and velocity for each patch of gravel (as determined by the channel unit they were in).

As an example for pools that contained spawnable gravel, a flow increase from 13 to 20 cfs produced a depth increase of 0.08 to 0.18 meters in, and a flow increase from 13 cfs up to 40 cfs increased those depths by 0.25 to 0.5 m. Depth was an important variable in determining the suitability of gravel patches for spawning by large-bodied steelhead and salmon. The range of depth increases was largely driven by the differences in width between channel units. Channel unit 19, which showed the greatest increase in depth per flow increase, had a channel width of only 4 m. In contrast, unit 13 had a channel width of 12 m and showed the least change in depth per flow increase. This large and intuitive difference illustrates the value of predicting the effect of flow changes for each channel unit according to their unique dimensions. In contrast to accounting for these unique features, PHABSIM uses representative cross sections and expands them to the whole reach, assuming those cross sections are representative unmeasured portions of the stream, which in reality, they are not.

The response of width, depth, and velocity to increasing levels of flow was also predicted for each channel unit. The rates of response averaged across all units of each channel unit type indicated there were modest differences in responses between types of channel units. In response to increasing flow, width increased fastest in riffles, but velocity in riffles changed slower than other unit types (Figure 18). Velocity changed fastest in cascade units and slowest in riffle units. Depth changed at similar rates.

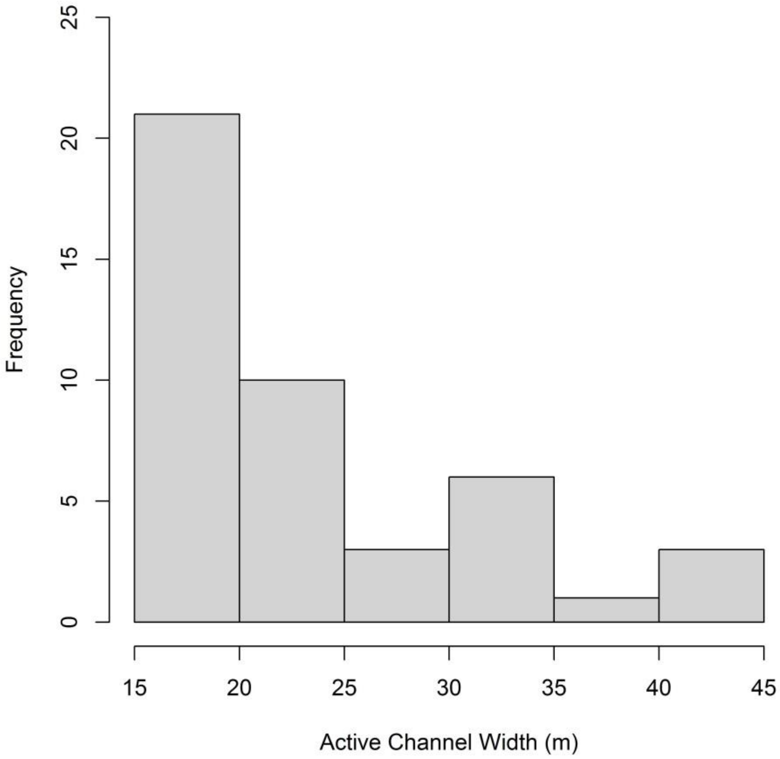

Figure 1-3. Frequency histogram of active channel width measured for each channel unit in the project reach below Angel Falls. Data from Sellheim and Cramer (2013).

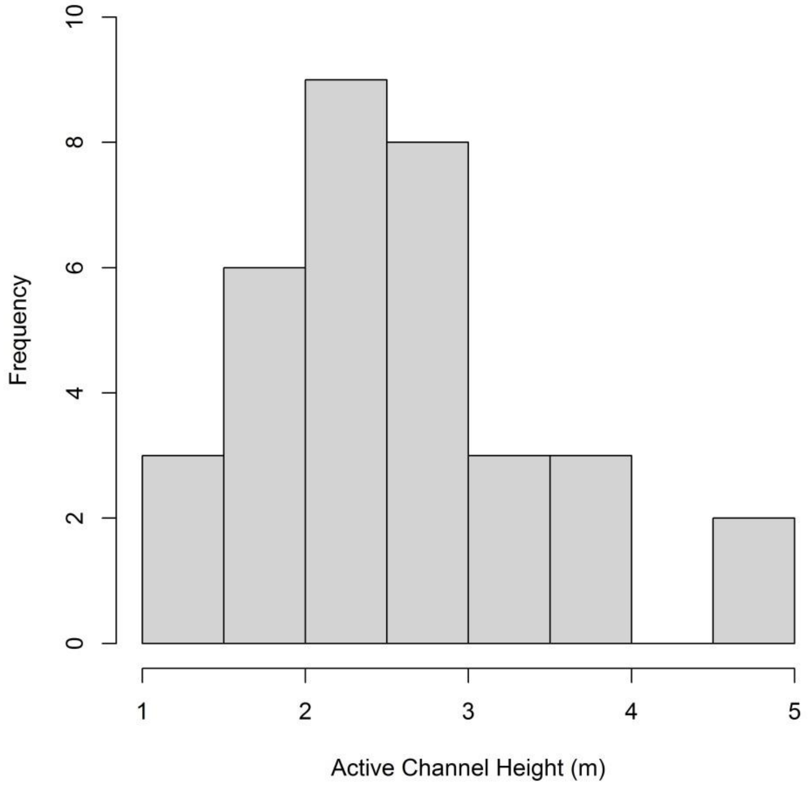

Figure 1-4. Frequency histogram of active channel height measured for each channel unit in the project reach below Angel Falls. Data from Sellheim and Cramer (2013).

It appears that agency reviewers may misunderstand how PHABSIM expands data from the sampled transects to predict total weighted usable area. Although people often refer to "cells" of habitat predicted by the PHABSIM calculations, the method does not predict cells of habitat. Rather, each point sample is converted to the percentage of all point measurement in the reach, and those percentages are multiplied by the total area in the sampled reach. Those same percentages are multiplied by the total area outside the sample reach to predict WUA in those outside areas that the reach is chosen to represent. Thus, percentages inside the study reach are assumed to equally available outside the reach in areas that represented by the study reach. In the case of the Unit Characteristic Method used in the present license application, these expansions were not made by reach or outside the reach, but rather within each and every channel unit by itself. Cramer and Ackerman (2009) review the available evidence that indicates salmonids tend to choose their location based on the suite of features available in a channel unit, and not by the features available at a specific point within a channel unit. Salmonids do exercise strong preference for depth, velocity and cover, but those preferences for an individual fish vary over the course of a 24-hour period depending on whether the fish is feeding, resting, or hiding. The consistent differences that are found in salmonid rearing densities between channel unit types substantiate that channel units are an effective basal strata for estimating rearing capacity in streams (Cramer and Ackerman 2009a and 2008b). The two initial publications of Cramer and Ackerman that describe the UCM and its application are included as Appendices B and C.

Commenters criticized the use of average depth and average velocity for each channel unit, and asserted that separate expansion for each point of measurement would yield a more reliable estimate of habitat suitable for rearing.

Comments by the National Marine Fisheries Service suggested that the UCM method would cause a bias to underestimate the optimum flow for rearing or spawning, but they did not explain how they reasoned such a bias would arise. The calculation procedures used have been thought carefully, where any uncertainty (random error) arises in steps of calculation is understood, but there has been no indication found that a clear bias is present. One possible source of bias might result from averaging the shallow and deep points across the channel, such that areas too shallow for use are credited as usable in the average value. The UCM assigns a linear increase in weighting of rearing density as depth increases from 0.1 m up 0.8m. Given a linear increase, then the average of any depth values within this range, when multiplied by the weight for that average, gives the identical answer to multiplying each depth by its individual weight. This equality would not be true for points outside the range of the linear function (depths <0.2 or > 0.8). Frequency histograms that include each of the three depths measured in each channel unit are shown for riffle and rapid type units in Figure 1-5. Riffles and rapids together composed 80% of surface area in the project reach. Figure 1-5 shows that only about 8% of depth measurements for riffles (56% of total area) and about 13% of those in rapids (26% of total area) fell outside the linear range. Thus, the potential for averaging to bias the depth was quite small. In pools, only the maximum depth was used, because the fish densities in pools observed in wadeable streams correlate better to maximum depth than to average depth, presumably due to the advantage of maximum depth as a form of cover (Cramer and Ackerman 2009).

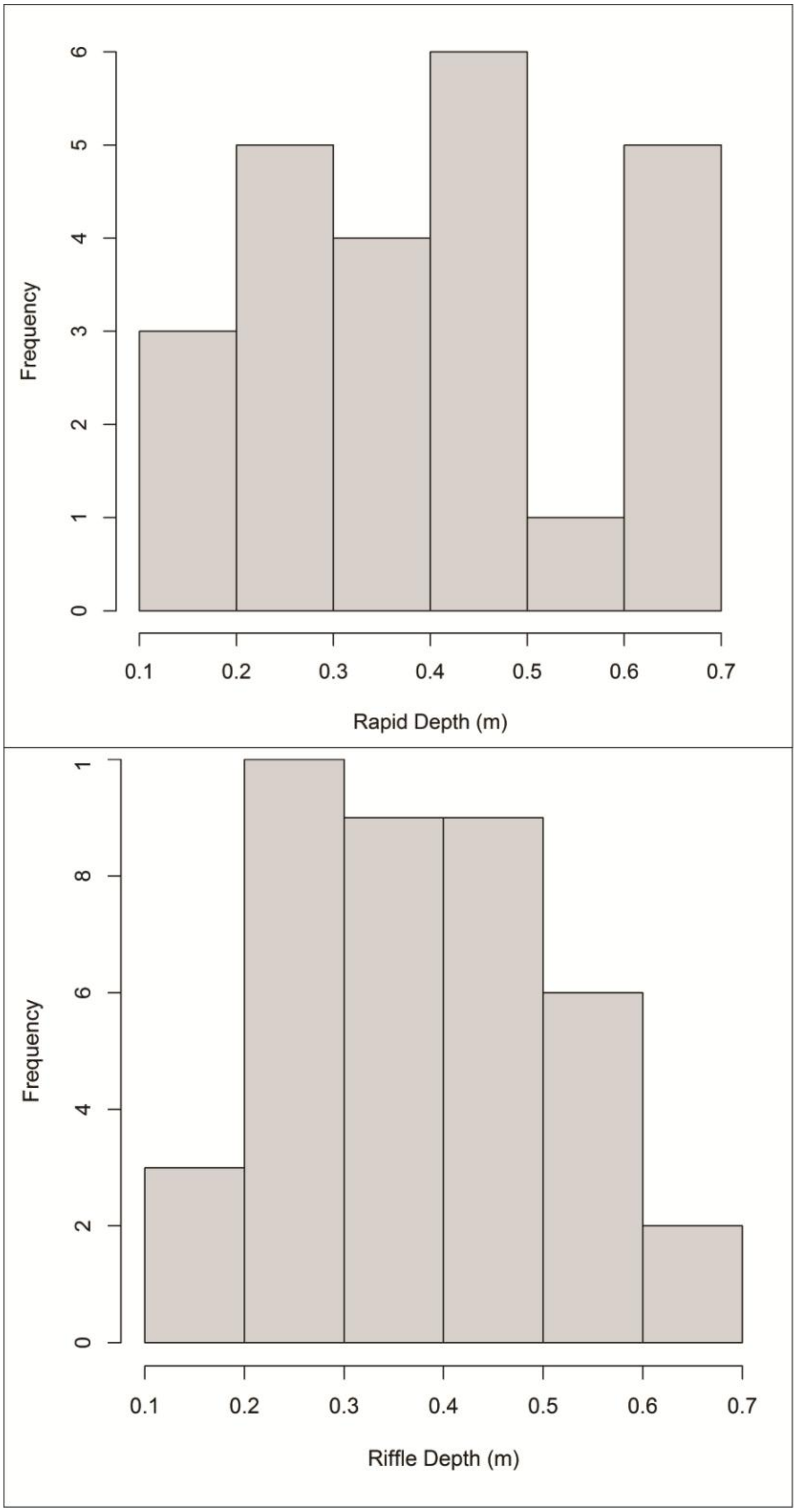

Figure 1-5. Frequency distribution of depths measured at three points at a representative line across each channel unit. Top graph is for units classified as rapids and bottom graph is for units classified as riffles. All point measurements are included. Data from Sellheim and Cramer 2013.

What about capacity downstream that excess juveniles could migrate to?

Agency reviewers asserted that excess spawning in the project area would still be add to overall production by supply juveniles to fill habitats downstream. Such could be the case if rearing capacity was unfilled downstream. However, the information already discussed shows that spawning capacity (and access to it) is far superior downstream of Panther Grade than it is above Panther Grade and then further up stream in the project reach. For that reason, the downstream reach is likely to have ample supply of juveniles and be even more rearing limited (with respect to the spawning capacity) than the LLHP Project Reach.

The NMFS Biological Opinion (NMFS 2005, Table 5) for the Battle Creek Restoration plan concluded there were presently 0.12 acres of suitable spawning gravel in the South Fork between Inskip and South Diversion Dams, and this would increase to 0.95 acres after restoration measures were implemented. An additional 3.7 acres of steelhead spawning area would be added in downstream reaches of the South Fork after restoration. Thus, the restoration of adult passage and instream flows in the South Fork is expected to increase spawning area for steelhead by over 35-fold within the South Fork downstream from South Diversion Dam. The estimated increase in rearing area between Inskip and South dams was proportionally less, with the present estimated rearing area of 4.26 acres increasing to 6.82 acres in the Inskip to South reach, and an overall increase under 3-fold in rearing.

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Exhibit 1: Email from Tom Payne regarding his PHABSIM analysis for a past version of the LLHP.

----- Forwarded Message -----

From: "Thomas Payne" <tpayne@normandeau.com>
To: "Steve Cramer" <steve@fishsciences.net>
Sent: Thursday, August 14, 2014 11:47:54 AM
Subject: RE: South Fork Battle Creek

Hi Steve,

There are several reasons why I would not consider the instream flow study we started back in 1983 to be even remotely applicable to assessing the potential aquatic habitat impacts of the current South Fork Battle Creek project. These include:

1. The study site location is outside the current project boundary. The map between pages 1 and 2 of our 1986 report (TRPA 1986) shows the study site to be approximately a quarter-mile upstream of the confluence between the South Fork and Panther Creek. This is about a mile downstream of the new proposed powerhouse location.

2. The study site is not representative of the current project bypass. When we scoped the original instream flow study project bypass reach by low-level helicopter, we selected the study site based on feasibility and access. As we said in the report *"... the selected study site was appropriate and was virtually the only place within the bypass where a study could be conducted.*" Further, "*The reach represented the lowest gradient, most flow-sensitive section of the project area and was not representative of the area as a whole*."

3. The study site used only five transects in a representative reach and does not meet current standards. The five transects selected within the study site were placed to represent all modelable pocket water and pool habitat over a total distance of 232 feet, separated by 35, 63, 35, and 99 feet, respectively. Within a few years of this study, the California Department of Fish and Game (CDFG) established a minimum standard of ten transects, which has increased more recently to 18-20 transects, and even higher in some cases.

4. The study site no longer exists with the same topography. I revisited the study site about six years ago, accompanied by Gary Smith of CDFG, and found that flood flows had completely altered the stream channel. We were able to locate the site only by finding an old bridge abutment landmark. Where once the river was lower gradient (in comparison to anywhere between Panther Creek and Angel Falls), it is now high gradient (about 6%) like the rest of the project area, flows on the opposite (northern) side of the canyon, and contains habitat features (e.g. stepped pools, cascades) that are not readily compatible with standard one-dimensional transect hydraulic modeling methods.

5. The study itself was judged inadequate for evaluating streamflow-dependent habitat relationships. In 2003, a new study plan was developed to "*validate and update the available models and tools*" (NSR 2003). Scoping meetings held with resource agencies for a revised project configuration identified several of the issues listed above, along with some additional concerns. This scoping process resulted in an agreement to conduct a completely new instream flow study with more study sites, more transects, additional fish species and macroinvertebrates, different calibration flows, and the use of habitat mapping to weight transects by habitat type.

In the context of all of these reasons, it would be highly unusual for anyone to consider relying on the data we collected and analyzed thirty years ago, and I would not support them doing so. I hope this brief description of issues is what you are looking for. Given that this summary is only a statement of facts as I understand them, I don’t believe it would be appropriate for me to invoice the project proponents for my time.

Regards,

Tom

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2. WATER TEMPERATURE AND TEMPERATURE MODELING

This Section addresses agency comments S-1, S-4, S-5, S-7, S-9, S-10, S-13, S-14, S-15, C-3, C-8, N-6

- Comment: S-1. Study Title Requested: Modeling to Predict the Effects of Flow Regime Changes On Water Temperatures
- *Response:* In coordination with the applicable agencies, flow and temperature modeling will be developed to support water temperature assessments in the project area. The modeling effort will provide a means to assess the effects of flow regime changes on water temperatures in the proposed bypass reach associated with project operations. The requested study will inform the SWRCB regarding potential Project impacts to beneficial uses and water quality objectives for the South Fork Battle Creek. The Applicant will consult with SWRCB, CDFW, and NMFS, regarding the study's methodology and objectives.

- Comment S-4: The FLA should include all raw data (e.g ., water temperature) in an appendix.

- *Response:* All available raw flow and water temperature data will be outlined in the modeling study documentation and made available in electronic form.

- Comment S-5: The State Water Board will require access to any modeling performed for the Project.

- *Response:* The developed model will be available to the State Water Board and other interested agencies.

- Comment S-7: Page E-18 of Exhibit E is missing Figure 1.2-1.

- *Response:* Correction will be made.

- Comment S-9: Figure 2 of Appendix A should include the measured maximum and minimum daily water temperatures. Additionally, the x-axis should be more detailed, specifying the months for each year.

- *Response:* Correction will be made.

- Comment S-10: Figure 3 of Appendix A is missing the information and a Key for Logger 6.

- *Response:* Correction will be made.

- Comment S-13: The Project proposes to operate approximately six to eight months of the year during the winter and spring. Page 18 of Appendix A states, "*The proposed bypass flow for the project is 13 cfs which is sufficient to maintain water quality and temperature* *conditions in the studies to ensure flow and water quality conditions would not be impaired substantially and that all existing beneficial uses are fully maintained. The proposed diversion of streamflows to generate power during high flow events and on the tails of these peaking events is not expected to substantially impair water quality conditions and associated beneficial uses due to the very high water quality characteristics of SF and that diversions would not occur during the low flow season."*

- *Response:* Comment noted. Implications for water quality will be addressed separately, below.
- Comment S-14: Exhibit E, page E-56, explains that water temperature would be monitored at six locations: 1) the diversion/intake structure; 2) the bridge at State Route 36; 3) within the bypass reach above the tailrace; 4) within the bypass reach below the tailrace; 5) within the tailrace; and 6) the wooden bridge at Ponderosa (downstream of Panther Grade). Water temperature should also be monitored above the bypass reach (above the diversion dam pool/above the influence of the Project) for comparison.
- *Response:* The Applicant will monitor water temperature above the bypass reach before coming into the project sphere of influence as requested.
- Comment S-15: The FLA explains qualitatively that the temperature of water that would flow through the penstock and powerhouse would not increase and therefore, when water returns to the South Fork Battle Creek the water temperature of the creek would not increase. The State Water Board has identified Battle Creek to the California State Legislature as a high priority tributary to the Sacramento River and Delta. The State Water Board will require the Applicant to explain further why temperature downstream will be unaffected by the proposed Project. If data exists, additional analysis is needed to verify that the Applicant's assumption is correct. If data does not exist, additional analysis and monitoring would be needed.
- *Response:* A temperature analysis will be included with the development of a temperature model. This tool will require a review of available information, including current monitoring efforts for flow and temperature.
- Comment C-3: Page A-8, Figure 2-1 and page 49, Figure 28. Figure 2-1 and 28 are the same figure displaying the mean year water temperature and median flow. The figures display the daily flow and projected turbine flow and the resulting bypass flows of the proposed 13 cubic feet per second (cfs) minimum instream flow (MIF) and any additional spill.

Mean daily water temperature data, collected at the powerhouse site from 2004-2006, is also displayed. While the figures give an overall picture of the hydrology and the effects of the maximum diversion of 95 cfs, the scale is too large to understand the true effects on flow in the bypass reach, especially in regards to flow in the spring and summer.

The figures are also misleading regarding the temperature data. The figures correctly display the limited two years of data collected at the powerhouse site for temperature, however, it does not display the same effect on temperatures in the bypass reach as the hydrology data does for the maximum 95 cfs diversion flow. The FLA does not include any temperature analysis resulting from Project operations.

- *Response:* Figures and other tabulated data will be more clearly presented. A temperature analysis will be included with the development of a temperature model.
- Comment Page E-17: Section 1.2.1.3. Daily water temperature data for south fork Battle Creek near the powerhouse were collected from November 2003 to December 2006 and plotted in Figure 1.2-1. Figure1.2-1 is missing from the FLA, but it is supposed to show maximum temperatures ranging from 64 to 65 degrees Fahrenheit (OF). Those temperatures may be protective for aquatic species, such as steelhead/trout (*Oncorhynchus mykiss*) and Pacific salmon (*0. tshawytscha*); however, as stated above, these temperatures do not represent the temperature affects that would be associated with Project operations. The FLA does not discuss how these temperatures would or would not be protective of various salmonid life stages that could be present during this time period. Since temperature modeling was not conducted and included in the FLA, the Department does not have the ability to determine what would be an appropriate and protective MIF in the bypass reach, and needs this information.
- *Response:* In cooperation with the Applicant, temperature modeling to support water temperature assessments in the project area will be developed. This modeling effort will provide a means to assess the effects of flow regime changes on water temperatures in the proposed bypass reach associated with project operations. The requested study will inform the State Water Board regarding potential Project impacts to beneficial uses and water quality objectives for the South Fork Battle Creek. The Applicant will consult with the State Water Board, California Department of Fish and Wildlife, National Marine Fisheries Service, and United States Fish and Wildlife Service regarding the study's methodology and objectives.
- Comment Page E-19: Figure 1.2-2. Figure 1.2-2 depicts eight water temperature probes at the proposed diversion site, the powerhouse, above and below the springs at Panther Grade, and downstream at south fork Battle Creek at the wooden bridge. The

temperature data does show baseline temperatures from the diversion to below the Project and gives a basic understanding of water temperature dynamics in the Project reach without the effects of operations. However, this data is limited because it was only collected from September to November (three months) for the 2013 water year. The data does not capture any spring or summer temperatures and misses the peak temperature periods. The Department understands that the Project could be off-line in some years during these periods, but basic baseline temperature data should have been collected over the past 20+ years since the original permit was filed.

- *Response:* Data in the project area will be investigated for the period of available data. The applicant will make a formal request with agencies to identify any available data.
- Comment Page E-21:
- Section 1.2.2.2. The Applicant states in the second to last sentence in the sections that, ''The Project is not expected to significantly change water temperature dynamics in the bypass reach or downstream of the powerhouse because it would maintain instream flows of 13 cfs and large cold springs enter the stream at and below Panther Grade below the Project reach. The FLA does not include any temperature modeling to substantiate this statement. FERC should require additional water temperature monitoring and modeling in order to determine what the impacts would be from the Project in the bypass reach on temperatures at a range of different MIF.
- *Response:* In cooperation with the Applicant, temperature modeling to support water temperature assessments in the project area will be developed. This modeling effort will provide a means to assess the effects of flow regime changes on water temperatures in the proposed bypass reach associated with project operations. The requested study will inform the State Water Board regarding potential Project impacts to beneficial uses and water quality objectives for the South Fork Battle Creek. The Applicant will consult with the State Water Board, California Department of Fish and Wildlife, National Marine Fisheries Service, and United States Fish and Wildlife Service regarding the study's methodology and objectives. Both project extent and periods of analysis will be developed in concurrence with agencies. Fisheries elements presented in this comment will be addressed elsewhere.
- Comment C-8: Page 13, Section 2.1.3 (see comments above). The FLA is insufficient in properly characterizing the baseline temperature or analysis regarding Project effects. FERC should require additional water temperature monitoring and modeling in order to determine what the impacts would be from the project in the bypass reach on temperatures at a range of different MIF.

- *Response:* In cooperation with the Applicant, temperature modeling to support water temperature assessments in the project area will be developed. The modeling effort will provide a means to assess the effects of flow regime changes on water temperatures in the proposed bypass reach associated with project operations. The requested study will inform the State Water Board regarding potential Project impacts to beneficial uses and water quality objectives for the South Fork Battle Creek. The Applicant will consult with the State Water Board, California Department of Fish and Wildlife, National Marine Fisheries Service, and United States Fish and Wildlife Service regarding the study's methodology and objectives. Fisheries elements presented in this comment will be addressed elsewhere.

- Comment N-6: The FLA is significantly lacking in its characterization of the baseline water temperatures and the Project's potential impacts to water temperature - a primary component of anadromous fish habitat for multiple life stages.

- *Response:* Comment noted.

- Comment N-6 (cont.): The FLA provides a graphical plot of three years (November 2003 to November 2006) of historical water temperature data near the proposed powerhouse location (Figure 2 of Appendix A to Exhibit E). However, the plot is so coarse (especially the x-axis or dates), it is impossible to discern in which months particular water temperatures are occurring. For example, it is not possible to determine what the water temperatures are in June vs. July (the approximate divide between diversion and non-diversion periods).

- *Response:* Plot will be clarified and other plots will be presented in a clear fashion.

- Comment N-6 (cont.): Furthermore, Figure 2 in Appendix A only plots daily average water temperature and does not evaluate the daily maximum water temperature. No additional tabular or written analysis is provided of either daily average or daily maximum water temperatures that could at least characterize temperatures by weekly or monthly time periods.

- *Response:* Additional presentation of daily maximum water temperature will be included in future documents.

- Comment N-6 (cont.): Figure 3 in Appendix A to Exhibit E depicts detailed water temperature information at multiple locations from September to December 2013. While the water temperature monitoring approach depicted in Figure 3 does have some utility in understanding water temperature dynamics in the proposed Project reach, the data in Figure 3 are severely limited by covering such a short time period (3 months) and does not capture any of the summer time or peak temperatures periods. Figure 3 does illustrate that the diurnal water temperature fluctuation near the proposed diversion site (logger 1) can be as high as 8 degrees F in September, which further illustrates the need to analyze water temperature data on a daily maximum basis in addition to daily average temperatures.

- *Response:* Additional data is being collected at this time at multiple locations in the project area to augment existing data. This monitoring is coupled with stage and flow monitoring.

- Comment N-6 (cont.): NMFS believes in order to adequately characterize the baseline conditions, FERC should order additional water temperature monitoring (in an approach similar to that depicted in Figure 3 of Appendix A) that covers the summer months and FERC should also request additional analysis of all available (existing plus future monitoring data) water temperature data (e.g. exceedance plots by month of daily average and maximum temperatures). The Environmental Report states that "the Project should have little effect on stream temperature" (pg. E-149). However, NMFS could not identify any modeling or analysis within the FLA that would appear to substantiate this conclusion and the statement appears to be based on professional opinions regarding the reported typical cessation of diversion in early July once a minimum inflow of 13 cfs to the Project is reached. As described above, it appears the Project would typically divert water during most of July and into August. The Project is proposing to significantly reduce the monthly median flow (Table I Appendix A to Exhibit E) in multiple months that can potentially have warm water temperatures, including April (an 88% reduction from 107 cfs to 13 cfs), May (a 74% reduction from 129 cfs to 34 cfs), and June (an 81% reduction from 69 cfs to 13 cfs). In order to evaluate the effects to stream temperatures from this significant level of flow reduction, an analytical approach must be developed - in all likelihood a water temperature model is necessary. The Project's effects to stream temperatures should be quantitatively evaluated over a range of climatic and water year types (e.g., wet, normal, and critical years). Furthermore, the changes in water temperature to water diverted through the Project works and its subsequent return to the stream channel should also be quantitatively evaluated. While the Applicant noted that the water in the pipe should remain cool because the pipe is buried, the cumulative effect to water temperature downstream of the Project is not known because the remaining water in the bypass reach could significantly heat up due to its reduced thermal mass. Without a quantitative analysis of how much warming will occur in the bypass reach with the significantly reduced instream flow, it is not possible to assess whether that warmer water in the bypass reach will alter or negate the cooling effects of the natural spring inflows near Panther Grade and, thus, affect in-channel water temperatures downstream of the Project. Unfortunately, without the understanding that a water temperature model could provide, potential habitat alterations remain unknown during the holding, spawning, and rearing seasons tor all types of anadromous fish that would be able to reach areas downstream of the Project and within the bypass reach as well. The FLA's simplistic mitigation of not operating during certain low flow periods (which appears to reliably occur only in September and October, based on Hydmet's (2012) Flow Duration Report) does not address potential water temperature changes during other possible important anadromous fish lifestage seasons (migration, holding, spawning, and rearing). At any time during the year, the relatively warmer water in the bypass reach could cause the net downstream water temperatures to be outside the preferred water temperature tolerance of an anadromous fish's life stage at that particular time of year. Thus, NMFS believes that a more robust amount of water temperature data is needed to assess baseline conditions and provide input to develop a water temperature model that should be applied to a hydrologic record of substantial length that covers a variety of water year types. Water temperature modeling would then be able to inform potential Project operations that would be truly protective of all anadromous fish resources.

- *Response:* In cooperation with the Applicant, a flow and temperature modeling to support water temperature assessments in the project area. The modeling effort will provide a means to assess the effects of flow regime changes on water temperatures in the proposed bypass reach associated with project operations. The requested study will inform the State Water Board regarding potential Project impacts to beneficial uses and water quality objectives for the South Fork Battle Creek. The Applicant will consult with the State Water Board, California Department of Fish and Wildlife, National Marine Fisheries Service, and United States Fish and Wildlife Service regarding the study's methodology and objectives. Both project extent and periods of analysis will be developed in concurrence with agencies. Fisheries elements presented in this comment will be addressed elsewhere.

The following Stream Monitoring Stations have been established in the summer of 2014 as noted:

STREAM MONITORING STATIONS

Purpose: To monitor and record, during this low-flow period, the stream flow, water and air temperatures, and accretion (inflow) that may occur above, below, and within the project bypass reach, from the project intake to the powerhouse, the gauging site approximately 150 feet downstream of the Ponderosa Way bridge, and the water and air temperatures in the Upper South Fork of Battle Creek canyon approximately 1/8 of a mile downstream of Battle Creek Meadows.

Station Descriptions: (See Also Appendix E for topo map of station locations)

1. **Below Mineral Bridge Temperature Station (RM 24.72):** This station has data loggers continually recording the water temperature of the stream and ambient air temperature at a point where the stream exits Battle Creek Meadows.
2. **Intake-Temperature Station (RM 22.65):** This station has data loggers continually recording the water temperature of the stream and ambient air temperature at a point approximately 150 feet upstream of the proposed project intake.
3. **Above Old Hwy. 36 Bridge - Temperature/Flow Station (RM 22.50):** This station has data loggers continually recording the water flow and temperature of the stream and ambient air temperature located at the Above-Bridge Gauging site.
4. **Above P.H. Spring Temperature Station (21.00):** This station has data loggers continually recording the water temperature of the stream and the ambient air temperature at a point approximately 1,000 feet upstream of the proposed powerhouse and approximately 150 feet downstream at the point where a cold-water spring (named Above Powerhouse Spring) emanates from the south canyon wall.
5. **Powerhouse - Temperature/Flow Station (RM 20.60):** This station has data loggers continually recording the water flow and temperature of the stream and ambient air temperature, approximately 200 feet downstream of the proposed Powerhouse tailrace and located in the pond immediately downstream of the Powerhouse/8-Foot waterfall.
6. **Montarbo - Temperature Station (RM 19.28):** This station has data loggers continually recording the water temperature of the stream and the ambient air temperature at a point approximately 500 feet upstream of the first observed substantial spring inflow above Panther Grade.
7. P**onderosa Bridge - Temperature/Flow Station (RM 18.43):** This station has data loggers continually recording the water flow and temperature of the stream and ambient air temperature, located approximately 150 feet downstream of the Ponderosa Way bridge. This station records the accretion (inflow) that occurs in the stream from the Montarbo - Temperature Station (RM 19.28) above Panther grade to its location.

In addition to this ongoing monitoring for flow and temperature, the project team is planning to do flow and temperature measurements over a short period of time to define the "base flow" from springs and side creeks coming into the South Fork of Battle Creek.

The plan for the base flow study is as follows:

1. Do a flow and temperature measurement **below the confluence of Panther Creek** where the 3 inputs (Battle Creek from Panther, the springs river left and Panther Creek river right) (Approximately **RM 18.60** to be confirmed by GPS) to compare it to the flows at the monitoring station just below the Ponderosa Way bridge. This will serve to confirm if that are there any springs coming in between Panther Creek and the just below Ponderosa Way Bridge monitoring station, and, if there are, to quantify it/them.
2. Do a temperature and flow measurement in **Panther Creek** just above the confluence with Battle Creek (Approximately **RM 18.65** to be confirmed by GPS) to confirm that input and temperature into the system from there.
3. Do a temperature and flow measurement in **each of the channels of Battle Creek above Panther Creek but below Panther Grade Pool** (Approximately **RM 18.75** to be confirmed by GPS) to quantify each channel. In the field visit of Aug. 28, 2014 it was observed that the right channel (looking downstream) contains the flow that just came over Panther Grade and the few "small" springs above the "larger" springs that are coming out from under the south bank rock wall flow entirely into a separate the left channel (looking downstream) just below Panther Grade but above Panther Creek.
4. Do a temperature and flow measurement **immediately above and "on top" of Panther Grade** (Approximately **RM 18.91**) to quantify the springs observed coming in just above Panther Grade with a flow measurement on the "left" channel (looking downstream) where there springs come out from under the rock wall just before the springs in the left channel drop over Panther Grade. Also measure flow and temperature on the "right" channel (looking downstream) above Panther Grade that was observed as coming in from the stream above from and does not yet contain the input of the springs coming in from under the rocks on the separate left channel at this location.
5. Do a flow measurement near the temperature monitoring station set up **at Montarbo** (**RM 19.28**).
6. Do a flow measurement to complement the temperature monitor set up **just below the "Above Powerhouse Springs"** approximately (**RM 20.80**) to determine what flow coming down the system in the effected reach.

In the field visit of Aug. 28, 2014 it was observed that there is no flow and a dry streambed, except for a few isolated pools, above "**Above Powerhouse Springs" approximately (RM 20.80)** to **above Angel Falls and just below the Old Hwy. 36 Bridge (Approximately RM 22.35)**.

The stationary flow and temperature monitors set up **just below Ponderosa Way Bridge (RM 18.43)** and at the **pool below Powerhouse/8' falls (RM 20.60)** will complete the data collection for the "base flow" inputs into the Battle Creek.

3. STREAM HYDROLOGY

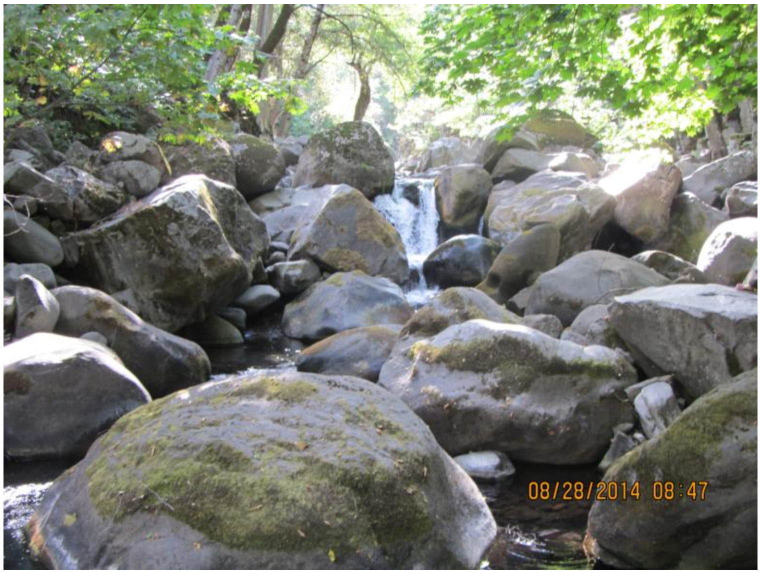
This Section will address Agency comments S-8, C-4, N-4

Comment S-8, Water Boards, pg 4, comment #7:
Response: Agree; applicant will improve display of the information presented in Figure 1.

Comment C-4, California DFWL, first paragraph at top of pg 3:
Comment: . . .*"The Hydrology section in Volume Two Appendix A and Figure 28 are lacking detail, especially for this time period;" and "More analysis and additional hydrology data is needed in order to adequately determine impacts from Project operations."*
Response: Applicant is currently developing additional hydrologic data to support evaluation of project operations, key sediment transport processes and environmental analyses. This effort is focused on the development of an extended daily flow record for South Fork Battle Creek for the Project area based on limited locally observed data and measured longer term streamflow records from nearby hydrologically similar watersheds. Measured local data from the project area will be included as available (primarily for water years 1960-1967) and will be recommended as the basis for further analyses where possible.

Comment N-4, NOAA Fisheries, Section 3.2 on pg. 7 and 8:
Comment: *In addition, there may be times during the year that the resulting restricted flow in the bypass reach, limited by concurrent diversion rate, is not adequate to transport spawning gravels, maintain riparian habitats, maintain hydraulic connection to floodplains, or maintain proper channel geomorphology.*
Response: Applicant is currently developing additional hydrologic flow data to support evaluation of project operations, key sediment transport processes and related environmental analyses.

Comments: *Statement in FLA that notes: "due to channel gradient, much natural LWD is lacking."*
Response: Agree, this statement was misleading. However, the availability of LWD and seasonal loading is actually quite large (see attached site Photos below). However, because the creek channel is very steep (average channel gradient >5%) with swift flows, narrow and laterally confined with large boulders and bedrock substrate, the primary agents forcing the creation of pools and pocket water are the large boulder obstructions in most reaches along the creek (see attached photos). Therefore, this statement will be clarified with more in-depth discussions and more accompanying photographs that show the typical size and high availability of LWD and physical processes controlling important in-channel habitats along the Creek.



Typical steep gradient boulder, bedrock channel characteristics

Typical steep gradient boulder, bedrock channel characteristics

LWD is typically deposited along the high banks and elevated terraces

Occasional LWD dams do occur in the creek channel

4. PROJECT OPERATIONS AND DIVERSION

This Section addresses Agency comments: S-11, S-12, S-20, S-21, C-4, C-5, C-7, N-5

- Comment: *Describe operating rules for each month and flow condition.*
- <u>*Response:*</u> The proposed plant operating rules are to retain a minimum of 13 cfs in the bypass reach. The minimum operating flow through the plant is 5 cfs, so, until summer flow drops below 18 cfs and until the fall flows raises up to18 cfs, the plant will not operate. The recommended design capacity flow through the turbine is 95 cfs. Once stream flow at the diversion structure exceed 108 cfs (95 plus 13 cfs) the intake to the diversion structure will limit any additional flow into the penstock and all flows greater than approximately 108 cfs will supplement (add to) the 13 cfs minimum retained flow. During very high flows the project operation plan calls for the project to go “off-line.” The project operation plan may also determine to take the project off line when substantial amounts of woody debris and sediment material are visibly being transported in the stream at the diversion site. Therefore, when flow conditions become hazardous to the plant it will go off-line, the diversion structure will close and the entire natural flow will pass downstream in the natural South Fork Battle Creek channel. The flow-through bypass facility in the diversion structure will also be opened during these events to allow sediment to flow unimpeded through the diversion structure. When high flow events recede, the operation plan allows the plant come back into operation if pre-operation maintenance to remove debris isn't required. If sediment materials have accumulated in the A or B portions of the diversion structure the sediment flow-though bypass facility in the diversion structure may stay open for some period of time during continued high flows to allow sediment to pass through much as it does now for existing, no-project conditions. These combined operating rules for diversion and sluicing have been designed to protect all structural plant facilities equipment, and for the safety of the plant operators as well as maintain very high flow in the stream as they would naturally occur without the plant in existence. Therefore, the plant operation rules have been designed to protect the plant, personnel safety and to preserve the overall health of the stream by allowing environmentally important high discharge pulsing flows to pass downstream as they do today. During normal fall, winter and spring seasons when no extreme high flow event(s) occur, during the higher flows of that year (likely late April through early June depending on type of flow year), the flow-through bypass facility in the diversion structure will be opened to allow approaching sediment to pass unimpeded through the diversion structure without interfering with normal project operations. As flows and stream velocities reduce with the season, the flow-through bypass facility will be adjusted and eventually be closed to maintain the diversion pool level at sufficient operating level until the project goes off-line due to lower flows later in the season. Once the project goes off-line for the season, the flow thorough bypass facility in the diversion will be left open for the balance of the season until operations start up once again in the fall. Timing of this occurrence depends on the characteristics of the water year and when lower flows arrive, however low flows typically occur from about June through August. Once the flows recede below the safe operating range after the spring/summer snow melt is over and flows are less than 18 cfs, the plant will shut down and not resume operations until sustained substantial flows greater than 18 cfs return once again. Therefore, depending on flow conditions, the project could be shut down for measurable periods of time during dry periods.

The concept of differing operating rules for different flow condition types and/or months will be explored based on analysis of all of the current and future data.

- Comment: *Provide specific examples for each water year type –*
- *Response:* Existing flow records will be supplemented with additional flow analysis to define various water year types – very dry, dry, normal, wet, and very wet. An operational rules model has been developed so that flows can be analyzed for each of the different water year types. This model will be provided to the agencies so that they can input and review various operational scenarios. As a part of the operational model, the project flows in the bypass reach with and without the project operating will be identified and this model will also be used to ensure that flow and water quality conditions will not be impaired.
- Comment: *proposed ramping rates*.
- *Response:* As a part of the Applicant's commitment to work with CDFWS on the final diversion, fish passage and intake design, the Applicant will work with CDFWS to define acceptable ramping rates based on different operating conditions.

5. DIVERSION AND INTAKE STRUCTURE DESIGN

This Section will address Agency comments S-2, S-3, C-1, C-2

- **Comment:** Final diversion and fish passage facilities design
- *Response*: Applicant has committed to work with CDFWS to finalize design for resident fish passage within the diversion dam and fish screen structure
- Comment: Revise FLA to explain how often the trash rack will be inspected and cleaned.
- *Response:* There are multiple level transducers that will detect the water surface level differential between the retention pond and the intake structure. When the water surface differential reaches certain thresholds, a sensor will alert the operations team that the trash rack needs attention and potentially requires cleaning. The operations team will be deployed to the site and the trash rack will be cleared. If there are no water surface differentials reported, the Applicant proposes that the trash rack be inspected monthly during ongoing operational periods.
- Comment: Revise FLA to explain where intake structure sediments will be flushed to
- *Response*: Sediments will be flushed through the diversion and into the channel below the diversion. The design of the diversion will be completed by the Applicant in coordination with CDFWS. This issue is also addressed in Section 4 above in the discussion about proposed project operations.

6. MACROINVERTEBRATE COMMUNITY

This Section will address Agency comment S-17

Impacts of Lassen Lodge Hydroelectric Project flow changes to macroinvertebrates

The State Water Resources Control Board (SWRCB) issued comments on the final license application for the Lassen Lodge Hydroelectric Project (LLHP), Federal Energy Regulatory Commission (FERC) Project No. 12496 on Battle Creek in Tehama County, CA. The LLHP proposes to build a structure to divert water to a hydrological dam, which would reduce normal stream flows. SWRCB requested more information regarding how LLHP proposed flows would affect macroinvertebrates.

Studies have been performed throughout the world to understand how reduced stream flow due to hydrological projects has impacted invertebrate communities. Dewson et al. (2007) reviewed many studies and found that invertebrate density can either increase or decrease in response to natural flow reductions and decreased flow regimes. McIntosh et al. (2002) suggested that the density decreased below a diversion because of changes in competition and predation due to decreased habitat area and changes in food quality and quantity due to the reduced flow. Similarly, food quality and quantity changes in other systems can cause an increase in macroinvertebrate density. Changes in nutrient flow can cause different food resources (e.g., filamentous green algae or diatom-dominated periphyton) to become more prevalent in the stream, and macroinvertebrate assemblages respond accordingly based upon their preferences (Suren et al. 2003). While this may cause an increase in overall macroinvertebrate density, the invertebrate richness may decrease, changing the natural community composition.

Across many studies, Dewson et al. (2007) found that reduced stream flow often decreased taxonomic richness and frequently modified community composition. Habitat loss and change (e.g., increased temperature and sedimentation, changes in food resources) are often considered the cause of decreased richness (Cazaubon & Giudicelli 1999, Wood and Armitage 1999, McIntosh et al. 2002). As flows are reduced and sedimentation increases, the macroinvertebrate composition shifts to species preferring these habitat characteristics (Castella et al. 1995, Jowett 1997).

The California Department of Fish and Game (Rehn 2010), developed an index to specifically measure benthic macroinvertebrate (BMI) status as an indicator of stream health below hydropower diversion dams on the west slope Sierra Nevada streams, and tested multiple sites to determine what factors influenced the index. The development of the hydropower-specific multimetric index of biotic integrity (IBI) led researchers to determine that BMIs in this region were most affected by modified hydrologic schemes resulting in decreased flows below dams. Overall, sites with consistent flow had low IBI (low BMI health), while those below dams with highly fluctuating flows had higher IBI, highlighting the importance of natural flow regimes (Rehn 2010). Many sites with lower IBI scores also had lower habitat variability and substrate coarsening below dams (Rehn 2010).

In 2001 and 2002, Ward and Kvam (2003) used multiple measures and multimetric indices to assess the aquatic macroinvertebrate diversity at 44 sites in the Battle Creek Watershed. Overall, they found that Battle Creek macroinvertebrates were mostly healthy throughout the Watershed during the fall 2001 and summer 2002 sampling periods, but overall health decreased in fall of 2002 (Ward & Kvam 2003). The seasonal and yearly variation in overall system health in this study is common to many streams, especially in Northern Californian Mediterranean climates, and understanding the system can assist in choosing appropriate monitoring metrics (Resh et al. 2013). Along the south fork of Battle Creek, Ward and Kvam chose one sample site for macroinvertebrate sampling near the proposed hydropower project in summer of 2002. General taxa richness was found to be mostly in the “good” to no impact condition ranges (Ward & Kvam 2003), indicating, during the sampling period, this stretch of the stream had a healthy macroinvertebrate community.

The proposed minimum bypass flows for the LLHP would not fall below 10 cfs, which is the approximate yearly minimum mean daily flow of Battle Creek in normal years, typically seen from July through October. The bypass flow schedule also proposes higher output during peak flow of Battle Creek, which would simulate the natural flow regime, typically at the end of April through May. By maintaining more natural flow fluctuations and not diverting water during normal low flow periods, the impacts of the LLHP on benthic macroinvertebrate assemblages are expected to be less than significant.

7. FOOTHILL YELLOW-LEGGED FROG

This Section will address Agency comment C-6

The Applicant did not include the foothill yellow-legged frog (*Rana boylii*; FYLF) in table 1.5-2 for non-TES wildlife species observed within the Survey Area because this species was not observed during terrestrial surveys conducted in 2013. However, presence of this species within the Project Area is acknowledged in Section 1.12, Threatened, Endangered, and Sensitive Species and Critical Habitats. Table 1.12-2 lists TES wildlife species known to occur or potentially occurring within the Project area, including FYLF on page E-134. Potential impacts and proposed mitigation are discussed and presented in Section 1.12.2.2. Mitigation for potential impacts to FYLF, developed through consultation with CDF&W, includes the following (from page E-158):

In-water work and/or construction in riparian areas will be avoided during the time that egg masses of foothill yellow-legged frogs are present (typically mid-April through mid-May). Preconstruction surveys for juvenile and adult foothill yellow-legged frogs will be conducted immediately prior to construction if in-water work will occur during the breeding season (mid-March to August, depending on local water conditions). If egg masses are found, construction will be delayed until eggs have hatched. If juveniles or adults are found within the Project reach or 500 feet downstream, they will be relocated outside of the Project area (e.g., outside of the area of impact, immediately upstream of the Project area). Rocks shall not be collected from in-water environments between March 1 and August 31 to avoid disturbing foothill yellow-legged frogs, and disturbance to pools and slow runs will be minimized. Mitigation measures proposed for protection of fish (e.g., minimum in-stream flows) will provide long-term mitigation for cumulative impacts.

Additional detail regarding the habitat assessment and associated field efforts conducted is presented in Appendix H – Threatened, Endangered, and Sensitive Wildlife Species Habitat Assessment.

8. PROJECT EFFECTS ON STREAM CHANNEL

This Section will address Agency comments S-16, S-18, S-19, S-22

- Comment S-16, Water Boards, Comment #15, pg 5: *"The FLA should describe the type of construction equipment that would be used in the bed and banks of South Fork Battle Creek."*
- *Response:* The following is a list of equipment that would most likely be used within and adjacent to the stream bed:

Instream:

TYPE	MODEL (or equivalent)
Excavator	Caterpillar 210-235
Loader (rubber tired)	Caterpillar 966
Back Hoe (rubber tired)	Case 680
Dozer	Caterpillar D4-6
Pad Foot Roller	Caterpillar CP-563
Water/Trash Pumps	Rental - To be Determined.
Air Compressor	Rental - To be Determined.

On bank Adjacent/Off Stream:

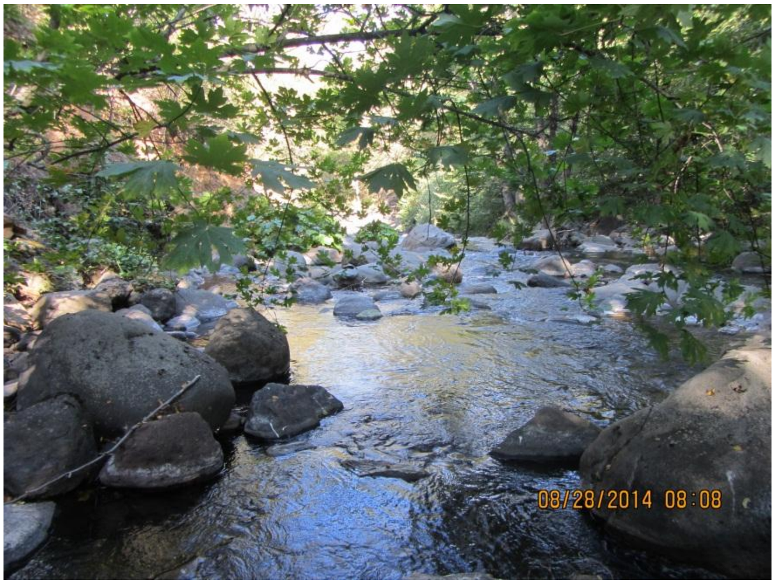
Excavator	Caterpillar 210-235
Loader (rubber tired)	Caterpillar 966
Back Hoe (rubber tired)	Case 680
Dozer	Caterpillar D4-6
Pad Foot Roller	Caterpillar CP-563
Water Truck	As available
Haul Truck	Volvo 40T
Grader	Caterpillar 140H
Fire Pump and Tank	As available
Rough Terrain Mobile Crane	Terex Rough Terrain CD-200

- Comment S-18, Water Boards, Comment #17, pg 5: *"The FLA should discuss if potential impacts to the stream channel are expected due to vegetation encroachment resulting from an absence of flows."*
- *Response:* Although operation of the proposed Project will decrease stream flows during late fall to early summer, this reduction in flow is not expected to result in noticeable vegetation encroachment within the Project bypass reach and; therefore, is not expected to result in impacts to the stream channel. South Fork Battle Creek, including the proposed Project bypass Reach, is located in a narrow, steep, geologically controlled valley (possibly a Rosgen A-Type VI channel classification). Fluvial processes in these valley types are heavily controlled by geologic blockages, boulder dominated channel

bottoms, debris dams, and colluvial processes. Therefore, the channel is comprised of a very stable complex mixture of huge boulders, very large boulders (see attached photos), large cobbles and gravels, while the presence of fines is rare. During annual periods of high runoff the upper and lateral watersheds and steep valley walls produce large course material sediment loads (boulders, cobbles, gravels and coarse sand size materials) along with significant amounts of Large Woody Debris (LWD). However, due to the creek valley's very steep gradient (>5%) and confined condition, channel velocities in the creek are quite high during months with runoff resulting in very little perennial vegetation growth in the active channel. There is a lack of in-channel vegetation because there is little suitable substrate for vegetative growth, and because the vegetation and/or suitable substrates are frequently washed away by deep, swift flows.

The steep slopes and rocky soils within the proposed Project bypass reach have also prevented extensive riparian vegetation from developing along the banks of the stream (see Photos below). Vegetation that does exist in the riparian zone consists primarily of white alder (*Alnus rhombifolia*), red willow (*Salix laevigata*), scattered sandbar willow (*Salix exigua*) and the occasional black cottonwood (*Populus trichocarpa*), Pacific dogwood (*Cornus nuttallii*), and big leaf maple trees. Herbaceous species within the active channel and adjacent banks include torrent sedge (*Carex nudata*), slender hairgrass (*Deschampsia elongata*), common horsetail (*Equisetum arvense*), mugwort (*Artemisia douglasiana*), monkeyflower (*Mimulus moschatus* and *M. guttatus*), and American brooklime (*Veronica americana*). These are the species that are likely to colonize or “encroach” if reduced flows during Project operations expose substrate suitable for seasonal colonization of vegetation; however, exposed suitable substrate is likely to be minimal and high-energy flows during the winter may damage or wash out plants before they become established.

Although a reduction of flows during periods of Project operation would reduce the wetted width of the channel and; thus, potentially expose additional portions of the active channel, the exposed substrate would be composed primarily of large boulders and cobbles. Thus, encroachment of vegetation along much of the Project bypass reach resulting from reduced flows is not expected due to the lack of suitable habitat for vegetative growth that would be exposed during periods of operation. Additionally, as this stream is a steep, high-energy stream, vegetation that is able to colonize within the active channel or along the margins during low flow periods may have difficulty surviving periods of high-energy flows. Vegetation that does manage to become established within the proposed Project bypass reach may actually have a temporary positive impact on the stream channel by helping to stabilize banks and in-channel sediment deposits, providing additional shade and benthic habitat, and providing an additional source of large woody debris.



- <u>Comment S-19, Water Boards, Comment #18, pg 5</u>: *"The State Water Board will require the Applicant to model potential Project effects to Battle Creek due to Project operations altering existing flow and sediment regimes."*
- <u>*Response*</u>: Applicant is currently developing additional hydraulic flow data and analytical procedures to further evaluate potential effects on the South Fork Battle Creek channel due to Project operations that might alter existing flow and sediment regimes or adversely affect riparian vegetation.
- <u>Comment S-22, Water Boards, last paragraph on bottom of pg 6</u>: *"The suspended sediment load and suspended sediment discharge rate of surface waters shall not be altered in such a manner as to cause nuisance or adversely affect beneficial uses."*

- *Response*: Additional hydraulic analyses will be conducted to evaluate potential changes and effects that Project operations may have on sediment. The hydraulic analyses will include an evaluation of how operation of the diversion structure may affect sediment for a range of important stream flow and project operational conditions.

9. PROJECT CONSTRUCTION SCHEDULE

This Section addresses Agency comment S-6

The Construction Schedule has been modified to reflect final issuance of permits by April 21, 2015, one year after submission of the FLA to FERC, as follows:

CONSTRUCTION SCHEDULE

The beginning of site construction of the Project is scheduled for May 1, 2015. The planned commercial operation date is October 15, 2015.

A more detailed proposed construction milestone schedule is as follows:

▪ Obtain final permits and approvals	April 21, 2015
▪ Issue Notice to Proceed (NTP) for construction	April 22, 2015
▪ Complete preconstruction biological monitoring and staking	Apr. 31, 2015
▪ Contractors mobilize on-site	May 1, 2015
▪ Commence powerline, substation, and switchyard construction	May 4, 2015
▪ Commence grading of powerhouse access road	May 4, 2015
▪ Commence grading of powerhouse foundation	May 5, 2015
▪ Commence penstock and HDPE pipeline excavation	May 6, 2015
▪ Form and pour concrete powerhouse foundation	June 2, 2015
▪ Excavate powerhouse/tailrace	June 16, 2015
▪ Install tailrace precast concrete box culvert and backfill	June 20, 2015
▪ Excavate, form, and pour concrete transition structure	June 25, 2015
▪ Complete HDPE piping and backfill	July 15, 2015
▪ Complete steel penstock installation and backfill	July 31, 2015
▪ Excavate diversion & intake south section (depends on streamflow)	Aug. 1, 2015
▪ Excavate control/fish screen structure	Aug. 1, 2015
▪ Pour concrete diversion and intake S. section footings and slabs	Aug. 3, 2015
▪ Pour concrete footing and slab control/fish screen structure	Aug. 3, 2015
▪ Excavate diversion north section (depends on streamflow)	Aug. 4, 2015
▪ Pour concrete diversion north section footings	Aug. 7, 2015
▪ Erect diversion, intake, control structure precast walls	Aug. 10, 2015

▪ Backfill diversion, intake, and control structure	Aug. 10, 2015
▪ Install trash rack, fish screens, valves at diversion, intake, control	Aug. 12, 2015
▪ Build powerhouse building	July 1, 2015
▪ Set turbine and generator into powerhouse	Aug. 1, 2015
▪ Hook up turbine and generator controls	Aug. 2, 2015
▪ Finalize electrical for transmission line substation and switchyard	Aug. 15, 2015
▪ Test System – in-house	Aug. 16, 2015
▪ Send test energy to PG&E POI	Sept. 15, 2015
▪ Commercial Operation	Oct. 15, 2015

Lassen Lodge Hydroelectric Project
FERC No. 12496

Appendix A
Agency Comment Letters on Final License Application

APPENDIX A

State of California – Natural Resources Agency
DEPARTMENT OF FISH AND WILDLIFE
Region 1 – Northern
601 Locust Street
Redding, CA 96001
www.wildlife.ca.gov

EDMUND G. BROWN JR., Governor
CHARLTON H. BONHAM, Director

June 20, 2014

Ms. Kimberley D. Bose, Secretary
Federal Energy Regulatory Commission
888 First Street, N.E.
Washington, DC 20426

Subject: Comments on Rugraw, LLC's (Applicant) Final License Application (FLA) For Lassen Lodge Project, Federal Energy Regulatory Commission (FERC) No. 12496, South Fork of Battle Creek, Tehama County

Dear Ms. Bose:

The California Department of Fish and Wildlife (Department) received the Final License Application (FLA) for the Lassen Lodge Hydroelectric Project (Project) on April 21, 2014. The Department respectfully submits the following general comments, specific FLA comments, and includes our recommended additional studies.

General Comments:

The Department has been working on the Project since Rugraw filed the original application (P-11157) for license in October 1994. Since then, the Project has gone through multiple iterations and three additional preliminary permits (P-11894-000, P-12496-000, and P-12496-001). The Project design has changed throughout this process and project features (i.e. powerhouse, transmission line) have also moved to their current locations proposed in the FLA. While a lot of background information has been gathered, the Department is disappointed in the lack of quantitative, site specific, baseline information. The Department believes the FLA poorly analyzed the Project's effects on hydrology, temperature, and instream biological needs.

FLA VOLUME ONE Comments:

C-1 Page A-2, Section 1.1.1. The Applicant proposes to work with the Department post-license to finalize the ultimate design for fish passage within the diversion dam instream bypass flow channel. The Department agrees, and will work with the applicant on final design after minimum instream flows are determined.

C-2 Page A-2, Section 1.1.3. The Department will also work with the Applicant on final design of the fish screen structure to ensure it meets the Department's and National Marine Fisheries Service's fish screen criteria.

C-3 Page A-8, Figure 2-1 and page 49, Figure 28. Figure 2-1 and 28 are the same figure displaying the mean year water temperature and median flow. The figures display the daily flow and projected turbine flow and the resulting bypass flows of the proposed

13 cubic feet per second (cfs) minimum instream flow (MIF) and any additional spill. Mean daily water temperature data, collected at the powerhouse site from 2004-2006, is also displayed. While the figures give an overall picture of the hydrology and the effects of the maximum diversion of 95 cfs, the scale is too large to understand the true effects on flow in the bypass reach, especially in regards to flow in the spring and summer.

The figures are also misleading regarding the temperature data. The figures correctly display the limited two years of data collected at the powerhouse site for temperature, however, it does not display the same effect on temperatures in the bypass reach as the hydrology data does for the maximum 95 cfs diversion flow. The FLA does not include any temperature analysis resulting from Project operations.

Page E-17, Section 1.2.1.3. Daily water temperature data for south fork Battle Creek near the powerhouse were collected from November 2003 to December 2006 and plotted in Figure 1.2-1. Figure1.2-1 is missing from the FLA, but it is supposed to show maximum temperatures ranging from 64 to 65 degrees Fahrenheit (ºF). Those temperature may be protective for aquatic species, such as steelhead/trout (*Oncorhynchus mykiss*) and Pacific salmon (*O. tshawytscha*); however, as stated above, these temperatures do not represent the temperature affects that would be associated with Project operations. The FLA does not discuss how these temperatures would or would not be protective of various salmonid life stages that could be present during this time period. Since temperature modeling was not conducted and included in the FLA, the Department does not have the ability to determine what would be an appropriate and protective MIF in the bypass reach, and needs this information.

C-3
(cont'd)

Page E-19, Figure 1.2-2. Figure 1.2-2 depicts eight water temperature probes at the proposed diversion site, the powerhouse, above and below the springs at Panther Grade, and downstream at south fork Battle Creek at the wooden bridge. The temperature data does show baseline temperatures from the diversion to below the Project and gives a basic understanding of water temperature dynamics in the Project reach without the effects of operations. However, this data is limited because it was only collected from September to November (three months) for the 2013 water year. The data does not capture any spring or summer temperatures and misses the peak temperature periods. The Department understands that the Project could be off-line in some years during these periods, but basic baseline temperature data should have been collected over the past 20+ years since the original permit was filed.

Page E-21, Section 1.2.2.2. The Applicant states in the second to last sentence in the sections that, “The Project is not expected to significantly change water temperature dynamics in the bypass reach or downstream of the powerhouse because it would maintain instream flows of 13 cfs and large cold springs enter the stream at and below Panther Grade below the Project reach.” The FLA does not include any temperature modeling to substantiate this statement. FERC should require additional water temperature monitoring and modeling in order to determine what the impacts would be from the Project in the bypass reach on temperatures at a range of different MIF.

C-4 Page E-55, Section 1.4.2.4. The FLA states, "Flows would also naturally exceed 108 cfs (95 cfs turbine capacity plus 13 cfs bypass flow) during the spring runoff season (April to June), resulting in bypass flow frequently in the 30 to 60 cfs range." The hydrology section in Volume Two Appendix A and Figure 28 (see comment above) are lacking in detail, especially for this time period. It is hard to quantify how frequent operations would allow 30-60 cfs down the bypass reach. More analysis and additional hydrology data is needed in order to adequately determine impacts from Project operations.

C-5 Page E-56, Ramping Rate. The FLA states, "The standard rate-of-change would meet the agreed upon criteria of the CDFW of 30 percent of the existing stream flow per hour (10 percent load every 20 minutes) or less". The Department is not aware of this agreement and proposed ramping rate. The Department will file recommended ramping rates later in our 10 (J) recommendations.

C-6 Page E-60, Section 1.5.1.2. The Applicant did not include foothill yellow legged frog (*Rana boylii*)(FYLF) in table 1.5-2 for non-TES wildlife species observed within the Survey Area. The Department's staff on multiple site visits has observed adult FYLF in the Projects bypass reach. Hydroelectric projects have the potential to adversely affect FYLF (California Species of Special Concern) particularly during the breeding season in April and May by scouring or stranding egg masses. The Applicant did not conduct FYLF surveys and the FLA does not analyze the Project's effects to FYLF. The Department is requesting, and FERC should require the Applicant to conduct these surveys and produce an analysis describing the effects. FYLF surveys should be conducted for basic baseline information (i.e., breeding sights and number of breeding females) and an analysis included to determine potential effects.

FLA VOLUME TWO Comments:

C-7 Page 3, Section 1.1.3. Figure 1 in the FLA shows the south fork Battle Creek site hydrology measured and normalized by month and day. The data gives a big picture look at what flow ranges could be expected in the Project location. However, this data and the data provided in Table 1 on page 4, is deficient in displaying the hydrology for the Project. The Department needs more specific hydrology displayed to make determinations about Project impacts than what is presented in the FLA. Throughout the FLA, the Applicant claims the Project would be offline for some years as early as June or July. The Technical Report, Flow Duration Analyses (Hydmet 2012), and the information in Table 1 do not support this generalization. Table 1 shows average flows in August and July at 17 and 41 cfs, respectfully. The maximum flow for those months is 62 and 214, respectfully. Clearly, in some years the Project would be operating beyond the June/July time period with a 13 cfs MIF and a 5 cfs intake flow. The FLA inadequately bases affects from the Project based on this assumption. Additional analysis should be conducted on stream flow, water temperature, and aquatic impacts throughout the summer months.

C-8 Page 13, Section 2.1.3 (see comments above). The FLA is insufficient in properly characterizing the baseline temperature or analysis regarding Project effects. FERC should require additional water temperature monitoring and modeling in order to

C-8 (cont'd) determine what the impacts would be from the Project in the bypass reach on temperatures at a range of different MIF.

C-9 Appendix C, Page 1. The FLA correctly identifies rainbow trout/steelhead (*O. mykiss*) as the only salmonid found above Panther Grade at this time. Anadromous fish will be able to access the Project's bypass reach when the South Diversion Dam of the Battle Creek Hydroelectric Project, FERC Project No. 1121, is removed. The Department does not consider Panther Grade to be a barrier to upstream migration in all years for salmonids. It is reasonably certain that salmonids will have access to the Project's bypass reach before final construction is completed or soon after.

C-10 Appendix C, Page 2. The Applicant uses the Unit Characteristic Method (Cramer and Ackerman 2009), to estimate rearing capacity for juvenile Central Valley spring-run Chinook salmon and steelhead within the study reach. The Department is not sure why the FLA did not include or use the previously filed, and more traditionally accepted PHABSIM study, South Fork Battle Creek Amended Instream Flow Study (Tomas R. Payne & Associates 2001), in addition to the Unit Characteristic Method. The FLA should include the results from the PHABSIM study.

C-11 The FLA on Page 2 states, "The number of spawners a patch can support is determined by area of the patch, with the area required per spawner increasing exponentially with the length of the spawning fish." This is an oversimplified assumption made throughout the UCM study, and in reality spawners in smaller streams, like the south fork of Battle Creek, will use smaller gravel patches than the model predicts.

C-12 The FLA used the width, depth, and velocity of each channel unit at base flow (13 cfs) compared to their width and depth at bank-full flow to estimate the rate that width, depth and velocity change with flow. The model only uses the two flow points (13 cfs base flows, and estimated bank-full in the range of 500 to 700 cfs) to understand how habitat parameters such as flow, depth, and velocity change with different discharges. The Department believes that this approach is over simplified due to the lack of data points and is therefore unreliable.

C-13 Appendix C, Page 16. The FLA states, "Gravel suitable for spawning was found in small patches (average area of 15 m^2; range 5-46 m^2) distributed throughout the reach. The area required for spawning of a single pair of Chinook salmon of average size is 20.4 m^2 (Burner 1951)." The Burner 1951 paper actually found that spring-run Chinook salmon redds in the Ohanapecosh River were 2.9 square yards, and in Nason Creek were 4.9 square yards (Burner 1951). The conversion of 2.9 and 4.9 square yards to square meters is 2.4 and 4.0, respectively. This is one-tenth of the area used in the model to estimate numbers of spawning pairs in the Project reach. If this is the case, the model and their conclusions are flawed and should be reanalyzed.

C-14 Appendix C, Page 47. The FLA states, "We determined that habitat within the project reach is not suitable to support spring-run Chinook, so we address only steelhead and resident trout in our discussion of possible project effects." The Department understands that the bypass reach is limited in supporting spring-run Chinook salmon; however, the FLA should not just dismiss analyzing effects from the Project. Also

C-14 (cont'd) based on our comment above, we believe the UCM model erroneously limited the amount of available spawning area which affected the results.

C-15 Apendix C, Page 47. The FLA states, "Given the low potential we found for the project reach to support steelhead or spring-run Chinook, it seems prudent to prescribe minimum flows focused on protecting resident rainbow trout. We find it unlikely, but possible that salmon and steelhead will pass above Panther Grade in the future, so monitoring should be established to detect if they arrive." As stated above, the Department does not believe that Panther Grade is a barrier, and we believe it is likely that salmonids will be present in the Project reach. The Department does agree that monitoring should occur after the Project is built and when the South Diversion Dam of the Battle Creek Hydroelectric Project, FERC Project No. 1121, is removed.

C-16 The FLA does not include any analysis with regard to Sacramento River winter-run Chinook salmon (winter-run). It is likely that after the South Diversion Dam is removed that winter-run could access the bypass reach and an analysis should be included.

<u>Conclusion:</u>

The Department has determined that the FLA has not accurately analyzed Project effects on temperatures and the effects to FYLF. The Department therefore recommends FERC require the Applicant to: 1) Conduct a temperature model study, and analyze effects from Project operations; 2) Conduct a FYLF analyses during the breeding season until the Project goes off-line; 3) Utilize the previously filed PHABSIM study (Tomas R. Payne & Associates 2001) in the FLA analysis; 4) make the appropriate changes to the FLA that address our other comments provided above; and, 5) where applicable display results in a more clear and precise manner. If you have any questions regarding the above comments, please contact Senior Environmental Scientist (Specialist) Matt Myers at (530) 225-3846.

Sincerely,

for **NEIL MANJI**
Regional Manager
Region 1 – Northern

Enclosure A

cc: FERC Service List

ec: Page 6

APPENDIX A

ec: Messrs. Neil Manji, Curt Babcock, Curtis Milliron, Jason Roberts, Doug Killam,
and Matt Myers; Mss. Donna Cobb and Annie Manji
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References

Burner, C. J., 1951. Characteristics of spawning nests of Columbia River salmon. U.S. Fish Wildlife Service, Fish. Bull. 61:97-110.

Cramer, S.P, and N.K. Ackerman. 2009. Linking stream carrying capacity for salmonids to habitat features. Pages 225-254 *in* E.E Knudsen and J.H. Micheal, Jr., editors. Pacific salmon environmental and life history models: advancing science for sustainable salmon in the future. American Fisheries Society, Symposium 71, Bethesda, Maryland.

Hydmet, 2012. Technical Report, Lassen Lodge Hydropower Project, Flow Duration Analyses. Prepared for Rugraw Inc., March 9. Knight Peisold Consulting, 2012. Lassen Lodge Project, Hydropower Technical Pre-Feasibility Analysis. Prepared for Rugraw Inc., April 30.

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APPENDIX A

Enclosure A

UNITED STATES OF AMERICA
FEDERAL ENERGY REGULATORY COMMISSION

Rugraw, LLC)
Lassen Lodge Hydroelectric Project) **Project No. 12496**

CERTIFICATE OF SERVICE

I hereby certify that I have this day served, by first class mail or electronic mail, a letter to Secretary Bose, Federal Energy Regulatory Commission, containing the California Department of Fish and Wildlife's comments on the Final License Application for the Lassen Lodge Hydroelectric Project (P-12496). This Certificate of Service is served upon each person designated on the official service lists compiled by the Commission in the above-captioned proceeding.

Dated this 20th day of June 2014

Matthew P Myers

Matthew P Myers
California Department of Fish and Wildlife

APPENDIX A

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NOAA FISHERIES SERVICE
WEST COAST REGION
650 Capitol Mall, Suite 5-100
Sacramento, California 95814-4706

June 12, 2014

In response, refer to:
WF/WCR/FERC P-12496

Kimberly D. Bose, Secretary
Federal Energy Regulatory Commission
888 First Street, NE
Washington, D.C. 20426

Re: NOAA Fisheries Service's Comments on the Final License Application for the Lassen Lodge Hydroelectric Project, Federal Energy Regulatory Commission Project No. 12496, South Fork Battle Creek, California.

Dear Secretary Bose:

Thank you for the opportunity to provide comments. NOAA Fisheries Service (NMFS) submits in Enclosure A our comments on Rugraw, LLC's (Applicant) Final License Application (FLA) for the Lassen Lodge Hydroelectric Project, Federal Energy Regulatory Commission (FERC or Commission) Project No. 12496 (Project).

The Applicant's FLA contains a Biological Assessment (BA) (FLA, Exhibit E, Appendix D) for the distinct population segment of California Central Valley (CCV) steelhead (*Oncorhynchus mykiss*) and for the evolutionarily significant unit (ESU) of Central Valley (CV) spring-run Chinook salmon (*O. tshawytscha*). The Applicant's FLA also includes an Essential Fish Habitat Assessment (EFHA) for Pacific salmon (*O. tshawytscha*) in its Exhibit E, Appendix D. However, the Applicant did not include the ESU of Sacramento River winter-run (winter-run) Chinook salmon (*O. tshawytscha*) in its BA. The ESU of winter-run Chinook salmon is listed as endangered under the Endangered Species Act (ESA), both CCV steelhead and CV spring-run Chinook salmon are listed as threatened under the ESA, and these listed runs of Chinook salmon and steelhead can access the South Fork Battle Creek. NMFS has designated critical habitat for CCV steelhead and CV spring-run Chinook salmon, pursuant to the ESA, and also designated EFH for Pacific salmon, pursuant to the Magnuson-Stevens Fishery Conservation and Management Act, in the South Fork Battle Creek. Finally, the Applicant's FLA does not include consideration of the ESU of CV fall-/late fall-run Chinook salmon, which can also access the South Fork Battle Creek.

NMFS has determined that the FLA is deficient and not yet ready for environmental analysis. The FLA has not included consideration of the Project's effects on all of the anadromous fish resources noted above. Additionally, the FLA, including the BA and EFHA, is inadequate due to the following reasons: Inappropriate derivation and application of the Hydraulic Geometry (HG) method to determine all aquatic habitat and discharge relationships; a lack of water temperature modeling; an insufficient baseline analysis of existing water temperatures; and an insufficient analysis of when the Project would be operational under the proposed minimum instream flow. The HG method was used to model flow-stage relationships that were then used to predict available habitat quantity and quality. This flawed analysis was then utilized in additional salmonid production modeling that supported the protection, mitigation, and enhancement measures in the FLA and provided the foundation for the determinations made in the BA and EFHA. Thus, NMFS provides details in Enclosure A as to why we believe that the HG method is inappropriate for quantifying habitat and flow relationships. Finally, the fundamental flaws in the derivation of the HG relationships and other deficiencies noted above have rendered much of the supporting fisheries, habitat, and instream flow analyses inadequate to support the conclusions presented in the FLA, BA, and EFHA at this time.

Thank you for your cooperation in the above. If you have questions regarding these documents, please contact William E. Foster (916-930-3617) of my staff.

Sincerely,

Steve Edmondson
FERC Branch Supervisor
NMFS, West Coast Region

Enclosures

cc: FERC Service List for P-12496.

APPENDIX A

Enclosure A

UNITED STATES OF AMERICA
FEDERAL ENERGY REGULATORY COMMISSION

Lassen Lodge, LLC	**)**	**Project No. P-12496**
Lassen Lodge Hydroelectric Project	**)**	
South Fork Battle Creek	**)**	

NOAA FISHERIES SERVICE'S COMMENTS ON THE FINAL LICENSE APPLICATION FOR THE PROJECT

1.0 Introduction

NOAA Fisheries Service (NMFS) submits our comments on Rugraw, LLC's (Applicant) Final License Application (FLA) for the Lassen Lodge Hydroelectric Project, Federal Energy Regulatory Commission (FERC or Commission) Project No. 12496 (Project), South Fork Battle Creek, California. The Applicant's FLA contains a Biological Assessment (BA) (FLA, Exhibit E, Appendix D) for the distinct population segment of California Central Valley (CCV) steelhead (*Oncorhynchus mykiss*) and for the evolutionarily significant unit (ESU) of Central Valley (CV) spring-run Chinook salmon (*O. tshawytscha*). The Applicant's FLA also includes an Essential Fish Habitat Assessment (EFHA) for Pacific salmon (*O. tshawytscha*) in Exhibit E, Appendix D. However, the Applicant did not include the ESU of Sacramento River winter-run (winter-run) Chinook salmon (*O. tshawytscha*) in its BA. Furthermore, the Applicant's FLA does not include consideration of the ESU of CV fall-/late fall-run (fall-run) Chinook salmon, which can also access the South Fork Battle Creek. Finally, NMFS notes that the anadromous fish above will be able to access the Project's bypass reach when the South Diversion Dam (RM 14.35) of the Battle Creek Hydroelectric Project, FERC Project No. 1121, is removed from the South Fork Battle Creek. The Battle Creek Salmon and Steelhead Restoration Project (BCSSRP) has full funding and written plans to remove this last barrier to anadromous fish by 2016 (USBR *et. al*., 2004). This restoration action is reasonably certain to occur prior to the issuance of a new license for the P-12496 Project (USBR 2014).

2.0 Status of Anadromous Fish

NMFS is a federal agency with jurisdiction over anadromous fish resources affected by the licensing, operation, and maintenance of hydroelectric projects. See Reorganization Plan No. 4 of 1970 (84 Stat. 2090), as amended; the Federal Power Act (FPA) (16 U.S.C. § 803(j) and 811); the Fish and Wildlife Coordination Act (FWCA) (16 U.S.C. § 661 and 662); the Magnuson-Stevens Fishery Conservation and Management Act (MSA) (16 U.S.C. §1801 *et seq*.); and the Endangered Species Act (ESA) (16 U.S.C. §1531 *et seq*.).

N-1

NMFS is concerned with the following ESA / MSA federally managed anadromous fish and resident *O. mykiss* resources that can access the South Fork Battle Creek and be affected by the Project, once the South Diversion Dam (RM 14.35) of the BCSSRP is removed by 2016:

- Winter-run Chinook salmon ESU (*Oncorhynchus tshawytscha*), (Endangered) (59 FR 440, January 4, 1994);
- CV spring-run Chinook salmon (*O. tshawytscha*) (Threatened/Critical Habitat) (64 FR 50394, September 16, 1999 / 70 FR 52488, September 2, 2005);
- CCV steelhead (*O. mykiss*) (Threatened/Critical Habitat) (71 FR 834, January 5, 2006 / 70 FR 52488, September 2, 2005);
- Fall-run Chinook salmon (*O. tshawytscha*) (Species of Concern) (69 FR 19975, April 15, 2004);
- Pacific Chinook salmon, all ESUs (*O. tshawytscha*) (Essential Fish Habitat) (71 FR 61022, October 17, 2006) and
- Resident *O. mykiss* above man-made (RM 14.35) and natural (RM 22.3) barriers.

N-2

NMFS notes above that there is no critical habitat designated within the South Fork Battle Creek (it is designated in Battle Creek up to the Coleman Hatchery weir). In addition, studies have shown that isolated populations of non-anadromous *O. mykiss* can revert to the anadromous form if given an

N-2 (cont'd) opportunity - even after over 70 years of isolation (Docker and Heath 2003; Thrower *et al*. 2004). Thus, such isolated *O. mykiss* populations could serve as sources for the eventual recovery of CCV steelhead within the Battle Creek watershed, as well as contribute to the diversity of life-history strategies which contributed to the over-all viability of the *O. mykiss* complex within the Battle Creek watershed.

3.0 Comments on FLA

3.1 Comments on Hydraulic Geometry Method.

N-3 Throughout the FLA, the Applicant utilizes a Hydraulic Geometry (HG) method to attempt to understand how wetted width, flow depth, flow velocity, and aquatic habitat change with varying instream flow levels. The HG method within the FLA is, by in large, substituted for more traditional and accepted approaches (e.g., PHABSIM) often used in FERC licensing proceedings to analyze and quantify how aquatic habitat changes with different discharges. A major limitation of the HG method compared to more traditional approaches is that it only predicts cross-sectionally averaged depths and velocities (i.e., one average depth and velocity across an entire station or cross-section) and assumptions are further made that this one averaged depth and velocity is somehow reflective of available habitat. In a steeper, coarse-bedded stream such as South Fork Battle Creek, parameters such as flow, depth, and velocity are very dynamic and highly variable at any given location (as evidenced in many of the field photos submitted with the FLA Appendices). NMFS finds the use of cross-sectionally averaged depths and velocities at the habitat-unit and micro-habitat unit scale to be a fundamental flaw in the use of the HG method within the FLA to quantify available habitat at varying flow levels.

In addition to the inherent limitations of trying to use a HG method to quantify habitat vs flow relationships, the Applicant's approach to constructing their HG relationships is too coarse to have any reliability in the parameterization of their HG relationships. Standard practice for developing "at-a-station" HG relationships (what is utilized in the FLA) is to collect data at several different flow stages and discharges (see Hogan and Church (1989), where each “at-a-station relationship is derived from six different measurements). The Applicant collected habitat data at one discharge, 13 cubic-feet-per-second (cfs). They attempted to quantify habitat parameters at a second flow level (bankfull discharge) through various indirect or back-of-the-envelope methods. The Applicant estimates that the bankfull discharge is in the range of 510 to 700 cfs, or roughly 50 times the discharge of their one measured point at 13 cfs. Even if the Applicant’s estimated bankfull parameters were reliable (discussed in greater detail below), having only one data point (within the range of possible Project induced instream flows being evaluated, including the range of flows most impacted by the Project) severely limits the HG method and resulting habitat analysis in ascertaining small differences in baseflow or in minimum instream flow as presented in the FLA. In other words, the HG methods developed in the FLA cannot reliably speak to how habitat parameters, such as rearing area, vary from 8 to 13 to 20 cfs (as presented in Figure 23 of Appendix C).

N-3
(cont'd)

Typically, HG relationships are developed through fitting a power function through several points (e.g., Hogan and Church 1989). Because the Applicant is attempting to parameterize the HG power functions with only two data points, they follow an approach presented in Jowett (1998) that utilizes ratios of two different depths, widths, and discharges to develop the parameters for HG relationships. First off, Jowett (1998) actually *measured* widths, depths, and discharges at two calibration flows. Second, Jowett (1998) represents their rapid two point calibration and development of HG relationships as a broad, regional tool to aid in initial assessment of proposed environmental flow changes (pg 465 Jowett 1998). They do not represent it as a method to develop site specific instream flows (such as determining rearing habitat changes from 8 to 13 to 20 cfs), but rather as a screening tool to understand when mean or modal depths or velocities were approaching a threshold that would trigger more detailed habitat survey and analysis. The Applicant’s use of the Jowett (1998) method to determine that 13 cfs is an appropriate instream flow appears to be a misapplication of the Jowett's proposed method of a rapid, regional assessment tool.

As previously discussed, the Applicant measured habitat data at one discharge (13 cfs) and extrapolates data at a second discharge (bankfull discharge). Thus their HG relationships are entirely dependent on the second extrapolated bankfull discharge point. NMFS believes that several assumptions made in the extrapolation of the bankfull discharge data point render this data point as nothing more than a coarse estimate that is far too unreliable to be the primary building block of an assessment that attempts to set a minimum instream flow. First, the Applicant assumed they could consistently identify a bankfull indicator (or stage) in the field in a coarse, step stream. Identifying bankfull indicators in the field is a notoriously subjective process that varies greatly between field crews, and this uncertainty exponentially increases in steep, confined streams with bank materials composed of large boulders (like South Fork Battle Creek). Identifying field bankfull indicators is a more reliable process in lower gradient meandering streams with consistent riparian vegetation (e.g., willow) lines. Second, the Applicant has assumed that identified field bankfull indicators are equivalent to a 2-year return interval flow. This is a suspect assumption and is without additional evidence to determine if this is applicable to South Fork Battle Creek. Typical bankfull stage commonly varies from a 1.5 to 2.33-year return interval flow, and is known to vary as low as 1.2-year return interval flow and as high as 5-year return interval flow. Thus the confidence that the 2-year return interval correlates to the bankfull discharge is very low. The third set of assumptions that is problematic with the bankfull discharge data point is the method for calculating what the 2-year return flow actually equates to. The first method used a peak flow analysis of a 9-year flow record, which is too short of a record to reliably determine peak flow return intervals (typically a 20-year period is viewed as the minimum record length for calculating a peak flow analysis). Presumably, because the flow record was so short, a second

N-3
(cont'd)

method using a regional USGS regression equation was deployed to calculate a 2-year return interval flow. USGS regional regression equations are coarse, generalized tools designed to inform projects were only rough peak flow estimates are needed – such a generalized tool does not provide precise control for hydraulic relationships. The two approaches estimated 510 and 700 cfs, respectively, and they were averaged together to get a 600 cfs 2-year return interval flow, which was then assumed to have produced the stage identified as bankfull. NMFS believes the confidence in the correlation of 600 cfs to bankfull stage (notwithstanding issues in identifying bankfull stage) is very low, which in turn renders the HG relationships entirely dependent on this point (because there are only two points deriving the relationship) to be unreliable. This problem is then compounded by the fact that the estimated bankfull is nearly 50 times greater than the 13 cfs observation and there is no additional observation within the flows of interest (e.g., 8 to 50 cfs).

N-3
(cont'd)

In summary, the Applicant's attempt to understand how habitat parameters such as flow, depth, and velocity change with different discharges by only measuring data at one flow (13 cfs) is completely insufficient and will not provide the necessary information to assess the proposed Project's impacts from diverting water, which could be as high as 88% of the natural inflow when the inflow to the reach is 108 cfs. NMFS believes that the HG method (itself based on limited hydrological information) would tend to underestimate the volume/depth-stage at particular flows and does not account for variations in hydrology due to either wetter/cooler or drier/hotter water years. Furthermore, the Applicant's claim that such data result in a remarkable "fit" is simplistic at best, as data is only collected about two points (which do define a line), but there is no accounting for variance. Finally, the Applicant's claim that the HG method utilizes the "linear relationships" observed when such habitat parameters are plotted on a log-log scale is misstated. More correctly, the claimed "straight line fit to data plotted on a log-log

N-3 (cont'd) scale" is not a linear relationship, it is a power function (which hints at the potential for the coarse type of relationship being investigated).

3.2 Comments on Proposed Minimum Instream Flow and Fish Habitat Assessments

N-4 NMFS believes that the proposed minimum instream flow of 13 cfs and the proposed amount of fish habitat are likely far too low because they are based on the results from the faulty HG method. The HG method supplies the depth and width of water in the channel at particular flows. The extent of that volume of water determines how much holding, spawning, and rearing habitat is available. The amount of sufficiently wetted habitat determines the relative amount of fish production. However, the Applicant determined that rearing habitat would limit ultimate production within the reach, based in part on the HG method. While limited rearing may be true within this small reach (with any method), NMFS believes that rearing habitat in general should not be considered as "limited" because fish will displace downstream (even out of the 1.7 mile reach) and will find such habitat. Thus, basing the proposed minimum instream flow on 13 cfs because it ”would over-seed the available rearing habitat" is not a valid means to determine a minimum instream flow in this case. In addition, there may be times during the year that the resulting restricted flow in the bypass reach, limited by the concurrent diversion rate, is not adequate to transport spawning gravels, maintain riparian habitats, maintain hydraulic connection to floodplains, or maintain proper channel geomorphology.

NMFS believes that because most of the anadromous fish that will access the upper South Fork Battle Creek are listed under the ESA, actions which do not limit potential production should be realized. NMFS suggests that a significantly higher minimum instream flow should be considered in conjunction with the anchoring of large woody debris (LWD). The FLA notes that due to channel gradient, much natural LWD is lacking. Nevertheless, NMFS believes that the depths of certain riffles and pools may be augmented by the anchoring of LWD at selected locations, thus improving available habitat. LWD helps create complex channels and floodplain habitats and important spawning and rearing habitat by trapping sediment, nutrients, and organic matter, creating pools, sorting gravels, providing cover and hydrologic heterogeneity, and creating important spawning and rearing areas for salmonids (Harmon *et al*. 1986; Montgomery *et al*. 1999). However, NMFS is not proposing terms and conditions at this time, for it is too early and this FLA is deficient.

N-4 (cont'd)

In addition, while NMFS understands how various habitats were typed, we are not commenting on the fish/habitat utilization or on the proposed fish production at this time. This is because the theoretically available habitats, theoretical fish use of such habitats, and resulting theoretical production were inherently supported by the use of the faulty HG method that likely underestimates the amount of water that would provide such theoretical habitat. In addition, the Applicant erred when they assumed that the "4 times redd area" (for defensible space, per Burner (1951)) is limited to just the available spawning gravel area. However, this is not the case, as the "4 times redd area" of Burner (1951) does not need to be comprised of or limited to just spawning habitat. Such "defensible space" also includes any other types of suitable habitat as long as there is sufficient water quality and depth. This error incorrectly reduces the amounts of available "spawning" habitat. NMFS believes that fish would utilize the habitats in this reach and that would vary with different water years. Furthermore, whatever habitats are utilized and whatever fish production occurs, this reach can only add to or assist in supporting populations of listed anadromous fish that can access the larger Battle Creek basin.

3.3 Comments Regarding Periods of Diversion

N-5

The FLA proposes to keep a minimum instream flow of 13 cfs in the bypass reach, the turbines require at least 5 cfs to operate, and thus the proposed Project would cease diverting water for generation

N-5 (cont'd)

at inflows of 17 cfs or less. Throughout the FLA the Applicant states that this would typically occur in "early July" and diversions would start up again in November. However, the hydrology data provided in the *Technical Report, Lassen Lodge Flow Duration Analyses* (Hydmet 2012 - *Flow Duration Report*, filed as an Appendix with the License Exemption Application in 2012) does not appear to support this generalization of the Project not affecting stream flows from July through October. Based on Figure 21 in the *Flow Duration Report* (Hydmet 2012), in the month of July flows exceed 17 cfs at least 70% of the time, and flows exceed 30 cfs about 40% of the time. Based on Figure 22 in the *Flow Duration Report* (Hydmet 2012), in the month of August flows exceed 17 cfs at least 40% of the time, and flows exceed 30 cfs about 10% of the time. Based on Figure 23 and 24 in the *Flow Duration Report* (Hydmet 2012), in the months of September and October flows exceed 17 cfs about 25% and 20%, respectively, of the time. Thus, this generalized view that the Project will be offline in July and August does not appear supported by data previously filed by the Applicant. Furthermore, it appears that the Project will, at times, reduce the natural minimum flow at a significant level (e.g., reducing the natural flow by more than half from 30 cfs to 13 cfs) during peak water temperature periods in late July and August. A more robust quantification of the time periods when the Project would be diverting and what the reduction in instream flow would be should be ordered by FERC. Furthermore, based on Hydmet's (2012) *Flow Duration Report*, the Project and its effects on stream flows, water temperatures, aquatic habitat, and designated critical habitat should be, at a minimum, extended through July and August.

3.4 Comments Regarding Water Temperature

N-6

The FLA is significantly lacking in its characterization of the baseline water temperatures and the Project's potential impacts to water temperature – a primary component of anadromous fish habitat for multiple life stages. The FLA provides a graphical plot of three years (November 2003 to November 2006) of historical water temperature data near the proposed powerhouse location (Figure 2 of Appendix

N-6 (cont'd)

A to Exhibit E). However, the plot is so coarse (especially the x-axis or dates), it is impossible to discern in which months particular water temperatures are occurring. For example, it is not possible to determine what the water temperatures are in June vs July (the approximate divide between diversion and non-diversion periods). Furthermore, Figure 2 in Appendix A only plots daily average water temperature and does not evaluate the daily maximum water temperature. No additional tabular or written analysis is provided of either daily average or daily maximum water temperatures that could at least characterize temperatures by weekly or monthly time periods. Figure 3 in Appendix A to Exhibit E depicts detailed water temperature information at multiple locations from September to December 2013. While the water temperature monitoring approach depicted in Figure 3 does have some utility in understanding water temperature dynamics in the proposed Project reach, the data in Figure 3 are severely limited by covering such a short time period (3 months) and does not capture any of the summer time or peak temperatures periods. Figure 3 does illustrate that the diurnal water temperature fluctuation near the proposed diversion site (logger 1) can be as high as 8 degrees F in September, which further illustrates the need to analyze water temperature data on a daily maximum basis in addition to daily average temperatures. NMFS believes in order to adequately characterize the baseline conditions, FERC should order additional water temperature monitoring (in an approach similar to that depicted in Figure 3 of Appendix A) that covers the summer months and FERC should also request additional analysis of all available (existing plus future monitoring data) water temperature data (e.g. exceedance plots by month of daily average and maximum temperatures).

The Environmental Report states that “the Project should have little effect on stream temperature” (pg. E-149). However, NMFS could not identify any modeling or analysis within the FLA that would appear to substantiate this conclusion and the statement appears to be based on professional opinions regarding the reported typical cessation of diversion in early July once a minimum inflow of 13 cfs to

N-6 (cont'd)

the Project is reached. As described above, it appears the Project would typically divert water during most of July and into August. The Project is proposing to significantly reduce the monthly median flow (Table 1 Appendix A to Exhibit E) in multiple months that can potentially have warm water temperatures, including April (an 88% reduction from 107 cfs to 13 cfs), May (a 74% reduction from 129 cfs to 34 cfs), and June (an 81% reduction from 69 cfs to 13 cfs). In order to evaluate the effects to stream temperatures from this significant level of flow reduction, an analytical approach must be developed – in all likelihood a water temperature model is necessary. The Project's effects to stream temperatures should be quantitatively evaluated over a range of climatic and water year types (e.g., wet, normal, and critical years). Furthermore, the changes in water temperature to water diverted through the Project works and its subsequent return to the stream channel should also be quantitatively evaluated. While the Applicant noted that the water in the pipe should remain cool because the pipe is buried, the cumulative effect to water temperature downstream of the Project is not known because the remaining water in the bypass reach could significantly heat up due to its reduced thermal mass. Without a quantitative analysis of how much warming will occur in the bypass reach with the significantly reduced instream flow, it is not possible to assess whether that warmer water in the bypass reach will alter or negate the cooling effects of the natural spring inflows near Panther Grade and, thus, affect in-channel water temperatures downstream of the Project.

Unfortunately, without the understanding that a water temperature model could provide, potential habitat alterations remain unknown during the holding, spawning, and rearing seasons for all types of anadromous fish that would be able to reach areas downstream of the Project and within the bypass reach as well. The FLA's simplistic mitigation of not operating during certain low flow periods (which appears to reliably occur only in September and October, based on Hydmet's (2012) *Flow Duration Report*) does not address potential water temperature changes during other possible important

N-6 (cont'd) anadromous fish lifestage seasons (migration, holding, spawning, and rearing). At any time during the year, the relatively warmer water in the bypass reach could cause the net downstream water temperatures to be outside the preferred water temperature tolerance of an anadromous fish's life stage at that particular time of year. Thus, NMFS believes that a more robust amount of water temperature data is needed to assess baseline conditions and provide input to develop a water temperature model that should be applied to a hydrologic record of substantial length that covers a variety of water year types. Water temperature modeling would then be able to inform potential Project operations that would be truly protective of all anadromous fish resources.

3.5 Comments on the Draft BA and EFHA

N-3 NMFS make the following determinations regarding the Draft BA and EFHA:

- NMFS does not agree with the BA's "Effect Determination" of "*No Effect*" for both CCV steelhead and spring-run Chinook salmon.
- NMFS does not agree with the BA's "Critical Habitat Determination" of "*May Affect, but is Not Likely to Adversely Affect*" for both CCV steelhead and spring-run Chinook salmon.
- NMFS does not agree with the EFHA's "EFH Determination" of "Will Not Adversely Affect" for Pacific Chinook salmon.

NMFS finds that the draft BA for CCV steelhead and CV spring-run Chinook salmon and the EFHA for Pacific salmon are deficient because much of their support was derived from data that resulted from the use of the Hydraulic Geometry method. NMFS believes that the use of the HG method (itself based on limited hydrological information) is inappropriate. The HG method supplies the depth and width of water in the channel at particular flows. The extent of that volume of water determines how much holding, spawning, and rearing habitat is available. The amount of sufficiently wetted habitat determines the relative amount of fish production. However, the HG method tends to underestimate the volume/depth-stage at particular flows and does not account for variations in hydrology due to either wetter/cooler or drier/hotter water years. Thus, the theoretically available habitats, theoretical fish use

N-3 (cont'd) of such habitats, and resulting theoretical production were inherently supported by the use of the faulty HG method that likely underestimates the amount of water that would provide such theoretical habitat.

N-1 Finally, the fall-run Chinook salmon and the federally endangered winter-run Chinook salmon were not considered in either the draft BA or in the EFHA. All four of the above anadromous fish can access the South Fork Battle Creek currently and all of these anadromous fish will be able to access the Project's bypass reach once the South Diversion Dam (RM 14.35) of the Battle Creek Hydroelectric Project, FERC Project No. 1121, is removed from the South Fork Battle Creek. The BCSSRP has full funding and written plans to remove this last barrier to anadromous fish by 2016 (USBR *et. al*., 2004).

In closing, NMFS has determined that there is not enough accurate or sufficient information to evaluate the effects of the Project, as described in the FLA by the Applicant, on anadromous fish resources. Thus, NMFS considers this FLA, the BA, and the EFHA to be deficient and not ready for environmental analysis, based on our comments provided above.

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APPENDIX A

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APPENDIX A

Enclosure B

UNITED STATES OF AMERICA
FEDERAL ENERGY REGULATORY COMMISSION

Lassen Lodge, LLC) **Project No. P-12496**
Lassen Lodge Hydroelectric Project)
South Fork Battle Creek)

CERTIFICATE OF SERVICE

I hereby certify that I have this day served, by first class mail or electronic mail, a letter to Secretary Bose, Federal Energy Regulatory Commission, containing the NOAA Fisheries Service's comments on the Final License Application for the Lassen Lodge Hydroelectric Project (P-12496). This Certificate of Service is served upon each person designated on the official Service List compiled by the Commission in the above-captioned proceeding.

Dated this 12th day of June 2014

William E Foster
William E. Foster
National Marine Fisheries Service

APPENDIX A

CALIFORNIA
Water Boards

EDMUND G. BROWN JR.
GOVERNOR

MATTHEW RODRIQUEZ
SECRETARY FOR
ENVIRONMENTAL PROTECTION

State Water Resources Control Board

JUN 19 2014

Ms. Kimberly D. Bose, Secretary
Federal Energy Regulatory Commission
888 First Street, N.E.
Washington, DC 20426

Dear Ms. Bose:

COMMENTS ON THE FINAL LICENSE APPLICATION AND ADDITIONAL STUDY REQUEST FOR THE LASSEN LODGE HYDROELECTRIC PROJECT, FEDERAL ENERGY REGULATORY COMMISSION PROJECT NO. 12496

The State Water Resources Control Board (State Water Board) has authority under the federal Clean Water Act (33 U.S.C. § 1251-1357) to restore and maintain the chemical, physical and biological integrity of the Nation's waters. Throughout the licensing process the State Water Board maintains independent regulatory authority to condition the operation of the Project to protect water quality and beneficial uses of stream reaches consistent with section 401 of the federal Clean Water Act, the Water Quality Control Plan (Basin Plan) for the Sacramento River and San Joaquin River Basins, State Water Board regulations, California Environmental Quality Act (CEQA), and any other applicable state laws.

On April 29, 2014, the Federal Energy Regulatory Commission (FERC or Commission) published the notice of application tendered for filing with the Commission and soliciting comments and additional study requests for Rugraw, LLC's (Applicant) Lassen Lodge Hydroelectric Project (Project), FERC Project No. 12496. The State Water Board has an additional study request and comments on the Final License Application (FLA) for the Project.

This letter lists the State Water Board's comments and request for studies pertaining to the proposed Project. The following study request and comments are organized into two sections: A) Study Request and B) General Comments.

A. Study Request:

The study request is organized around the criteria outlined in Code of Federal Regulation (CFR) 18 CFR 4.38(b)(7) (see below), required by FERC under the Traditional Licensing Process.

The criteria in 18 CFR 4.38(b)(7) includes, *"For any such additional study request, the requestor must describe the recommended study and the basis for the request in detail, including who should conduct and participate in the study, its methodology and objectives, whether the recommended study methods are generally accepted in the scientific community, how the study* *and information sought will be useful in furthering the resource goals that are affected by the proposed facilities, and approximately how long the study will take to complete, and must explain why the study objectives cannot be achieved using the data already available. In addition, in the case of a study request by a resource agency or Indian tribe that had failed to request the study during the pre-filing consultation process under § 4.38 of this part or § 16.8 of this chapter, the agency or Indian tribe must explain why this request was not made during the pre-filing consultation process and show good cause why its request for the study should be considered by the Commission."*

The following addresses criteria for requesting a study (18 CFR 4.38(b)(7)):

a. *Describe the recommended study and the basis for the request in detail, including who should conduct and participate in the study, its methodology and objectives.*
b. *Explain whether the recommended study methods are generally accepted in the scientific community.*
c. *Explain how the study and information sought will be useful in furthering the resource goals that are affected by the proposed facilities.*
d. *Describe approximately how long the study will take to complete.*
e. *Explain why the study objectives cannot be achieved using the data already available.*
f. *Explain why this request was not made during the pre-filing consultation process and show good cause why its request for the study should be considered by the Commission.*

1. Study Title Requested: Modeling to Predict the Effects of Flow Regime Changes On Water Temperatures

   a. *Describe the recommended study and the basis for the request in detail, including who should conduct and participate in the study, its methodology and objectives:*

   The Applicant should model to predict the effects of flow regime changes on water temperatures in the proposed bypass reach. The State Water Board has identified Battle Creek to the California State Legislature as a high priority tributary to the Sacramento River and Delta. The requested study would inform the State Water Board regarding potential Project impacts to beneficial uses and water quality objectives for the South Fork Battle Creek. The Applicant would consult with the State Water Board, California Department of Fish and Wildlife, National Marine Fisheries Service, and United States Fish and Wildlife Service regarding the study's methodology and objectives.

S-1

   b. *Explain whether the recommended study methods are generally accepted in the scientific community:*

   Methodologies recommended by the State Water Board are generally accepted practices. State Water Board staff in collaboration with other resource agencies, use vetted scientific methodologies in the studies it requests. Current EPA guidelines and peer reviewed studies inform the State Water Board's methodologies.

   Using models (such as SNTemp) to predict the effects of flow regime changes on water temperatures is an accepted practice. The State Water Board is willing to work with the Applicant and resource agencies to ensure that the selected model collectively meets the needs of the resource agencies.

c. *Explain how the study and information sought will be useful in furthering the resource goals that are affected by the proposed facilities:*

The State Water Board is responsible for the protection of beneficial uses of the South Fork Battle Creek and its tributaries. The Project, as described, has the potential to impact multiple beneficial uses and water quality objectives of South Fork Battle Creek. Information provided by the Applicant is not sufficient for the State Water Board to make informed decisions regarding Project impacts to beneficial uses and water quality objectives.

S-1 (cont'd)

d. *Describe approximately how long the study will take to complete:*

The State Water Board expects that it may take approximately two months to complete a temperature modeling study.

e. *Explain why the study objectives cannot be achieved using the data already available:*

The FLA did not include a model to predict the effects of different flow regime changes on water temperatures.

f. *Explain why this request was not made during the pre-filing consultation process and show good cause why its request for the study should be considered by the Commission:*

The State Water Board expected to receive information regarding the Project and stream flow/water quality analysis during the pre-filing consultation process in order to provide comments to the Applicant. However, the Applicant filed the Final License Application with FERC, without providing the information to the State Water Board beforehand, for comment as planned. The study requested will help inform both the Commission and the State Water Board's environmental documents and decisions regarding the Project.

B. General Comments:

S-2

1. Page A-2 of the FLA states that "Debris accumulating on the trash rack will be manually removed when debris impedes flow into the intake structure, and hauled away from the influence of the stream." The FLA should explain how often the trash rack will be inspected for debris.

S-3

2. Volume One Exhibit A, on page 2, states "The intake structure will have facilities to flush accumulated sediments. This will be accomplished by manually opening debris valves installed within the intake structure." The FLA should explain where the accumulated sediments will be flushed to. The FLA should explain how the design of the diversion dam would allow sediments to pass through the dam/intake structure to downstream and how often this may occur.

S-4

3. The FLA should include all raw data (e.g., water temperature) in an appendix.

S-5

4. The State Water Board will require access to any modeling performed for the Project.

S-6

5. Page A-14 of Exhibit A - Project Description states that final permits and approvals are expected by September 30, 2014. The proposed construction milestone schedule should be updated to reflect a current schedule.

JUN 19 2014

S-7 6. Page E-18 of Exhibit E is missing Figure 1.2-1.

S-8 7. Figure 1 of Appendix A includes information for several years. The Applicant should separate the hydrographs by year and include all of the months and days on the x-axis.

S-9 8. Figure 2 of Appendix A should include the measured maximum and minimum daily water temperatures. Additionally, the x-axis should be more detailed, specifying the months for each year.

S-10 9. Figure 3 of Appendix A is missing the information and a Key for Logger 6.

S-11 10. Page 47 of Appendix C - Stream Flows and Potential Production of Spring-Run Chinook Salmon and Steelhead in the Upper South Fork of Battle Creek (Appendix C) states, "It appeared, based on professional judgment of the passage impediment at each location, that modest flows of 30-50 cfs (and possibly less) would be sufficient to enable passage between all channel units within the project reach." Page 48 states that "Occasional higher flows reaching 30-50 cfs would be desirable, based on professional judgment, to ensure that resident trout can move between channel units within the reach." Additionally, page 48 states, "…bypass flows in the range of 30-60 cfs should be sufficient to provide adequate passage opportunities for trout to move about within the reach to position themselves for spawning."

Based upon this information, it is unclear why the Applicant would propose a minimum instream flow of 13 cfs for the proposed Project reach, when higher flows (according to professional opinion) may be needed for fish passage between channel units within the proposed Project reach. It is unclear why the modeling used did not account for movement of fish within the reach. The FLA indicates that 13 cfs is not sufficient for fish passage within the proposed Project reach. The Applicant should not assume that there will be excess flow available in the proposed Project bypass reach for fish passage. The minimum instream flow should include the flows necessary for fish passage/migration, spawning, rearing, and holding, which as referenced above, appears to be higher than 13 cfs.

S-12 11. Table 1 of Appendix A - Water Quantity and Quality Technical Study includes estimates of the monthly average flow and median flow for South Fork Battle Creek. The State Water Board prefers that minimum instream flows mimic the natural hydrograph of South Fork Battle Creek rather than using one numeric value to assign flow for six to eight months of each year.

The Applicant should either:

a) Propose year-round minimum instream flows for each month of the year (with the year beginning in October) and for each of the different water-year types (e.g, Wet, Normal, Below Normal, Dry, Critical); **or**

b) Propose minimum instream flows for each month of the different water-year types to span the period when operation is anticipated, including dates when operations will commence and cease each year.

S-13 12. The Project proposes to operate approximately six to eight months of the year during the winter and spring. Page 18 of Appendix A states, "The proposed bypass flow for the project is 13 cfs which is sufficient to maintain water quality and temperature conditions in the

S-13 (cont'd)

bypass reach based on field measurements collected during low flow conditions in July and September 2013. The proposed LLHP operations scenario have been optimized by the applicant in modeling studies to ensure flow and water quality conditions would not be impaired substantially and that all existing beneficial uses are fully maintained."

The FLA seems to assume that a bypass flow of 13 cfs is "sufficient to maintain water quality and temperature conditions in the bypass reach" because flows have been 13 cfs in the proposed bypass reach during the low flow season. The FLA should explain how the existing water quality and temperature conditions in the bypass reach will be protected when the Project is in operation during the winter and spring. According to the FLA, South Fork Battle Creek is considered to have "high water quality" and the average and median flows during the winter and spring are much higher than 13 cfs.

S-14

13. Exhibit E, page E-56, explains that water temperature would be monitored at six locations: 1) the diversion/intake structure; 2) the bridge at State Route 36; 3) within the bypass reach above the tailrace; 4) within the bypass reach below the tailrace; 5) within the tailrace; and 6) the wooden bridge at Ponderosa (downstream of Panther Grade). Water temperature should also be monitored above the bypass reach (above the diversion dam pool/above the influence of the Project) for comparison.

S-15

14. The FLA explains qualitatively that the temperature of water that would flow through the penstock and powerhouse would not increase and therefore, when water returns to the South Fork Battle Creek the water temperature of the creek would not increase. The State Water Board has identified Battle Creek to the California State Legislature as a high priority tributary to the Sacramento River and Delta. The State Water Board will require the Applicant to explain further why temperature downstream will be unaffected by the proposed Project. If data exists, additional analysis is needed to verify that the Applicant's assumption is correct. If data does not exist, additional analysis and monitoring would be needed.

S-16

15. The FLA should describe the type of construction equipment that would be used in the bed and banks of South Fork Battle Creek.

S-17

16. The FLA did not discuss how the proposed minimum instream flows would affect benthic macroinvertebrate communities. The FLA should discuss how the proposed flows would affect benthic macroinvertebrates.

S-18

17. The FLA should discuss if potential impacts to the stream channel are expected due to vegetation encroachment resulting from an absence of flows.

S-19

18. The State Water Board will require the Applicant to model potential Project effects on the South Fork Battle Creek channel due to Project operations altering existing flow and sediment regimes. Specifically, any 3D model should address Project operation impacts to: 1) bank stability; 2) sediment transport; and 3) riparian and invasive vegetation.

The information obtained would inform the State Water Board's CEQA document and water quality certification conditions regarding minimum instream flow requirements for the Project. Therefore, State Water Board staff considers the information necessary prior to issuing a water quality certification.

19. Page 18 of the Water Quantity and Quality Technical Study (Appendix A) states "The proposed LLHP operations scenario have been optimized by the applicant in modeling

S-19 (cont'd) studies to ensure flow and water quality conditions would not be impaired substantially and that all existing beneficial uses are fully maintained. The proposed diversion of streamflows to generate power during high flow events and on the tails of these peaking events is not expected to substantially impair water quality conditions and associated beneficial uses due to the very high water quality characteristics of SF and that diversions would not occur during the low flow season."

S-20 Regarding the statement, "The proposed LLHP operations scenario have been optimized by the applicant in modeling studies to ensure flow and water quality conditions would not be impaired substantially…" State Water Board staff recommends that the Applicant revise the proposed operations scenario in modeling studies to ensure that flow and water quality conditions will not be impaired. The State Water Board requires a copy of any operational model for the Project, so that State Water Board staff can use the model to compare the different operating scenarios for the Project.

S-21 Regarding the statement, "The proposed diversion of streamflows to generate power during high flow events and on the tails of these peaking events is not expected to substantially impair water quality conditions and associated beneficial uses…", the Applicant needs to explain: 1) How the proposed diversion is expected to impair water quality conditions and beneficial uses; and 2) What criteria are being used to discern the level of significance with respect to these impacts.

S-22 The Basin Plan's water quality objectives for inland surface waters states, "The suspended sediment load and suspended sediment discharge rate of surface waters shall not be altered in such a manner as to cause nuisance or adversely affect beneficial uses." The FLA should address potential effects of the Project on the sediment distribution in the channel above and below the diversion dam. This information will inform the State Water Board staff, so that a determination can be made on how the proposed Project can avoid adversely affecting water quality and the beneficial uses of the South Fork Battle Creek.

If you have any questions regarding this letter, please contact Michelle Lobo, Project Manager, at (916) 327-3117 or by email at Michelle.Lobo@waterboards.ca.gov. Written correspondence should be addressed as follows:

State Water Resources Control Board
Division of Water Rights
Water Quality Certification Program
Attn: Michelle Lobo
P.O. Box 2000
Sacramento, CA 95812-2000

Sincerely,

Michelle Lobo

Michelle Lobo
Environmental Scientist
Water Quality Certification Program

cc: Mr. Adam Beeco
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American Fisheries Society Symposium 71:225–254, 2009

Linking Stream Carrying Capacity for Salmonids to Habitat Features

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Abstract.—Stream carrying capacity for anadromous salmonids that rear to the smolting stage in freshwater can be predicted from a sequence of cause-response functions that describe fish preferences for macro-habitat features. The channel unit (e.g., pool, glide, riffle) is a useful stratum for quantifying rearing capacity for salmonids, and is a hydrologically meaningful unit for predicting the response of stream morphology to watershed processes. Thus, channel units are the natural link between habitat-forming processes and habitat requirements of salmonids. Maximum densities of juvenile salmonids that can be supported in a channel unit are related to availability of preferred habitat features including velocity, depth, cover, and substrate. Within channel unit types, maximum densities of salmonid parr will shift predictably as availability of cover from wood and boulders increases. Within stream reaches, additional variation in maximum rearing densities can be accounted for by light penetration and nutrient load. As salmonids grow, their habitat preferences change and the preferred habitat associated with their increasing size becomes less and less available. Further, territory size of salmonids increases exponentially with fish length, such that the demand for territory to support surviving members of a cohort increases at least through their first year of life. Changing habitat preferences and space demands, juxtaposed against shrinking habitat availability with the onset of summer low flows often results in a bottleneck to rearing capacity for age >1 salmonids in wadable streams. Habitat measurements in Oregon streams indicate that depths preferred by steelhead (anadromous rainbow trout) *Oncorhynchus mykiss* become scarce as parr exceed 15 cm in length, which coincides with the approximate threshold length for steelhead smolts. We present a generalized framework, called the Unit Characteristic Method, for accumulating effects of these habitat factors at the channel unit and reach-level scales to estimate carrying capacity for rearing salmonids in a basin. Our subsequent chapter in this book presents a demonstration of how this method can be applied to predicting salmonid production in streams.

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Introduction

How many salmon or trout should a given stream be capable of sustaining, and how will human actions affect those production capabilities? This is an urgent and often debated question, especially when resource managers constrain harvest, choose a hatchery strategy, regulate land or water use, or propose habitat restoration. All strategies to manage human activities so as to sustain desirable fish populations share a need to understand the primary drivers of fish population trends. The traditional approach to determining carrying capacity for anadromous salmonids has been through stock–recruitment analysis (Ricker 1954; Beverton and Holt 1957). That approach arose from an era that focused on determining maximum sustainable yield (MSY) for harvest. However, traditional approaches to quantifying stock–recruitment relationships have proven to be imprecise, because they are often based on an inadequate range of population sizes (Walters 1997) and they incorporate variation in survival through both the freshwater and marine phases of life. In the present era of depleted salmonid stocks across much of North America, with a mandate under the Endangered Species Act (ESA) to design recovery plans for ESA-listed populations, we need habitat-based approaches for estimating salmonid stream production capacities to inform harvest and habitat decisions.

Stock–recruitment analysis requires a long time-series of data that includes a wide range of run sizes, but such data are lacking for the great majority of salmonid-producing basins. Even when data are available, the approach usually leaves a large share of recruitment variation unexplained (Figure 1), and leads to wide confidence intervals on estimated parameters of the curve (Cramer 2000). Some of the most robust data sets available appear as a cloud of data points when scattered against one another, without a clear pattern to indicate the form of the stock–recruitment curve that should best fit them. Further, that approach is not helpful for identifying the specific habitat factors that are limiting the population, or for estimating the benefits from potential stream alterations in a small portion of the watershed.

If stream features change, those changes will influence the stream's capacity to produce salmonids. Field studies of salmonids and their habitats have rapidly expanded over the last decade, and provide opportunities to develop more accurate and utilitarian approaches for parameterizing the stock-recruit function of salmonid populations. Promising methods have emerged and are being refined to estimate carrying capacity and productivity directly from measures of stream habitat (e.g., Bartholow et al. 1997; Cramer and Ackerman 2009, this volume; Blair et al. 2009, this volume). An ideal approach to predicting carrying capacity and survival rates of salmonids based on habitat features in a stream would offer the advantages of easily available data, and the potential to predict fish benefits from proposed habitat restoration or protection strategies.

A great challenge in determining the effects of land and water management on fish has been the inadequacy of efforts to quantify cause-effect relationships between watershed changes and changes in fish populations (Imhof et al. 1996). The key to quantifying this linkage is to first determine the specific stream features that substantially influence salmonid populations, and then use watershed process models to predict how those features will change due to watershed management actions.

In this chapter, we synthesize empirical evidence to link stream carrying capacity for salmonids to habitat features, and we explore possible cause-response relationships that determine the life stage of salmonids for which suitable habitat is most limiting. We show that channel unit types provide reliable

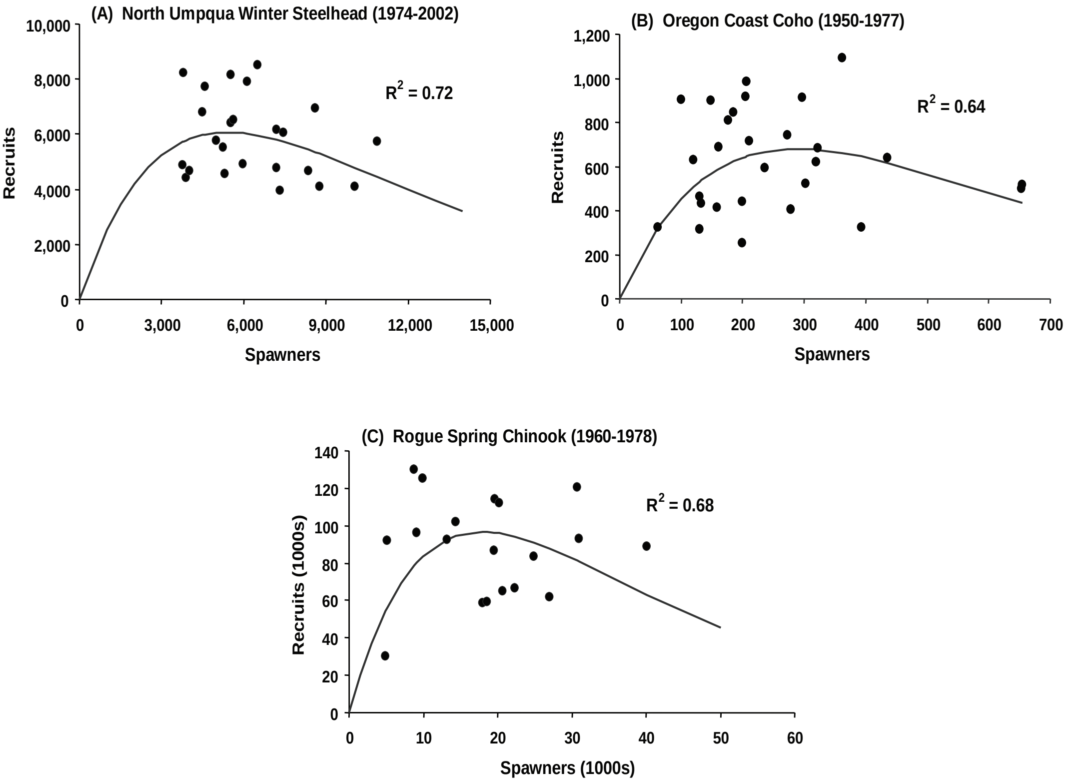

Figure 1. Examples of Ricker stock–recruitment curves fitted to a long time series of spawner and adult recruitment estimates, illustrating the typical wide dispersion of data. (A) North Umpqua Winter Steelhead (Mark Chilcote, Oregon Department of Fish and Wildlife, Portland, OR, personal communication), (B) Oregon Coast coho (Cramer 2000), and (C) Rogue Spring Chinook (Cramer 2000).

strata for predicting maximum rearing densities, and that these units can be used to link habitat-forming processes to stream carrying capacity for salmonids. In addition to the physical features of habitat, we also account for the influence of food supply on the capacity of streams to produce salmonids. We recognize that competition, predation, and water quality also influence carrying capacity, but these complex features are beyond the scope of this paper. High summer temperatures, for example, commonly restrict or reduce salmonid use from certain areas of basins where the habitat is otherwise suitable. The framework described here for determining habitat production potential was developed from studies in salmonid-producing streams, and therefore will produce best results when applied to stream reaches having the typical range of conditions for streams that consistently support salmonids.

Importance of Stream Area

At the broadest scale, the size of a basin constrains its capacity to produce salmonids. Correlations have been demonstrated between several measures of basin size and the run sizes of anadromous salmonids it produces (Figure 2). These correlations clearly indicate that salmonid production is a function of stream area or volume, but more detail

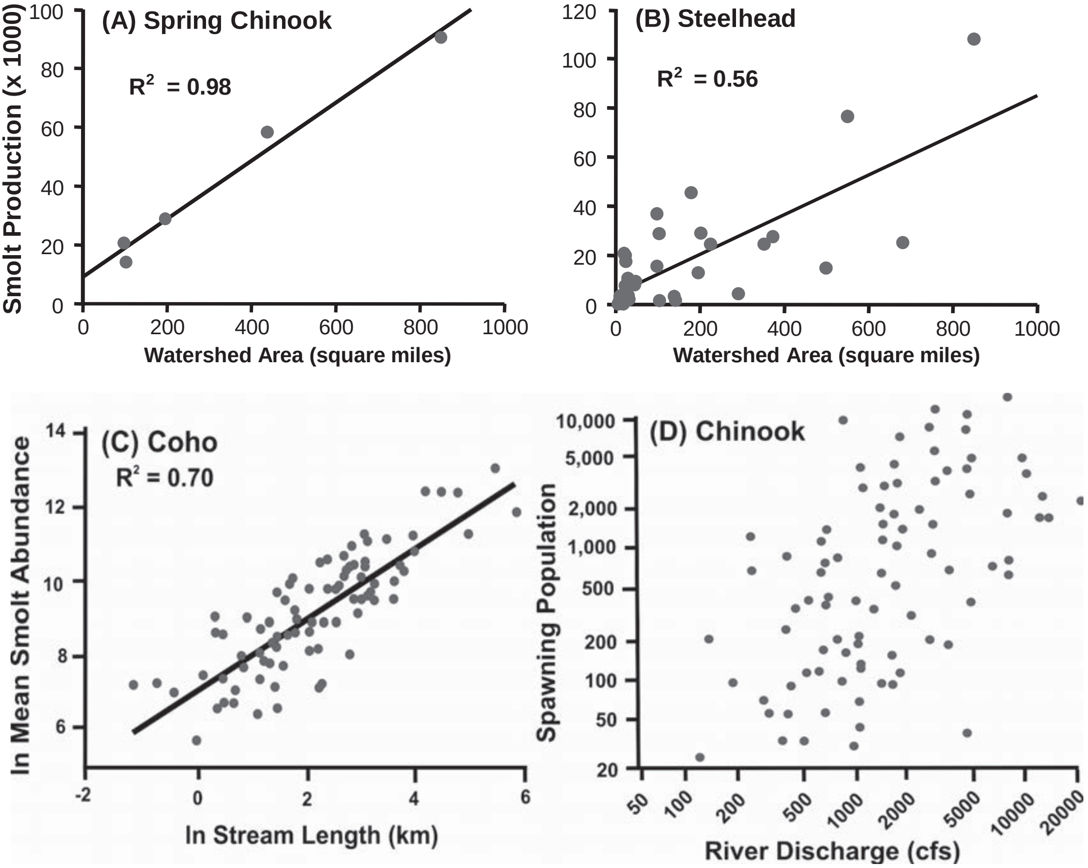

Figure 2. Example relationships of salmonids production to various measures of stream size. (A) maximum out-migration estimates of yearling spring Chinook in five watersheds of the Snake River Basin (Underwood et al. 2003); (B) maximum smolt estimates for steelhead in 39 watersheds of the Pacific Northwest (Underwood et al. 2003); (C) coho smolt production across 86 streams in western North America versus length of stream network with coho presence (Bradford et al. 1997), and (D) average spawning population of Chinook in British Columbia Rivers during 1952–76 (Healey 1991).

is needed about the specific habitat features that salmonids depend on before we can determine how human actions will influence salmonid habitat.

A fundamental concept in relating salmonid production to stream habitat is that stream-dwelling salmonids either defend, or rely on food from a characteristic area of territory (see Allen 1968 for an early review). Allen (1968) points out that territory requirements of individual fish of a given size vary little, whether fish are abundant or scarce, which therefore leads to competition for space, and displacement when the sum of territory requirements for individual fish exceeds the area of available suitable habitat. Allen (1968) assembled data from 35 published studies on territory sizes of six salmonid species, and found a positive linear relationship between the logarithm of territory area and the logarithm of fish length across all six species. The data Allen assembled were measurements of area used by individual fish, not the area that a group of fish used. These areas of use changed dramatically as fish length changed, but not as fish density changed (Allen 1968). This relationship was supported by the subsequent analysis and data of Grant and Kramer (1990). Allen (1968) concluded that densities of salmonids in streams had an upper capacity determined by the size of individual territories and "*the proportion of the bed accessible to and suitable for occupation by the fish*." Further, he found that only 2–20% of stream area was used by the territories of salmonids at maximum observed densities in the 35 published studies and, therefore, there must be other stream features that limited the proportion of stream area suitable for salmonids of a given size. Similarly, Grant and Kramer (1990) found that density-dependent responses to competition were detectable in more than 50% of salmonid populations that exhibited greater than 27% of territory saturation. In a compilation of more recent studies in natural streams, Keeley (2003) found that reported densities rarely achieved the full saturation of territory sizes as reported by Grant and Kramer (1990). Keeley (2003) found through controlled manipulations of fish densities and food availability that, as fish grew over time, fish density decreased at a rate best predicted by the territory size function for individual fish as reported by Grant and Kramer (1990). This notion of carrying capacity is also implicit in stock–recruitment theory for salmonids (e.g., Ricker 1954: Beverton and Holt 1957), and in the Instream Flow Incremental Methodology (IFIM) methodology to assess effects of in-stream flow changes on salmonids (Bovee et al. 1998).

The finding that much of a stream remains unused by salmonids even when the population is at capacity leads to the question, "What are the features within a stream that determine the area suitable for salmonids to establish territories?" We now proceed through the evidence which indicates for juvenile anadromous salmonids that (1) territory size increases with fish length, (2) carrying capacity increases with food availability, and (3) habitat preferences change with fish length. This generalization would not apply to chum and pink salmon that emigrate as swim-up fry, nor to sockeye that rear in lakes.

Territory size increases with fish length

Grant and Kramer (1990) synthesized data from 10 studies that included observations of territory size for seven species of salmonids, and found that 87% of variation in territory size could be accounted for by fish length (Figure 3). The relationship they found is described by the following regression equation:

$$\log_{10} \text{Territory Area (m}^2\text{)} = 2.61*\log_{10} \text{fish length (cm)} - 2.83 \qquad (1)$$

Grant and Kramer (1990) established that this relationship was consistent with the predicted increase in food intake to satisfy the energetic requirements of fish. The breadth of data used by the authors demonstrates that this relationship is transferable to populations across species and regions for salmonids. This relationship makes it possible to determine the relative amount of rearing area that fish will require at progressive life stages. Further, the relationship can be rearranged to predict the maximum rearing density that should be expected for a given size of salmonid under average environmental conditions. When testing the relationship against an independent set of studies with salmonids, Grant and Kramer (1990) found that it correctly predicted the occurrence of density-dependent growth, mortality, or emigration in 81% of the cases. This indicates that the density limit predicted by the relationship is analogous to the carrying capacity parameter for a stock–recruitment relationship (at the stage studied).

Although length accounted for 87% of variation in territory size, Grant and Kramer

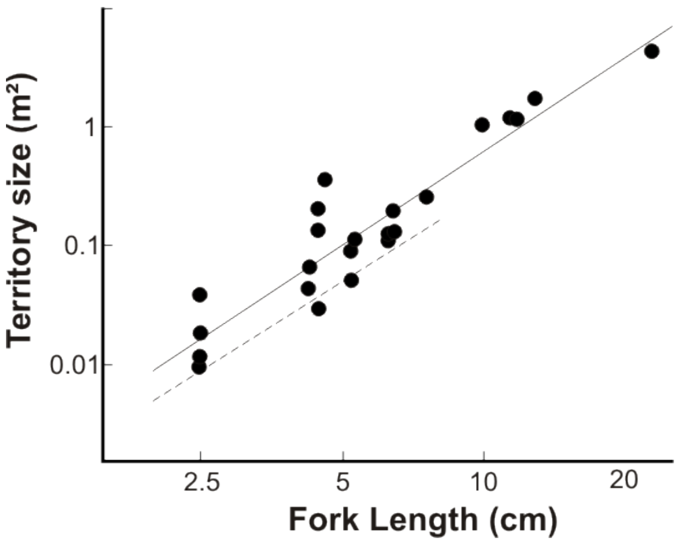

FIGURE 3. Relationship of territory size (m^2) and fork length (cm) for stream dwelling salmonids (from Grant and Kramer 1990). Numbers with points identify data source given in Grant and Kramer (1990). Dashed line is regression for territory size of brook trout, and solid line is regression for other salmonids including rainbow trout, Atlantic salmon, brown trout, and coho salmon.

(1990) noted there was still an order-of-magnitude variation about the mean territory size for a given length of fish, and they presented evidence that some of that variation was related to environmental conditions. They cited specific studies within their data set that demonstrated territory size was influenced by food density and intruder pressure, which we consider later in this paper. Grant and Kramer (1990) also showed that salmonid densities in pools often exceeded the maximums predicted by territory size for fish length. They concluded that, in pools of sufficient depth, trout were vertically stratified, thereby increasing the density that could be sustained per surface area of pool relative to that of a riffle.

Carrying capacity increases with food availability

Data from several studies show that stream capacity for salmonids is related to fish size, food supply, and the factors affecting that supply (Grant and Kramer 1990; Grant et al. 1998; Slaney and Northcote 1974; Keeley 2001). Juvenile salmon and trout in streams feed primarily on drift invertebrates, and studies show that the invertebrates most likely to occur in the drift are the species produced in riffles (Rader 1997). Field and laboratory studies indicate that production of invertebrate drift is strongly determined by at least four factors: (1) availability of riffles, (2) amount of light penetrating to the stream, (3) percentage of fines in the riffle substrate, and (4) nutrient levels. Riffles provide the physical habitat (combination of substrate and velocity) that invertebrate taxa favored by salmonids are produced in, and sunlight and nutrients provide the energy and raw materials for the primary production (algae and plants) that serves as food for the invertebrates (Figure 4). In this chapter, we summarize evidence that demonstrates the role of each of these four factors in determining stream productivity, while Cramer and Ackerman (2009) describes how these factors are integrated into a functional relationship that quantifies their influence on productivity (an index of food availability).

Importance of macroinvertebrates in riffles.—Though aerial insects and spawned salmon carcasses are important food sources for juvenile salmonids during portions of the year (Bilby et al. 1996; Wipfli 1997), salmonids feed predominantly on drift invertebrates in streams (Rader 1997; Elliot 1973 as cited by Murphy and Meehan 1991). The primary source of drift invertebrates are riffle habitat types (Hawkins et al. 1983; Rader 1997). Hawkins et al. (1983) studied 13 coastal streams, and found that salmonid density was correlated to invertebrate density in riffles, but not to invertebrates typically found in pools. Further, most invertebrates in pools were in shells or protective casings, and did not drift, while invertebrates found in riffles were those most likely to drift.

Because riffles provide invertebrates upon which salmonids feed, it follows that low frequency of riffles will lead to a limitation in food supply for salmon and trout in streams. The percentage of area composed by riffles in a stream is largely a function of gradient (Hicks 1989). Hawkins et al. (1983) showed that salmonids were present at all sites in 13 coastal streams where gradients were greater than one percent, but were absent at eight of 10 sites with gradient less than one percent. Further, Hawkins et al. (1983) found the percentage of fines in the substrate was highly related to gradient, and that excess fines was correlated to reduced production of both invertebrates and juvenile salmonids.

Influence of sunlight exposure.—Several studies have demonstrated that the amount of sunlight penetrating the forest canopy limits primary production, the source of food for invertebrates, and therefore limits food production for salmonids. Such studies in West Coast forests have evaluated streams where part or the entire forest canopy was removed and have shown that production of algae, aquatic invertebrates and salmonids increased in the affected stream reach (Carlson et al. 1990; Newbold et al. 1980; Murphy et al. 1981; Murphy and Hall 1981; Hawkins et al. 1983). In each of the studies, the authors related the increases in macroinvertebrates to an increased production of algae and vascular plants following the increased exposure of the stream to sunlight (Figure 4).

Combined results from field and laboratory studies demonstrate that primary production increases only up to a saturation level of light that is comparable to partial shade. If nutrients are sufficient, primary production can increase with increased light up to an optimum, or saturation level, of about 1–2 lumens/cm^2 (McIntire 1975), which is about 10–20% of full sunlight. McIntire (1975) found that primary production in laboratory streams was also influenced by temperature, and was about 50% greater at 20°C than at 10°C, apparently from the accelerating effect of temperature on chemical reactions.

The amount of sunlight reaching a stream is often estimated from measurements of angular canopy density in forested streams. Carlson et al. (1990) found in 11 undisturbed watersheds in northeast Oregon that 83% of variation in macroinvertebrate density was accounted for by regression on elevation and angular canopy density (%). This relation indicated that, as angular canopy density decreased from 80% to 40% (i.e., as light penetration doubled), invertebrate density doubled at an elevation of 1,500 m, and increased by 50% at an elevation of 1,000 m. The effect of elevation in this analysis probably reflected the combined influence of cooler temperatures and fewer nutrients in higher elevation streams. The data of Carlson et al. (1990) indicated that maximum effective sunlight for primary production occurred at angular canopy densities of $\leq$35%, which was the lowest value they sampled.

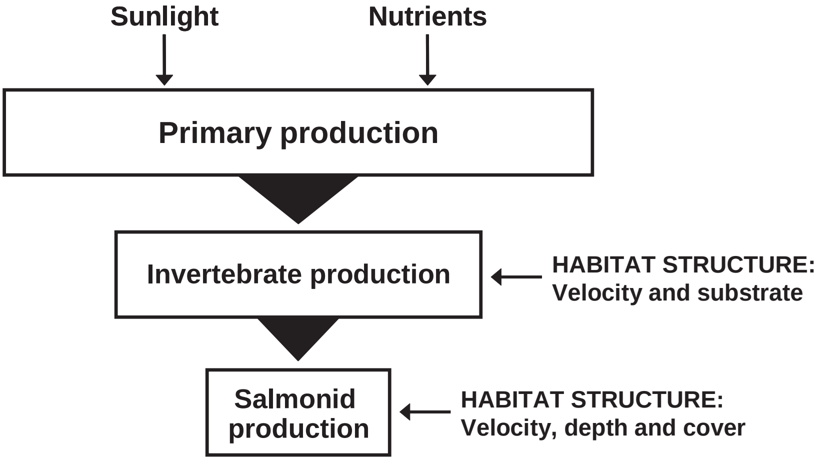

Figure 4. Diagram showing general pathways of influence by sunlight, nutrients, and habitat structure on salmonid production.

Influence of turbidity.—As sunlight penetration of the vegetative canopy influences stream production, so does light penetration into the water column. Rivers that are turbid experience a unique limitation to production in that light penetration is reduced. Lloyd et al. (1987) found that a turbidity level of only 5 NTUs can decrease primary production in shallow streams by 3–13%. An increase of 25 NTUs may decrease primary production by 13–50% in shallow streams. Primary production in streams deeper than 0.5 m would be reduced even further.

Influence of fine sediment.—Substrate embeddedness with fines is a key factor that influences both the production of invertebrate drift and the cover for juvenile salmonids. Hawkins et al. (1983) found that increasing percentages of fines in riffles across reaches in 13 coastal streams of Oregon was correlated to reduced production of both invertebrates and juvenile salmonids. Newly emerged fry can occupy the voids within gravel of 2–5 cm diameter, but presmolts need cobble (>7.5 cm) and boulder-sized rock to provide interstitial spaces they can occupy. These interstitial spaces can be filled by sediment, which reduces available cover, availability of drift, and therefore rearing densities (Bjornn et al. 1977; Thompson and Lee 2000; Figure 5).

Influence of nutrients.—Invertebrate production generally increases as nutrient levels increase. Studies in British Columbia have shown that addition of fertilizer to a stream substantially increased production of invertebrates, and even increased the growth rate and density of juvenile salmonids (Ward et al. 2003; Wilson et al. 2003). Following addition of dry or liquid agricultural fertilizer to the Keogh River, British Columbia, benthic insects increased two- to seven-fold in a treatment area, mean weights of steelhead parr increased 30–130%, and smolt yield increased 62% (Ward and Slaney 1993).

Natural differences between streams in dissolved nutrient concentrations show strong correlation to the density of juvenile salmonids that can be supported. Bjornn and Reiser (1991) reported that standing crop of age-0 Chinook *Oncorhynchus tshawytscha* compared between streams in Idaho was 10 times higher in a stream reach with a 10-fold higher conductivity (40 versus 400 µS/cm^3). Several authors have shown a positive relationship between stream alkalinity and salmonid production (Degerman et al. 1986; Scarnecchia and Bergerson 1987; Kwak and Waters 1997). Ptolemy (1993) found a positive relationship between total alkalinity and salmonid abundance across 226 streams in British Columbia (r^2 = 0.86), and this relationship was valid when applied to 37 streams in six countries. Kwak and Waters (1997) showed that, at a broad geographic scale, alkalinity and salmonid biomass were positively and significantly related ($P < 0.0001$).

Habitat preferences change with fish length

Chinook parr generally move to deeper and faster water as they increase in size (Lister and Genoe 1970; Everest and Chapman 1972; Hillman et al. 1987). They also, as a result of seeking deeper and faster water, move farther from shore (e.g., Everest and Chapman 1972; Don Chapman Consultants 1989). Everest and Chapman (1972) found a highly significant correlation between fish size and the depth or velocity at which juvenile Chinook and steelhead *O. mykiss* hold (Figure 6). Bjornn and Reiser (1991) found velocity so important to the preferences of salmonids that they concluded, "If velocities are unsuitable, no fish will be present." Although most salmonid species that rear in streams are also well adapted to rearing in lakes, salmonids in streams feed primarily on invertebrate drift (Rader 1997) which tends to increase with velocity (Smith and Li 1983). Thus, foraging opportunities appear to drive their preference for velocity in streams. Studies by Rosenfeld et al. (2005) in experimental channels demonstrated that juvenile coho shifted to higher

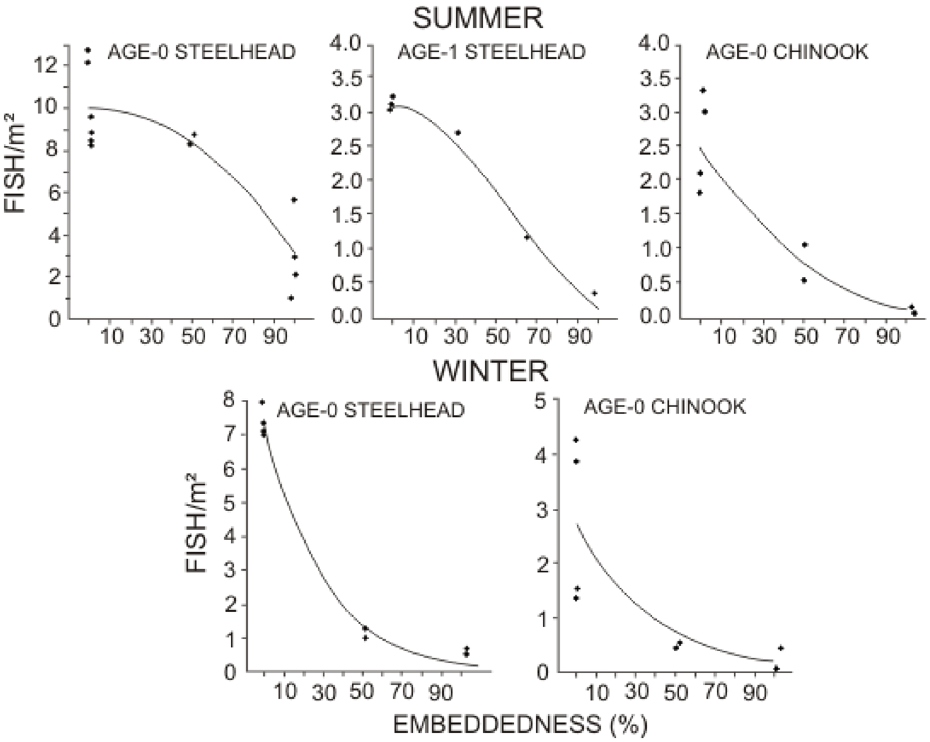

Figure 5. Densities of Chinook salmon and steelhead juveniles remaining after 5 d during summer and winter tests in laboratory stream channels with varying amounts of embededness by fines <6 mm. From Bjornn et al. (1977).

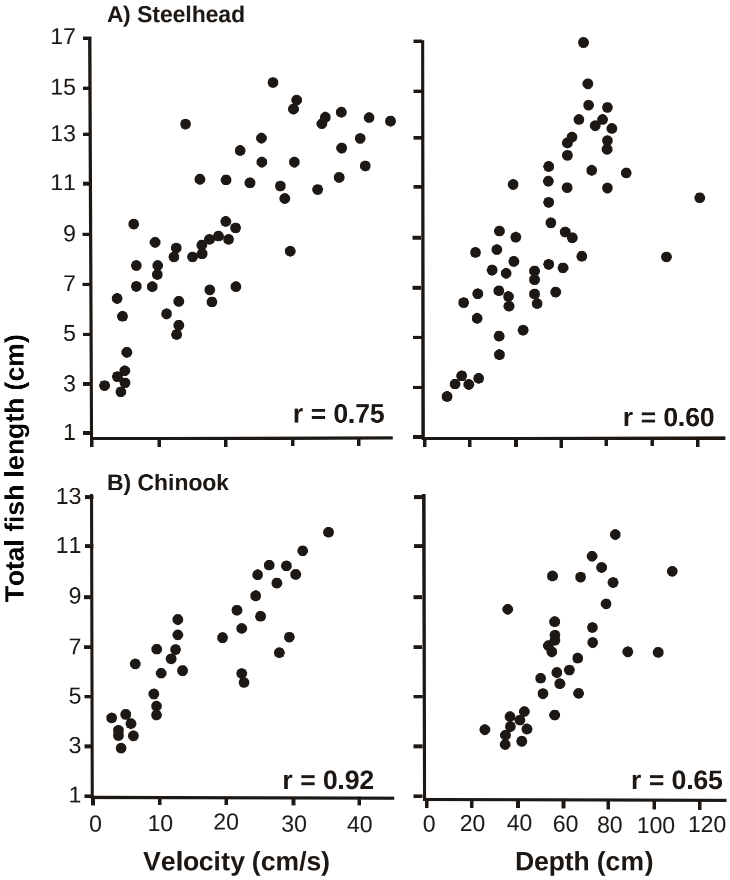

FIGURE 6. Scatter plot showing relationship between length of juvenile (A) steelhead and (B) Chinook and the depth and velocity of water at their focal point. From Bjornn and Reiser (1991), as redrawn from Everest and Chapman (1972).

average focal velocities as invertebrate drift was increased, and that growth rate was highly correlated to drift abundance.

At the typical length in late summer for age-1 steelhead parr (~12 cm) or age-0 Chinook parr (~9 cm), their preferred depth is roughly 0.8 m (Figure 6). The changing preferences of growing juveniles results in a reduction in the area of riffles and pools that are suitable to them. This is strikingly evident from the depth frequencies of pools and rifles in typical steelhead streams spread across Oregon. We assembled data from stream surveys by the Oregon Department of Fish and Wildlife and U.S. Forest Service from seven watersheds that were important steelhead producers (see Cramer and Ackerman 2009). The surveys covered 528 km of stream and included measurements of over 10,000 channel units (pool, riffles, etc.). From these streams, we found that about 25% of riffles and 90% of pools have depths ≥0.3 m, but this availability drops to 10% of riffles and 60% of pools at 0.5 m, and to <1% of riffles and 25% of pools at 0.8 m (Figure 7). As juvenile salmonids grow beyond presmolt size, the data from Oregon streams show that the preferred steelhead stream habitat is rare. Thus, habitat availability at the parr stage in the summer is most likely to limit a watershed's carrying capacity for salmonids that over-summer in streams because this life stage represents the convergence of increasing fish length and territory size requirements, and decreasing availability of water and suitable habitat.

The average stream area of suitable habitat required to raise a cohort of salmonids can be determined by combining the territory versus fish length relationship from Grant and Kramer (1990) with survival between life stages reported in the literature. Although the type of habitat that is suitable for each life stage will vary, at least the relative area of stream required can be determined. For example, a pair of steelhead defends a territory of roughly 3–5 m^2 around their redd (Wydoski and Whitney 2003), spawn an average of 4,900 eggs (Quinn 2005), and an average

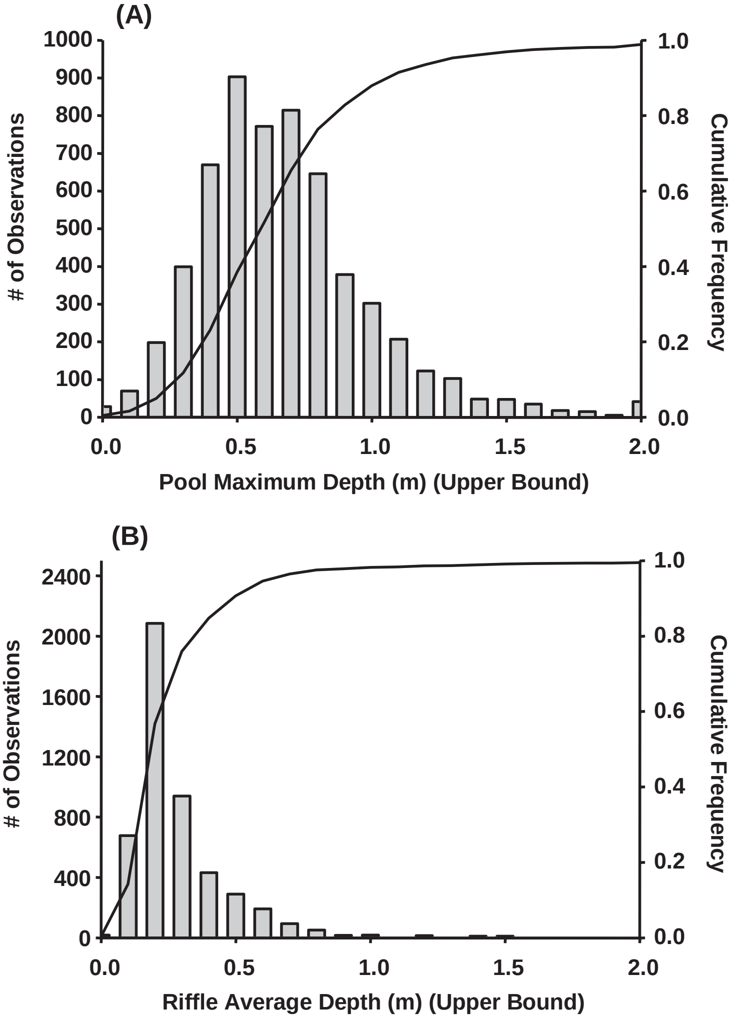

Figure 7. Frequency of (A) pool and (B) riffle depths throughout the channel networks used by steelhead in seven Oregon watersheds where steelhead smolt production has been monitored. See Cramer and Ackerman (2009) for a description of the watersheds. Channel unit data from U.S. Forest Service and Oregon Department of Fish and Wildlife Aquatic Inventories. Database available online at http://oregonstate.edu/Department/ODFW/freshwater/inventory/habitgis.html.

Table 1. Survivorship and predicted area required for a steelhead family cohort, based on the relationship of territory size to fish length (Grant and Kramer 1990). Fecundity and egg survival from Quinn (2005). Mid-range of parr survival from age 0 to age 1 reported by Bjornn (1978), Ward and Slaney (1993) and Johnson et al. (2005).

Parameter	Spawner	Fry	Age-0 Parr	Age-1 Parr
Length (cm)	72	3.5	8.0	12.0
Survival from previous stage	- -	0.29	0.5	0.4
Survivors in cohort	4,900 eggs	1,421	711	294
Area needed (m^2) for cohort	5	55	239	276

29% survive to be fry (Quinn 2005). Using the values presented in Table 1, 50% of those fry survive to be parr at the end of summer, and 40% of those parr survive through the winter to become age-1+ parr the next summer. This means that a spawning pair of steelhead produce about 1,421 fry, of which 711 survive to the end of the first summer, and 284 survive to age-1+ parr the second summer (Table 1). Even though the number of survivors in the cohort rapidly declines over time, the total area of suitable habitat required for territories of the surviving individuals increases with age of the cohort (Figure 8). The 711 surviving age-1+ parr in combination require nearly five times the area needed by the 1,421 fry. Given the large increase in habitat area required with increasing age, coupled with a decreasing fraction of habitat that is suitable, it is likely that habitat availability will be most limiting when increasing fish size and flow-related decreases in habitat converge. This is typically the parr life stage rearing during low summer flows.

Territory dynamics are altered during winter when metabolic demands are lowest and refuge is the habitat priority. Due to the strong tendency of coho *O. kisutch* to seek off-channel and protected habitats during winter, their area required for winter habitat is often the factor limiting their carrying capacity (Nickelson 1998). However, there is evidence that coho production is limited by low summer stream flows in some areas (Bradford et al. 1997). In contrast to coho, Chinook and steelhead do not seek off channel habitat for winter, and have a strong tendency to enter interstices of cobble and boulder substrates within the same channel types they occupy during summer (Hartman 1965; Bustard and Narver 1975; Hillman et al. 1987; Bjornn and Reiser 1991). Therefore, summer rearing habitat will determine the carrying capacity for yearling Chinook and steelhead. This concept has been illustrated for streams by multiple authors. Data from numerous studies suggests there is substantial density compensation after the age-0 rearing year (Bjornn 1978; Ward and Slaney 1993; Everest et al. 1987). Anadromous species that rear less than one year in freshwater (e.g., ocean-type Chinook) may experience habitat limitations for either spawning or rearing, depending on the species and stream-specific situation.

Now that we have substantiated that rearing habitat for the parr life stage is likely to be the most common bottleneck to salmonid carrying capacity in streams, we can describe a framework for quantifying that habitat. We find that channel units are a useful basal measure of habitat, and that variation in depth and cover can account for much of the difference in rearing density between units.

Channel Units as the Basal Habitat Unit

A substantial body of evidence indicates that the channel unit is an appropriate and useful starting point from which estimates of stream carrying capacity should be constructed. A channel unit is an area of stream of relatively homogenous depth and velocity that is bounded by sharp gradients in depth and/or velocity. Fisheries biologists refer to these channel units by such terms as pools, riffles and glides (see Hawkins et al. for descriptions). The use of channel units as a basic metric for stream habitat largely grew out of the work of Bisson et al. (1982) who described a system of channel unit classification and related it to the hydraulic processes that formed them. The system was affirmed and updated by Hawkins et al. (1993), who pointed out that coho salmon, steelhead trout, and cutthroat trout segregate within stream segments by using different types of channel units. Further, Hawkins et al. (1993) noted that geomorphic units in a stream, as described by watershed process models, are equivalent to the habitat units measured in stream surveys by fisheries biologists. Fluvial geomorphologists recognize pools and riffles as primary channel unit types. At low summer flow, pools have greater depth, finer substrate, and slower current than riffles. The biota inhabiting riffles and pools differs markedly, both in taxonomic composition and the morphological, physiological, and behavioral traits they posses (Hawkins et al. 1993).

Because the composition of channel units is the outcome of watershed processes, and fish production is strongly influenced by the composition of channel units, the effects of human actions in watersheds to the production of salmonids can be quantified through the common currency of habitat units (Figure 9). The three watershed processes that shape channel unit composition are sediment supply, transport capacity, and riparian vegetation (Montgomery and Buffington 1998). The surface geology influences sediment supply, while climate determines precipitation and snowmelt, which govern flow and the transport of material down the channel. The formation of these channel units can be related to hydraulic forces, sediment load, and resistance to flow provided by structural

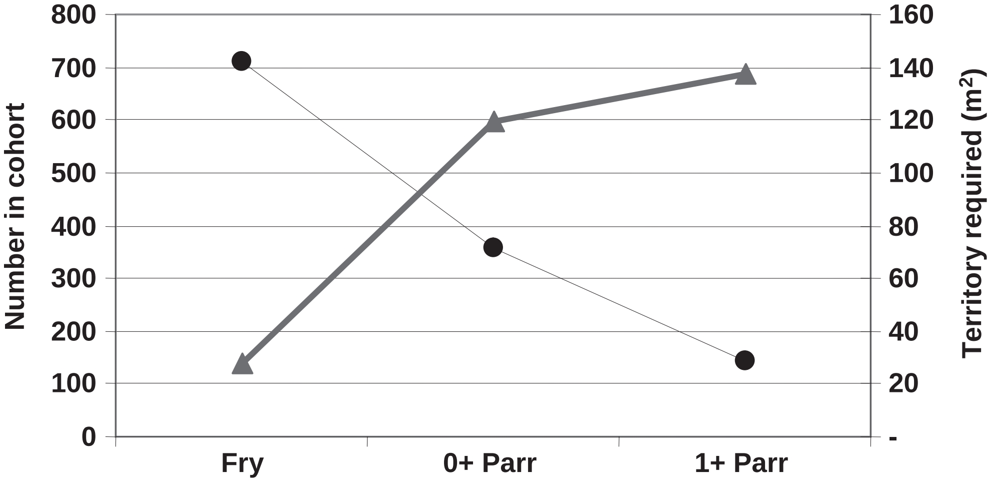

FIGURE 8. Change in abundance of fish (•) and their combined demand for territory (▲) for the survivors of a typical steelhead cohort produced by a single spawning pair (data from Table 1).

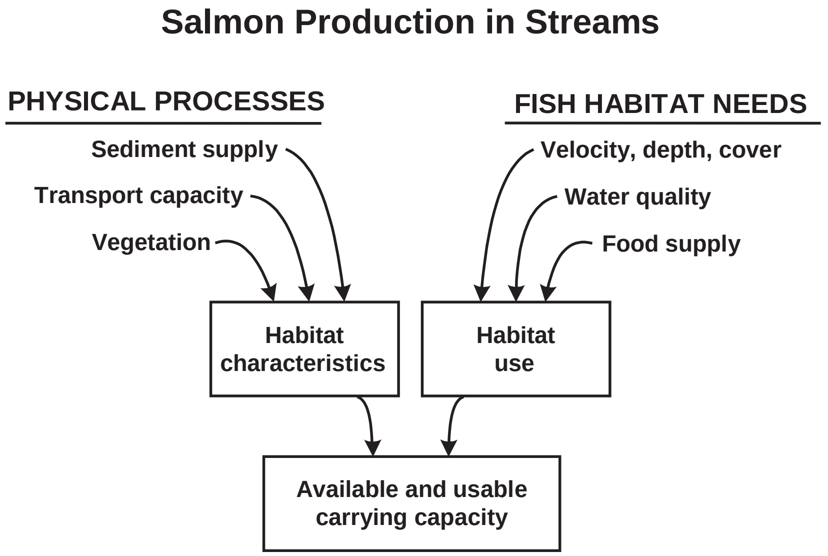

Figure 9. Average densities (points) and two standard deviation (lines) of (A) age ≥1 steelhead in 19 streams and (B) age ≥1cutthroat trout in 30 streams thought to be fully seeded on the Oregon coast. Data from Johnson et al. (1993).

elements such as wood or rock (Leopold et al. 1964). Riparian vegetation influences bank stability and introduces large woody debris to the channel where it can be a forcing agent to guide flow and sediment deposition. Data and empirical functions have been developed to estimate how channel unit composition is affected by gradient and rock type (Hicks and Hall 2003), woody debris and channel width (Beechie et al. 2000), and sediment supply (Benda et al. 1998). See Naiman and Bilby (1998) for a review of watershed processes affecting fish habitat.

Classification and measurement of fish habitat should begin with units that are meaningful both to fish and to the physical processes that shape fish habitat. Although micro-habitat factors such as velocity, depth and cover have been widely used in the IFIM methodology as the starting point for classifying suitability for salmonid habitat, validation tests show that the method sometimes poorly predicts the distribution of fish densities. Several studies have shown that salmonid rearing densities are more correlated to channel unit type than to velocity, depth and cover (e.g., Kershner and Snider 1992; Guay et al. 2000). Based on such evidence, Rosenfeld (2003) concluded, “Predicting fish density by habitat classes (e.g., riffle versus pool habitat units) is often more accurate than predicting density based on continuous variables (e.g., water depth), which suggests that discrete habitat classifications may characterize habitats in a more biologically meaningful way than continuous measurements.”

Each channel unit type presents a characteristic suite of depths, velocities, and cover combinations available to fish, and these suites consistently differ between channel unit types. Field studies of salmonid behavior in stream habitats over a season, or even within a day, have shown that habitat preferences change with environmental circumstances, time of day, and degree of satiation. Bradford and Higgins (2003) found that most feeding activity by juvenile Chinook salmon and steelhead trout occurred at dusk and night rather than day, even when temperatures were 10–14°C. Most fish were concealed in the substrate during day. Thus, the daytime holding positions of the fish that were out and active were not representative of the substrate interstices that most fish were choosing during the day. For this reason, juvenile salmonid densities should only be compared between channel unit types with data that is expanded to account for sampling efficiency (e.g., snorkel observations calibrated against mark–recapture population estimates in each channel unit type).

Habitat preferences can also change with environmental conditions. Juvenile salmonids change positions in a channel unit as temperature and day length change (Vondracek and Longanecker 1993). Velocity preferences change with food availability (Wilzbach 1985; Grant et al. 1998). Density of competitors and predators has been shown to dramatically influence habitat preference (Brown and Moyle 1991; Fausch and White 1986; Rosenfeld and Boss 2001). We deduce from these changing habitat preferences that fish choose to occupy a channel unit for an extended time (days to years), depending on the suite of desirable features available in the immediate area. Thus, fish would be more likely to choose a home territory first on the basis of a channel unit type than they would on the basis of a specific velocity or depth, although preferred velocities and depths must be present in the unit for it to be selected. Once a fish has chosen a unit type for its favorable suite of habitat opportunities, the fish then selects the specific depth, velocity and cover combination that it desires at the moment. Such a selection sequence would account for the observations, such as that of Rosenfeld (2003), showing that salmonid rearing densities are more related to unit type than to a microhabitat feature.

Numerous data sets in which densities of fish were measured for distinct channel units illustrate that each salmonid species exercises consistent preferences for different types of channel units. Hankin (1984) and Hankin and Reeves (1988) showed that statistically stratifying fish population estimates according to channel unit types improved estimation accuracy and reduced variance. Hankin and Reeves (1988) concluded that extrapolation from data collected in only one of several "representative" reaches could give a highly biased and very misleading picture of true fish abundance, because variation was more aligned with differences between channel unit types than with reaches. Bjornn and Reiser (1991) present data on the densities of Chinook parr and yearling steelhead found within stream unit types averaged over 22 streams surveyed in Idaho during 1985 and 1986. They found that relative densities between unit types were consistent across streams and years. Chinook were most abundant in pools (21–22 fish/100 m^2) and moderately abundant in runs (14 fish/100 m^2), and least abundant in pocket water (5–10 fish/100 m^2) and riffles (2–5 fish/100 m^2). Age-1+ steelhead were most abundant in pocket water (2–5.5 fish/100 m^2), and varied from 2.0 to 3.5 in pools, 1.5–2.5 in runs, and 0.5–2.0 in riffles. Don Chapman Consultants (1989) and Roper et al. (1994) report similar differences in habitat preferences of Chinook parr and steelhead age 1+. These differences indicate that Chinook have a greater preference for low velocity channel units, while steelhead prefer higher velocity channel units. In another study, Johnson et al. (1993) sampled numerous Oregon coastal tributaries and presented average density by unit type for 19 streams that satisfied their criteria for full seeding with steelhead, and 30 streams that satisfied their criteria for full seeding with cutthroat trout (Figure 10). Again, those data show strong preferences by both species for pools, and a much lower use of other unit types by cutthroat trout than steelhead.

Framework for Habitat Capacity Estimation

We now describe a generalized framework, referred to as the Unit Characteristic Method (UCM), for estimating stream carrying capacity for salmonids. As the name implies, the channel unit is the basal building block for quantifying fish habitat. The most common channel units are referred to as pools, riffles and glides, and are defined as follows:

pool: a unit with no surface turbulence, except at the inflow, and has depth extending below the plane of the streambed.

riffle: a unit with discernable gradient and surface turbulence.

glide: a unit that has relatively uniform velocity down the channel, little surface turbulence, and no depth below the plane of the streambed.

The UCM assigns a standard density for each fish species to each unit type (Table 2), and then increments or decrements that density according to the amount that substrate, depth, and cover deviate from average. The magnitude of incremental change in fish density per increment of a habitat feature is derived from preferences demonstrated by each fish species for each habitat feature, as we will describe. The UCM predicts a stream's carrying capacity under average conditions by multiplying fish density by surface area in each unit, and then adjusts for differences between stream reaches in factors that influence food supply, as described in the section below. The general form of the predictor for a given species in a specific stream reach is:

$$\text{Capacity}_i = (\Sigma\ area_k \cdot den_j \cdot chnl_{jk} \cdot dep_{jk} \cdot cvr_{jk}) \cdot prod_i \qquad (2)$$

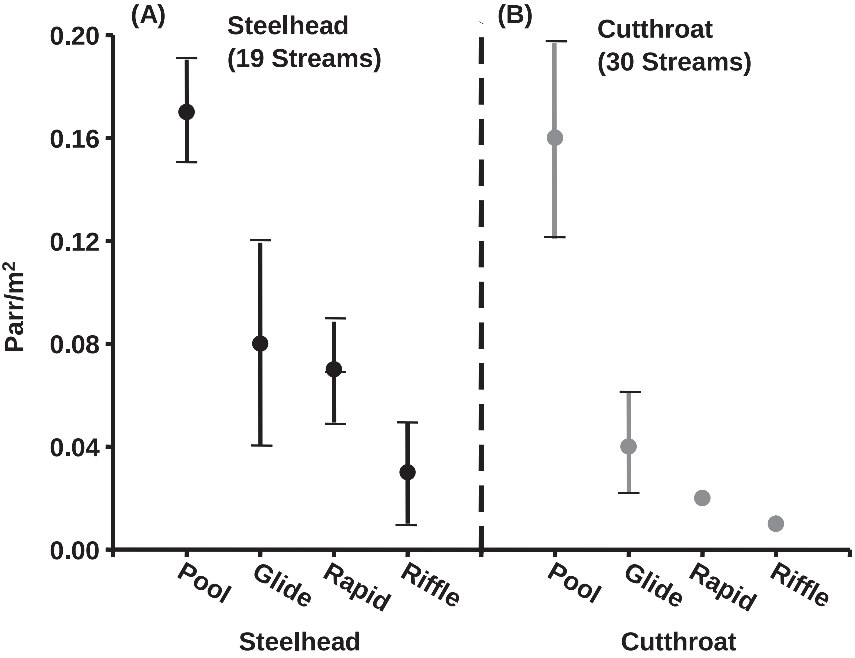

FIGURE 10. Linkage of watershed processes and salmonid preferences for habitat that together determine stream carrying capacity for salmonids.

TABLE 2. Relative density of juvenile salmonids, by channel unit type, determined from typical streams where these species are abundant. Densities scaled relative to densities in pool units. Data sources: spring Chinook from personal communication, D.B. Lister, British Columbia; coho from Solazzi et al. (1998): steelhead and cutthroat from Johnson et al. (1993).

		Coho			
Unit Type	Spring Chinook	Summer	Winter	Steelhead	Cutthroat
Pool	100%	100%	100%	100%	100%
Beaver Pond	79%	106%	450%	41%	24%
Backwater	54%	71%	150%	29%	12%
Glide	29%	47%	25%	47%	24%
Riffle	10%	6%	3%	18%	6%
Rapid	10%	6%	3%	41%	12%
Cascade	10%	12%	0%	18%	0%

Where;

i = stream reach. “Reach” is a sequence of channel units that compose a geomorphically homogenous segment of the stream network,

j = channel unit type,

k = individual channel unit,

area = area (m^2) of channel unit k,

den = standard fish density (fish/m^2) for a given species in unit type j,

dep = depth scalar with expected value of 1.0,

cvr = cover scalar with expected value of 1.0,

chnl = discount scalar for unproductive portions of large channels with expected value of 1.0, and

prod = productivity scalar for the reach, with expected value of 1.0. This scalar combines the separate effects from four additional factors defined in equation (3).

$$prod_i = turb_i \cdot drift_i \cdot fines_i \cdot alk_i \qquad (3)$$

Where;

turb = turbidity during summer low flow (measured in NTUs),

drift = percentage of reach area in fastwater habitat types that produce invertebrates,

fines = percentage of substrate in riffles composed by fines, and

alk = alkalinity during summer low flow (measured as mg/l CaCO$_3$).

The several variables that are represented as scalars having mean of 1.0 must each be defined by a separate function that relates that variable to fish density and must be determined by the average value for the data set from which the standard fish density was determined. For example, the standard densities for steelhead parr presented in Cramer and Ackerman (2009) are taken from a set of Oregon coastal streams, so the scalar value for *dep* would be set to 1.0 at the average value of depth in the Oregon coastal streams that were sampled. The scalar would then take on values >1.0 if *dep* was greater than average, or values <1.0 if *dep* was less than average. The rate of change in each scalar per change in the represented variable is unique for each variable, and is the subject of further evidence presented in this paper. Mathematical functions to describe these scalars specifically for steelhead parr are presented in Cramer and Ackerman (2009).

Salmonids in streams show clear preference for a set range of water velocities, but velocity is not explicitly included in the framework described by this equation. Velocity is a microhabitat feature, and the base scale of our framework is the channel unit, a macro habitat feature. Different channel unit types offer different ranges of velocity, as acknowledged in the classification of channel units into fast-water and slow-water types (Hawkins et al. 1983). We assume that the UCM accounts for fish velocity preferences through the differences in densities it assigns to the channel unit types.

We assembled sufficient data from various field studies of four species of salmonids (spring Chinook, coho, steelhead, and coastal cutthroat trout *O. clarkii*) to establish expected densities of parr at full seeding in different channel unit types. Unit-specific densities for spring Chinook were derived from observations in the fully seeded Coldwater River, British Columbia (data provided by D.B. Lister & Associates). Relative coho densities from summer and winter sampling of fully seeded Oregon coastal streams were derived from the Habitat Limiting Factors model (HLFM) described by Solazzi et al. (1998). Both steelhead and cutthroat trout densities were derived from the study of Johnson et al. (1993), who sampled numerous, fully seeded Oregon coastal tributaries and presented average density by unit type for each species.

Although there were consistent differences in juvenile densities between channel unit types, densities within each unit type were strongly influenced by depth and cover. To predict how fish will choose habitat, it is important to understand the priority order of preferences they display if some preferred factors are lacking. For example, combined observations from several experiments indicate that steelhead exercise habitat preferences in the priority order of depth first, velocity second, and cover third. In a study where effects of cover where held constant, Beecher et al. (1993) compared depth and velocity preferences of steelhead parr (75–200 mm) in a fully seeded Washington stream that was uniformly lacking in cover; large boulders accounted for less than 1% of surface area and there was no LWD. The authors found that steelhead parr strongly avoided shallow habitats, but once depth was sufficient, velocity preference influenced habitat selection. Parr of all salmonid species strongly avoided areas with depths <0.2 m, and steelhead and cutthroat parr showed increasing densities as unit depths increased up to at least 1 m (Figure 11). Beecher et al. (1993) found that most parr were observed at velocities of 27.4–33.2 cm/s, but velocities most preferred were less available and were 21.3–27.1 cm/s. Similar preferences by steelhead parr for depth and velocity were found in an Idaho stream by Everest and Chapman (1972) (see Figure 6), and have been confirmed in an experimental setting by Fausch (1993).

A variety of field and laboratory studies have demonstrated that increasing cover in a habitat unit leads to greater densities of juvenile steelhead and Chinook in summer or winter. Cover can be provided from above, laterally, or below in the substrate, and each type is used to varying degrees by different species. Cover provided by woody debris is often noted as important to salmonid parr, and a study by Johnson et al. (1993) was able to quantify the benefit of cover by assigning a cover complexity score to the pools in which fish were sampled. Parr density in pools for both steelhead and cutthroat increased about three fold as woody debris complexity increased from none to high complexity (Figure 12).

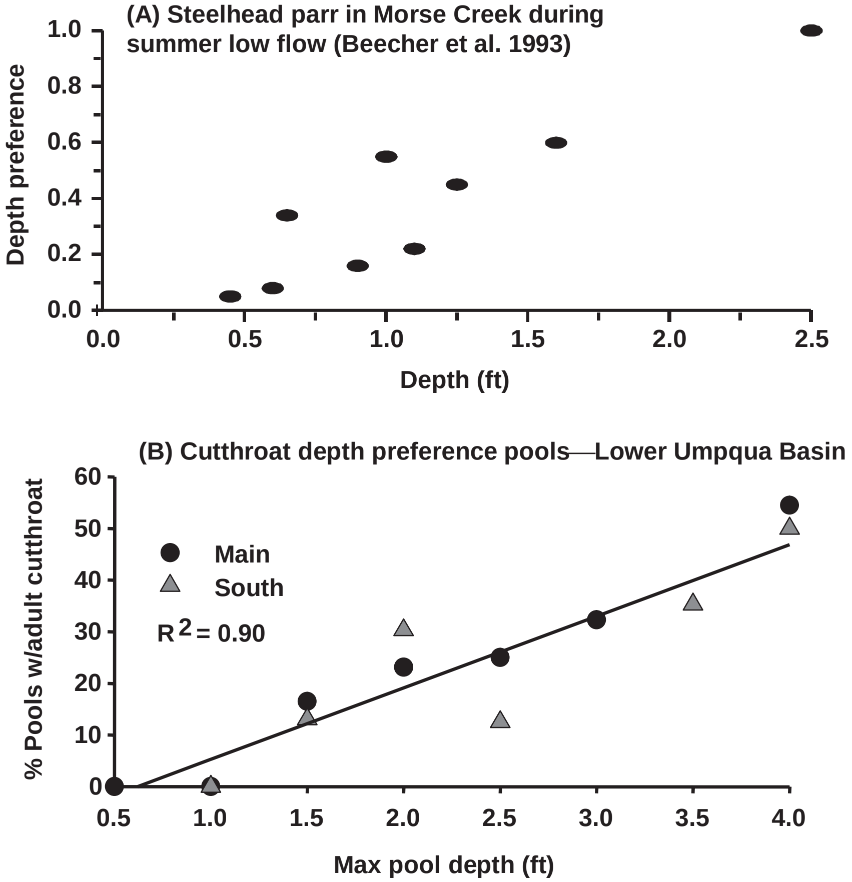

FIGURE 11. Examples of salmonid preference for depth in streams. (A) Upper graph is steelhead parr in a stream nearly devoid of wood or boulder cover, adapted from Beecher et al. (1993). (B) Bottom graph is snorkel observations of adult cutthroat presence within pools of tributaries to the main and South Umpqua Basin, author's data.

Boulders provide a form of cover in streams, particularly in riffles. Don Chapman Consultants (1989) found that steelhead parr in high gradient reaches (>5%) of the Wenatchee River, Washington, generally selected stations where adjacent velocities were six to eight times their nose velocity and were usually stationed individually behind boulders where surface turbulence provided cover. Ward and Slaney (1993) found that placement of boulders resulted in about one steelhead parr rearing per boulder where none had reared previously. Dambacher (1991) found, in the Umpqua River Basin, Oregon, that stream channels with relatively high ($0.02/m^2$) and low abundances ($<0.02/m^2$) of age >1 steelhead were separated, with some overlap, by the relative amount of large boulder substrate. Johnson (1985) used snorkel surveys to estimate parr densities in a number of western Washington rivers, and his data show over a 10-fold variation between reaches in average parr densities within riffles. We obtained and examined his data and found that parr densities in riffles where boulders were the most prevalent substrate size-class averaged about five times greater than in riffles with other substrate size classes (e.g., cobbles, gravel) as most prevalent (Figure 13).

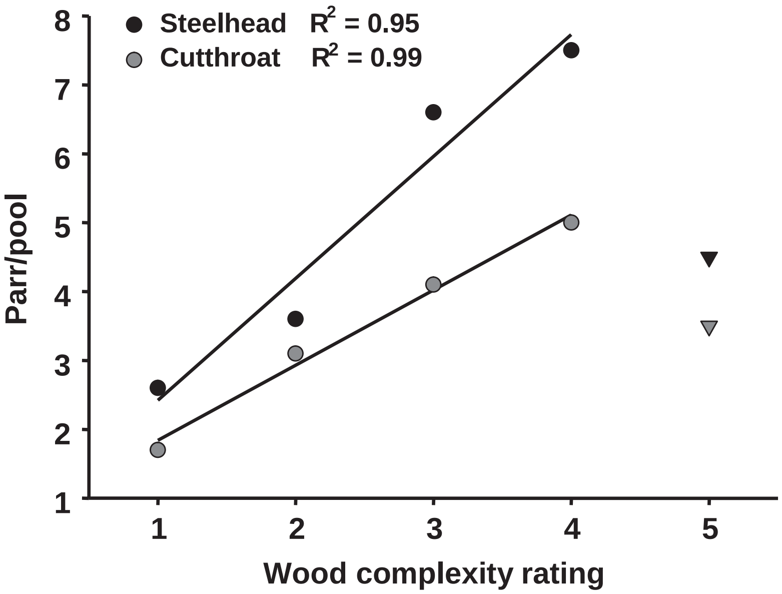

FIGURE 12. Relationship of steelhead and cutthroat parr densities in pools to wood complexity within Oregon coastal streams (redrawn from Johnson et al. 1993). Values for the complexity rating of 5 (triangles) omitted from the regressions, because sampling effectiveness was impaired.

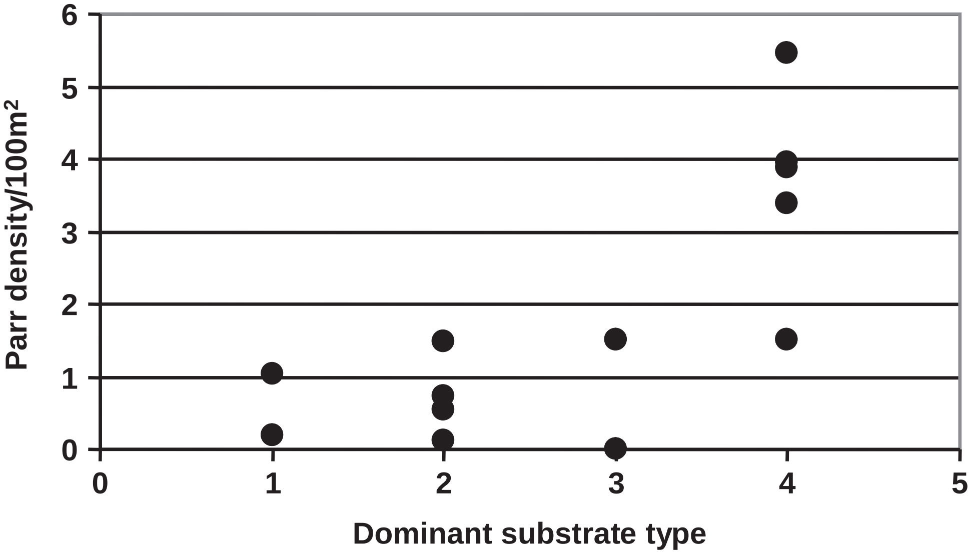

FIGURE 13. Relationship of steelhead parr density in riffles to the dominant substrate type in those riffles of western Washington rivers. Data from Johnson (1985). Substrates are: 1 = large gravel; 2 = small cobble; 3 = large cobble, and 4 = boulders.

Discussion

Potential uses of UCM

We have found that the UCM has a credible basis for applying stream habitat measurements to estimate a basin's capacity for rearing stream-dwelling anadromous salmonids. Because the territory size needed for each salmonid increases exponentially with fish length, the total area of suitable habitat needed to support a cohort generally increases at a faster pace than mortality thins the population, at least through the first two years of rearing in a stream. Thus, the availability of suitable habitat during low flow in the summer prior to smolting will typically determine the carrying capacity of a stream for salmonids that over-summer in streams. Exceptions can certainly arise in streams with little spawning gravel or where preferred winter habitat is in short supply, such as is often the case for coho. However, habitat measurements in typical steelhead-producing streams show the preferred depths of steelhead rapidly become scarce as parr approach the length of smolts (15–20 cm). The increasing mismatch between territory requirements and availability of suitable habitat in typical steelhead streams suggests that lack of habitat for larger fish may be a key reason that such streams support anadromous rather than resident *O. mykiss*.

Equation (2) provides a generalized framework for predicting salmonid rearing capacity in streams. This equation then provides the quantitative link between stream habitat features and the population dynamics of anadromous salmonids. Maximal rearing densities differ between types of channel units, and observations of fish densities in numerous streams make it possible to establish the mean maximum densities and their confidence intervals that can be expected in typical channel units. Within a specific unit type, field observations have also established that juvenile salmonid densities vary as a function of depth and cover. Thus, maximal densities can be predicted by first assigning the expected average density for a given unit type, and then incrementing or decrementing that density according to the amount that depth or cover deviate from the average for that unit type. Dissolved nutrients in the stream, turbidity, and fine sediment also influence the density of salmonids that can be supported, so rearing capacity for a given stream reach must also be decremented or incremented to the extent that these factors deviate from average.

Cramer and Ackerman (2009) tested the fit of UCM predictions for steelhead parr to observed smolt production in seven watersheds dispersed across Oregon with widely differing environmental conditions. They found that observed smolt production corroborated the UCM carrying capacity predictions. Further, they found that habitat quality and the habitat factors most limiting to steelhead production varied widely both within and between basins, which suggests that basic habitat surveys conducted by fisheries agencies provide sufficient information to distinguish production bottlenecks and predict fish benefits of proposed habitat restoration or enhancement actions.

The use of channel types as a starting point for estimating stream carrying capacity offers substantial advantages to natural resource managers. First, measurements of channel units and their basic features are widely available from the standard habitat surveys performed by state and federal agencies to inventory the state of fish-producing streams. Unit type, area, depth, substrate composition, and some score of cover are recorded as part of the standard protocol by state and provincial fisheries agencies and federal land management agencies. Secondly, the surface area of natural channel units provides a means to quantitatively link the effects of human activities on land or in water to the production of salmonids. Channel units (also known as geomorphic units) are a predictable output from models of watershed processes that shape streams. The formation of channel units can be related to the combination of physical forces and structure from discharge, sediment load and structural elements that resist flow, such as wood or rock (Leopold et al. 1964). Because channel units are output quantities from watershed process models, and inputs to models of salmonid carrying capacity, future efforts to link the two model types could make it possible to predict fish benefits from proposed habitat restoration strategies, land use activities, and flow alteration.

The number of fish predicted by equation (2) estimates the potential maximum production that would be achieved with full seeding of fish under average conditions. Salmonid populations vary substantially between years in response to variable spawner abundance and environmental conditions. As a consequence, estimated abundance falls below the predicted capacity in most years and only exceeds the average capacity in years with sufficient spawners and beneficial environmental conditions. Thus, the capacity value estimated by equation (2) is useful as the estimate of the upper bound on stock-recruit curves in which the recruits are parr rather than adults. In the case of a Ricker curve, the expected number of recruits (R) is expressed as a function of the number of parent spawners (P) that produced them:

$$R = \alpha P e^{(-ßP)} \qquad (4)$$

where;

α = parameter defining maximum value of R/P, and

ß = parameter defining maximum value of R.

The parameter values of this function are typically estimated from a least squares regression of $\ln(R/P)$ on P from a long-term data set of adult recruits and spawners. However, if ß were estimated separately from habitat measurements as we described here, the value of α, which is the recruitment rate at low population density, would need to be determined separately. This might be based on a meta-analysis of estimates for α in comparable populations. Most values of α reported in the literature, however, are expressed in terms of adult recruits per adult spawner. In order to convert an α value expressed as adults per adult to one expressed as parr per adult, the former must be divided by the average parr-to-adult survival rate (S):

$$\alpha_{\text{(parr/spawer)}} = \alpha_{\text{(adults/spawner)}} \div S \qquad (5)$$

This conversion assumes that mortality after the parr stage is independent of population density. Parr-to-adult survival is certainly variable between years, but if the parr stage is the final density bottleneck to survival, then the form of the stock–recruitment relationship will not be altered by the variation in density-independent mortality.

The Ricker equation can be rearranged, and the value of ß, can be calculated in two steps. In the first step, we estimate the abundance of parents that exactly replaces themselves with recruits, P_r, and in the second step, ß is estimated. Ricker (1975) demonstrated that the maximum number of recruits, R_{max}, is given by:

$$R_{maxs} = (e^{a-1})(P_r)/a \qquad (6)$$

where,

$a = \ln(\alpha)$, and

P_r = Number of parents at the level of replacement (the level where $R = P$).

We proceed by choosing an independent

estimate of α , converting its units of measure to parr per spawner, and then substituting $a = \ln(\alpha)$ into equation (6).

The only remaining unknown in equation (6) is P_r which can then be solved. Once we have solved for P_r, we can calculate ß based on the relationship of Ricker (1975):

$$ß = a/P_r \qquad (7)$$

Example applications

The UCM has been applied in several basins of Oregon to help resolve specific issues relating to stream potential for producing salmon and steelhead. We describe two of these applications, one in the Hood River Basin and one in the Deschutes River Basin, as examples of the different uses for UCM.

The 10-year progress evaluation of the Hood River Production Program in Oregon (Underwood et al. 2003) provides an example of these calculations and their application. That program, first implemented in 1992, provided extensive supplementation of spring Chinook, summer steelhead, and winter steelhead with hatchery fish in the three main forks of the Hood River basin, and also implemented a variety of habitat restoration measures to improve natural production of anadromous salmonids. The combination of hatchery supplementation and habitat restoration was intended to raise natural production to the full potential of the basin. However, program goals for the natural production that could be achieved had been based on sketchy information. Underwood et al. (2003) used the UCM to estimate carrying capacity for steelhead and spring Chinook parr, based on more extensive and recent habitat surveys completed by natural resource agencies. Underwood et al. (2003) were able to use the UCM capacity estimates to derive the capacity parameter in stock–recruitment relationships for each species, and with those stock–recruitment relationships determine how the populations were performing compared to their production potential.

In the Hood River example, the UCM estimate of winter steelhead capacity was 49,827 parr for the entire basin. Further, survival of parr to smolting was estimated to be 35% and the survival of smolts to adult recruits was estimated to be 3.9%. Thus, we have

$$(R_{max,\ parr}) = 49{,}827$$

Expected survival (S) of these parr to adults would be

$$S = 0.3500 \cdot 0.0390 = 0.0137$$

Because there was no estimate of adult recruitment rate, a review of stock–recruitment analyses for steelhead in other Columbia Basin streams then led to the decision that α = 6 (adult recruits/adult spawner) was a reasonable assumption for the maximum recruitment rate among Hood River winter steelhead. This provides the information needed to convert the α value for adult recruitment rate to a parr recruitment rate and then convert the parr capacity to the ß parameter for the Ricker function. From equation (4) we have:

$$\alpha\ (\text{parr/spawer}) = 6 \div 0.0137 = 439$$

$$P_r = \ln(439) \cdot 49{,}827 \div e^{(\ln(439)-1)} = 1{,}881$$

$$ß = \ln(439) \div 1{,}881 = 0.00324$$

And thus,

$$\text{parr recruits} = 439 \cdot P \cdot e^{-0.00324 \cdot P}$$

The Ricker function for parr could then be combined with estimates of density-independent survival from parr to adult to estimate harvestable surpluses for the fisheries that the Hood River Production Program was intended to support.

Separate from their use to derive the stock–recruitment function, the UCM estimates of parr carrying capacity revealed that Hood River Basin's capacity for natural smolt production was far less than the rough estimate used in the 1992 planning to determine appropriate rates of supplementation with hatchery fish. The UCM prediction of natural production capacity was only 24% of the 1992 planning target for steelhead and 37% of the target for spring Chinook, as can be seen from the following data derived from Underwood et al. (2003).

Species	Planning target rearing capacity	UCM estimate of Capacity	Maximum observed production (1994–2001)
Steelhead	101,968 smolts	25,337 smolts	24,488 smolts
Spring Chinook	120,500 parr	44,835 parr	11,745 parr

Actual production of smolts, estimated from expanded catches in screw traps during 1994–2001 (a period of supplementation and habitat restoration) was even less than the UCM-predicted capacity. The maximum observed production for spring Chinook in any year reached only 26% of the UCM capacity, and averaged less than 10% of predicted capacity. The maximum number of steelhead smolts leaving the basin (24,488) only approached the UCM-predicted capacity (25,337) above the trap location in one of seven years, and averaged about half of capacity. The observed smolt production indicated that the UCM capacity estimates were more reasonable than those originally used as planning targets, and the corroborating examples presented by Cramer and Ackerman (2009) further confirm reliability of the UCM estimates. These large discrepancies between planning targets for a major fish enhancement project and the carrying capacities predicted from habitat measurements may reflect the human tendency to subjectively over-estimate potential benefits of proposed projects when attempting to justify expenditures of public monies. Further, they illustrate the utility of the UCM framework as an objective basis for benefit-to-cost predictions to be used by decision makers as they prioritize investment in habitat restoration or enhancement actions.

The Hood River example also illustrates that habitat measurements included in the UCM clearly distinguish where and how serious the habitat conditions are that limit natural production of steelhead and Chinook salmon. Glacial turbidity, fine sediments (glacial sand), and a low percentage of area composed by pools were the primary habitat characteristics responsible for a lower production potential than had been assumed at the Program outset. Glacial turbidity was estimated by the UCM to reduce parr production by up to 50% in reaches of the Middle Fork Hood River, and up to 20% in many reaches throughout other portions of the basin. Parr production begins to decrease when fines in riffles exceed 15% (Figure 5), and values for fines (dominantly glacial sand) were generally 25–30% in the main stem and West Fork, and were 38–44% in the East Fork. Further, channel morphology was not favorable for salmonid production as gradient was typically high (>2.5%), and led to a low proportion of surface area composed by pools (generally <20%). The variation in percentage of surface area composed by pools had over a two-fold effect on predicted parr capacity between reaches.

The case of the Hood River Production Program also illustrates the utility of the UCM as a tool to assist with hatchery reform. Repeated findings that hatchery programs have unintended negative consequences on natural production of salmonids have led to the development of new guidelines for hatchery practices (Mobrand et al. 2005). The Hatchery Scientific Review Group (HSRG) was tasked by Congress to determine how hatcheries could be managed to continue supporting sustainable fisheries while, at the same time, assisting with the conservation and recovery of naturally spawning populations. The HSRG concluded that supplementations programs, such as that on Hood River, should, "necessarily be limited by the habitat available to the natural populations with which it is integrated" (Mobrand et al. 2005). The UCM analysis of fish habitat in the Hood River basin demonstrated that use of professional judgment to define natural production goals for hatchery supplementation has low reliability. However, the UCM provides a relatively rapid assessment method to develop realistic predictions of habitat carrying capacity, and these can be used to design hatchery strategies that are compatible with sustainable natural production.

Habitat-based estimates of salmon or steelhead carrying capacity can be used to assess cost effectiveness of restoring passage to streams above barriers. The UCM was used in the Deschutes River Basin of Oregon to determine the population size of steelhead that could be supported above Pelton and Round Butte dams if passage were restored. The dams blocked effective fish passage after their construction in 1958. Prior to construction, the distribution of steelhead spawning in various tributaries had been well established, but the abundance of steelhead had not been estimated. We used existing data from stream habitat surveys by various agencies to apply the UCM and predicted that 41,059 age-1+ steelhead parr could be produced in the entire basin upstream of the Pelton-Round Butte complex (Cramer and Beamesderfer 2002). These predictions were compatible with adult run sizes that arrived at the base of the dam during its construction. Further, the UCM was also applied to habitat surveys in the Trout Creek watershed of the Deschutes Basin below the Pelton-Round Butte complex, and direct sampling of smolt production from that watershed corresponded with the UCM estimate of carrying capacity (Cramer and Ackerman 2009). The UCM prediction of carrying capacity above the Pelton-Round Butte complex was split between 17,346 age-1+ parr in the Whychus Creek watershed, and 23,613 produced in the Crooked River watershed. This split was important to the planning process, because access to the Whychus Creek watershed was unimpaired, but passage into the Crooked River would require the removal of an additional dam at substantial cost. Achieving successful passage of steelhead smolts downstream through Pelton and Round Butte reservoirs was highly uncertain, so the estimated parr capacities were used further in the development of a steelhead life cycle model for the Deschutes Basin. It was then possible to simulate the abundance of wild steelhead that could be sustained above the Pelton-Round Butte complex, given different rates at which parr might residualize in the reservoirs (Cramer and Beamesderfer 2002).

Needs for further development of UCM

Additional work is needed to expand the UCM framework to include special circumstances that strongly influence salmonid production in some streams. One such circumstance is interaction with abundant competitors or predators, which may alter habitat usage by rearing salmonids (Brown and Moyle 1991; Fausch and White 1986; Rosenfeld and Boss 2001). Brown and Moyle (1991) showed on the Eel River that habitat use by salmonids substantially shifted after northern pikeminnow *Ptychocheilus oregonesis* were introduced to the basin. Bradford and Higgins (2003) found that densities and behaviors of age-0 steelhead and Chinook salmon differed between two reaches of the same river where risk of predation from bull trout *Salvelinus confluentus* differed. In the lower reach where the risk of predation was greater, juveniles were less dense and feeding behavior was almost exclusively nocturnal. The effect on rearing capacity of these behavioral responses to predators has not been quantified and warrants further study.

Estimates of rearing capacity in a basin based on the UCM framework are likely to be most accurate when the actual limits of rearing distribution for juvenile salmonids in a stream network are established by field observations. Distribution of fish presence in remote headwater streams must sometimes be predicted from environmental attributes of the area. Other workers have developed such predictive approaches that rely on factors such as gradient, watershed area, rainfall, and temperature (Fransen et al. 2006). Given that rearing capacity for salmonids in streams is typically limited by demands for habitat during the last summer or winter they spend in freshwater, it is important that all channels in a network with suitable habitat for that life stage be included in any estimate of a basin's carrying capacity. Although spawning may occur in only portions of the stream network, juveniles may disperse both up and downstream to find suitable rearing areas. Thus, the full range of rearing opportunities accessible to mobile juveniles should be included in estimates of rearing capacity.

Future work is also warranted to determine how functions can be included in the UCM framework to account for variable factors such as the availability of marine nutrients and stream temperatures. Nutrients from spawned salmon carcasses enhance food supply, and thus rearing populations of juvenile salmonids (e.g., Bilby et al. 2001; Wipfli et al. 1999). Salmonids are coldwater fishes, and stream temperatures frequently restrict salmonid use in portions of a basin. Most salmonids show preference for temperatures cooler than about 18°C, but temperature heterogeneity in a stream channel can provide opportunities for juveniles to find satisfactory habitat within restricted areas of the channel, perhaps even in the same channel unit where they have been rearing (e.g., Ebersole et al. 2003). Thus, temperatures above optimum for salmonids would likely act to progressively reduce rearing density (Bovee 1978; Isaak and Hubert 2004) until the point is reached that thermal refuges are completely eliminated. Factors that vary substantially between years, such as the supply of marine nutrients, stream temperatures, and even flow, might be best accounted for as separate factors in a stochastic or year-by-year simulation combined with a base-level capacity predicted by the UCM.

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Prediction of Stream Carrying Capacity for Steelhead: the Unit Characteristic Method

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Abstract.—We describe and demonstrate the Unit Characteristic Method (UCM) as a means by which measurements of habitat from typical stream surveys can be used to estimate the capacity of a stream to rear juvenile steelhead *Oncorhynchus mykiss*. Channel unit features of importance include surface area by unit type, depth, substrate, and cover. The influence of a stream's primary productivity is represented in the method through measures of alkalinity and turbidity. We tested the fit of model predictions to juvenile steelhead production observed in seven watersheds ranging in size from 26 to 1,420 km^2. Model predictions of capacity were significantly correlated to observed maximum production of juvenile steelhead ($P < 0.005$, $R^2 = 0.88$), as was watershed area ($P < 0.005$, $R^2 = 0.88$). The UCM predictions revealed that parr capacity was unevenly distributed in the watersheds, and that habitat quality (smolt capacity/m^2) differed between reaches among all watersheds by up to 15-fold across seven basins surveyed, and ranged more than 10-fold between reaches within four of seven test watersheds. Thus, the UCM can be used to discriminate stream reaches and features that either warrant habitat restoration or conservation. Key factors driving high or low habitat quality differed between reaches, and included pool area, riffle depth, boulder substrate, alkalinity, fine sediment, and turbidity. The UCM provides a framework for understanding the habitat features that determine the production potential of a basin, for identifying factors that limit production, and for predicting potential fish benefits from differing habitat management strategies.

Introduction

Problem and Need

The need to accurately estimate carrying capacity of streams for salmonids has been accentuated by the recent focus on assessing population viability and planning for recovery of salmon and steelhead populations listed under the Endangered Species Act (ESA). This focus on restoring healthy fish populations has placed a burden on resource managers to choose among competing proposals designed to restore stream habitats, restore fish passage, reduce harvest, or alter the use of hatchery fish. More than ever, resource managers need a reliable basis for determining which combination of projects will provide the greatest benefits to targeted fish

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populations. Estimation of fish benefits from each strategy relies on accurate knowledge of the suite of factors, and the magnitude of influence from each, that determine a stream's capacity to produce the species of interest. Further, this same knowledge is needed to determine how a population is performing relative to its potential in a given basin.

Fisheries managers are often frustrated by the poor precision of carrying capacity estimates derived from stock-recruitment relationships, and the high cost of estimating all components of adult recruitment restricts data collection to a few streams. The estimation of stream carrying capacity has long been a foundation of assessments and strategies for managing salmon and trout populations, primarily as a parameter of stock-recruitment functions that predict harvestable surpluses (Beverton and Holt 1957: Ricker 1975). The traditional approach for estimating carrying capacity has been to fit a relationship between adult recruits and the number of parents that spawned them. This approach requires a long time series of data, but such data are lacking for the great majority of salmonid-producing basins. Even when the data are available, the statistical fit, and thus the confidence in capacity estimates, is often poor (Cramer 2000). Further, the statistical approach is not helpful for identifying the specific habitat factors that are limiting the population, nor in estimating the benefits from selected stream alterations in a small portion of the watershed.

The joint need to estimate (1) carrying capacity and (2) fish benefits from specific habitat changes, highlights the value of developing methods to estimate salmonid carrying capacity directly from measurements of stream habitat features. Cramer and Ackerman (2007) describe the Unit Characteristic Method (UCM) as an analytical framework intended to fill these needs. In this chapter, the UCM to predict carrying capacity of steelhead (anadromous rainbow trout) *Oncorhynchus mykiss* is described and tested in seven basins ranging in size from 26 to 1,420 km^2. Data from state and federal agencies on stream features and juvenile steelhead abundance are used to determine the fit of predicted to observed smolt production at carrying capacity. Results from these test basins are used to evaluate the sensitivity of UCM to the different habitat factors it includes, and to evaluate variation in habitat quality for producing steelhead within and between basins.

Approach

The UCM quantifies stream carrying capacity for salmonids in terms of stream features that can be targeted by actions to conserve or restore habitat, and are measured during stream habitat surveys that follow protocols typical of most natural resource agencies. Hawkins et al. (1983) noted from their review of studies on channel unit classifications that, "variation in the structure and dynamics of the physical environment are primary factors affecting production and diversity of stream biota." Further, "differences in habitat quality among channel units are often associated with differences in morphology (e.g., depth, width, shape), water velocity (hydraulics) and bed roughness (substrate size)." The UCM is based on empirical evidence of relationships between fish production and driving factors such as those noted by Hawkins et al. (1983), and utilizes stream inventory data as model inputs. The UCM is similar to the method used by Nickelson (1998), who described methods for estimating stream capacity for rearing juvenile coho based on the area of channel unit types.

We define stream carrying capacity as the maximum number of juveniles that a stream can produce under average environmental conditions for the juvenile life stage most limited by availability of suitable space. This definition recognizes that realized maximum production will vary temporally with environmental conditions, and that the life stage most constrained by space may vary between streams. Capacity is generally most constrained for steelhead during summer for age >1 parr (Bjornn 1978; Everest et al. 1987; Reeves et al. 1997; Cramer and Ackerman 2007), thus this is the season and life stage targeted by the UCM for predicting capacity.

In some instances, availability of overwinter habitat may limit production (Solazzi et al. 2000; Solazzi et al. 2002). Accordingly, a winter capacity function is included in the UCM in case the number of parr entering the winter exceeds the capacity of winter habitat.

Methods

Model development and structure

A combination of literature search, researcher interviews, and findings from our own field studies was used to assemble data from which parameters could be estimated to relate maximum rearing densities to habitat features. Habitat features incorporated into the model included those features that can be, and typically are, measured during stream survey inventories conducted by government agencies (e.g., USFS 1999; Pleus et al. 1999; Moore et al. 2002). In addition, the water quality variables of turbidity and alkalinity are included within the model, and regional samples of these parameters are generally available through state and federal agencies.

The UCM assigns a standard density of age >1 parr to each unit type, and then increments or decrements that density according to the amount that habitat features of channel size, substrate, depth, and cover deviate from the model's expected value. The combined capacity of units within a reach is then scaled by factors affecting productivity. That is:

(1) $\text{Capacity}i = (\Sigma\, area_k \cdot den_j \cdot chnl_{jk} \cdot dep_{jk} \cdot cvr_{\text{jk}}) \cdot prod_i$;

Where

Capacity = maximum number of age >1 parr supported under average environmental conditions,

i = stream reach. "Reach" is a sequence of channel units that compose a geomorphically homogenous segment of the stream network,

j = channel unit type,

k = individual channel unit,

area = area (m^2) of channel unit k,

den = standard fish density (fish/m^2) for species *i* in unit type *j*,

chnl = discount scalar for unproductive portions of large channels with expected value of 1.0,

dep = depth scalar with expected value of 1.0,

cvr = cover scalar with expected value of 1.0, and

prod = productivity scalar for the reach, with expected value of 1.0. This scalar combines the separate effects from four additional factors defined in equation (2).

Variables that are represented as scalars having an expected value of 1.0 in this function are defined by a separate function that relates that variable to fish density. These scalars represent proportional changes to parr density compared to the standard fish densities (*den*). The value of the variable when the scalar is 1.0 represents the average value of that variable for the data set from which the standard fish density was determined. For example, the standard densities for steelhead parr (Table 1) are taken

TABLE 1. Formulas, definitions and values of variables and parameters used in the UCM.

Parameter/Function		Value/Equation	Source(s)
den (fish/m^2)			
	Backwaters	0.05	Johnson et al. 1993
	Beaver Ponds	0.07	
	Cascades	0.03	
	Glides	0.08	
	Pools	0.17	
	Rapids	0.07	
	Riffles	0.03	
chnl			
	Glides	If $W > 24$: $(W - 24)*0.35/W + 24/W$	Cramer et al. 1998; O'Neal and Cramer 1999; Romey et al. 2001
	Pools	If $W > 24$: $(W - 24)*0.75/W + 24/W$; and If $L > 4*W$: $L = 4*W$	
	Riffles	If $W > 24$: $(W - 24)*0.15/\mathrm{W} + 24/\mathrm{W}$	
dep			
	Pools	If D is <0.10: $0.0*D$ If D is 0.10 – 0.80: $(0.30*D - 0.027)/0.17$ If D is >0.80: 0.22/0.17	Beecher et al. 1993; Dambacher 1991; Bisson et al. 1998; et al. 1995; Bovee 1978; D. B. Lister and Associates, unpublished data
	Riffles	If D is <0.1: $0.0*D$ If D is 0.10 – 0.16: $(0.5*D - 0.050)/0.03$ If D is 0.16 – 0.30: $(0.29*D - 0.017)/0.03$ If D is 0.30 – 0.80: $(0.25*D - 0.003)/0.03$ If D is 0.80 – 0.90: 0.20/0.03 If D is 0.90 – 1.50: $(-0.32*\mathrm{D} + 0.485)/0.03$ If D is >1.50: 0	
cvr			
	Pools and Glides	If wood complexity = 1: 0.58 If wood complexity = 2: 1.00 If wood complexity = 3: 1.42 If wood complexity = 4 or 5: 1.84	Johnson et al. 1993; Johnson 1985
	Boulders	If B_{Pr} <0.25: 1.0 If B_{Pr} is 0.25 – 0.75: $1 + 12*(B_{Pr} - 0.25)$ If B_{Pr} is >0.75: 7.0	

Table 1. Continued.

Parameter/Function	Value/Equation	Source(s)
den (fish/m²)		
turb		
	If D_R is <0.3m: $10^{(2-(1+0.024*T)*0.1)}/10^{2-0.1}$ If D_R is 0.3–0.5m: $10^{(2-(1+0.024*T)*0.3))}/10^{2-0.3}$ If D_R is > 0.5m: $10^{(2-(1+0.024*T)*0.5))}/10^{2-0.5}$	Lloyd et al. 1987
drift		
	If R_P >0.5: 1.0 If R_P is $\geq$0.5: 0.1+1.8*R_P	Waters 1962; Waite and Carpenter 2000
fines		
	If F_P is <0.1: 1.0 If F_P is $\geq$0.1: 1.11 – 1.1*F_P	Bjornn et al. 1977
alk		
	Alkalinity $(\mathrm{mgCaCO_3/l})^{0.45}/4.48$	Ptolemy 1993
winter		
	If C_P < 0.15: 0.20+(C_P)/0.15*0.8 If C_P > 0.15: 1.0	USFWS 1988; Bjornn 1971; Bustard and Narver 1975; Hartman 1965; Swales et al. 1985

W = wetted width of unit in meters.
L = length of unit in meters
D = depth in meters (maximum in pools; mean in riffles)
B_{Pr} = Proportion of substrate in riffles that is comprised of boulders
D_R = Mean depth of riffles within the reach
R_P = Proportion of surface area of reach comprised of riffle and rapid habitat types
F_P = Proportion of substrate in riffles that is comprised of fines
C_P = Proportion of substrate in the stream comprised of cobbles

from a set of Oregon coastal streams, so the scalar value for *dep* would be set to 1.0 for the average depth in the Oregon coastal streams that were sampled. Depths greater than average would receive a scalar >1, and depths shallower than average would receive a scalar <1. The sequence of calculations is illustrated in Figure 1, and the formulas and range of values for each of these scalars are given in Table 1 and Figure 2. To estimate smolt output at capacity, the parr capacity is multiplied by an overwinter survival rate, which is assumed to be density independent.

Substantiating evidence for the functions used in the UCM has been described by Cramer and Ackerman (2009, this volume). Here we describe the logic for translating that evidence into quantitative functions describing steelhead habitat.

Model functions

Standard Fish Densities (den).—Rearing densities for different channel unit types from Johnson et al. (1993) were chosen to represent the *den* term in equation (1) (Table 1). Johnson et al. (1993) presented findings from

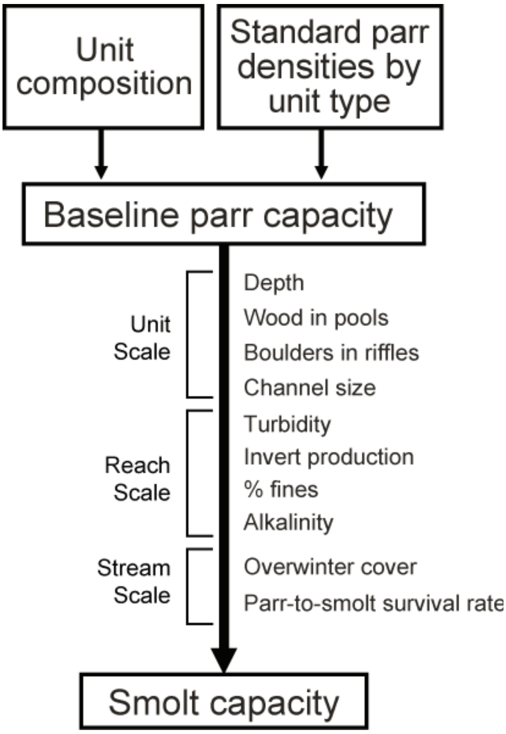

Figure 1. Diagram of the sequence of functions within the UCM.

19 coastal Oregon streams that were sampled over multiple years and were fully seeded. These densities are referred to in the UCM as the “standard densities” and the streams from which they were derived are termed the “standard streams.” These “standard densities” were applied to all seven watersheds, and the various scalars in equation (1) then adjusted these densities to be appropriate for the habitat features in each channel unit, reach, and watershed, as described below.

Channel Size (chnl).—Large river channels tend to support much lower densities of rearing parr per area than smaller channels (Johnson 1985; Jepsen and Rodgers 2004) due primarily to the preference of steelhead parr for shoreline areas, and to the head and tail sections of pools within larger channels. Bjornn and Reiser (1991) showed that counts of age-0 chinook increased with pool surface area up to pool sizes of 200 m^2. Beyond this pool size, there was no further increase in the number of fish counted. Data from the Sandy River, Oregon, suggest that calm areas (velocity <0.15 m/s) tended to form in mid-sections of pools longer than four channel widths, and 80% of pools were under that length (Cramer et al. 1998). We have observed that such calm areas are seldom used by juvenile steelhead, so we set the UCM to only assign pool area for the pool length up to four channel widths.

Fish use of the mid-river portion of wide river channels is limited (Beechie et al. 2005). Direct underwater observation data from the Salmon River (tributary to the Sandy River, Oregon) and the Clackamas River, Oregon, indicate there is a stream size at which channel geometry and hydraulics result in less favorable habitat for juvenile salmonids in midstream, and that this difference depends on the type of channel unit (pool, riffle, or glide) (O’Neal and Cramer 1999; Romey et

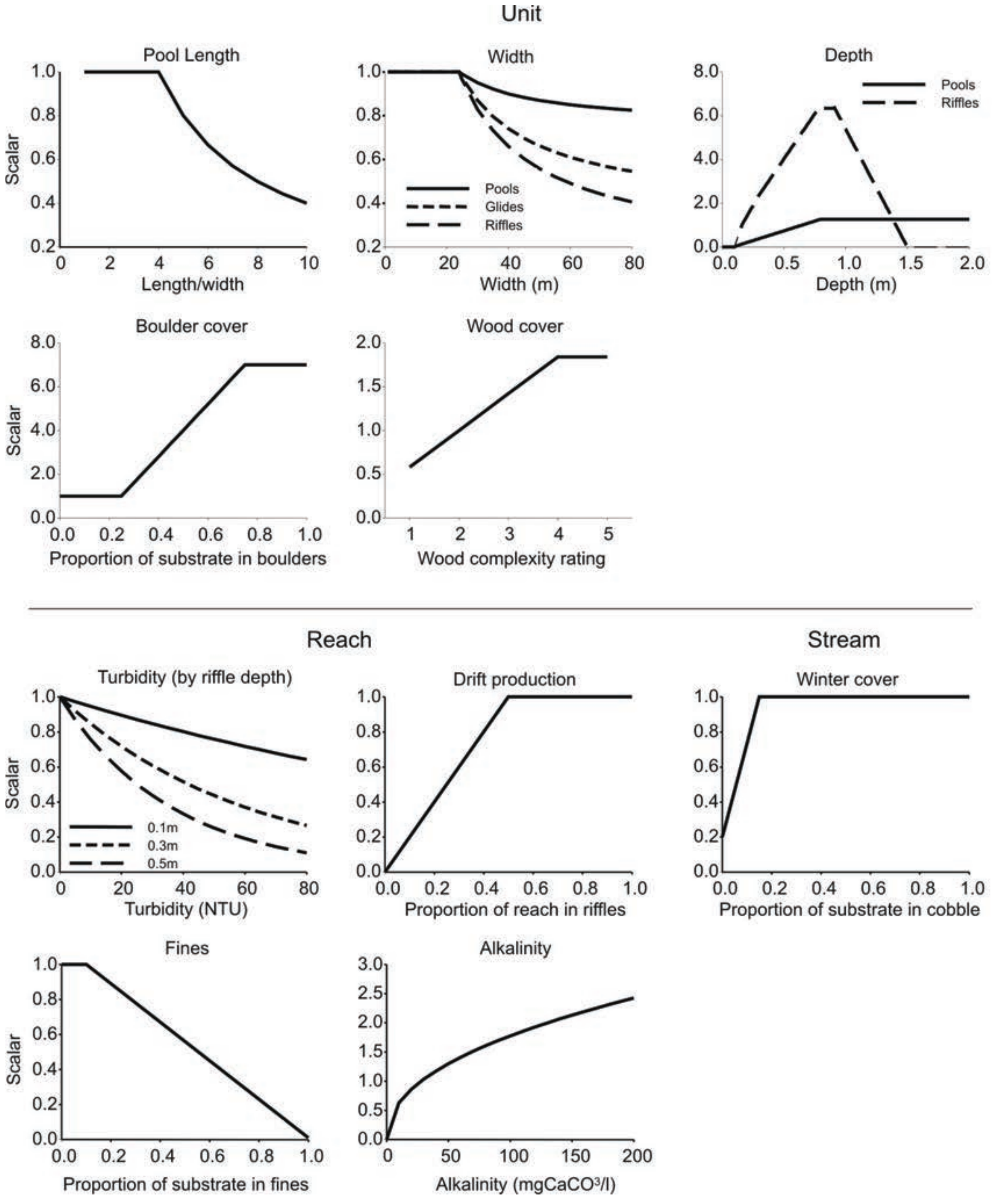

FIGURE 2. Habitat preference relationships applied within the UCM for scaling standard parr densities to those expected under the specific habitat features in a given stream.

al. 2001). In the smaller of the two rivers, the Salmon River, the mean channel width was 21 m and steelhead parr counts in the midstream lane, averaged for 16 channel units, was significantly ($P < 0.05$) greater than from either of the side lanes. However, in the Clackamas River where mean channel width was 40 m, the midstream lane consistently produced much lower counts of steelhead than the side lanes ($P < 0.01$) in riffles (15% of side lanes) and glides (35% of side lanes). Accordingly, the UCM incorporates these findings into the *chnl* scalar of equation (1), by assigning densities in the midstream portion of large channels (>12 m from shore) that are 15% of the standard in riffles, 35% of the standard in glides, and 75% of the standard in pools (Table 1; Figure 2).

Depth (dep).—The depth scalar accounts for the effect of depth on juvenile steelhead use independent of cover. In a study of a Washington stream in which cover from wood, vegetation, or boulders was absent, Beecher et al. (1993) found that steelhead parr strongly avoided areas with depth <0.15 m, and their use increased with depth from 0.15 to 0.76 m, with no change in depth preference beyond 0.76 m. Preference of steelhead parr for a similar range of depths was confirmed in separate studies by Everest and Chapman (1972), Fausch (1993) and Dambacher (1991). Bisson et al. (1988) and Roper et al. (1994) also reported that steelhead parr use increased with depth in wadable streams.

Although steelhead parr prefer increasing depth in riffles up to 0.8 m, there is also evidence that this preference declines as riffle depth exceeds 0.9 m (Bovee 1978; Conner et al. 1995). Conner et al. (1995) found that the range of depths preferred by juvenile steelhead grew smaller as velocity increased, and that juvenile steelhead only preferred deep areas where velocity was moderate. Hydraulic forces dictate that mid-depth velocities in riffles will increase as depth increases, due to the reduced influence of friction with the streambed. Thus, increasing velocity is likely the cause of reduced preference by steelhead parr for depths >0.9 m., We accordingly assumed parr densities would decrease at depths >0.9 m in riffles. The "*dep*" scalar increases linearly with increasing depths of 0.1–0.8 m in pools and riffles, and decreases linearly at increasing depths from 0.9 m, to a value of 0 at depths >1.5 m in riffles (Table 1; Figure 2). We found no clear correlation of steelhead parr densities to depth in other unit types, so we made no depth adjustment for other unit types.

The weighting factor for depth preference in the UCM was set at 1.0 for the average depth in the streams from which standard densities were derived by Johnson et al. (1993). However, Johnson et al. (1993) did not report depth, so the standard depth was defined as the mean of those reported by Oregon Department of Fish and Wildlife (ODFW) (online data, 2005b) for channel units in 10 of the streams sampled by Johnson et al. (1993).

Cover (cvr).—The UCM accounts for the effects of cover (cvr term in equation (1)) on steelhead capacity by relating availability of wood in pools and glides, and boulders in riffles, to steelhead densities (Table 1; Figure 2). Cramer and Ackerman (2009) further describe the evidence from key studies used to establish the UCM functions for cover.

Boulders provide important cover for steelhead parr in riffles (Don Chapman Consultants 1989; Dambacher 1991; Ward and Slaney 1993). Two approaches were developed to use existing stream survey data to account for the effect of boulder cover in riffles on steelhead capacity. In cases where only the dominant type of substrate was recorded, boulder dominance received a multiplier of 6.0, and other substrates had a multiplier of 1.0 (based on data of Johnson 1985). If substrate was recorded as percentage composition, then the multiplier was 1.0 for <25% boulders, and increased linearly up to 7.0 when boulders composed 75% of substrate. Boulders composed 25% of substrate in the streams from which standard densities were derived.

While boulders are the key form of cover in riffles, woody debris provides the most important form of cover in pools and glides (Bustard and Narver 1975; Johnson et al. 1993). The scalar for effects of woody debris cover was based on findings from Johnson et al. (1993), as described in Cramer and Ackerman (2009). The UCM uses inputs of wood complexity rated for each channel unit on a scale of one to five, with fish densities increasing as the wood score increased (Table 1; Figure 2). The wood cover scalar was calibrated to a value of 1.0 for the median wood complexity score of 2.0 observed in pools and glides of the standard streams.

Productivity (prod).—At the reach scale, there are stream productivity factors (*prod*) that influence all units of a reach in common. The UCM scales the effects of productivity on parr capacity based on four factors: turbidity (*turb*), invertebrate habitat (*drift*), fine sediments (*fines*), and stream alkalinity (*alk*). That is:

(2) $prod_i = turb_i \cdot drift_i \cdot fines_i \cdot alk_i$

where:

turb = turbidity during summer low flow (measured in NTUs),

drift = percentage of reach area in fastwater habitat types that produce invertebrates,

fines = percentage of substrate in riffles composed by fines, and

alk = alkalinity during summer low flow (measured as mg/l $CaCO_3$).

Before being used to calculate $prod_i$, each of these variables were converted to a scalar with a value of 1.0 corresponding to the mean or median value of the variable in the standard streams.

Turbidity (*turb*) influences productivity by reducing light penetration, which reduces primary production. Cramer and Ackerman (2009) review published evidence for biological production in streams that links sunlight to primary production, then to invertebrate production, and finally to salmonid production. In the UCM, any reduction in primary production during the low flow season would reduce steelhead capacity by the same percentage. A relationship described by Lloyd et al. (1987) was used to predict the effect of turbidity on primary production (Table 1; Figure 2), accounting for increasing attenuation of light with water depth. Mean riffle depth is used for the value of depth in the equation, because riffles are the primary location in the stream that produces most invertebrates that salmonids feed on (Hawkins et al. 1983; Rader 1997). The maximum depth we applied was 0.5 m, because velocity increases with depth in riffles, and may limit invertebrate production. If turbidity data were not available, and the stream was regarded to be a typical clear stream, the turbidity scalar was assumed to be 1.0.

The UCM uses the percentage of area in fastwater habitats (riffles, rapids, and cascades) as an index of invertebrate production (*drift*) (Cramer and Ackerman 2009). Juvenile salmon and trout feed predominantly on invertebrate drift in streams (Rader 1997), and Hawkins et al. (1983) demonstrated that salmonid density in 13 streams was correlated to invertebrate density in riffles (collector-gatherers), but not to invertebrates typically found in pools. Waters (1962) found that trout consumption of mayflies per surface area in pools (0.45 g/m^2) exceeded the production of mayflies per area of riffles (0.28 g/m^2) where the drifting mayflies were produced, which indicated that at least 60% of the stream area had to be riffles to produce the abundance of mayflies that were consumed in the pools. This finding was the basis for the assumption in the UCM that invertebrate food supply limits production in a stream reach if fastwater habitat types compose less than 50% of the surface area of the reach. We assumed that food capacity to support salmonids dropped linearly as the percentage of fastwater habitat types dropped below 50%, and we assumed that a minimum of 10% food capacity was retained even where fastwater habitat types were absent (Table 1; Figure 2). These assumptions were corroborated by observations in low-gradient streams of the Willamette Valley where abundance of salmonids was positively correlated to the percentage of area in riffles over the range of 4–50%, with salmonids composing less than 1% of fish in streams that had less than 11% riffle (Waite and Carpenter 2000).

The findings of Bjornn et al. (1977) were used to establish a UCM scalar that reduces stream capacity for parr rearing as fine sediments (*fines*) reach 10% or higher of substrate in riffles (Table 1; Figure 2). Density of juvenile steelhead in summer and winter was reduced by more than half when enough sand was added to fully embed the large cobble substrate in an experimental stream (Bjornn et al. 1977).

Alkalinity (*alk*) is a commonly measured analyte in streams that is useful as a surrogate of nutrient concentrations. Ptolemy (1993) found a positive relationship between total alkalinity and salmonid abundance across 226 streams in British Columbia and confirmed the relationship with data from 37 streams in six countries ($R^2 = 0.86$). We used the relation developed by Ptolemy (1993) to scale the effects of stream productivity to the median alkalinity of 28 mg/l $CaCO_3$ in midsummer for Oregon coastal streams from which standard parr densities were derived (Table 1; Figure 2).

Overwinter survival

The UCM predicts the capacity of age >1 parr, but these parr must still survive through the winter before they undergo parr-to-smolt transformation and migrate to sea the next spring. Many studies have demonstrated that steelhead typically seek refuge in the winter within the interstices of cobble and boulder substrate (Hartman 1965; Bjornn 1971; Bustard and Narver 1975; Swales et al. 1986; and USFWS 1988). Several studies have demonstrated that steelhead presmolts will migrate from an area in the fall where cobble-boulder substrate is in short supply, but these fish typically find appropriate winter habitat further downstream (Bjornn 1978; Tredger 1980; Leider et al. 1986). Thus, the model uses availability of cobble substrate throughout the stream network as an index of winter capacity for steelhead parr (*winter* in equation (1). The UCM assumes that 15% of substrate comprised by cobbles is sufficient to support the numbers of parr surviving the summer, and winter capacity would drop linearly to a minimum scalar value of 0.20 if cobbles were absent (Table 1; Figure 2).

The overwinter capacity scalar is subsequently multiplied by the expected winter survival for age >1 parr to complete the translation of parr capacity into smolt capacity. Overwinter survival of steelhead parr is typically between 35 and 65% (Chilcote et al. 1984; Reeves et al. 1990; Tautz et al. 1992; Ward and Slaney 1993; Kiefer and Lockhart 1999). We assumed 50% survival to convert parr capacity to smolt capacity, unless data for a specific basin led us to assume otherwise.

Test basins

Capacity estimates from the UCM were corroborated through comparison to observed parr and smolt production from seven steelhead-producing basins (referred to as test basins) of varied habitat characteristics and locations throughout Oregon (Figure 3). Though the UCM predicts parr capacity during summer low flow, abundance of juvenile steelhead is most often sampled when they emigrate from a stream as smolts in the spring. The abundance of smolts reflects the cumulative effects of all freshwater limitations to production, and thus is a useful index of carrying capacity. Our application of the parr-to-smolt survival rate described earlier facilitated comparisons of UCM estimates to juvenile steelhead production.

Watershed areas ranged from 26 to 1,420 km^2 (Table 2). One of the basins (Hood River) was strongly influenced by glacial meltwaters during summer, three basins drained arid watersheds to the east of mountain ranges (Trout Creek, Catherine Creek, and Little Butte Creek), and three basins were in a wet coastal region (Cummins Creek, Tenmile Creek, and Little North Fork Wilson River). Either parr or smolt production of steelhead had been estimated by the ODFW in these watersheds using direct sampling methods for five to 11 years (Table 2).

Habitat data that were inputs to the UCM were obtained from surveys by ODFW and U.S. Forest Service (USFS) using their standard protocols (Table 3). Steelhead distribution in these basins was defined using 1:100K data from the ODFW Fish Distribution Data Development Project (ODFW 2005a, online data). Water quality data were obtained from the Oregon Department of Environmental Quality (ODEQ 2006, online data). In some basins, habitat data did not provide complete coverage for the range of steelhead rearing

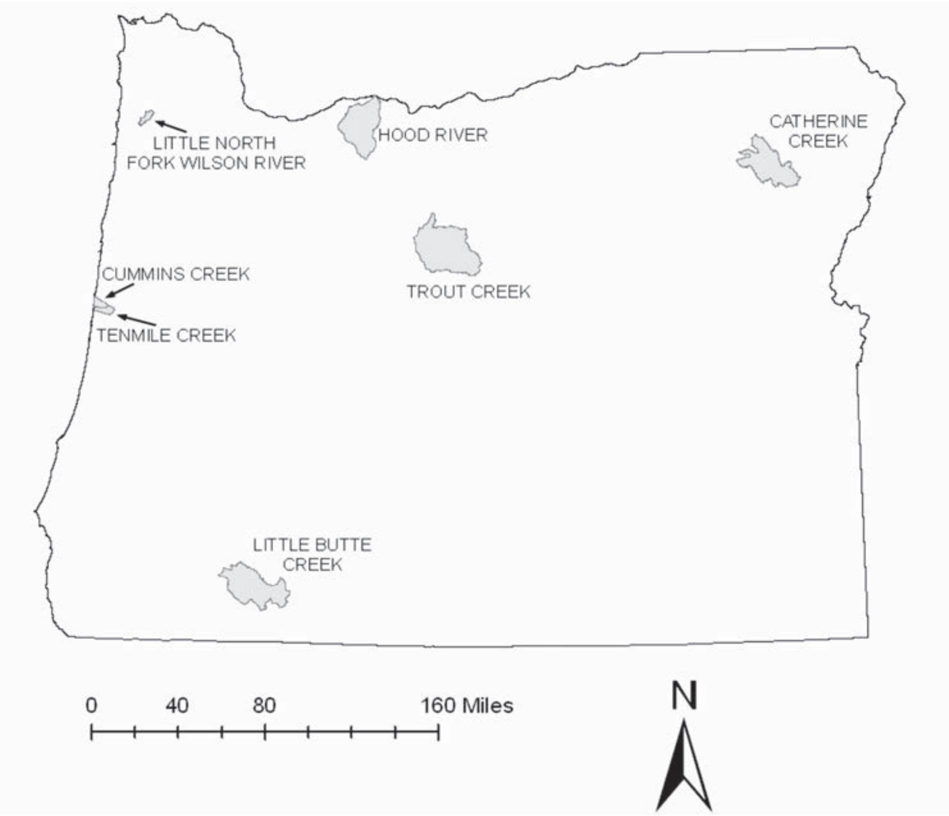

FIGURE 3. Map displaying relative location of test watersheds within Oregon.

TABLE 2. Drainage area and estimated abundance of juvenile steelhead in watersheds used to test the UCM. Tenmile and Cummins Creek population estimates are in terms of parr. Remaining watersheds are in terms of smolts.

Watershed	Watershed Area (km²)[1]	Years of Population Estimation	Minimum Population	Average Population	Maximum Population
Tenmile Creek[2]	60	1991–1995	12,180	15,270	19,784
Cummins Creek[3]	26	1996–2000	4,798	5,743	7,171
Little North Fork Wilson River	52	1998–2004	3,524	10,108	20,686
Little Butte Creek	966	1998–2004	15,634	21,801	27,425
Hood River	912	1994–2004	4,936	14,242	27,193
Trout Creek[4]	1,420	1998–2004	11,643	25,888	51,199
Catherine Creek[4]	267	1997–2001	10,377	13,029	19,865

[1] Approximation of watershed area above downstream migrant trap.

[2] Population was monitored in 1996-2000, but ODFW (who conducted sampling and population estimates) determined that production estimates in those years were unreliable.

[3] Population was monitored in 1991-1995, but data indicated the basin was underseeded in those years.

[4] Population estimates reflect smolts normalized to age 2. See subsequent methods section.

TABLE 3. Sources of outmigrant and habitat data used within the UCM test basins.

Basin	Outmigrant Data	Habitat Survey Data
Tenmile Creek	Solazzi et al. 2002	Pers. comm., Steve Johnson, ODFW
Cummins Creek	Solazzi et al. 2002	Pers. comm., Steve Johnson, ODFW
Little North Fork Wilson	Dalton 2001; Pers. comm.	ODFW online data 2005b, Tim Dalton, ODFW
Little Butte Creek	Vogt 2004; Pers. comm., Jay Doino, ODFW	ODFW online data 2005b
Hood River	Olsen 2005	ODFW online data 2005b; Unpublished data, US Forest Service, Mt. Hood NF.
Trout Creek	Pers. comm., Tom Nelson, ODFW	ODFW online data 2005b; Unpublished data, US Forest Service, Ochoco NF.
Catherine Creek	Reischauer et al. 2002	ODFW online data 2005b; Unpublished data, US Forest Service, Wallowa-Whitman NF

distribution. Typically, unsurveyed habitat was at the upper extent of steelhead presence and in small tributaries. In these situations, we assigned parr per meter values predicted by the UCM from the surveyed reach that we judged to be most similar. Similarity was judged by such factors as gradient, watershed area, valley form, channel form, flow, elevation and precipitation. Most often, this judgment led to use of the nearest reach with similar width and gradient.

In some instances, measurements of some habitat attributes were not directly applicable to the UCM. For instance, substrate composition was only classified into dominant and sub-dominant types in some reaches. In this particular situation, habitat data from streams around Oregon were used to draw correlations between dominant/sub-dominant substrate types, and the percentage of substrate most likely represented by those classifications. If a clear basis could not be derived to translate existing survey data into the inputs called for by the UCM, then no adjustment was made for the function (e.g., wood complexity data were not collected in Trout Creek). This practice assumes that the unmeasured factor value was equal to the average from the standard streams. Basin coverage of habitat data to supply inputs for the UCM was generally good. The reaches that accounted for over 90% of the capacity predictions were fully surveyed in all test streams except Little Butte Creek and Trout Creek, where 81% and 69% of the predicted capacities were generated from the reaches that had been surveyed.

Directly sampled production data from each test basin was examined for evidence that juvenile production reached capacity (full seeding) in some of the years sampled. Evidence of full seeding with juveniles was deduced from high smolt production in some years relative to that expected based on watershed area (Cramer and Ackerman 2009), or consistency in smolt production across several years. Only Catherine Creek in the Grande Ronde Basin appeared not to have reached full seeding.

In Tenmile Creek and Cummins Creeks, both direct ocean tributaries in Oregon, the size of the summer rearing population of parr was estimated via snorkeling and electrofishing surveys by the ODFW between 1991 and 2000. In Tenmile Creek, only population estimates from 1991 to 1995 were included in the analysis, because those were the only years ODFW deemed the estimates sufficiently reliable (Steve Johnson, ODFW, personal communication). In Cummins Creek, we used parr population estimates for 1996 to 2000 in our analysis, because smolt abundance was high and stable compared to lower, but increasing abundance during 1991 to 1995. Parr estimates for these two basins were converted to estimates of smolt production by assuming 50% survival from parr to smolt.

Hood River was the only basin tested where we assigned other than 50% for overwinter survival. Glacial influences in Hood River resulted in a high volume of fines, which embedded the available cobble and restricted overwinter cover. High percentages of fines in the substrate have been implicated in stimulating emigration and reducing overwinter rearing densities for salmonids (Bjornn et al. 1977; Bjornn 1978; Hillman et al. 1987). Accordingly, we applied a 35% par–smolt survival rate to the Hood basin as was done by Underwood et al. (2003).

We defined observed capacity as the 80th percentile of population estimates for each watershed. The 80th percentile was chosen to ensure that the estimate represented years in which production was maximized, yet avoided positive bias that could result if we used only the year of greatest production, which may have resulted from unusual circumstances.

Results

Range of habitat features tested

A wide range of habitat features used in the UCM were represented across the test basins. The UCM was populated with data from 190 reaches across seven basins. For most habitat attributes, there was a several-fold range in the median values between reaches within each basin (Figure 4). Only a few notable differences existed between basins including: the proportion of pools, the proportion of fines in riffles, and alkalinity (Figure 4). The percentage of pools was generally higher, and the percentage of fines was lower in coastal basins than elsewhere. The percentage of stream surface area composed by pools, riffles, rapids, and glides was consistent between the three coastal basins, and more variable among the interior and glacial basins (Table 4). Alkalinity was higher in the interior basins than in coastal or glacial basins. Hood River basin, although having a full range of channel sizes from small tributaries to the main river, included the widest channels, lowest proportion of pools, deepest riffles, and the highest percentage of fines. Wood complexity rarely exceeded a score of 2.0 in any of the basins, and only reached a median of 2.0 in the Cummins Creek basin, where landslides and habitat restoration had recently introduced substantial quantities of large wood.

Observed and predicted smolt capacity

Direct sampling of parr or smolt production in test basins showed variability between years (Figure 5). Repeatability of high juvenile production was a criterion for determining full seeding of capacity. Production for the highest three years ranged less than 25% within each basin, except in Trout Creek and Catherine Creek. In Trout Creek, unusually high smolt abundance in 1998 resulted from exceptionally rapid growth in 1997, followed by an unusually high percentage (64%) of age-1 smolts in 1998. Most smolts have been age 2 in other years (T. Nelson, ODFW, Madras, OR, personal communication). Thus, the unusually high abundance of smolts in 1998 was not regarded as evidence of unmet capacity in other years. No such event occurred in the highest year of smolt production in Catherine Creek and spawner abundance was

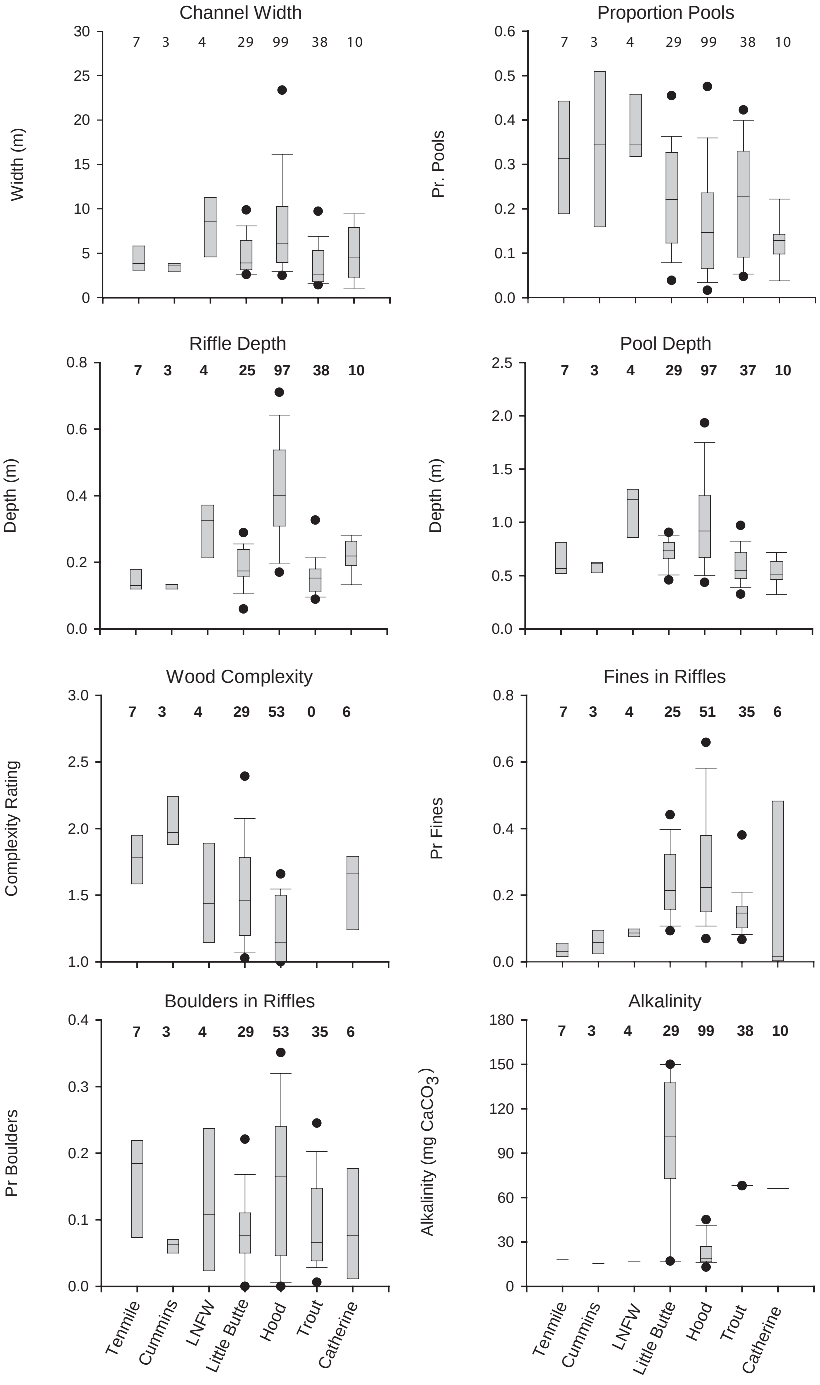

FIGURE 4. Habitat attributes associated with each basin where UCM capacity estimates were made. Plots constructed using mean values from reaches within each basin where data for a particular attribute were available. Box is defined by 25th 50th, and 75th percentiles, whiskers represent the 10th and 90th percentiles, and points represent 5th and 95th percentiles. Sample size (*n*) is located above each box and varies between plots because data on all attributes was not collected in every reach.

TABLE 4. Habitat unit composition of test basins. Values represent the mean value from all reaches incorporated into the UCM.

	% Glide	% Pool	% Rapid	% Riffle
Coastal Basins				
Tenmile Creek	7%	41%	22%	28%
Cummins Creek	3%	41%	31%	24%
Little N. Fk. Wilson	14%	40%	12%	26%
Interior Basins				
Little Butte Creek	9%	38%	23%	24%
Hood River	2%	16%	54%	19%
Trout Creek	6%	30%	8%	50%
Catherine Creek	3%	13%	38%	45%

believed to be low compared to historic levels (R. Carmichael, ODFW, La Grande, OR, personal communication). Therefore, direct estimates of smolt production in Catherine Creek did not qualify for estimating observed carrying capacity. Estimates of observed capacity for the six qualifying test basins are given in Table 5.

Parr capacity predictions from the UCM ranged from 5,127 in Cummins Creek (the smallest of tested watersheds) to 91,505 in the Hood River basin (Table 5). These capacities expressed in terms of smolts were 2,563 and 23,843 respectively. Because parr in the Hood River basin were assigned lower winter survival (35%) than other test basins (50%), predicted smolt capacities in Little Butte Creek and Trout Creek were greater than for Hood River basin (Table 5). Basin-wide averages for predicted densities at parr capacity ranged from 5.4 parr/100 m^2 in the Hood River to 11.0 parr/100 m^2 in Catherine Creek (Table 5).

Smolt capacities predicted by the UCM were highly correlated to observed capacities across the six test basins that had evidence of full seeding ($R^2 = 0.88$; $P < 0.005$) (Figure 6). However, watershed area by itself was equally well correlated to observed capacities across the six test basins ($R^2 = 0.88$; $P < 0.005$; Figure 7), and the UCM predicted capacity was also correlated to basin area ($R^2 = 0.92$). Predicted capacities in the three largest basins all exceeded the 80th percentile of observed juvenile production, indicating there may be a tendency for the UCM to over-predict capacity in larger basins. Deviations of predicted from observed capacities were modest for five of the six basins, ranging from –22 to + 34% (Table 5). Only in the Little North Fork Wilson basin did predicted capacity (3,957) deviate substantially from observed capacity (14,797; –73%).

Observed parr abundances were most consistently near the predicted capacity in Cummins and Tenmile creeks, where parr abundance was slightly above or below the predicted value in a balanced number of years (Figure 5). These were the only two basins in the test set for which juvenile production was estimated directly for age-1+ parr, rather than for smolts. Thus, no assumption about overwinter survival was necessary for these basins, but in all other basins, an assumed winter survival rate had to be assigned to the parr capacity estimate to calculate smolt production the following spring.

In two of the six basins analyzed, Little Butte Creek and Hood River, the observed annual parr abundance, derived from smolt sampling, fell below the UCM predicted capacity in all years sampled. If we assumed winter

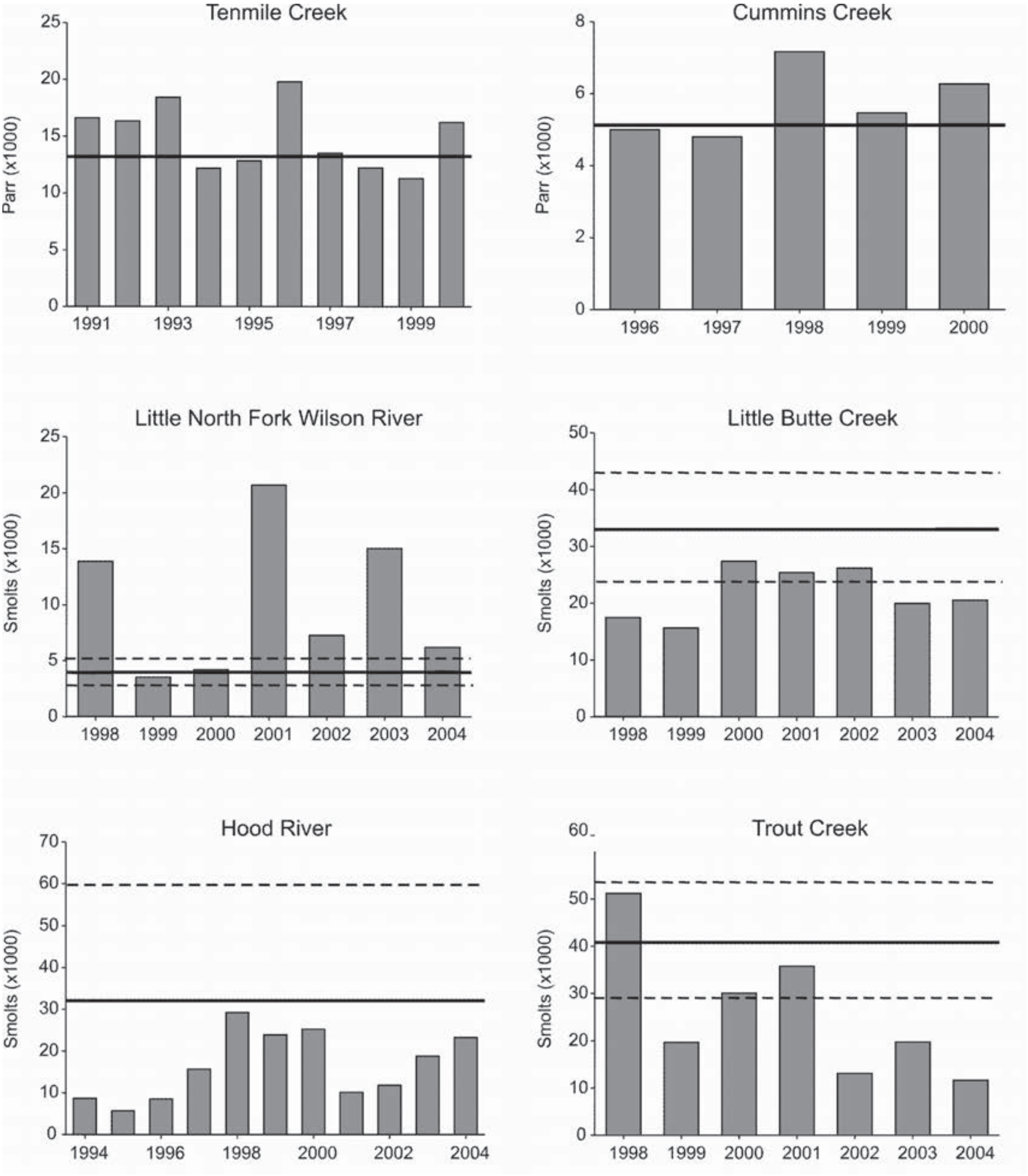

FIGURE 5. Annual estimates of steelhead parr or smolts produced in each test basin. Data from sources in Table 3. Solid horizontal line represents the UCM capacity estimate based on a 50% S_{ow} (35% in Hood River). Dotted lines represent the range of the UCM capacity estimates assuming a 35–65% S_{ow}.

Table 5. UCM predictions of parr and smolt capacity at the assumed over-winter survival (S_{ow}) in test basins, compared with observed capacity based on direct estimates of juvenile production. The observed capacity represents the 80th percentile of observed production estimates (Table 2). The observed capacity and prediction deviations are based on parr for Tenmile and Cummins creeks, and based on smolts for the remainder of the basins.

Basin	Predicted Parr Capacity	Predicted Parr/100m^2	Assumed S_{ow}	Predicted Smolt Capacity	Observed Capacity	Prediction Deviation
Tenmile Cr.	13,253	6.7	50%	6,676	16,974	–22%
Cummins Cr.	5,127	7.0	50%	2,562	6,452	–21%
Little N. Fk. Wilson	7,913	6.4	50%	3,957	14,797	–73%
Little Butte Creek	65,982	8.1	50%	32,991	26,024	+27%
Hood River	91,505	5.4	35%	32,026	23,843	+34%
Trout Cr.	81,575	9.9	50%	40,787	34,620	+18%
Catherine Cr.	47,787	11.0	50%	23,894	--	--

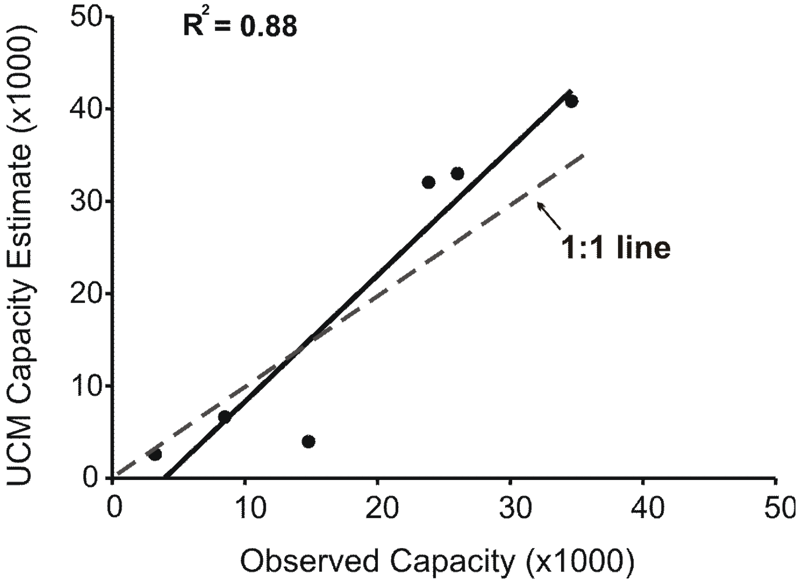

Figure 6. Relationship of predicted to observed smolt capacities for the six test basins. Catherine Creek excluded from the comparison because it was not believed to be fully seeded. Solid black line is least-squares regression line. The dashed gray line indicates 1:1 relationship.

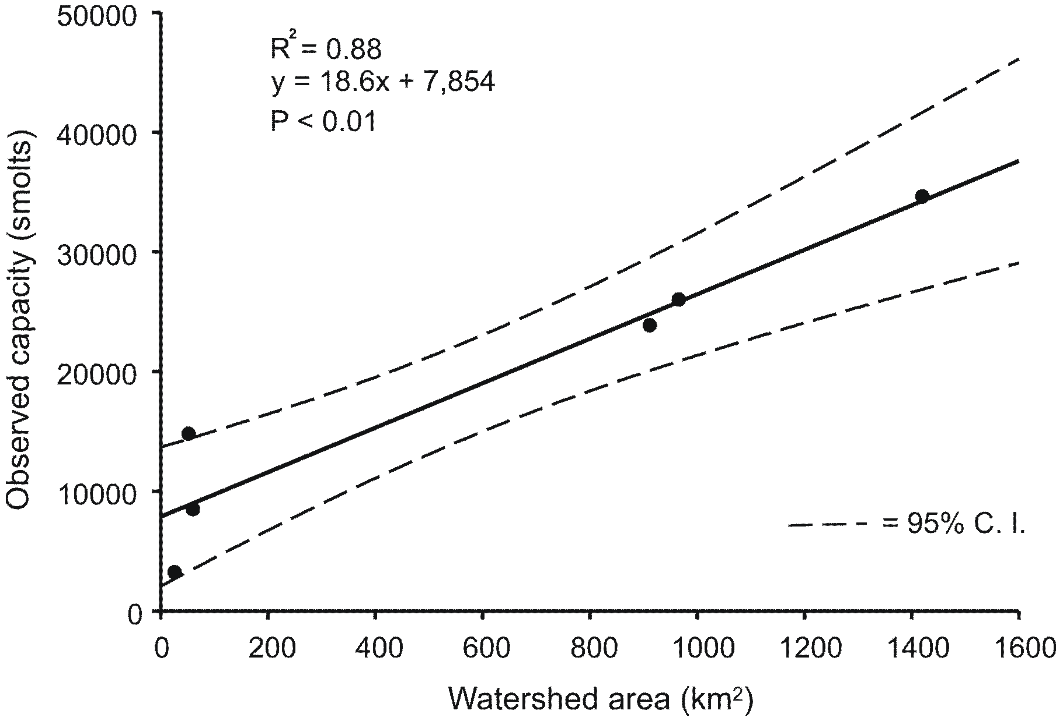

Figure 7. Regression of observed smolt capacity on watershed area in the six test basins.

survival was 35% in Little Butte Creek, then estimated parr abundance reached the UCM predicted capacity in three of seven years (Figure 5). The Hood River was the only test basin for which smolt sampling indicated parr abundance was less in all years sampled than that predicted by UCM, assuming the low range of winter survival (35%). In contrast, smolt abundance exceeded the predicted capacity in six of eight years sampled in the Little North Fork Wilson River, and deviations from predicted capacity were greatest there for any of the test basins (Table 5).

Distinction of habitat quality

The UCM provided a quantitative measure of habitat quality by predicting the density of parr or smolts that a given basin, or stream reach within the basin, could support. Although basin area was highly correlated to observed smolt production, the UCM predicted that four of the seven test watersheds had widely differing habitat quality between reaches. Only the three coastal watersheds had consistent habitat quality, as indicated by the low variability in predicted density among reaches, compared to the interior basins (Figure 8). All of the interior and glacial basins had some low quality reaches that would support less that 0.01 smolts/m^2, and high quality reaches that would support greater that 0.06 smolts/m^2. Median values of smolt density at capacity were about 50% higher in interior basins than those for coastal basins.

Prediction sensitivity to habitat factors

Differences between basins.—Alkalinity (*alk*) had a greater effect on capacity predictions than any other model term (Figure 9). Alkalinity strongly distinguished watersheds in dry, interior climates from those in wet, coastal climates. The adjustment for alkalinity substantially increased predicted capacities for Trout, Catherine, and Little Butte creeks, while slightly decreasing capacities in the other four basins. Predictions of basin capacity were moderately influenced by *dep* and *cvr*, with *dep* having more influence (Figure 9). The depth scalar for all basins exceeded 1.0, indicating that depths in the test basins were generally greater than in the standard streams. The cover scalar had mixed effects on model outcomes. Cover quality was better in Cummins Creek, Trout Creek, and Catherine Creek, but lower in other test basins than for the standard streams (Figure 9).

The attributes, *turb*, *drift*, and *fines*, generally had small effects on most predictions, but notable effects in specific watersheds. The Hood River was the only glacially turbid stream tested, and the predicted effect of turbidity there was to reduce capacity by 21% (Figure 9). The largest effect of *drift* on capacity predictions was to reduce capacity approximately 10% for three of seven watersheds (Figure 9). The proportion of fines in the substrate was only high enough in the Hood River Basin to have a notable negative effect (–15%) on predicted capacity (Figure 9). Fines averaged 26% in riffles in the Hood River basin, but only ranged from 2 to 17% in other test basins (Table 6).

Differences between reaches.—More variation in habitat features was expressed between reaches than between basins, so we examined the effect of reach-level attributes on predictions of smolt capacity and density in 137 reaches where all, or nearly all, habitat attributes were evaluated in surveys. Stream surface area within a reach had the greatest influence on predicted reach capacity, but was not related to habitat quality (parr capacity/m^2). Reach surface area ranged from under 5,000 m^2 to over 270,000 m^2, a 50-fold difference, among all reaches studied. Predicted habitat quality (parr/m^2) varied substantially by 15-fold between reaches, but the range of predicted capacities was still driven by the 50-fold range in stream surface area between reaches.

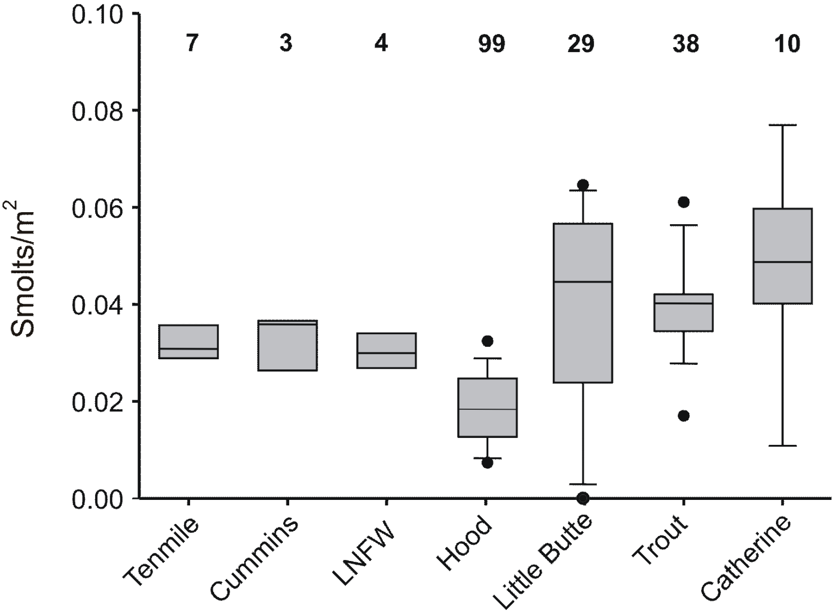

FIGURE 8. Predicted smolt capacity densities among reaches within each basin. Sample size (*n*) is labeled above each box. Box is defined by 25th 50th, and 75th percentiles, whiskers represent the 10th and 90th percentiles, and points represent 5th and 95th percentiles.

In the first calculation step of the UCM, the surface area for each type of channel unit is multiplied by the standard parr density for that unit type. We refer to this initial stage of calculations as the "base capacity" predicted by the model. The base capacity density (parr/m^2) in test reaches increased as a function of the percentage that pools composed of the stream surface area (Figure 10). The expected parr density at base capacity approached 0.04 parr/m^2 as the proportion of pools in a reach approached zero, and increased up to 0.13 parr/m^2 at 70% pools, the highest percentage observed. This is a three-fold range in the densities predicted at this initial calculation step. Baseline capacity densities were higher in coastal Oregon watersheds, where pools comprised 40–41% of habitat, compared to 13–38% of the habitat in interior and glacial basins (Table 4).

Sensitivity of capacity density predictions to functions within the UCM were determined by adding each UCM factor in stepwise fashion to the UCM calculation, and computing the proportionate change in the fish density prediction with each new factor added (Figure 11). We refer to this accumulating product of scalars as the cumulative density multiplier. The median value of this multiplier accumulated for all habitat factors in the UCM was 1.09 (little different than the base density of $(\Sigma\ arean_{jk} \cdot den_j)/\Sigma\ area_k)$), but ranged up to 3.0 for the 90th percentile of reaches and down to 0.2 for the 10th percentile (Figure 11). Alkalinity produced the greatest difference in the density multiplier between reaches, ranging from 0.8 to over 2.0 (Figure 11). The percentage of fines was the second most influential factor, and generally reduced the density multiplier, ranging from 1.0 down to 0.5. Lesser effects from pool and riffle depths tended to increase the multiplier, while channel width, wood cover (lack thereof), and fines tended to reduce it. Boulder cover, drift availability and turbidity usually produced scalars near 1.0, and only

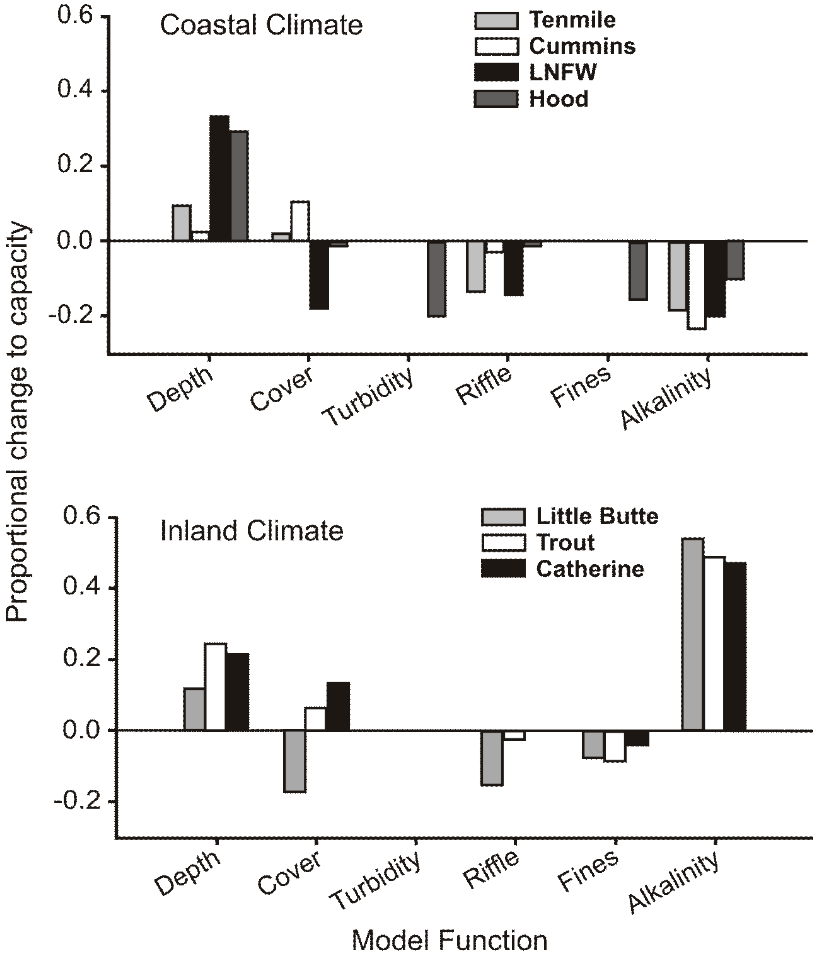

FIGURE 9. Response of UCM predicted capacity within each test basin to each habitat attribute.

had notable effects in a few reaches. The multiplier for winter cover had no effect in any of the reaches surveyed.

Discussion

Accuracy of prediction

Parr capacities predicted with the UCM using habitat measurements at the channel unit level showed a high correlation (R^2 = 0.88) to direct estimates of smolt production in six test watersheds of widely different size and habitat characteristics. This finding suggests that the UCM predictions of smolt capacity are reasonably accurate at the basin scale, but we also found that basin area by itself was similarly correlated to observed smolt production (R^2 = 0.88). Thus, the high correlation of predicted and observed smolt capacities should not be regarded as validation of the UCM. Such validation will require comparison of predicted and observed parr or smolt per unit area (i.e., fish densities) between reaches representing a wide range of predicted capacity densities. Data on parr densities in each reach were not available for four of our six

TABLE 6. Habitat attributes of test basins. Note: In some reaches, habitat substrate was surveyed as dominant and subdominant substrate types. Those classifications are not included in this table, but were included in model scenarios.

Basin	Depth (m) Pools	Depth (m) Riffles	Wood Complexity (1–5)	% Fines in Riffles	% Boulders in Riffles	Alkalinity ($mgCaCO_3/l$)
Tenmile Creek	0.6	0.1	1.9	2%	22%	18
Cummins Creek	0.6	0.1	2.2	8%	10%	16
Little N. Fk. Wilson	1.2	0.3	1.3	8%	14%	17
Hood River[2]	1.3	0.5	1.1	26%	19%	23[1]
Trout Creek	0.6	0.1	--[3]	17%	15%	68
Catherine Creek	0.5	0.2	1.7	2%	11%	66
Little Butte Creek	0.7	0.2	1.4	14%	7%	89[1]

[1] Several streams within the basin were assigned different values based on available data. Value is mean from streams included in the model. In other watersheds, a single value was applied to all streams within the basin.

[2] Estimate represents value from dominant steelhead producing reaches. Reaches listed in Table A12 of Underwood et al. (2003).

[3] No wood complexity data available for Trout Creek. Assumed no adjustment for wood complexity.

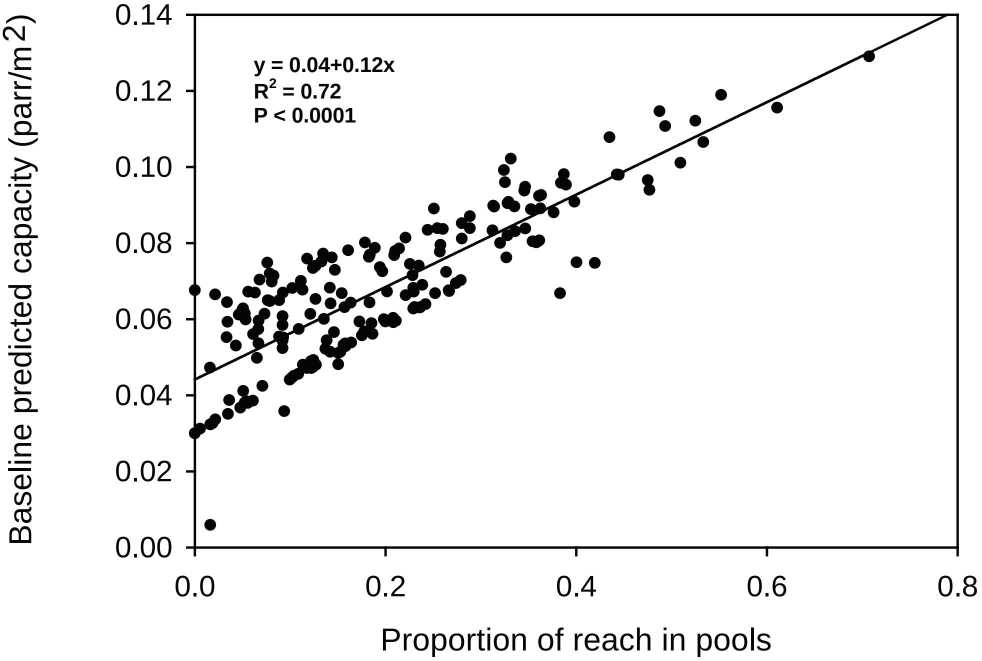

FIGURE 10. Relationship between the proportion of pools within a reach and the predicted base capacity in terms of parr/m^2. $n = 190$. The straight-line relationship among a large number of the observations in the lower left of the data array are reaches where only the pools were deep enough to support age >1 steelhead parr.

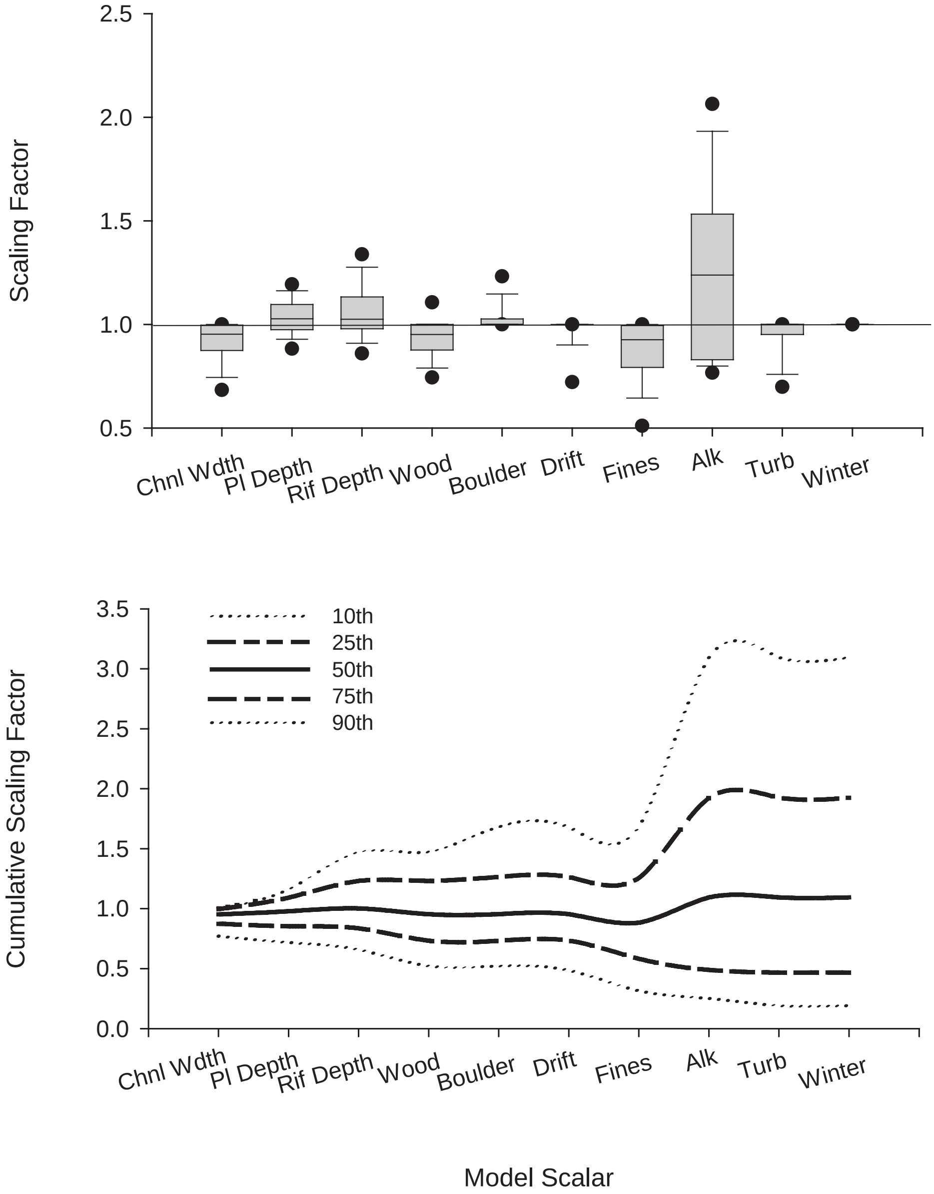

FIGURE 11. Effects of individual scalars on model outcomes. Top graph: each box represents the effect of that scalar on model outcomes independent of other scalars. Plot constructed by pooling data from all basins and all reaches where full suite of habitat data were available (n = 137). Box is defined by 25th 50th, and 75th percentiles, whiskers represent the 10th and 90th percentiles, and points represent 5th and 95th percentiles. Bottom graph: plot constructed from data in top graph by compounding 10th to 90th percentile scaling factors across all model scalars.

test basins. Though statistical procedures might be helpful to account for the separate effect of basin size on the fit of predicted to observed smolt capacity, our limited sample size of six basins with direct estimates of smolt production provides little statistical power to account separately for the effects of basin size.

However, by expressing these predictions in a per-unit-area scale, the overriding influence of reach area on basin predictions can be eliminated. Application of UCM to the test reaches demonstrated that the method could sharply distinguish habitat quality throughout the basin in terms of carrying capacity per unit area. The cumulative density multiplier in the UCM after all habitat factors were included ranged over 15-fold between reaches, from a high of 3.0 for the 90th percentile of reaches and to a low of 0.2 for the lower 10th percentile of reaches (Figure 11). Cramer and Ackerman (2009) presented evidence from a number of studies that demonstrate steelhead parr densities are strongly related to the habitat factors included in the UCM, and the habitat data from the test basins indicate that those factors important to steelhead were substantially different between some of the reaches in nearly every basin. In spite of the wide range of these habitat factors and the large differences they produce in predicted parr capacity between the 190 reaches analyzed in this study, the sum of these reach-level predictions still reflected the observed smolt production from the basin. Thus, the UCM prediction appeared to have accurately expressed both the heterogeneity of habitat quality in a basin, and the combined potential of those different habitat qualities to produce smolts from throughout the basin.

The results of our study support the notion that basin area is a reasonable predictor of carrying capacity for steelhead similar to that reported for other species (Underwood et al. 2003). Our results also demonstrate that much additional information about limiting factors and likely distribution of fish production in the basin can be gained from habitat measurements collected during typical state and federal stream surveys. Apparently, the averaging of a wide range of habitat qualities that exists between reaches within a basin leads to a central range of smolt densities that can be expected between basins. The predictions of the UCM for the test streams confirm this interpretation. As shown in Figure 11, the cumulative density multiplier, although ranging widely between reaches within a basin, still had a median value of 1.09; quite close to the 1.0 level that would indicate no difference compared with habitat quality in the streams from which standard parr densities were derived.

Sources of error

The correlation of predicted to observed parr capacity ($R^2 = 0.88$) was surprisingly high given the substantial source of error introduced by back-calculating of summer parr capacity from estimates of smolt out-migration in four of the six validation streams. Predicted parr capacity was most consistently near the observed parr production in the two streams, Cummins and Tenmile creeks, where parr abundance was estimated directly from sampling of parr. In those two streams, observed parr abundances were slightly above or below the predicted capacity in a balanced number of years (Figure 5).

In addition to sampling variation, there are at least two sources of error that enter into the back-calculation to parr from smolt abundance. First, immigration or emigration of parr during fall is a common behavior among juvenile salmonids in pursuit of winter habitat (Cederholm and Scarlett 1981; Leider et al. 1986; Bramblett et al. 2002). Either event confounds our ability to determine actual parr capacity based on smolt population estimates. Second, differences in flow stability between streams can lead to substantial differences in overwinter survival, with peak flows reducing survival (Seegrist and Gard 1972), and stable flows allowing high survival (Mundie and Trabor 1983). We assumed a constant 50% overwinter survival in all years sampled, and in all test streams except Hood River, where we assumed a 35% overwinter survival. Overwinter survival was estimated annually during field studies in two of the test streams, Tenmile and Cummins creeks, and found to vary by two to three-fold (32–59% in Cummins Creek and 18–48% in Tenmile Creek; Solazzi et al. 2002). Clearly, this variation contributed to error in estimation of annual parr production in the test streams for which only smolt production was sampled.

Our analysis suggests that the UCM may slightly over-predict capacity in the larger basins (>900 km^2), such as Trout Creek, Little Butte Creek, and Hood River, or in highly alkaline basins such as Trout Creek and Little Butte Creek. In each of these basins, the observed smolt production for most sampled years fell below the predicted smolt capacity (Figure 5). The deviation of predicted from observed was not large in these streams (18–34%), but the consistency of the pattern warrants scrutiny as further data are gathered. It may simply be that capacity is fully reached in large basins less frequently, because the larger stream network increases the probability due to random variation that some of the reaches will not be fully seeded. However, two of the three larger test basins were also assigned large increases in predicted capacity (about 150%) due to high alkalinity (Figure 9). It is possible that the high correlation found by Ptolemy (1993) for salmonid densities to alkalinity across 226 streams may have been influenced by correlations of alkalinity to stream morphology. Alkalinity tends to increase as runoff per km^2 watershed area decreases, and such differences in water yield may influence the formation of channel morphology. For example, pools comprised 40–41% of habitat in coastal basins, compared to 13–38% elsewhere for our test streams. These possible confounding factors warrant further study, but the results from our test streams suggest that little increase in prediction accuracy will be achieved by improvements to the basin size and alkalinity functions.

Smolt yield in the Little North Fork Wilson was anomalously high compared to the capacities predicted by both the UCM and watershed size (roughly four times the expected yield), and may have been influenced by immigration of parr from the main stem Wilson River in the fall. Substantial immigration would result in over-prediction of summer parr abundance when back-calculated from the abundance of smolts departing the stream the following spring. The Little North Fork Wilson enters the mainstem Wilson River near the upper end of tidewater, where it is a last-chance opportunity for nonnatal rearing of juveniles that arrive in tidewater before they are ready to smolt. Local biologists have found no unusual habitat morphology in the Little North Fork to account for exceptional production of anadromous salmonids in that stream (Tim Dalton, ODFW, personal communication).

A clear understanding of the distribution of steelhead rearing within a basin network of channels is important in determining juvenile production potential. The distribution of salmonids within a watershed varies seasonally and annually. These variations are driven in part by flow, temperature, and competition (Welsh et al. 2001; Jacobs et al. 2001; Bramblett et al. 2002). Greatest accuracy in applying the UCM can be achieved by excluding channels that may be used for migration or spawning, but not for rearing. For example, the uppermost reaches where steelhead spawn within a basin may provide an insufficient water supply during summer for parr rearing, in which cases parr move further down in the stream network to rear. Likewise, lower reaches that serve only as migration corridors should also be excluded from assignment of rearing capacity. Lack of rearing in lower reaches of a basin may result from the influences of factors such as high stream temperature or an abundance of predators, which are not included in the UCM.

UCM sensitivity to habitat factors

The variation in reach scalar values for each habitat factor in all seven test basins provided a realistic and practical context for examining model sensitivity to the factors included. The wide range of values for each habitat factor between basins (Figure 4) provided a useful test for how the model responds to combinations of habitat features found in steelhead streams. Although the values for scalars ranged widely (with the exception of winter cover) the effect of averaging multiple factors across multiple reaches within a basin proved to be a strong homogenizing force on predicted density at capacity for a basin. Though scalar values for each of the eleven habitat factors ranged up to sevenfold between reaches within a basin, the density multiplier accumulated across all factors had a median value of 1.09 and ranged only four fold between the 25th and 75th percentile of reach values (Figure 11). As a result, the median reach value for predicted smolt density ranged only 2.5 fold between the seven test basins. Alkalinity had a greater effect on capacity predictions than any other model term, and its primary effect was to distinguish watersheds in dry, interior climates from those in wet, coastal climates (Figure 9). The percentage of surface area in pools accounted for up to a threefold range in the base parr densities between reaches, and up to 50% difference between basins. The factor of depth in pools and riffles tended to increase capacity densities by 20–30% in large basins compared with those in the smallest coastal basins, Cummins and Tenmile creeks (Figure 9).

Data from the test streams illustrate that specific habitat factors may only cause anomalies in habitat quality predictions in specific basins, while having little effect in others. As one example, the Hood River was the only glacially turbid stream tested, and the predicted effect of turbidity there was to reduce capacity by 21% (Figure 9). In another example, boulder cover had little effect in most streams, and had its largest effect in Catherine Creek, despite the low average proportion of boulders in riffles (11%). However, a high value of boulder cover in a small number of riffles (7% of the stream's habitat area) accounted for a 20% increase in the capacity prediction for the Catherine Creek basin. This second example illustrates the importance of applying model functions at the unit scale rather than using average habitat values at the reach or stream scale to estimate capacity. Even though a particular habitat factor may have little effect in most basins and reaches, it can still have an important effect in specific areas.

No specific measurements of velocity were included in the UCM, because velocity is not typically measured on stream surveys. Steelhead show strong velocity preferences related to their size, so the absence of specific velocity information undoubtedly contributes to error in the UCM prediction of carrying capacity. However, some effect of velocity is captured in the predictor through the densities assigned to different channel unit types. For example, steelhead are typically found in riffles at higher densities than juvenile Chinook (Bjornn and Reiser 1991), or coho (Nickelson 1998). Thus, higher densities for steelhead than other salmonids in riffles reflects in part their unique velocity preferences, in combination with their preferences for other habitat features.

Applications of the UCM

Whether a proposed restoration strategy focuses on expanding stream habitats, improving fish passage, reducing the harvest fraction, or altering the use of hatchery fish, all of these strategies share a common need for accurate knowledge of a stream's capacity to produce the species of interest. The UCM offers the means to obtain such knowledge for many steelhead-bearing streams for which spawner abundance has not been monitored over the long term.

Both the UCM and basin area appear to offer rapid, accurate means to predict a stream's carrying capacity for steelhead. Traditional approaches to estimating carrying capacity have required 10–20 years of monitoring catch and spawner escapement, to statistically fit a stock–recruitment function such as the Ricker (1954) or Beverton and Holt (1957). Fits to these functions are generally mediocre, producing R^2 values in the range of 40–60%. For example, Chen and Holtby (2002) fit Ricker parameters for 83 populations of coho in British Columbia, and found the average model R^2 was 41%. While that approach will always remain useful, because it confirms real production of adult fish, basin area can be used to predict carrying capacity at least equally well with less than a few hours effort, and the UCM can be used with a few days to a few weeks of effort to distinguish habitat quality between reaches within a basin.

The novel information provided by the UCM about carrying capacity for steelhead in a stream is the present habitat value and limiting factors at specific locales throughout the basin. Further, the UCM quantifies stream carrying capacity in terms of stream features that can be targeted by habitat conservation/restoration actions, and makes it possible to predict changes in fish production that would result from changes to habitat features, even at the level of a single channel unit. Such an approach has been applied to coho by Nickelson and Lawson (1998) who used the habitat-based model of Nickelson (1998) to predict carrying capacity for coho in streams along the Oregon coast. Nickelson and Lawson (1998) then used a life cycle model to predict the future change in coho populations that would result from habitat improvements versus that which would result from allowing continued habitat degradation. They found that the fine-grained habitat information included in their model of coastwide populations, "provided insights into the dynamics of coho salmon population and the mechanisms controlling their distribution within a basin." Similarly, the UCM is well suited for application in life cycle modeling as a means to link habitat features and their modifications, even at the channel unit scale, to the performance of an entire population.

The UCM can be used to provide a common currency for expressing the effectiveness of various kinds of habitat conservation or restoration activities. Restoration effectiveness has often been expressed in terms of specific habitat features that have changed, such as pool surface area or wood complexity (e.g., Crispin et al. 1993; Johnson et al. 2005) The UCM would enable these changes to be expressed as predicted changes in parr rearing capacity. Restoration actions may cause gradual change in habitat characteristics, and some changes will be eliminated by floods or channel changes (Roni et al. 2002), so these factors must also be accounted for by explicit assumptions when using the UCM to predict probable future benefits of a restoration project. While monitoring of restoration success should include sampling of fish response, wide variation in salmonid abundances from year to year and out-of-basin influences pose significant statistical hurdles for detecting the magnitude of effects on fish (House 1995). Monitoring of stream habitat change can be used in conjunction with the UCM to provide earlier and reliable feedback on benefits realized from an action.

Additional uses of the UCM may include predicting the change in production potential that would be realized with elimination of man-made barriers, or with the addition of artificial side channels. At a larger scale, changes in watershed management could affect turbidity, fines, channel width, or channel complexity, and each of these changes can be specifically accounted for in the UCM to determine their effect on steelhead carrying capacity.

The UCM may also be used, in conjunction with other tools, to identify areas within a watershed where preservation or restoration may be targeted. For example, when paired with an approach such as that taken by Burnett et al. (2006), areas within a watershed can be compared in terms of both their intrinsic and current potential. Those areas where intrinsic potential is high, and there is great divergence between intrinsic and current potential, could be considered for restoration. Areas where current potential is near its intrinsic potential may be considered for conservation.

Possible enhancements to UCM

The UCM was developed for streams in which water quality and species composition were in the range typical of steelhead streams. Further studies may provide the data needed to derive scalars that would adjust for violation of these assumptions and broaden the set of streams for which UCM would be applicable.

Many water quality factors such as temperature, dissolved oxygen, pH, etc. are not included in the model, but can have significant impacts on habitat capacity. For example, high summer temperatures may totally exclude steelhead from certain areas where the habitat is otherwise suitable. Incorporation of this into the understanding of stream capacity is important and should be dealt with when establishing the distribution of steelhead rearing. Additionally, increased nutrient levels beyond those accounted for in the alkalinity adjustment, such as nutrients derived from carcass additions, may offer improvement to capacity predictions.

Although the model assumes that summer habitat for parr limits steelhead production, recent studies have found that stream restoration techniques, particularly the addition of large wood, can enhance overwinter survival and increased production of steelhead smolts (Johnson et al. 2005). The UCM attempts to account for winter habitat through the inclusion of cobble availability, but the dynamics that determine winter capacity or survival are certainly more complicated than the availability of cobble. Further studies on winter habitat use and survival of juvenile steelhead may reveal a means to improve the accounting for differences in winter habitat.

Interspecific competition is an important phenomenon that is not accounted for in the UCM, and may substantially affect steelhead carrying capacity in some situations. Harwood et al. (2002) noted that interspecific competition for shelter (Gregory and Griffith 1996) can result in density-dependent use of refuge habitat (Armstrong and Griffiths 2001) and thereby have important implications in terms of carrying capacity. This may have specific implications to a stream’s steelhead carrying capacity as competition with coho (*O. kisutch*) for summer habitat has been shown to cause steelhead to re-distribute themselves (Hartman 1965; Allee 1982). However, McMichael et al. (2000) found that competition between fish in the Yakima Basin was strongest between individuals of the *O. mykiss* species, but competition of steelhead with juvenile chinook and coho was negligible. Interspecific competitive interactions are highly complex, and whether or not they influence capacity depends partly on the life stage at which competition occurs. The streams used to test the UCM included varied species assemblages that covered the typical range for steelhead streams throughout Oregon. Thus, we expect that separate accounting for inter-species competition or predation may only lead to substantial change in predicted rearing capacity in a small fraction of steelhead-producing streams.

The UCM does not distinguish between capacity utilized by the different life-histories of *O. mykiss* that may rear and compete with one another in the same reach. Nonanadromous rainbow trout will compete with anadromous fish, and thus would share the available capacity when rearing in the same reach. Further, McMichael et al. (2000) found in the Yakima River that agonistic interactions were substantial between individual *O. mykiss*, regardless of whether they were resident or anadromous, and that the larger individuals were behaviorally dominant in over 80% of contests observed. Thus, larger resident rainbow trout will be competitively dominant, and will defend more habitat per individual than steelhead parr (Grant and Kramer 1990). To account for capacity consumed by nonanadromous *O. mykiss*, it will be necessary to account for additional habitat factors, and perhaps racial abundance.

Conclusions

The UCM provides estimates of basin carrying capacity for steelhead that are consistent with observed smolt yields for basins widely different in size and character. The UCM predictions indicate that habitat quality ranges widely between stream reaches within a basin, and the method provides specific metrics to identify factors most limiting and most beneficial for steelhead capacity. Such predictions can be used to prioritize and justify investments in habitat restoration or conservation. Factors that limit production are often quite different between stream reaches and even between basins. Given the range of habitat characteristics observed in the test basins, the predictions of steelhead capacity are most affected by the percentage of stream area in pools, alkalinity, and percentage fines in the substrate. Further validation of the model should be pursued at the stream reach level to compare predicted and observed parr densities across a wide range of habitat quality.

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PANTHER GRADE FALLS BARRIER ANALYSIS

SOUTH FORK of BATTLE CREEK

Lassen Lodge Hydroelectric Power Project

**Prepared
for**

Rugraw, Inc.

January 20, 2012

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Background

The Lassen Lodge Power Project (Figure One) is a proposed Run-of-the River small Hydroelectric Power Project, located on the upper reach of the South Fork of Battle Creek, sited solely upon private lands entirely within the County of Tehama, California. The proposed Power House location (western project boundary) is approximately 2 miles upstream (at River Mile (RM) 20.75) of the previously-identified natural barrier, the falls-boulder cascade at Panther Grade. The Panther Grade feature is cited multiple times within the Battle Creek Salmon and Steelhead Restoration Project, Final EIR/EIS (Jones and Stokes,2005) and USDI Bureau of Reclamation the South Diversion Dam Removal Reconnaissance Report, Battle Creek Project Bureau of Reclamation (1999) as both the Upper Project limit of the Battle Creek Restoration Project and the natural barrier falls to upstream migration on the South Fork of Battle Creek.

Site visits by agency personnel conducted in 1983 identified Panther Grade, (at RM 18.85), as a total barrier (California Department of Fish and Game, April 10, 2001, Thomas R. Payne and Associates, Aug 10, 2001).

Subsequent agency site visits conducted in 1998 resulted in one agency personnel, without taking any physical measurements, suggesting that the Panther Grade barrier may be in fact a partial barrier, due to possible structural changes of the boulder cascade that may have occurred as a result of the large 1997 flow event. Other significant channel adjustments in the South Fork of Battle Creek in the project area were noted (California Department of Fish and Game, ibid.

A subsequent site review performed at Panther Grade in November 18, 1998 by Douglas Parkinson and Associates (DPA, 1998) when stream flows were estimated at 60-80 cfs, confirmed that no significant visible changes to the structure of the barrier occurred. The impediments to adult anadromous fish passage observed prior to the 1997 extreme flow event; i.e. shallow jump pool depths, boulders in the jump pools, turbulence and severe air entrainment in the jump pools were essentially unchanged. Many visits to the Panther Grade barrier site since the mid-1990’s and have not been able to detect any visible physical evidence of changes that would affect the current status of the barrier that would improve the chances of passage for anadromous fish.

The information provided within this assessment presents the findings of the studies of the Panther Grade barrier, the objective of which is to provide site-specific scientific data to help resolve concerns as to the status of this natural feature. Also, this study will analyze the three recently identified secondary barriers identified between the Panther Grade barrier and the Powerhouse site.

These three additional barriers have been identified during stream habitat surveys between the Panther Grade Falls feature upstream to the proposed powerhouse site: Two additional 8 foot falls, about 4000 feet upstream of Panther Grade Falls, and a third, 6 foot falls at 6900 feet above Panther Grade, immediately below the new proposed powerhouse location (RM 20.75)(Figure 10)(NSR, 2000).

The same passage criteria will be applied to the natural falls at RM 20.75, located immediately downstream of the proposed power house location. Increased impediment to anadromous fish passage at this site was created by boulder movement during the December 1997- January 1998 storm event which caused the channel to degrade (Ward and Moberg, 2004).

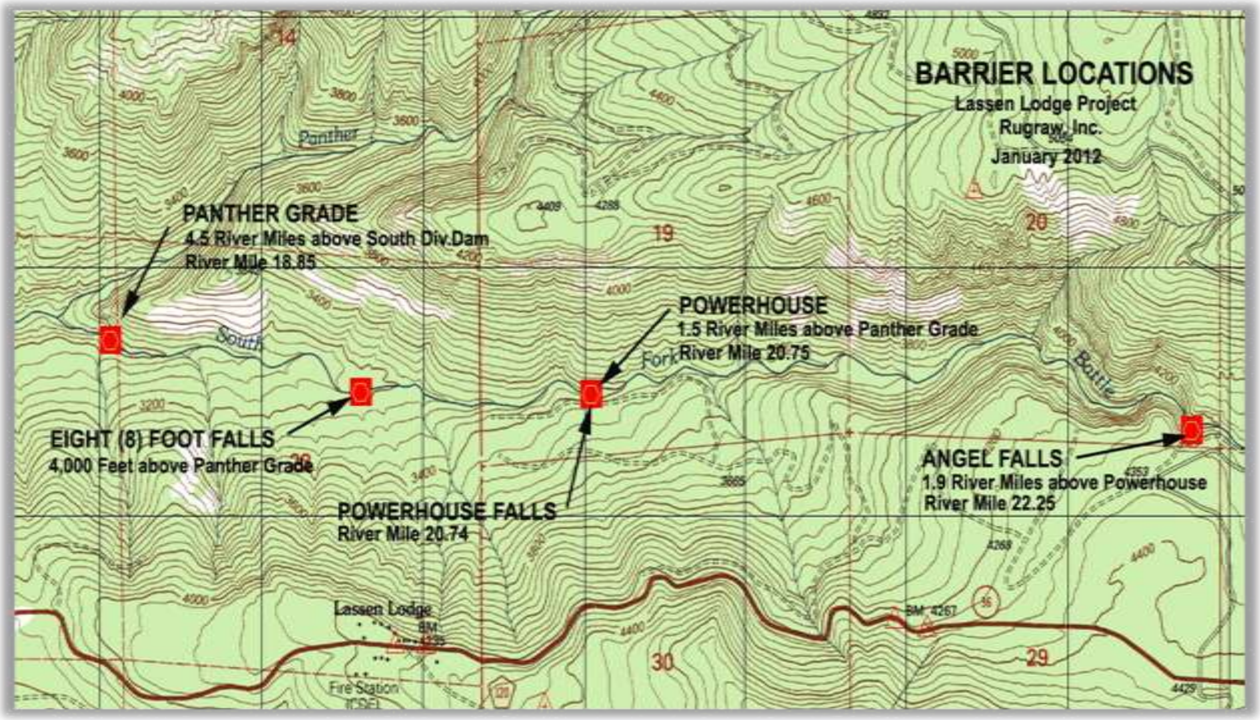

Figure One

Project Location and Features, Lassen Lodge Power Project
South Fork Battle Creek, Tehama Co., CA.

Methodology

The compound barrier composed of multiple falls, complex chutes and a boulder cascade stream feature on the South Fork Battle Creek at the Panther Grade (RM 18.85), has been assessed for passability by adult steelhead rainbow trout at a range of flows that fish might be present during migration from October through March. Adult salmon are not capable of passing through barriers that adult steelhead rainbow trout cannot pass, thus this study will be for all anadromous fishes that might reside in the South Fork of Battle Creek.

The stream features are being classified with the barrier assessment protocol of Powers and Orsborn (1985). Barrier passage criteria are being applied to four potential avenues of access at the Panther Grade boulder cascade feature and a single route at the bedrock falls at RM 20.75.

Classification and Typing of Panther Grade Passage Impediment

The Power's and Orsborn (1985) classification system applies channel hydraulics and known capabilities of anadromous fish to assess the ability of adult fish to pass/ascend natural stream structures and manmade channel impediments.

The system describes downstream approach conditions at the base of the barriers, central passage conditions to include chutes over falls and landing conditions upstream of the barrier.

The investigations at the Panther Grade Falls have been focused on the physical characteristics of the structure and are compared to the jumping abilities the steelhead rainbow trout.

The Panther Grade Falls passage impediment has been classified into one of three categories per Power's and Orsborn (1984) based on the physical structure of the barrier and the abilities of target fish species;

1. Total--impassable to all fish all of the time,
2. Partial--impassable to some fish all of the time, and
3. Temporary--impassable to all fish some of the time.

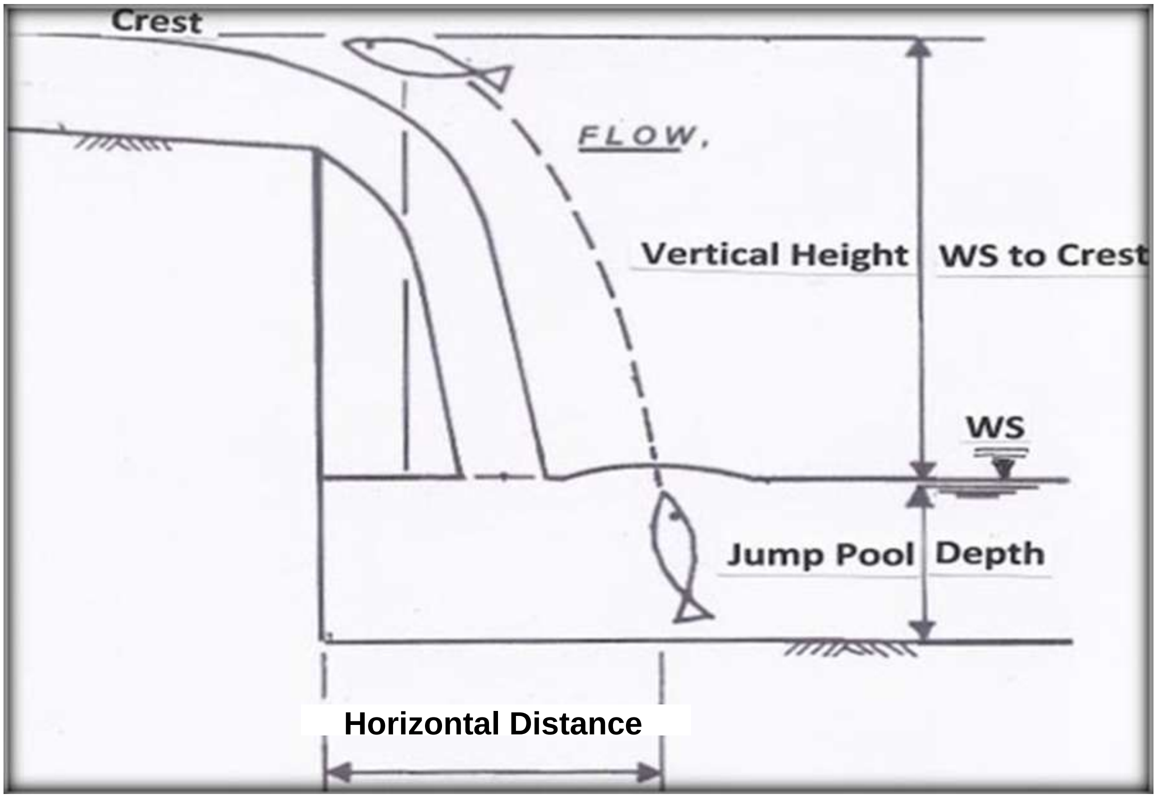

Figure 2.

Barrier Passage Criteria, Vertical Height, Pool Depth and Horizontal Distance for Panther Grade South Fork of Battle Creek, Lassen Lodge Power Project.

Four potential passage access routes have been identified at the Panther Grade site. Criteria being measured at the site include (Figure 2):

- H- Horizontal distance leaping fish travels from the jump pool to the landing at top of the obstacle
- D-Depth of jump pool

- V- Vertical distance from watersurface of jump pool to watersurface at top of obstacle
- A datum has been established at the site to provide water surface elevation and physical feature differentials at the range of flows measured. A discharge rating curve is in place to document the flows present during the range of measurements.

The site measurements occur at a range of flows to be identified from the monthly hydrograph (Figure 3) compared to the time of year steelhead are likely to be present (October to March).

Table One.

Characteristics of Barrier Classification Components

Classification Component	Characteristics
Class	Site geometry in plan view Number of fish passage routes Characteristics of fish passage routes
Type	Site geometry in profile Bed slopes, Pool depths
Magnitude	Elevation drops, Water velocities, and Slope lengths
Discharge	The flow rate at which the class, type and/or magnitude were measured.

Current Data Collection Efforts

The physical characteristics of the Panther Grade passage site and natural falls below the powerhouse site have been collected at a range of flows. Passage criteria collected (Table 2) include depths of jump pools, horizontal distance from jump pool to top of crest, and vertical distance from jump pool to water surface at the top or crest of the obstacle.. The information collected is presented on the photographs on the figures 4-11.

H - Horizontal distance leaping fish travels from the jump pool to the landing at top of the obstacle.

D - Depth of jump pool.

V - Vertical distance from watersurface of jump pool to water surface at top of obstacle (pool depth to vertical distance 1:1.25 feet)

The range of flows that would occur during the estimated migration time for steelhead from approximately October to March is presented in Figure 3. The average monthly flows for South Fork of Battle creek were developed from the gaging site at the Old Highway 36 Bridge.

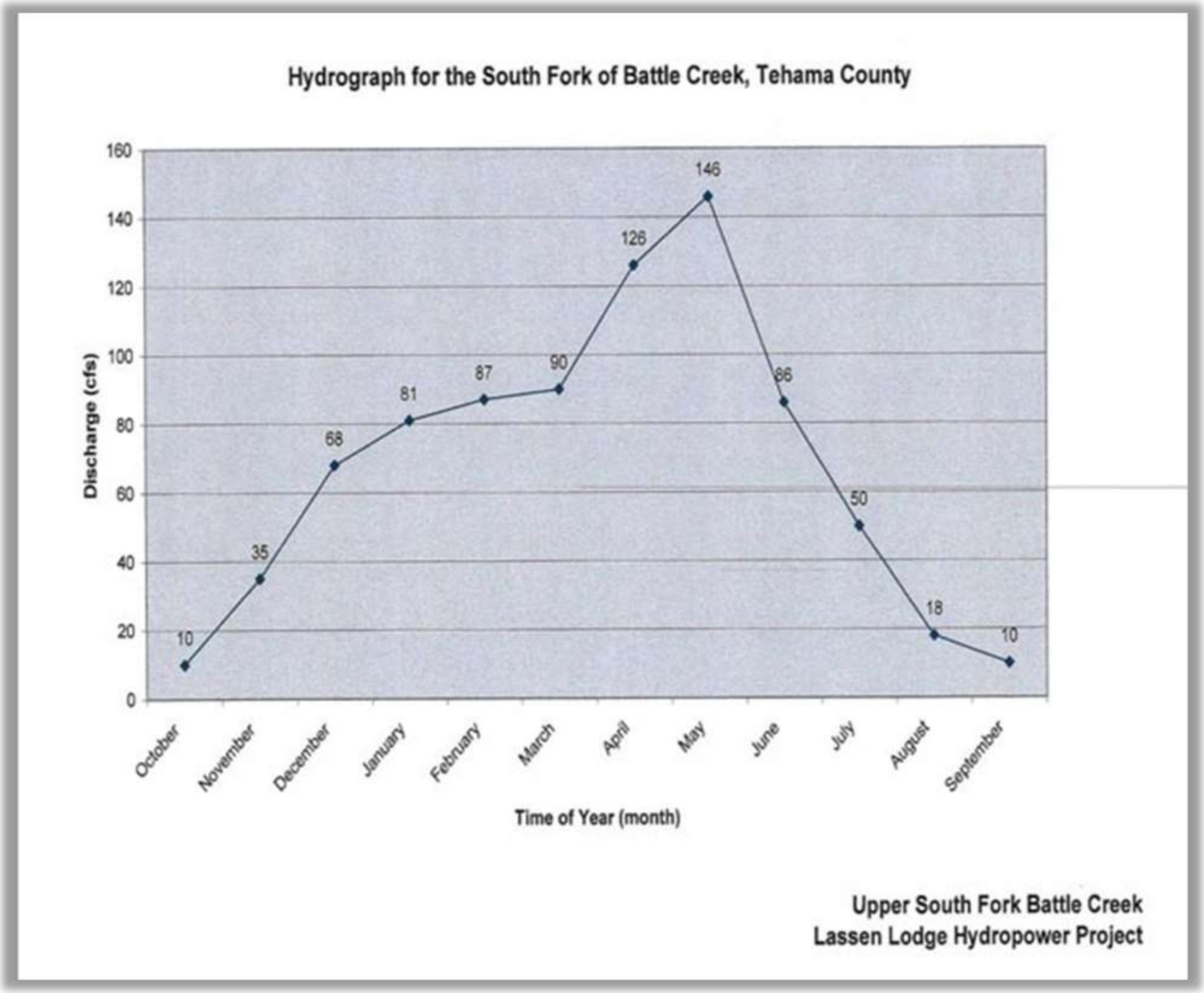

Figure 3.

Average monthly hydrograph, Lassen Lodge Hydropower Project, Upper South Fork of Battle Creek, Tehama Co., Ca.

Results

The Panther Grade streamflow during the two 2011 site visits were 200 cubic feet per second (cfs) in May and 24 cfs in Nov. The rocks present in the jump pools at both potential passage sites are the most formidable restrictions to the passage of anadromous fish.

Information collected from two site visits conducted in May 2011 and November 2011 is presented in Table 2. The passage criteria were measured at two primary access points because of the greater attraction flows at both sites.

The first photo illustrates the boulder at a lower stream discharge. The same boulder is completely covered at higher flows but its presence can still be noted by the air entrained rebounding water in Photo 2.

Fish passage at the access route three is the secondary passage site on the left margin and is hampered by a 4’ X 4’ boulder in the jump pool.

Table 2.

Leaping analysis parameter measurements at Panther Grade and powerhouse site (5), depth of jump pool, horizontal distance from pool to crest and vertical distance from water surface to crest of obstacle, South Fork Battle Creek, Tehama Co.

Site	Flow (cfs)	Depth Jump Pool (ft)	Horizontal Distance(ft)	Vertical Distance(ft)
1	34			
	200	4.0	12.0	11.0
2	200	4.3	8.0	10.0
3	34	1.5 (figure 4)	5.4	6.4
4	200	3.0	8.0	6.0
5	30	2.0	12.0	5.0

Site Discussion and Conclusions

Panther Grade

The presence of large boulders in the jump pools (Figures 4-9) of all of the four potential access points are the main impediment that restrict adult fish from ascending the barrier. These boulders displace water volume in the jump pools and create violently turbulent white water, which inhibits tracking for fish attempting to ascend the falls. The depth of a jump pool should be 1.25 times greater than the height of the obstacle for fish to successfully ascend. Stuart (1964) noted that the effect of turbulence is to reduce the propulsive power of the fishes tail. Powers and Orsborn (ibid) considered and water fall steep enough to create turbulent white water is a total barrier. Fish would only be able to pass if they can leap the horizontal distance beyond the area of turbulence.

The features that impede access over 3 secondary access routes 2, 3, and 4 have less vertical drop, but also have boulders within the jump pools that impede passage capability. The secondary potential access route at site 4 on the left channel margin, which was previously identified by agency personnel as best potential for passage at high flows, has been evaluated at a range of flows to ascertain the feasibility of fish passage. As previously noted, boulders in the jump pools appear to be the main impediment at this access route.

It appears that the large boulder in the larger passage channel is a constant impediment to passage between the lower flows and flows greater than 200 cfs.

Based upon personal observations, as the flows increase, the momentum of the water causes the majority of the flow to increase the horizontal leaping distance and land more directly on the boulder. The air entrained turbulent water refracting off the unseen boulders in the jump pools, is probably the main impediment to anadromous fish passage at the four routes being evaluated.

All previous and on-going studies and evaluations suggest that the combination of turbulence, air entrainment, and shallow jump pool depths, obstructions in jump pool and high chute velocities preclude passage for all of the access routes at the Panther Grade barrier.

Falls Barrier (Station 69+00)(RM 20.75), just below Powerhouse Location

The vertical drop at this location, extreme turbulence and boulders in the jump pool, are the limiting impediments to passage (Figure 11). At higher flows, the sloped landing area immediately above the vertical drop increases in velocity to additionally restrict passage. The combination of slopped landing area, and the vertical drop into the shallow jump pool and onto small boulders, creates multiple high-velocity, air-entrained flow conditions making this natural barrier impassable to anadromous fishes**.**

Figure 4.

Access route 3, depth of jump pool at 20 cfs, November 22, 2011, Panther Grade, South Fork Battle Creek.

Depth of jump pool 1.5 feet, vertical distance 6.0 feet from water surface to crest of falls, Horizontal distance 5 feet from jump pool to crest is 5 feet. At increasing discharge the flow from the falls migrates to the left and lands on the boulder.

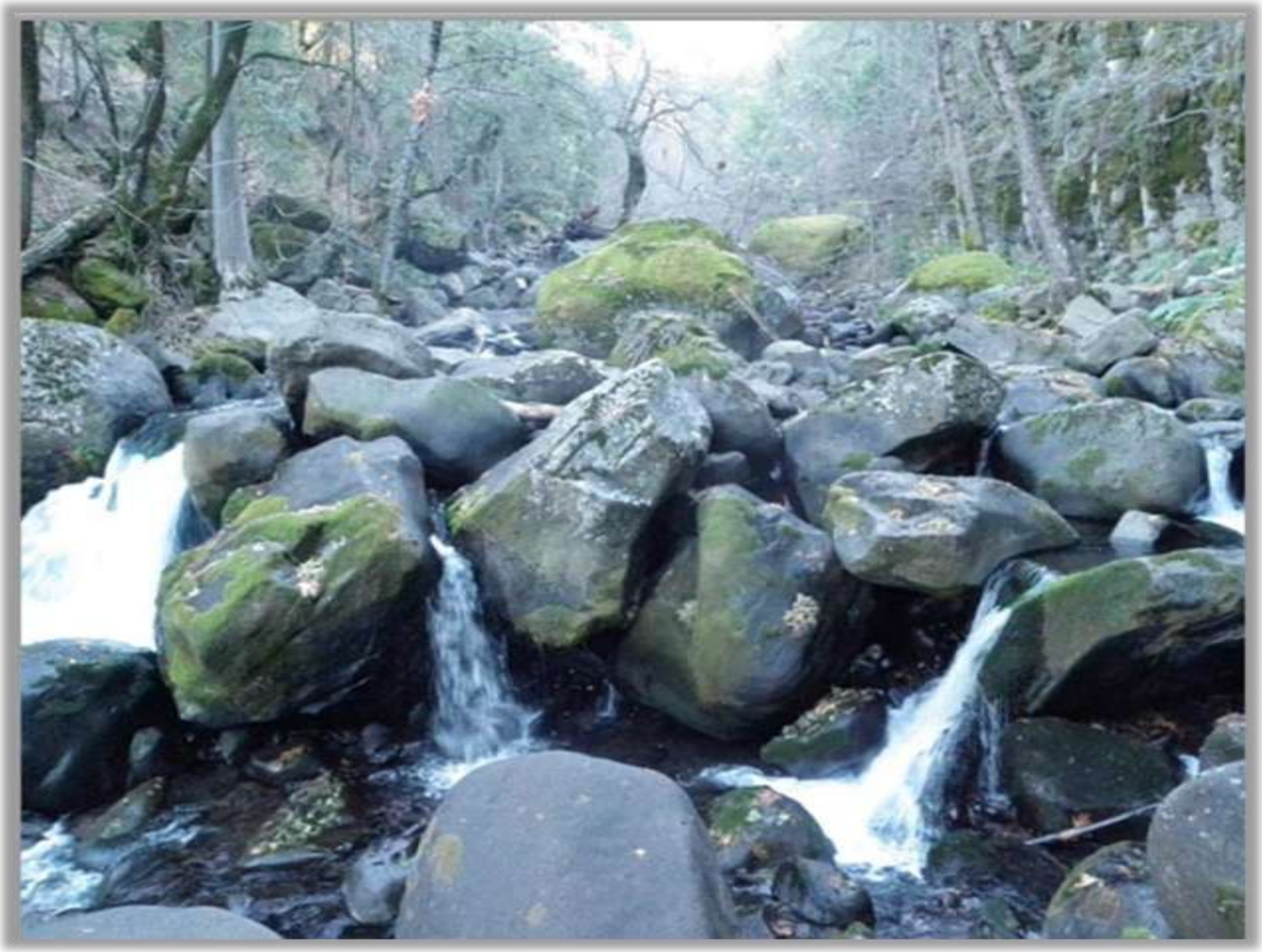

Figure 5.

Access routes 1, 2, 3, at 20 cfs, November 22, 2011, Panther Grade, South Fork Battle Creek.

Access route 1 at left of photo, access route 2 at left center and access route 3 (figure 4) all at 20 cfs. Boulders are present in all jump pools. Access route 4 is out of sight on right of photo.

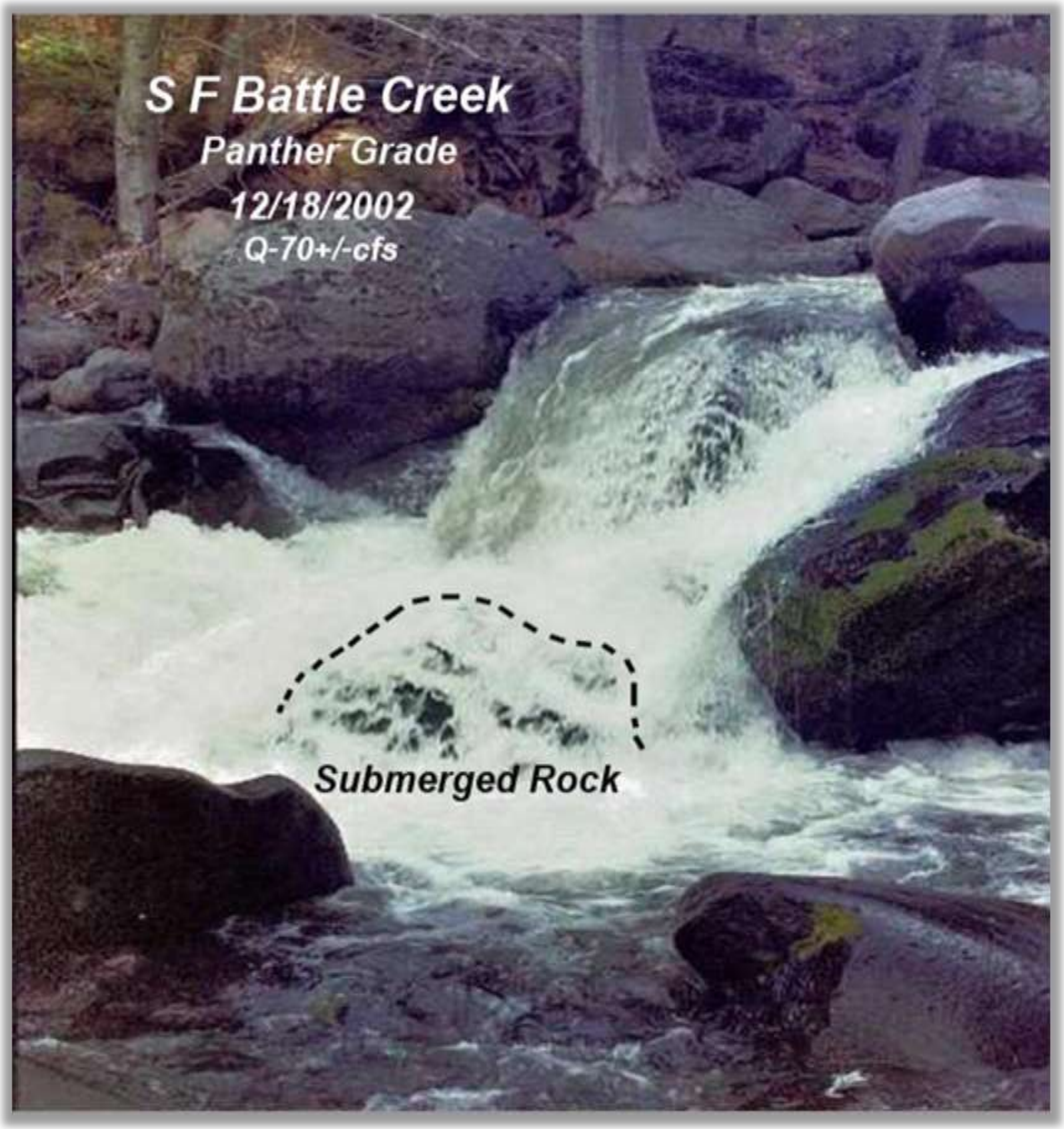

Figure 6.

Access route 1, boulder in jump pool. 70 cfs. Panther Grade falls, Lassen Lodge Power Project, South Fork Battle Creek.

Access site 1 large boulder is still partially visible at increasing flow. Turbulence, air entrainment created by falling water increases with flows. Water surface elevation of jump pool is at base of boulder.

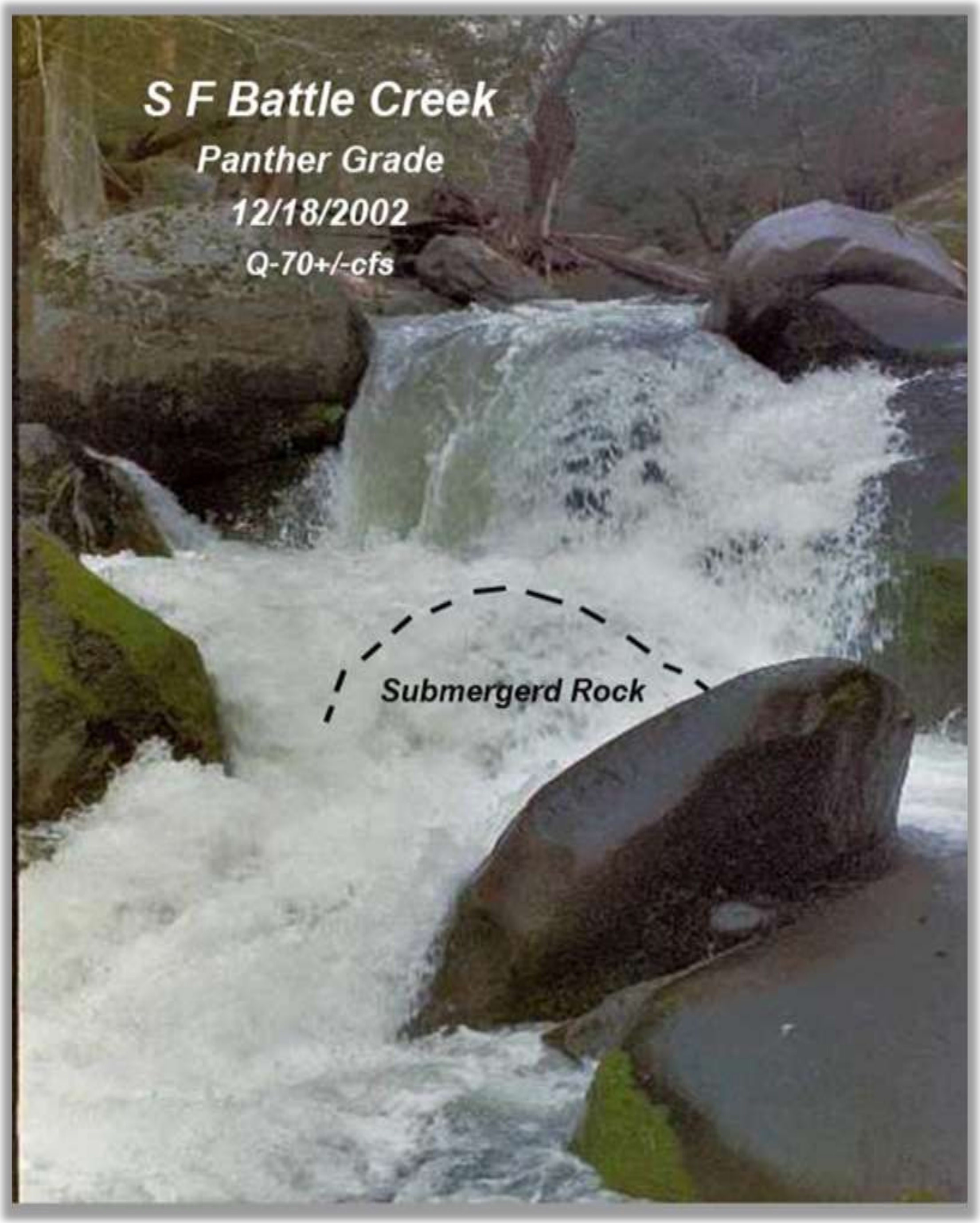

Figure 7.

Site One on river right, @ 70 cfs. Panther Grade falls-boulder cascade. Lassen Lodge Power Project, South Fork Battle Creek.

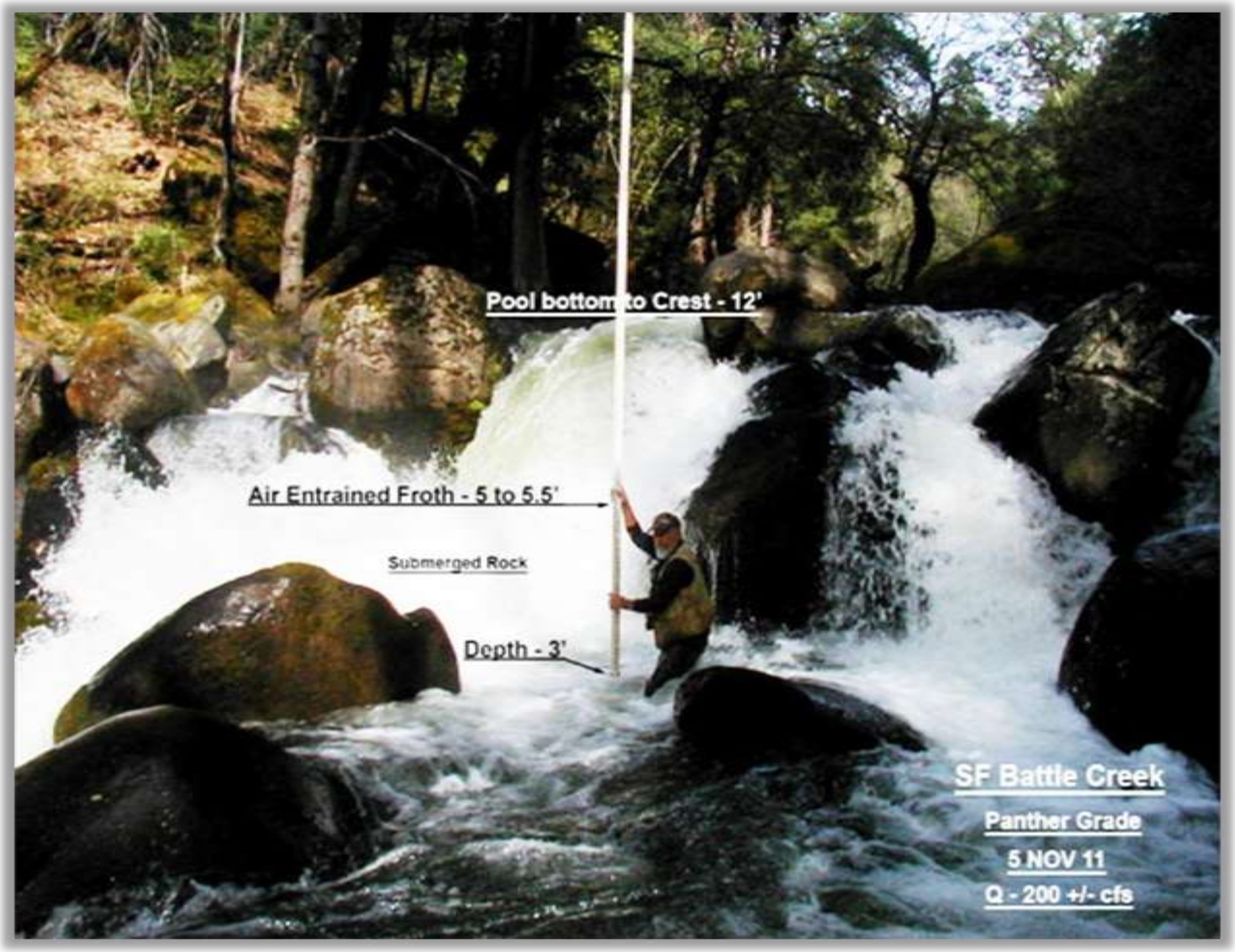

Figure 8 .

Site 1 and 2 passage points, depth of jump pool, and vertical height. 200 cfs. Lassen Lodge Power Project, South Fork Battle Creek.

Passage site 1 on right bank at @200 cfs. The air entrainment and turbulence creates a boil at least 5 feet above the water surface of jump pool surface. Vertical distance from water surface of jump pool to top of crest is approximately 12 feet. Jump pool depth range is 3 feet and 4 feet. Horizontal distance from jump pool in front of cascade to crest.

Site 2 to right of photo. Jump pool depth range 2 feet to 4 feet. Vertical distance from water surface at jump pool to crest is 10 feet.

<u>Figure 9.</u>

Access route 2. Jump pool depth 4.0 feet. 200 cfs. Lassen Lodge Power Project, South Fork Battle Creek.

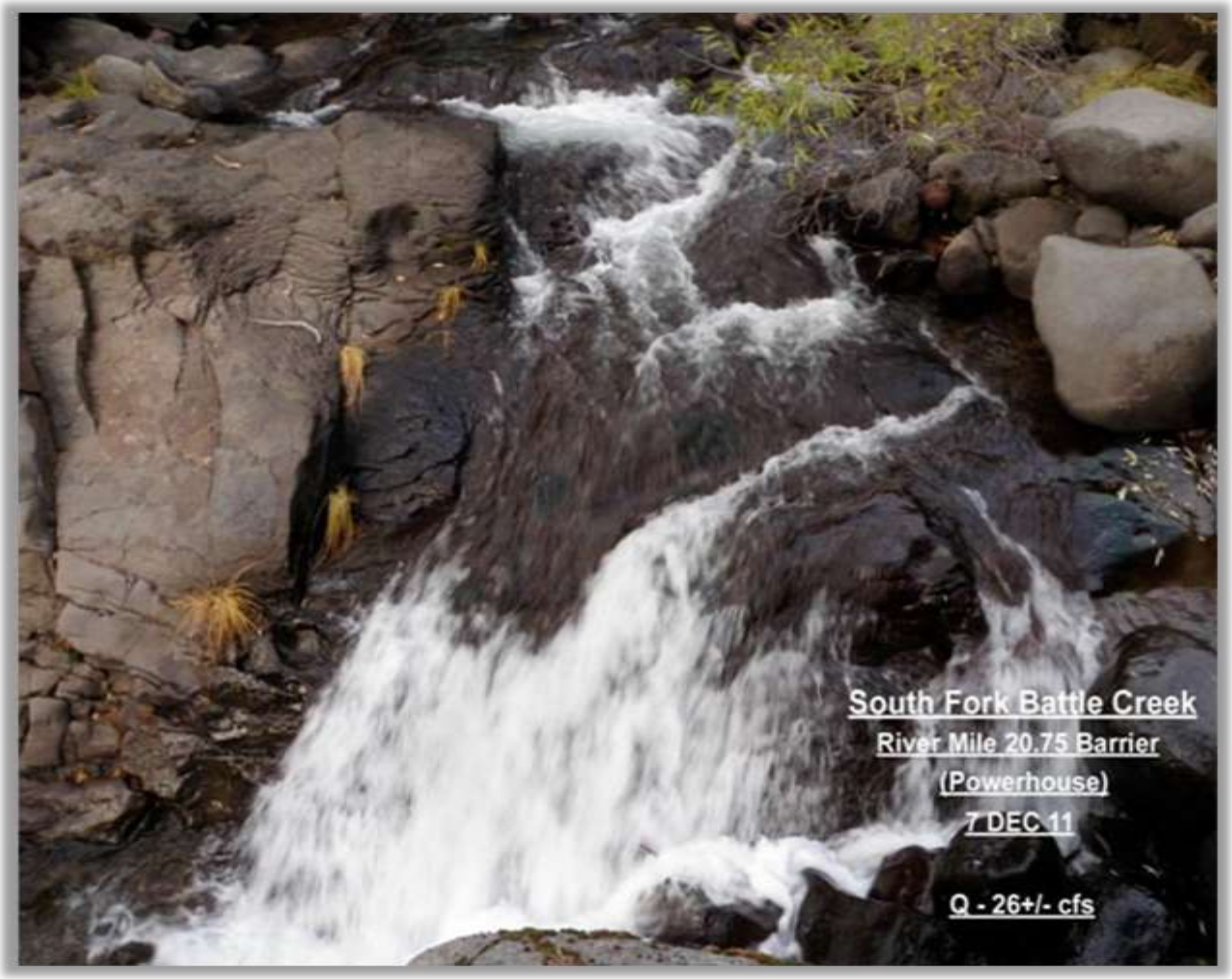

Figure 10.

Uncataloged barrier at Station 69+00, about 26 cfs 7 Dec 11. Immediately below the proposed Power House Location, Lassen Lodge Power Project, South Fork Battle Creek

Barrier site is bedrock falls with main flow sloping to the left side of channel. Base of falls in bedrock with small boulder accumulation at the base of the falls. No jump pool at low flow.

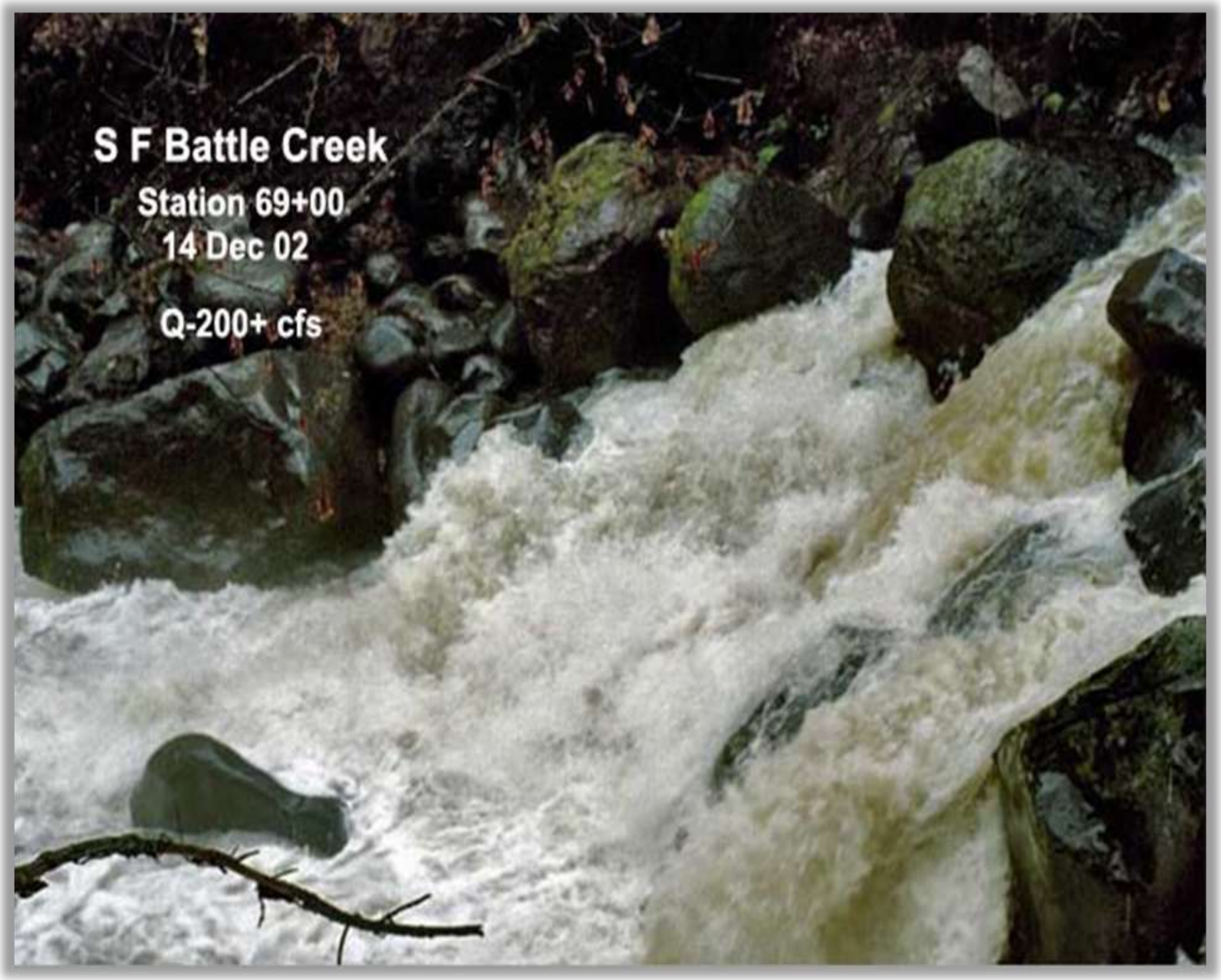

Figure 11.

Uncataloged barrier at Station 69+00, @ 200 cfs 14 Dec 02. Immediately below the proposed Power House Location, Lassen Lodge Power Project, South Fork Battle Creek.

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Panther Grade Barrier Analysis June 20, 2012

The Panther Grade stream feature is a compound barrier composed of multiple falls (four), complex chutes and boulder cascade on the South Fork of Battle Creek at Panther Grade at river mile (rm)18.85.

Physical passage criteria at a range of stream flows on anadromous fish passage is continuing to be collected at the Panther Grade site on South Fork Battle Creek downstream of the proposed Lassen Lodge Hydroelectric Power Project.

Criteria to determine passage conditions at the Panther Grade feature include; water surface elevations in the jump pools, vertical distances of falls, and horizontal distances from the crest of falls to jump pool and jump water depths were collected at the four potential passage locations have been collected since May, 2011. Three site visits have been performed; May 5, 2011 (200+/-cfs), November 22, 2011 (24+/-cfs) and May 11, 2012 (100+/- cfs). The anadromous fish passage criteria measurements for the three site visits are presented in Table One.

Stream flow was measured on May 11, 2012 at the established stream gauging location above the old Highway 36 Bridge. A stream flow accretion factor of approximately 7 cubic feet per second (cfs) was added to the discharge to allow for the spring inflow that occurs at the Panther Grade reach above the falls.

The stream discharge measurement was 93 cfs at the gauging site and allowing for a 7 cfs accretion the total discharge at the Panther Grade feature was approximately 100 cfs.

The depths of the jump pools at the range of the flows measured are insufficient to provide passage for anadromous fish past the Panther Grade structure.

Jump pool depths should be 1.5 times the height of the vertical distance of the water surface of the jump pool to the crest at the top of the falls.

Passage Conditions at Four Candidate Passage Locations:

Site One

The first candidate passage site is located on the right waters bank. The site passes the majority of the stream flow ranging from an estimated 60-80 % of the total flow for the site. The vertical distance from jump pool water surface to the crest of the falls exceeds the criteria of a jump pool depth 1.5 times greater than the vertical distance.

The jump pool contains a large boulder and adjacent boulders that the descending water lands on at all flows that observations were taken at. The position of the boulders at the base of the falls indicate that the boulders in the jump pool limit passage at higher flows than what were measured.

Site Two

The second candidate passage location passes an estimated flow of 10-20% of the total flow at different discharges. The presence of a rock in the jump pool completely restricts passage at low flow.

Jump pool depths increased with discharge. The jump pool depths are insufficient to meet the minimum depth criteria of 1.5 times the vertical distance for fish to pass the site.

Site Three

The third candidate passage location passes an estimated flow of 10-15% of the total flow at different discharges. The presence of a rock in the jump pool completely restricts passage at low flow.

Jump pool depths increased with discharge. The jump pool depths are insufficient to meet the minimum depth criteria of 1.5 times the vertical distance for fish to pass the site.

Site Four

The fourth candidate passage location passes an estimated flow of 05-10% of the total flow at different discharges. The presence of a rock in the jump pool completely restricts passage at low flow and high flows.

Jump pool depths increased with discharge. The jump pool depths are insufficient to meet the minimum depth criteria of 1.5 times the vertical distance for fish to pass the site.

Table One. Physical Passage Criteria Panther Grade, South Fork Battle Creek below Lassen Lodge Hydroelectric Project.

Panther Grade (RM 18.50) Passage Sites

	Site One	Site Two	Site Three	Site Four	Discharge
Jump Pool depth					
November 22, 2011	rock	rock	rock	rock	17 cfs
May 5, 2011	rock	3.80’	3.00’	2.40’	180 cfs
May 11, 2012	rock	3.00’	2.5’	rock	100 cfs
Vertical Height					
November 22, 2011	12.0’	7.00’	6.40’	4.50	17 cfs
May 5, 2011	10.00’	11.00’	N/A	6.00’	180 cfs
May 11, 2012	12.00	7.00	6.00	4.50	100 cfs
Gage Height					
November 22, 2011	N/A	N/A	N/A	N/A	17 cfs
May5, 2011	N/A	N/A	N/A	N/A	180 cfs
May 11, 2012	N/A	100.72’	100.72	100.72	100 cfs

Vertical Height-distance from water surface in jump pool to water surface at landing.

Jump Pool Depth-Depth of water in jump pool

Discharge-Stream flow estimated from rating curve or measured during time of visit.

Gage Height- Staff gage reading at Panther Grade to determine water surface elevations and depths of jump pools.

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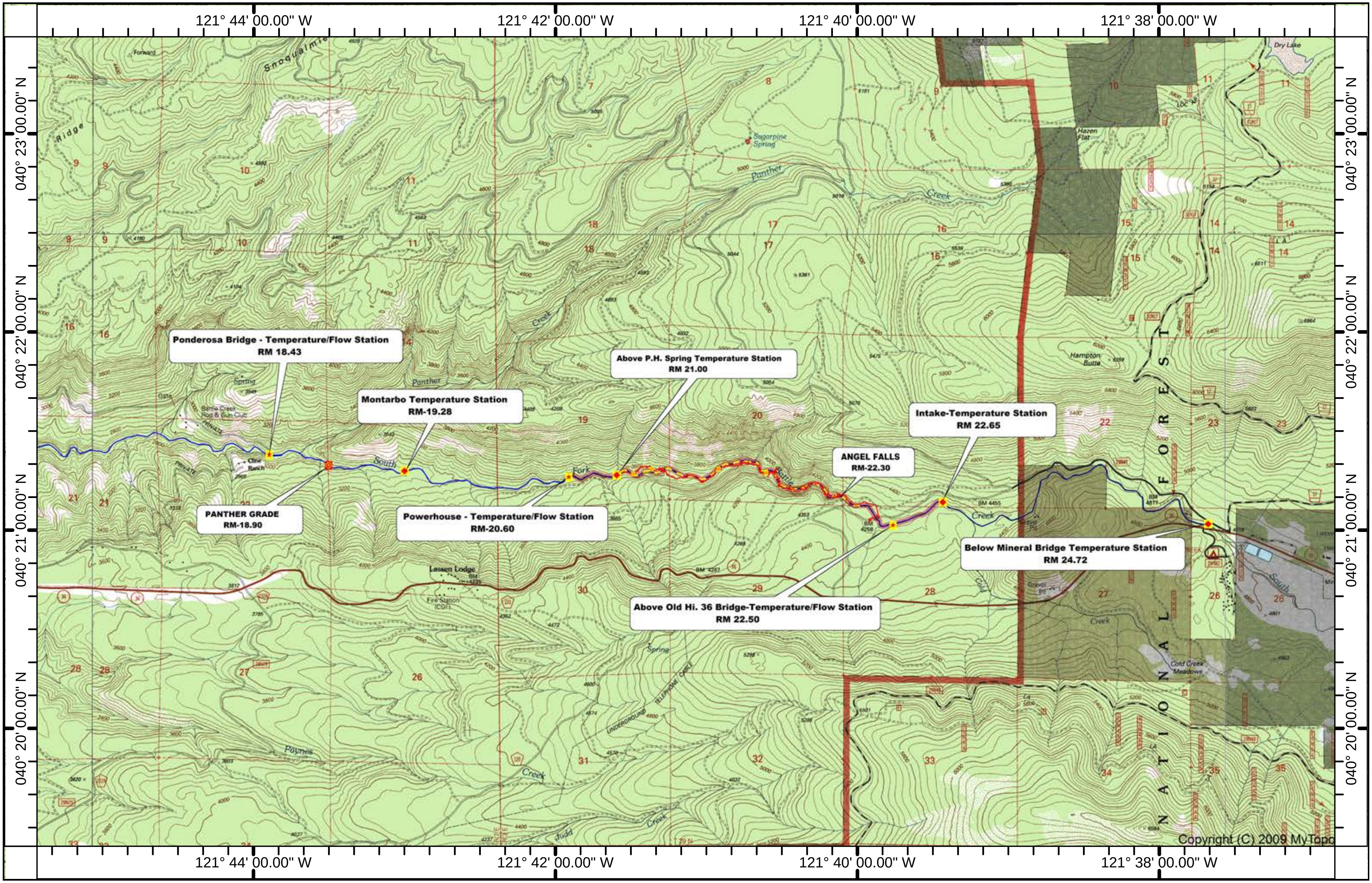

CONTOUR INTERVAL 40 FEET
NATIONAL GEODETIC VERTICAL DATUM

▬	Project Bypass Reach
- - -	Dry Streambed 8-04-14
◆	H2O /Air Temperature Station
★	Streamflow/H2O/Air Temperature Station
◎	Natural Barriers
⊙	Hyporheic Flow (Pond) 8-04-14

STREAM MONITORING STATIONS

Lassen Lodge Project
FERC No. 12496

Rugraw, LLC. **8-22-14**

Document Content(s)